EFFECT OF ZINC AND BORON ON GROWTH AND YIELD OF BARI MOTORSHUTI-1

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TO

MY BELOVED PARENTS

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CERTIFICATE

This is to certify that the thesis entitled **'Effect of Zinc and Boron on Growth and Yield of BARI Motorshuti-1'** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfilment 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 **Md. Maruf Hossain**, Registration number: **08-02672** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated:
Dhaka, Bangladesh

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The Author

EFFECT OF ZINC AND BORON APPLICATION ON GROWTH AND YIELD OF BARI MOTORSHUTI-1

ABSTRACT

The experiment was conducted during the period from November, 2013 to March 2014 at the farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh to study the effect of zinc and boron on growth and yield of BARI motorshuti-1. The experiment comprised of two factors; Factor A: Levels of zinc (4 levels)- Zn_0: 0 kg Zn ha^{-1} (control), Zn_1: 1.5 kg Zn ha^{-1}, Zn_2: 2.5 kg Zn ha^{-1}, Zn_3: 3.5 kg Zn ha^{-1} and Factors B: Levels of boron (3 levels)- B_0: 0 kg B ha^{-1} (control), B_1: 1.5 kg B ha^{-1} and B_2: 2.5 kg B ha^{-1}. The two factors experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. For different levels of zinc, at 20, 30, 40, 50, 60 DAT and at harvest, the tallest plant (15.75, 36.15, 55.60, 69.29, 81.67 and 86.76 cm, respectively) was recorded from Zn_3, whereas the shortest plant (12.23, 26.59, 37.50, 52.60, 65.96 and 72.94 cm, respectively) was found from Zn_0. The highest seed yield $hectare^{-1}$ (7.98 ton) was recorded from Zn_3, whereas the lowest (6.00 ton) from Zn_0. The maximum concentration in seed for N (0.446%), P (0.212%), K (0.283%), S (0.160%), Zn (0.0184%) and B (0.0150%) were observed from Zn_3, whereas the minimum concentration in seed for N (0.318%), P (0.163%), K (0.203%), S (0.132%), Zn (0.0116%) and B (0.0115%) from Zn_0. In consideration of different level of boron, at 20, 30, 40, 50, 60 DAS and at harvest, the tallest plant (15.76, 34.99, 52.89, 65.93, 78.89 and 85.69 cm, respectively) were recorded from B_2, while the shortest plant (12.32, 29.90, 45.21, 60.11, 69.62 and 77.04 cm, respectively) from B_0. The highest seed yield $hectare^{-1}$ (7.86 ton) from B_2, while the lowest seed yield $hectare^{-1}$ (6.15 ton) from B_0. The maximum concentration in seed for N (0.431%), P (0.197%), K (0.276%), S (0.159%), Zn (0.0166%) and B (0.0148%) were recorded from B_2 and the minimum concentration in seed for N (0.351%), P (0.180%), K (0.210%), S (0.128%), Zn (0.0132%) and B (0.0114%) from B_0. At 20, 30, 40, 50, 60 DAS and at harvest, the tallest plant (17.72, 39.29, 60.46, 73.75, 86.60 and 91.50 cm, respectively) were observed from Zn_3B_2 and the shortest plant (10.37, 25.18, 35.38, 51.36, 60.19 and 69.40 cm, respectively) from Zn_0B_0. The highest seed yield $hectare^{-1}$ (8.85 ton) was found from Zn_3B_2 and the lowest seed yield $hectare^{-1}$ (5.34 ton) from Zn_0B_0. The maximum concentration in seed for N (0.497%), P (0.216%), K (0.320%), S (0.175%), Zn (0.0206%) and B (0.0160%) were observed from Zn_3B_2, while the minimum concentration in seed for N (0.300%), P (0.162%), K (0.193%), S (0.121%), Zn (0.0103%) and B (0.0093%) from Zn_0B_0. Findings revealed that application of 3.5 kg Zn ha^{-1} & 2.5 kg B ha^{-1} and 2.5 kg Zn ha^{-1} & 1.5 kg B ha^{-1} showed statistically same seed yield and other yield contributing characters.

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CHAPTER I

INTRODUCTION

Motorshuti or garden pea (*Pisum sativum* L.) belongs to the family *Fabaceae* is one of the world's oldest domesticated crops cultivated before 10th and 9th millennia BC (Zohary and Hopf, 2000). The crop is grown in many countries and currently ranks fourth among the pulses in the world with a cultivated area of 6.33 million hectares (FAOSTAT, 2013). The garden pea is a legume with great nutritional potential because of its high content of protein (27.8%), complex carbohydrates (42.65%), vitamins, minerals, dietary fibre and antioxidant compounds (Urbano *et al*., 2003). Nevertheless, its nutritional importance may be limited by the presence of non-nutritional components that have a negative effect on the nutritional value of this legume. These non-nutritional components include trypsin inhibitors (TIA), lectins, a-galactoside oligosac-charides, polyphenols and phytic acid (Savage and Deo, 1989; Urbano *et al*., 2003).

Peas are cultivated for the fresh green seeds, tender green pods, dried seeds and foliage (Duke, 1981). The area for pea cultivation in 2013 was 36,132 acres and the production was 11,842 metric tons but in 2007 the area was 37,145 acres and the production was 12,610 metric tons (BBS, 2013). However, the area has been drastically reduced due to introduction of HYV of rice and wheat. In Bangladesh most of the pea varieties are inbred type and the average yield of pea is below 1.0 t ha^{-1} (BBS, 2013), whereas the average world yield of pea is around 1.70 t ha^{-1} (FAO, 2012). Yield of garden pea is very low in Bangladesh and such low yield however is not an indication of low yielding potentiality of this crop, but may be attributed to a number of reasons, viz., unavailability of quality seeds of high yielding varieties, delayed sowing after the harvest of boro rice, fertilizer management especially micronutrients, disease and insect infestation and improper or limited irrigation facilities. Among different factor micronutrients especially zinc and boron application are also the most important factor.

For optimal growth and development, 17 essential elements are required by crop plants. These minerals, when required in relatively high amounts, are called macronutrients or, in trace amounts, micronutrients. While micronutrients are required in relatively smaller quantities for plant growth, they are as important as macronutrients. If any element is lacking in the soil or not adequately balanced with other nutrients, growth suppression or even complete inhibition may result (Mengel *et al.,* 2001). Micronutrients often act as cofactors in enzyme systems and participate in redox reactions, in addition to having several other vital functions in plants. Most importantly, micronutrients are involved in the key physiological processes of photosynthesis and respiration (Marschner, 1995; Mengel *et al.,* 2001) and their deficiency can impede these vital physiological processes thus limiting yield gain.

Zn is an essential micronutrient involved in a wide variety of physiological processes and it plays an important role in several plant metabolic processes; it activates enzymes and is involved in protein synthesis and carbohydrate, nucleic acid and lipid metabolism (Marshner, 1986; Pahlsson, 1989). However, like other heavy metals when Zn is accumulated in excess in plant tissues, it causes alterations in vital growth processes such as photosynthesis and chlorophyll biosynthesis (Doncheva *et al*., 2001) and membrane integrity (De Vos *et al*., 1991). Within plants Zn seems to affect the capacity for water uptake and transport (Barcelo and Poschenrieder, 1990; Kasim, 2007; Disante *et al*., 2010) and to reduce the adverse effects of short periods of heat stress (Peck and McDonald, 2010) or of salt stress (Tavallali *et al*., 2010). Since Zn is required for the synthesis of tryptophan (Brown *et al*., 1993; Alloway, 2004), which is a precursor of IAA, this metal also has an active role in the production of auxin, an essential growth hormone (Brennan, 2005). An excess of Zn has been reported to have a negative effect on mineral nutrition (Chaoui *et al*., 1997). In several crops, higher soil phosphorus (P) contents may induce Zn deficiency (Chang, 1999; Foth and Ellis, 1997). Zinc (Zn) deficiency is a major yield-limiting factor in several Asian countries (Rehman *et al.*, 2012).

Boron is one of the essential micronutrients required for plant growth and productivity. It plays an important role in cell wall synthesis, RNA metabolism, and root elongation as well as phenol metabolism. Also, boron involved in pollen and tube growth as mentioned by (Marschner, 1995; Srivastava and Gupta, 1996). Fageria *et al.* (2007) found that boron application significantly increased common bean yield. Mary *et al.* (1990) observed that foliar application of boron resulted increase in the number of pods/branches, increased the number of seeds/plant and seed yield/plant. Kalyani *et al*. (1993) observed that boron applied as boric acid increased the plant height, relative growth rate, net assimilation rate and leaf area index in pea. The response of pea to boron application varied from 167 to 182 kg/ha with 2 kg B/ha (Sakal *et al*., 1995). Photosynthetic activity and metabolic activity enhanced with application of boron (Lalit Bhott *et al.*, 2004, Sathya *et al.*, 2009). Boron's involvement in hormone synthesis and translocation, carbohydrate metabolisms and DNA synthesis probably contributed to additional growth and yield (Ratna Kalyani *et al*., 1993) Born is a micronutrient essential for normal growth of pollen grains, sugar translocation and movement of growth regulators within the plant (Hamasa and Putaiah, 2012). Deficiency of B causes severe reductions in crop yield, due to severe disturbances in B-involving metabolic processes, such as metabolism of nucleic acid, carbohydrate, protein and indole acetic acid, cell wall synthesis, membrane integrity and function, and phenol metabolism (Dell and Huang, 1997; Tanaka and Fujiwar, 2008).

Hence, an experiment was conducted with different levels of zinc and boron application for motorshuti cultivation with the following objectives:

a. To find out the optimum dose of Zn and B on the growth and yield of motorshuti;

b. To find out the interaction effect of Zn and B on the growth and yield of motorshuti;

c. To assess the concentration of different nutrients by pods and stover for different levels of Zn and B.

CHAPTER II

REVIEW OF LITERATURE

In Bangladesh and in many countries of the world garden pea is an important pulse crop. The crop has conventional less attention by the researchers on various aspects because normally it grows without/less care or management practices. Based on this a very few research work related to growth and yield of garden pea especially using of micronutrients have been carried out in our country. However, researches are going on in home and abroad to maximize the yield of garden pea. Micronutrients play an important role in improving garden pea growth and yield. But research works related to micronutrients especially zinc and boron are limited in Bangladesh context. However, some of the important and informative works and research findings related to the zinc and boron so far been done at home and abroad have been reviewed in this chapter under the following headings-

2.1 Influence of zinc on growth and yield of pea and other pulse crop

Kumar *et al*. (2014) conducted an experiment to evaluate the effect of inorganic, organic and biofertlizers on growth, yield and economics of garden pea. The seed inoculation with biofertilizers + zinc @ 5 kg ha^{-1} gave the significantly higher growth and yield attributes; seed yield (10.73 and 11.97 q ha^{-1}), stover yield (19.65 and 21.15 q ha^{-1}) and biological yield (30.56 and 33.13 q ha^{-1}) in both the years, respectively. In both the years, gross return (Rs. 36131 and 40151), net return (Rs. 24495 and 28515), B: C ratio (2.07 and 2.42), production efficiency (9.67 and 10.99 kg day^{-1} ha^{-1}) and economic efficiency (Rs. 221 and 262 day^{-1} ha^{-1}) were obtained with the combined applied of biofertilizers + zinc @ 5 kg ha^{-1}.

The effects of Zn deficiency on antioxidant responses of two pea (*Pisum sativum* L.) genotypes, a Zn-efficient IPFD-99-13 and Zn-inefficient KPMR-500, grown in sand culture were studied by Pandey *et al*. (2012). In the pea genotype KPMR-500, Zn deficiency decreased dry matter yield, tissue Zn concentration, and antioxidant enzyme activities stronger than in the genotype IPFD-99-13. Zinc deficiency produced oxidative damage to pea genotypes due to enhanced accumulation of TBARS and H_2O_2 and decreased activities of antioxidant enzymes (Cu/Zn superoxide dismutase (SOD), catalase (CAT), peroxidase (POD), and ascorbate peroxidase (APX)). In the leaves of IPFD-99-13 genotype, the higher activity of ROS-scavenging enzyme, e.g., SOD, CAT, POD, and glutathione reductase, and antioxidants, such as ascorbate and non-protein thiols, led to the lower accumulation of H_2O_2 and lipid peroxides. These results suggest that, by maintaining an efficient antioxidant defense system, the IPFD-99-13 genotype shows a lower sensivity to Zn deficiency than the KPMR-500 genotype.

Two field experiments were carried out at EI-Bramoon Agricultural Research Farm of Mansoura Horticultural Research Station by El Sayed Hameda *et al*. (2012). The investigated effects of foliar spray with some microelements (Fe, Zn and Mn, 100 ppm) at different fertilizer sources (FYM, mineral fertilizer and control) and bio-fertilization with Rhizobium as well as their interactions on yield and yield components and chemical constituents of pea plant (*Pisum sativum*, L.) cv. Master-B. The foliar spraying pea plants with a mixture of microelements significantly increased yield components expressed as plant height, pod length, pod weight, number of green seeds/pod, weight of 100-green seed, seed index (1000-dry seed weight) and chemical constituents such as NPK, carbohydrates (%) and protein (%) of green seeds of pea plant in both seasons. The fertilization with FYM was the most reliable treatment compared with chemical fertilizer and control treatments.

An experiment was conducted by Alam *et al*. (2010) in the medium high land under irrigated situation at the Farming System Research and Development (FSRD) site, Elenga, Tangail during two consecutive years to evaluate the performance of different fertilizer treatment on garden pea varieties under farmers' field condition. Three verities viz. BARI Motor shuti-1 BARI Motor shuti-2 and BARI Motor shuti-3 were considered as first factor treatment. Fertilizer combination T_1: N_{50} P_{26} K_{42} S_{12} & T_2: N_{50} P_{26} K_{42} S_{12} + $B_{2.5}Mo_{2.5}$ $Zn_{2.5}$

kg/ha were taken as the second factor. BARI Motor shuti-1 and BARI motor shuti-2 along with the fertilizer dose N_{50}, P_{26} K_{42} S_{12} and 2.5 kg/ha of each Mo, B & Zn, produced the highest pod yield of 12.35 t/ha and 8.51 t/ha during 2006-07 and 2007-08 respectively.

Stoyanova and Doncheva (2002) conducted an experiment to study the influence of succinate treatment on Zn toxicity was investigated using plant growth and mineral uptake as stress indicators. Pea plants (*Pisum sativum* L., cv. Citrine) were treated with various Zn concentrations (0.67 to 700 mM Zn) in the presence and absence of 0.2 mM Na-succinate. Plants pre-treated with succinate and then exposed to Zn exhibited higher dry root, stem and leaf weight than the plants treated with Zn alone. The amount of Zn in the roots, stems and leaves increased with greater Zn rates. Lower Zn translocation in aboveground parts seemed to result from Zn complexing by organic anion in the roots. This probably caused less Zn transport to the stems and leaves and suggested that succinate has potential for complexing with Zn and may play a role in tolerance to high Zn levels.

Rizk and Abdo (2001) conducted two field experiments at Giza Experimental Station, ARC, Egypt to investigate the response of mungbean (*Vigna radiata*) with some micronutrients. Two cultivars of mungbean (V-2010 and VC-1000) were used in those investigations. Zn (0.2 or 0.4 g/l), Mn (1.5 or 2.0 g/l), B (3.0 or 5.0 g/l) and a mixture of Zn, Mn, and B (0.2, 1.5 and 3.0 g/l, respectively), in addition to distilled water as control were sprayed once at 35 days after sowing (DAS). All treatments increased significantly, yield and its components especially Zn (0.2 g/l) which showed a highly significant increase in all characters under investigation compared to the control. All adopted treatments increased significantly protein percentage in seeds of the two mungbean cultivars in both seasons. Among the treatments of micronutrients, B gave the highest percentage of crude protein.

2.2 Influence of boron on growth and yield of pea and other pulse crop

Moghazy *et al*. (2014) carried out an experiment to study the influence of a foliar application with boron and five levels of combinations between compost manure and mineral nitrogen fertilizer as well as their interaction on growth, yield and chemical composition of pea cv. Master B. The vegetative growth traits of green pea, i.e., plant length, number of leaves, number of branches, fresh weight per plant, relative growth rate, yields and its components had high significant values by foliar spraying with boron. The highest values of all vegetative growth traits, total yield, and yield components of pea, NPK content, protein % and total sugar as well as carbohydrate % in fresh seeds were obtained from a mixture of nitrogen fertilizer at levels 60 kg N fed^{-1} and compost at 2.5 ton fed^{-1}. It could be concluded that foliar spray with boron (boric acid 17% B) at 50 ppm with application of nitrogen fertilizer in compost form at 2.5 ton fed^{-1} and inorganic N-fertilizer at 60 kg fed^{-1} in pea field were the most effective treatment for improving quality and increasing yield.

Boron deficiency was established as the dominant nutritional problem causing flower and pod abortion. Banu (2003) reported that no pods or grains were formed in the absence of B in pea.

Rizk and Abdo (2001) conducted two field experiments at Giza Experimental Station, ARC, Egypt to investigate the response of mungbean (*Vigna radiata*) with some micronutrients. Two cultivars of mungbean (V-2010 and VC-1000) were used in those investigations. Zn (0.2 or 0.4 g/l), Mn (1.5 or 2.0 g/l), B (3.0 or 5.0 g/l) and a mixture of Zn, Mn, and B (0.2, 1.5 and 3.0 g/l, respectively), in addition to distilled water as control were sprayed once at 35 days after sowing (DAS). Among all treatments of micronutrients, B gave the highest percentage of crude protein. Seeds of mungbean cv. VC-1000 exceeded those of mungbean cv. V-2010 in crude protein percentage with significant difference in both seasons. In contrast, all sprayed treatments with micronutrients showed no statistical effect on the percentages of total carbohydrates, phosphorus and potassium in seeds of the two investigated mungbean cultivars in both seasons.

Liu et al. (2000) conducted an experiment on the effect of B and Mo stress on NR activity in leaves of three cultivars at different stages of growth and showed that NR activity was reduced due to boron and molybdenum toxicity.

Similarly, Srivastava *et al*. (1999) observed that the average grain yield of chickpea and other legume crops was 0.1 t ha^{-1} when B was not applied while the yield was 1.4 t ha^{-1} by the application of B 0.5 kg ha^{-1}. Further, plant growth, flowering and fruit development were also restricted by a shortage of B (Tisdale *et al*. 1999).

Verma and Mishra (1999) conducted a pot experiment with mungbean cv. PDM 54, boron was applied for seed treatment, soil application (basally or at flowering) or foliar spraying. It increased yield and growth parameters with the best results in terms of seed yield/plant when the equivalent of 5 kg borax/ha was applied at flowering stage.

Srivastava *et al*. (1997) reported that application of 0.5 kg B ha^{-1} optimally corrected the deficiency of B. They also found in a field experiment that at B-deficient soil, where no fertilizers, complete fertilizer (P, K, S, B, Zn, Mo, Cu, Mn and Fe) or the complete fertilizer minus each of the trace elements were applied flower abortion was the highest and no seed was produced in chickpea cv. Kalika in the treatment given no B.

Saha *et al*. (1996) carried out a field trial in pre-*Kharif* seasons of 1993-94 at Pundibari, India, yellow sarson was given 0, 2.5 or 5.0 kg borax and 0, 1 or 2 kg/ha of sodium molybdate was applied in soil, 66% soil + 33% foliar or foliar applications and the residual effects were studied on summer green gram [*Vigna radiata*]. In both years green gram seed yield was highest with a combination of 5 kg borax + 2 kg sodium molybdate. Soil application gave higher yields than foliar or soil + foliar application.

Boron has a beneficial effect on morphological characters in different crop plants. Sinha *et al.* (1994) conducted an experiment on the effect of B, Zn and Mo on morphological characters in lentil and showed that primary branch plant^{-1} and pods plant^{-1} increased significantly due to application of B. Srivastava (1994) reported that application of B increased the number of pods plant $^{-1}$ and grain yield in a susceptible chickpea variety, Kalika.

Nitrate reductase activity was lower when there was a B deficiency, especially when NO3 was present in the medium. Lin and Deng, (1992) applied B fertilizers at transplanting and observed that NR activity in leaves was increased.

The application of B fertilizer promoted the uptake of N, P and K in groundnut (Luo *et al*., 1990). Similarly, Luo *et al.* (1990) observed that B fertilizer application increased branches plant^{-1}, pods plant^{-1} in groundnut. On the contrary, uptake of Ca, K, P decreased with B application (Singh *et al*., 1990).

The possible effects of B on nitrate reductase (NR) activity were via the metabolism of nucleic acids and proteins (Kastori and Petrovic, 1989). The effect of variable levels of B-supply on nitrate reductase activity (NR) indicated that, both deficiency and high toxic levels of B-decreased the total N content and the activity of nitrate reductase in roots and shoots of sunflower plants. Yang *et al*. (1989) reported from their findings that application of B, N and K promoted growth, CO_2 assimilation, NR activity in rape seed leaves.

Sakal *et al*. (1988) reported that application of 2.0 and 2.5 kg B ha^{-1} increased grain yields of black gram and chickpea by 63% and 38%, respectively and a synergistic relationship between B and K was found in Black gram.

Dutta *et al.* (1984) reported that application of 1 Kg B ha^{-1} increased in leaf area ratio, leaf area index, number of leaves plant^{-1}, number of branches plant^{-1}, number of pods plant^{-1} mungbean.

Singh and Singh (1984) reported that the uptake of N, Na and B by grain and stover increased significantly with the application of boron in barley.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted during the period from November, 2013 to March 2014 to study the effect of zinc and boron on growth and yield of BARI motorshuti-1. This chapter includes materials and methods that were used in conducting the experiment are presented below under the following headings:

3.1 Experimental site

The experiment was conducted at the farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh. The experimental site is situated between $23^{0}74^{/}$N latitude and $90^{0}35^{/}$E longitude and at an elevation of 8.4 m from sea level (Anon., 1989).

3.2 Soil

The soil of the experimental site belongs to Tejgaon series under the Agro-ecological zone, Madhupur Tract (AEZ-28), which falls into Shallow Red Brown Terrace Soils. Soil samples were collected from the experimental plots to a depth of 0-15 cm from the surface before initiation of the experiment and analyzed in the laboratory. The soil was having a texture of silty clay with pH 5.6. The morphological characteristics of the experimental field and physical and chemical properties of initial soil are given in Table 1.

3.3 Climate

The climate of experimental site is subtropical, characterized by three distinct seasons, the monsoon from November to February and the pre-monsoon period or hot season from March to April and the monsoon period from May to October. The monthly average temperature, humidity and rainfall during the crop growing period were collected from Weather Yard, Bangladesh Meteorological Department, and presented in Appendix I.

Table 1. Characteristics of experimental field soil as analyzed by Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka

A. Morphological characteristics of the experimental field

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

B. Physical and chemical properties of the initial soil

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

Source: SRDI

3.4 Planting material

The variety BARI Motorshuti-1 was used as the test crop. The seeds were collected from the Agronomy Division of Bangladesh Agricultural Research Institute, Joydebpur, Gazipur. BARI Motorshuti-1 was the released variety of Motorshuti, which was recommended by the national seed board. Green pod of this variety may harvest within 70-75 days as green pods and highest pod yield of 10-12 t ha^{-1} may be harvest if cultivated following modern technology.

3.5 Land preparation

The land was irrigated before ploughing. After having 'zoe' condition the land was first opened with the tractor drawn disc plough. Ploughed soil was brought into desirable fine tilth by 4 ploughing and cross-ploughing, harrowing and laddering. The stubble and weeds were removed. The first ploughing and the final land preparation were done on 17th and 27th December, 2013, respectively. Experimental land was divided into unit plots following the design of experiment.

3.6 Treatments of the experiment

The experiment comprised of two factors

Factor A: Levels of zinc (4 levels)

i) Zn_0: 0 kg Zn ha^{-1} (control)

ii) Zn_1: 1.5 kg Zn ha^{-1}

iii) Zn_2: 2.5 kg Zn ha^{-1}

iv) Zn_3: 3.5 kg Zn ha^{-1}

Factors B: Levels of boron (3 levels)

i) B_0: 0 kg B ha^{-1} (control)

ii) B_1: 1.5 kg B ha^{-1}

iii) B_2: 2.5 kg B ha^{-1}

There were in total 12 (4×3) treatment combinations such as Zn_0B_0, Zn_0B_1, Zn_0B_2, Zn_1B_0, Zn_1B_1, Zn_1B_2, Zn_2B_0, Zn_2B_1, Zn_2B_2, Zn_3B_0, Zn_3B_1 and Zn_3B_2.

3.7 Fertilizer application

Urea, Triple super phosphate (TSP), Muriate of potash (MoP), gypsum, zinc sulphate and boric acid were used as a source of nitrogen, phosphorous, potassium, gypsum, sulphur, zinc and boron, respectively. Urea, Triple super phosphate (TSP), Muriate of potash (MoP) and gypsum were applied at the rate of 90, 60, 60 and 40 kg hectare^{-1}, respectively following the Bangladesh Agricultural Research Institute (BARI) recommendation and zinc & boron were applied as per treatment. All of the fertilizers except urea were applied during final land preparation.

3.8 Experimental design and layout

The two factors experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. An area of 25.5 m × 11.5 m was divided into blocks. The two varieties were assigned in the main plot and five supplementary treatments in sub-plot. The size of the each unit plot was 2.5 m × 1.5 m. The space between two blocks and two plots were 1.0 m and 0.5 m, respectively. The layout of the experiment is shown in Figure 1.

3.9 Sowing of seeds in the field

The seeds of motorshuti were sown on November 27, 2013 in solid rows in the furrows having a depth of 2-3 cm and row to row distance was 30 cm.

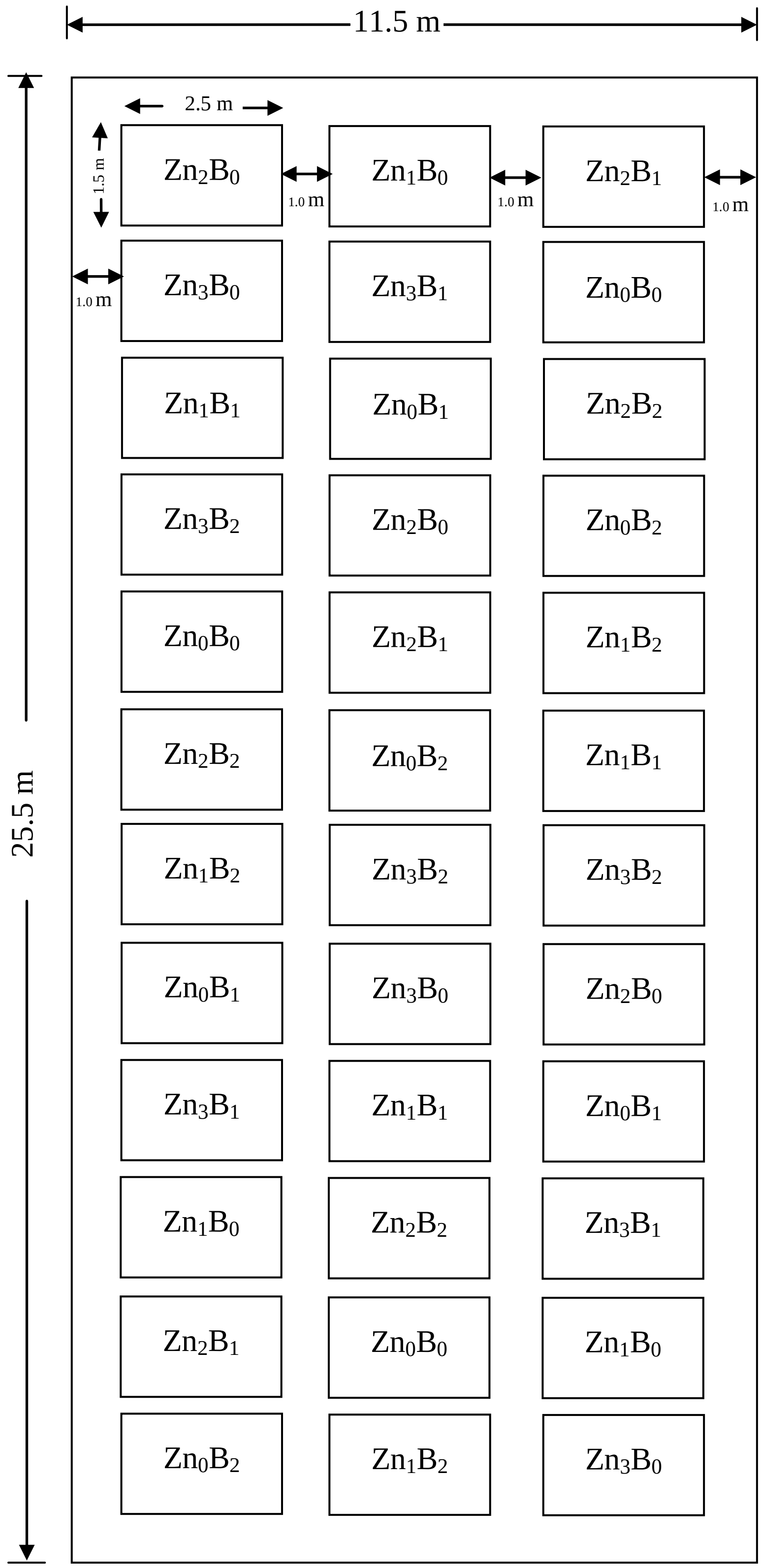
3.10 Intercultural operations

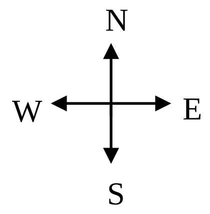
3.10.1 Thinning

Seeds started germination of four Days After Sowing (DAS). Thinning was done two times; first thinning was done at 8 DAS and second was done at 15 DAS to maintain optimum plant population in each plot.

3.10.2 Irrigation and weeding

Irrigation was provided before 30 and 45 DAS for optimizing the vegetative growth of motorshuti for the all experimental plots equally. The crop field was weeded as per necessary.





Plot size: 2.5 m × 1.5 m

Plot spacing: 0.50 m

Between block: 1.00 m

Factor A: Levels of zinc (4 levels)

Zn_0: 0 kg Zn ha^{-1} (control)

Zn_1: 1.5 kg Zn ha^{-1}

Zn_2: 2.5 kg Zn ha^{-1}

Zn_3: 3.5 kg Zn ha^{-1}

Factors B: Levels of boron (3 levels)

B_0: 0 kg B ha^{-1} (control)

B_1: 1.5 kg B ha^{-1}

B_2: 2.5 kg B ha^{-1}

Figure 1. Layout of the experimental plot

3.10.3 Protection against insect and pest

At early stage of growth few worms (*Agrotis ipsilon*) infested the young plants and at later stage of growth pod borer (*Maruca testulalis*) attacked the plant. Ripcord 10 EC was sprayed at the rate of 1 mm with 1 litre water for two times at 15 days interval after seedlings germination to control the insects.

3.11 Crop sampling and data collection

Five plants from each treatment were randomly selected and marked with sample card. Plant height, were recorded from selected plants at 10 days interval started from 20 DAS to 60 DAS and final harvesting of pod at 70 DAS.

3.12 Harvest and post harvest operations

Harvesting was done when 90% of the pods became mature to harvest**.** The matured pods were collected by hand picking from a pre demarcated area of 6.4 m^2 at the center of each plot.

3.13 Data collection

The following data were recorded

i. Plant height

ii. Pod length (cm)

iii. Number of pods $plant^{-1}$

iv. Number of seeds pod^{-1}

v. Weight of 1000 seeds (g)

vi. Seed yield $plant^{-1}$

vii. Stover yield $plant^{-1}$

viii. Seed yield $hectare^{-1}$

ix. Stover yield $hectare^{-1}$

x. N, P, K, S, Zn and B concentration of seeds and stover sample

xi. pH, organic matter, available Zn and B in post harvest soil

3.14 Procedure of data collection

3.14.1 Plant height

The plant height was measured at 20, 30, 40, 50, 60 DAS and at harvest with a meter scale from the ground level to the top of the plants and the mean height was expressed in cm.

3.14.2 Pod length

Pod length was taken of randomly selected ten pods and the mean length was expressed on pod^{-1} basis.

3.14.3 Number of pods plant^{-1}

Numbers of total pods of selected plants from each plot were counted and the mean numbers were expressed as plant^{-1} basis. Data were recorded as the average of 10 plants selected at random from the inner rows of each plot.

3.14.4 Number of seeds pod^{-1}

The number of seeds pods^{-1} was recorded from randomly selected 10 pods at the time of harvest. Data were recorded as the average of 10 pods from each plot.

3.14.5 Weight of 1000 seeds

One thousand cleaned, dried seeds were counted from each harvest sample and weighed by using a digital electric balance and weight was expressed in gram (g).

3.14.6 Seed yield plant^{-1}

The seeds from green pods were collected from 10 selected plants and weighted by a digital weighing machine and then converted the weight of five plants into per plant and expressed in gram.

3.14.7 Stover yield plant^{-1}

The stover was collected from 10 selected plants and weighted by a digital weighing machine and then converted the weight of five plants into per plant and expressed in gram.

3.14.8 Seed yield hectare^{-1}

The seeds collected from 3.75 (2.5 m ×1.5 m) square meter of each plot were cleaned. The weight of seeds was taken and converted the yield in t ha^{-1}.

3.14.9 Stover yield hectare^{-1}

The stover collected from 3.75 (2.5 m ×1.5 m) square meter of each plot was sun dried properly. The weight of stover was taken and converted the yield in t ha^{-1}.

3.15 Chemical analysis of seed and stover samples

3.15.1 Collection of samples

Seeds and stover samples were collected after threshing and finely ground by using a Wiley-Mill with stainless contact points to pass through a 60-mesh sieve. The samples were stored in plastic vial for analyses of N, P, K, S, Zn and B.

3.15.2 Preparation of samples

The plant samples were dried in an oven at 70^0C for 72 hours and then ground by a grinding machine to pass through a 20-mesh sieve. The seeds and stover samples were analyzed for determination of N, P, K, S, Zn and B concentrations as follows:

3.15.3 Digestion of samples with sulphuric acid for N

For the determination of nitrogen an amount of 0.2 g oven dry, ground sample were taken in a micro kjeldahl flask. 1.1 g catalyst mixture (K_2SO_4: $CuSO_4$. $5H_2O$: Se in the ratio of 100: 10: 1), and 5 ml conc. H_2SO_4 were added. The flasks were heating at 120^0C and added 2.5 ml 30% H_2O_2 then heated was continued at 180^0C until the digests became clear and colorless. After cooling, the content was taken into a 100 ml volumetric flask and the volume was made up to the mark with de-ionized water. A reagent blank was prepared in a similar manner. Nitrogen in the digest was estimated by distilling the digest with 10 N NaOH followed by titration of the distillate trapped in H_3BO_3 indicator solution with 0.01N H_2SO_4.

3.15.4 Digestion of samples with nitric-perchloric acid for P, K, S and Zn

A sub sample weighing 0.5 g was transferred into a dry, clean 100 ml digestion vessel. Ten ml of di-acid (HNO_3: $HClO_4$ in the ratio 2:1) mixture was added to the flask. After leaving for a while, the flasks were heated at a temperature slowly raised to 200^0C. Heating were stopped when the dense white fumes of $HClO_4$ occurred. The content of the flask were boiled until they were became clean and colorless. After cooling, the content was taken into a 100 ml volumetric flask and the volume was made up to the mark with de-ionized water. P, K, S, Zn and B were determined from this digest.

3.15.5 Determination of P, K, S, Zn and B from samples

3.15.5.1 Phosphorus

Phosphorus was digested from the plant sample (seeds and stover) with 0.5 M $NaHCO_3$ solutions, pH 8.5 (Olsen *et al.*, 1954). Phosphorus in the digest was determined by using 1 ml for seeds sample and 2 ml for stover sample from 100 ml extract was then determined by developing blue color with reduction of phosphomolybdate complex and the color intensity were measured colorimetrically at 660 nm wavelength and readings were calibrated with the standard P curve (Page *et al*., 1982).

3.15.5.2 Potassium

Five milli-liter of digest sample for the seeds and 10 ml for the stover were taken and diluted 50 ml volume to make desired concentration so that the absorbance of sample were measured within the range of standard solutions. The absorbance was measured by atomic absorption flame photometer.

3.15.5.3 Sulphur

Sulphur content was determined from the digest of the plant samples (seeds and stover) with $CaCl_2$ (0.15%) solution as described by (Page *et al*., 1982). The digested S was determined by developing turbidity by adding acid seed solution (20 ppm S as K_2SO_4 in 6N HCl) and $BaCl_2$ crystals. The intensity of turbidity was measured by spectrophotometer at 420 nm wavelengths (Hunter, 1984).

3.15.5.4 Zinc

Zinc content was determined from the digest of the seeds and stover samples (with $BaCl_2$ solution as described by Page *et al.*, 1982. The digested Zn was determined by developing turbidity by adding $ZnCl_2$ seeds and stover solution. The intensity of turbidity was measured by spectrophotometer at 420 nm wavelengths (Hunter, 1984).

3.15.5.5 Boron

For B, the extractant of $CaH_4(PO_4)_2$, HCl and phenol was used (Hunter, 1980). Boron concentration was measured by adding 2 ml Curcumin solution plus 0.5 ml concentrated H_2SO_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 Post harvest soil sampling

After harvest of crop soil samples were collected from each plot at a depth of 0 to 15 cm. Soil samples of each plot was air-dried, crushed and passed through a two mm (10 meshes) sieve. The soil samples were kept in plastic container to determine the physical and chemical properties of soil.

3.17 Soil analysis

Soil samples were analyzed for both physical and chemical characteristics viz. pH, organic matter Zn and B contents. The soil samples were analyzed by the following standard methods as follows:

3.17.1 Soil pH

Soil pH was measured with the help of a glass electrode pH meter, the soil water ratio being maintained at 1: 2.5 as described by Page *et al.*, 1982.

3.17.2 Organic matter

Organic carbon in soil sample was determined by wet oxidation method. The underlying principle was used to oxidize the organic matter with an excess of 1N $K_2Cr_20_7$ in presence of conc. H_2SO_4 and conc. H_3PO_4 and to titrate the excess

$K_2Cr_20_7$ solution with 1N $FeSO_4$. To obtain the content of organic matter was calculated by multiplying the percent organic carbon by 1.73 (Van Bemmelen factor) and the results were expressed in percentage (Page *et al.*, 1982).

3.17.3 Available Zinc

Available Zn content was determined by extracting the soil with $ZnCl_2$ solution as described by Page *et al*., 1982. The digested Zn was determined by developing turbidity by adding $ZnCl_2$ solution. The intensity of turbidity was measured by spectrophotometer at 420 nm wavelengths (Hunter, 1984).

3.17.4 Available Boron

For available B, the extractant composed of $CaH_4(PO_4)_2$, HCl and phenol was used (Hunter, 1980). Boron concentration was measured by adding 2 ml Curcumin solution plus 0.5 ml concentrated H_2SO_4 and 15 ml Methanol (Meth: water = 3:2) solution before taking reading. The concentration in the soil extract was read at 555 nm wave length in a double beam spectrophotometer (Model No. 200-20, Hitachi, Japan).

3.18 Statistical analysis

The data obtained for different parameters were statistically analyzed to find out the significant difference of different levels of zinc and boron. The mean values of all the characters were calculated and analysis of variance was performed by the 'F' (variance ratio) test. The significance of the difference among the treatment means was estimated by the Least Significant Difference (LSD) at 5% level of probability (Gomez and Gomez, 1984).

CHAPTER IV

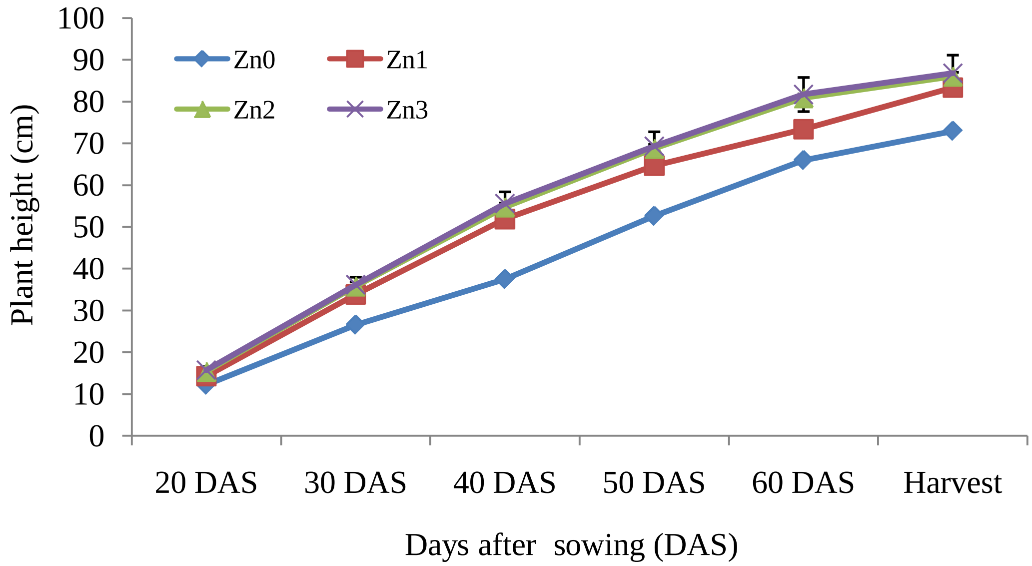
RESULTS AND DISCUSSION

The experiment was conducted to study the effect of zinc and boron on growth and yield of BARI motorshuti-1. Data on different growth parameter, yield, nutrient concentration in seeds and stover and characteristics of post harvest soil was recorded. The analyses of variance (ANOVA) of the data on different recorded parameters are presented in Appendix II-VI. The findings of the experiment have been presented and discusses with the help of table and graphs and possible interpretations were given under the following headings:

4.1 Yield contributing characters and yield

4.1.1 Plant height

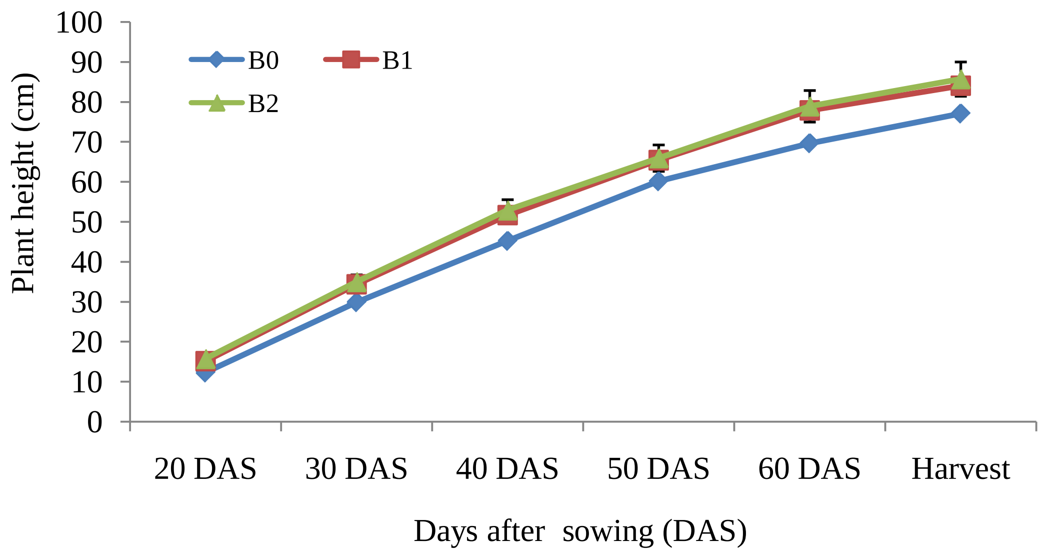
Different levels of zinc showed statistically significant variation on plant height of BARI motorshuti-1 at 20, 30, 40, 50, 60 days after sowing (DAS) and at harvest (Appendix II). At 20, 30, 40, 50, 60 DAT and at harvest, the tallest plant (15.75, 36.15, 55.60, 69.29, 81.67 and 86.76 cm, respectively) were observed from Zn_3 (3.5 kg Zn ha^{-1}), which were statistically identical (15.40, 35.81, 54.71, 68.72, 80.82 and 85.98 cm, respectively) with Zn_2 (2.5 kg Zn ha^{-1}) and closely followed (14.30, 33.82, 51.89, 64.68, 73.38 and 83.34 cm, respectively) by Zn_1 (1.5 kg Zn ha^{-1}), whereas the shortest plant (12.23, 26.59, 37.50, 52.60, 65.96 and 72.94 cm, respectively) were observed from Zn_0 (0 kg Zn ha^{-1}) (Figure 2). From Data revealed that with the increase of application of zinc nutrients plant height showed increasing trend. Zinc ensured the availability of other macro and micro nutrients that created a favorable condition for the growth of motorshuti with optimum vegetative growth and the ultimate results was the tallest plant. Zn is accumulated in plant tissues, it causes alterations in vital growth processes such as photosynthesis and chlorophyll biosynthesis and ultimate results was the elongation of plant (Stoyanova and Doncheva, 2002). Alam *et al*. (2010) reported longest plant with the application of 2.5 kg Zn ha^{-1} in earlier experiment.



Zn_0: 0 kg Zn ha^{-1} (control) Zn_1: 1.5 kg Zn ha^{-1}

Zn_2: 2.5 kg Zn ha^{-1} Zn_3: 3.5 kg Zn ha^{-1}

Figure 2. Effect of different levels of zinc on plant height of BARI motorshuti-1



B_0: 0 kg B ha^{-1} (control) B_1: 1.5 kg B ha^{-1}

B_2: 2.5 kg B ha^{-1}

Plant height of BARI motorshuti-1 varied significantly due to different levels of boron at 20, 30, 40, 50, 60 DAS and at harvest (Appendix II). At 20, 30, 40, 50, 60 DAS and at harvest, the tallest plant (15.76, 34.99, 52.89, 65.93, 78.89 and 85.69 cm, respectively) were recorded from B_2 (2.5 kg B ha^{-1}) which were statistically similar (15.18, 34.39, 51.67, 65.43, 77.86 and 84.04 cm, respectively) with B_1 (1.5 kg B ha^{-1}), while the shortest plant (12.32, 29.90, 45.21, 60.11, 69.62 and 77.04 cm, respectively) from B_0 (0 kg B ha^{-1}) (Figure 3). It was revealed that with the increase of boron fertilizer, plant height increased upto the highest level of boron that was applied. Tisdale *et al.* 1999 reported that plant growth was restricted by a shortage of B.

Statistically significant variation was recorded due to the interaction effect of different levels of zinc and born on plant height of BARI motorshuti-1 at 20, 30, 40, 50, 60 DAS and at harvest (Appendix II). At 20, 30, 40, 50, 60 DAS and at harvest, the tallest plant (17.72, 39.29, 60.46, 73.75, 86.60 and 91.50 cm, respectively) were observed from Zn_3B_2 (3.5 kg Zn ha^{-1} and 2.5 kg B ha^{-1}) and the shortest plant (10.37, 25.18, 35.38, 51.36, 60.19 and 69.40 cm, respectively) were found from Zn_0B_0 (0 kg Zn ha^{-1} and 0 kg B ha^{-1}) treatment combination (Table 2). El Sayed Hameda *et al.* (2012) reported that foliar spraying pea plants with a mixture of microelements significantly increased yield components expressed as plant height.

4.1.2 Pod length

Pod length of BARI motorshuti-1 showed statistically significant variation due to different levels of zinc (Appendix III). The longest pod (7.27 cm) was recorded from Zn_3 (3.5 kg Zn ha^{-1}), which were statistically identical (7.11 cm) with Zn_2 (2.5 kg Zn ha^{-1}) and closely followed (6.49 cm) by Zn_1 (1.5 kg Zn ha^{-1}), while the shortest pod (5.61 cm) was found from Zn_0 (0 kg Zn ha^{-1}) (Table 3). Rizk and Abdo (2001) reported that yield components showed a highly significant increase with the application of Zn (0.2 or 0.4 g/l) compared to the control. Kumar *et al.* (2014) reported that seed inoculation with zinc @ 5 kg ha^{-1} gave the significantly higher growth and yield attributes.

Table 2. Interaction effect of zinc and boron on plant height of BARI motorshuti-1

Treatment	Plant height (cm) at					
	20 DAS	**30 DAS**	**40 DAS**	**50 DAS**	**60 DAS**	**Harvest (70 DAS)**
Zn_0B_0	10.37 f	25.18 e	35.38 d	51.36 g	60.19 e	69.40 f
Zn_0B_1	13.13 de	28.05 de	39.65 d	55.53 fg	70.43 cd	76.37 de
Zn_0B_2	13.19 de	26.55 e	37.48 d	50.91 g	67.25 d	73.05 ef
Zn_1B_0	13.27 de	30.04 cd	46.35 c	60.36 ef	68.55 d	77.84 de
Zn_1B_1	14.98 c	35.68 b	54.59 b	67.16 b-d	75.65 b	84.70 bc
Zn_1B_2	14.64 cd	35.74 b	54.73 b	66.52 cd	75.94 b	87.49 ab
Zn_2B_0	12.65 e	32.10 c	48.82 c	63.79 de	74.55 bc	79.95 cd
Zn_2B_1	16.07 bc	36.94 ab	56.40 ab	69.82 a-c	82.15 a	87.26 ab
Zn_2B_2	17.49 ab	38.39 ab	58.90 ab	72.54 ab	85.77 a	90.72ab
Zn_3B_0	13.01 e	32.27 c	50.28 c	64.93 c-e	75.21 bc	80.95 cd
Zn_3B_1	16.52 ab	36.89 ab	56.04 ab	69.19 a-d	83.20 a	87.81 ab
Zn_3B_2	17.72 a	39.29 a	60.46 a	73.75 a	86.60 a	91.50 a
$LSD_{(0.05)}$	**1.443**	**3.101**	**4.126**	**5.241**	**4.647**	**5.502**
Level of Significance	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**
CV(%)	**5.91**	**5.53**	**4.88**	**5.96**	**4.64**	**6.95**

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

Zn_0: 0 kg Zn ha^{-1} (control)
B_0: 0 kg B ha^{-1} (control)
Zn_1: 1.5 kg Zn ha^{-1}
B_1: 1.5 kg B ha^{-1}
Zn_2: 2.5 kg Zn ha^{-1}
B_2: 2.5 kg B ha^{-1}
Zn_3: 3.5 kg Zn ha^{-1}

Table 3. Effect of zinc and boron on yield contributing characters and yield of BARI motorshuti-1

Treatment	Pod length (cm)	Seeds pod^{-1} (No.)	Seed yield $plant^{-1}$ (g)	Weight of stover $plant^{-1}$ (g)	Seed yield $hectare^{-1}$ (ton)	Weight of stover $hectare^{-1}$ (ton)
Levels of zinc						
Zn_0	5.61 c	5.23 c	6.07 c	10.10 c	6.00 c	10.65 c
Zn_1	6.49 b	6.43 b	7.31 b	11.75 b	7.16 b	12.95 b
Zn_2	7.11 a	7.67 a	7.66 a	12.19 ab	7.72 a	13.74 a
Zn_3	7.27 a	7.80 a	7.73 a	12.51 a	7.98 a	13.96 a
$LSD_{(0.05)}$	**0.439**	**0.542**	**0.336**	**0.640**	**0.418**	**0.646**
Level of Significance	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**
Levels of boron						
B_0	5.72 b	5.79 b	6.05 b	10.58 b	6.15 b	11.89 b
B_1	6.98 a	7.15 a	7.73 a	12.05 a	7.64 a	13.15 a
B_2	7.16 a	7.41 a	7.79 a	12.28 a	7.86 a	13.42 a
$LSD_{(0.05)}$	**0.439**	**0.469**	**0.291**	**0.555**	**0.362**	**0.559**
Level of Significance	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**
CV(%)	**6.79**	**8.17**	**4.78**	**5.63**	**5.93**	**5.15**

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

Zn_0: 0 kg Zn ha^{-1} (control)

Zn_1: 1.5 kg Zn ha^{-1}

Zn_2: 2.5 kg Zn ha^{-1}

Zn_3: 3.5 kg Zn ha^{-1}

B_0: 0 kg B ha^{-1} (control)

B_1: 1.5 kg B ha^{-1}

B_2: 2.5 kg B ha^{-1}

Statistically significant variation was recorded in terms of pod length of BARI motorshuti-1 due to different levels of boron (Appendix III). The longest pod (7.16 cm) was obtained from B_2 (2.5 kg B ha^{-1}) which were statistically similar (6.98 cm) with B_1 (1.5 kg B ha^{-1}) and the shortest pod (5.72 cm) was recorded from B_0 (0 kg B ha^{-1}) (Table 3).

Interaction effect of different levels of zinc and born influenced significantly the pod length of BARI motorshuti-1 (Appendix III). The longest pod (8.04 cm) was recorded from Zn_3B_2 (3.5 kg Zn ha^{-1} and 2.5 kg B ha^{-1}), whereas the shortest pod (4.57 cm) was observed from Zn_0B_0 (0 kg Zn ha^{-1} and 0 kg B ha^{-1}) treatment combination (Table 4). El Sayed Hameda *et al*. (2012) reported that foliar spraying pea plants with a mixture of microelements significantly increased yield components expressed as pod length.

4.1.3 Number of pods plant^{-1}

Statistically significant variation was recorded due to different levels of zinc on number of pods plant^{-1} of BARI motorshuti-1 (Appendix III). The maximum number of pod plant^{-1} (26.19) was found from Zn_3 (3.5 kg Zn ha^{-1}), which were statistically identical (25.97) with Zn_2 (2.5 kg Zn ha^{-1}) and closely followed (24.93) by Zn_1 (1.5 kg Zn ha^{-1}). On the other hand, the minimum number of pods plant^{-1} (21.60) was recorded from Zn_0 (0 kg Zn ha^{-1}) (Figure 4). Kumar *et al*. (2014) reported that seed inoculation with zinc @ 5 kg ha^{-1} gave the significantly higher growth and yield attributes.

Different levels of boron showed significant variation in terms of number of pod plant^{-1} of BARI motorshuti-1 (Appendix III). The maximum number of pods plant^{-1} (26.58) was found from B_2 (2.5 kg B ha^{-1}) which were statistically similar (26.25) with B_1 (1.5 kg B ha^{-1}), whereas the minimum number (21.18) from B_0 (0 kg B ha^{-1}) (Figure 5). Tisdale *et al*. 1999 reported that fruits development was restricted by a shortage of B. Sinha *et al.* (1994) reported that pods plant^{-1} increased significantly due to application of B.

Table 4. Interaction effect of zinc and boron on yield contributing characters and yield of BARI motorshuti-1

Treatment	Pod length (cm)	Seeds pod^{-1} (No.)	Seed yield plant^{-1} (g)	Weight of stover plant^{-1} (g)	Seed yield hectare^{-1} (ton)	Weight of stover hectare^{-1} (ton)
Zn_0B_0	4.57 h	4.97 e	5.47 c	10.03 c	5.34 e	10.48 c
Zn_0B_1	6.72 c-e	5.70 de	6.50 b	10.12 c	6.57 cd	11.05 c
Zn_0B_2	5.54 g	5.03 e	6.23 b	10.17 c	6.09 c-e	10.42 c
Zn_1B_0	5.66 fg	5.33 e	6.07 b	10.72 c	5.86 de	11.21 c
Zn_1B_1	6.63 c-e	6.93 c	7.93 a	12.22 b	7.86 b	13.59 ab
Zn_1B_2	7.20 b-d	7.03 bc	7.93 a	12.32 ab	7.75 b	14.04 ab
Zn_2B_0	6.22 e-g	6.37 cd	6.23 b	10.50 c	6.62 cd	12.79 b
Zn_2B_1	7.23 a-d	7.97ab	8.26 a	12.95 ab	7.80 b	13.91 ab
Zn_2B_2	7.86 ab	8.67 a	8.48 a	13.13 ab	8.74 a	14.51 a
Zn_3B_0	6.44 d-f	6.50 cd	6.44 b	11.07 c	6.78 c	13.10 b
Zn_3B_1	7.34 a-c	8.00 ab	8.21 a	12.93 ab	8.33 ab	14.05 ab
Zn_3B_2	8.04 a	8.90 a	8.53 a	13.52 a	8.85 a	14.72 a
$LSD_{(0.05)}$	**0.761**	**0.938**	**0.582**	**1.109**	**0.724**	**1.118**
Level of Significance	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**
CV(%)	**6.79**	**8.17**	**4.78**	**5.63**	**5.93**	**5.15**

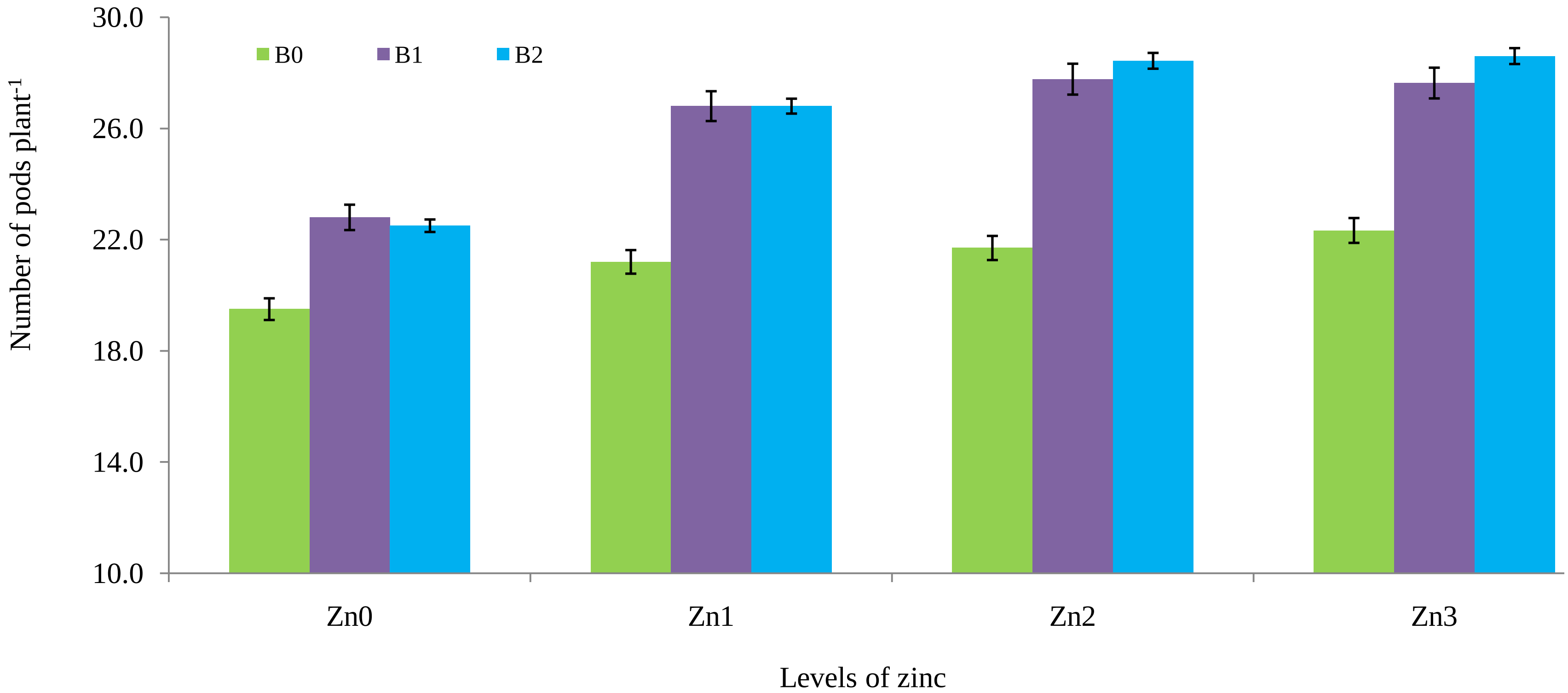
In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

Zn_0: 0 kg Zn ha^{-1} (control) — B_0: 0 kg B ha^{-1} (control)

Zn_1: 1.5 kg Zn ha^{-1} — B_1: 1.5 kg B ha^{-1}

Zn_2: 2.5 kg Zn ha^{-1} — B_2: 2.5 kg B ha^{-1}

Zn_3: 3.5 kg Zn ha^{-1}



Zn_0: 0 kg Zn ha^{-1} (control) Zn_1: 1.5 kg Zn ha^{-1} B_0: 0 kg B ha^{-1} (control) B_1: 1.5 kg B ha^{-1}

Zn_2: 2.5 kg Zn ha^{-1} Zn_3: 3.5 kg Zn ha^{-1} B_2: 2.5 kg B ha^{-1}

Figure 6. Interaction effect of different levels of zinc and boron on number of pods $plant^{-1}$ of BARI motorshuti-1. Vertical bars represent LSD value.

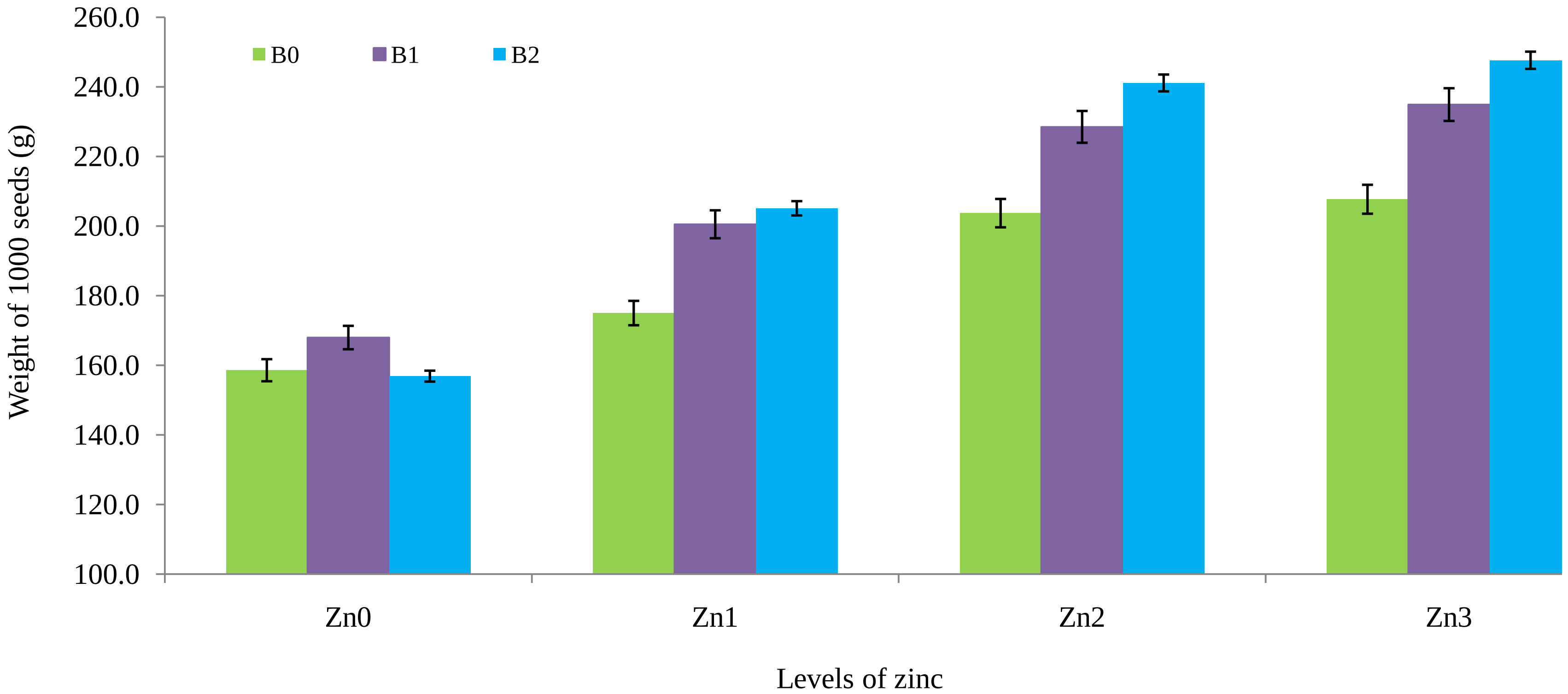
Number of pods plant^{-1} of BARI motorshuti-1 varied significantly due to the interaction effect of different levels of zinc and born (Appendix III). The maximum number of pods plant^{-1} (28.60) was found from Zn_3B_2 (3.5 kg Zn ha^{-1} and 2.5 kg B ha^{-1}), while the minimum number (19.50) was found from Zn_0B_0 (0 kg Zn ha^{-1} and 0 kg B ha^{-1}) treatment combination (Figure 6).

4.1.4 Number of seeds pod^{-1}

Different levels of zinc showed statistically significant variation on number of seeds pod^{-1} of BARI motorshuti-1 (Appendix III). The maximum number of seeds pod^{-1} (7.80) was recorded from Zn_3 (3.5 kg Zn ha^{-1}), which were statistically identical (7.67) with Zn_2 (2.5 kg Zn ha^{-1}) and closely followed (6.43) by Zn_1 (1.5 kg Zn ha^{-1}), while the minimum number of seeds pod^{-1} (5.23) was observed from Zn_0 (0 kg Zn ha^{-1}) (Table 3). Rizk and Abdo (2001) reported that yield components showed a highly significant increase with the application of Zn (0.2 or 0.4 g/l) compared to the control.

Number of seeds pod^{-1} of BARI motorshuti-1 varied significantly due to different levels of boron (Appendix III). The maximum number of seeds pod^{-1} (7.41) was found from B_2 (2.5 kg B ha^{-1}) which were statistically similar (7.15) with B_1 (1.5 kg B ha^{-1}) and the minimum number of seeds pod^{-1} (5.79) was obtained from B_0 (0 kg B ha^{-1}) (Table 3).

Statistically significant variation was recorded due to the interaction effect of different levels of zinc and born on number of seeds pod^{-1} of BARI motorshuti-1 (Appendix III). The maximum number of seeds pod^{-1} (8.90) was recorded from Zn_3B_2 (3.5 kg Zn ha^{-1} and 2.5 kg B ha^{-1}), again the minimum number of seeds pod^{-1} (4.97) was observed from Zn_0B_0 (0 kg Zn ha^{-1} and 0 kg B ha^{-1}) treatment combination (Table 4). El Sayed Hameda *et al*. (2012) reported that foliar spraying pea plants with a mixture of microelements significantly increased yield components expressed as number of green seeds/pod.



Zn_0: 0 kg Zn ha^{-1} (control) Zn_1: 1.5 kg Zn ha^{-1} B_0: 0 kg B ha^{-1} (control) B_1: 1.5 kg B ha^{-1}

Zn_2: 2.5 kg Zn ha^{-1} Zn_3: 3.5 kg Zn ha^{-1} B_2: 2.5 kg B ha^{-1}

Figure 9. Interaction effect of different levels of zinc and boron on weight of 1000 seeds BARI motorshuti-1. Vertical bars represent LSD value.

4.1.5 Weight of 1000 seeds

Statistically significant variation was recorded due to different levels of zinc in terms of weight of 1000 seeds of BARI motorshuti-1 (Appendix III). The highest weight of 1000 seeds (230.07 g) was observed from Zn_3 (3.5 kg Zn ha^{-1}), which were statistically identical (224.44 g) with Zn_2 (2.5 kg Zn ha^{-1}) and closely followed (193.54 g) by Zn_1 (1.5 kg Zn ha^{-1}), whereas the lowest weight of 1000 seeds (161.15 g) was observed from Zn_0 (0 kg Zn ha^{-1}) (Figure 7). Kumar *et al*. (2014) reported that seed inoculation with zinc @ 5 kg ha^{-1} gave the significantly higher growth and yield attributes.

Different levels of boron varied significantly for weight of 1000 seeds of BARI motorshuti-1 under the present trial (Appendix III). The highest weight of 1000 seeds (212.68 g) was recorded from B_2 (2.5 kg B ha^{-1}) which were statistically similar (207.97 g) with B_1 (1.5 kg B ha^{-1}), while the lowest weight of 1000 seeds (186.25 g) from B_0 (0 kg B ha^{-1}) (Figure 8).

Weight of 1000 seeds of BARI motorshuti-1 showed significant difference due to interaction effect of different levels of zinc and born (Appendix III). The highest weight of 1000 seeds (247.62 g) was observed from Zn_3B_2 (3.5 kg Zn ha^{-1} and 2.5 kg B ha^{-1}) and the lowest weight (158.59 g) from Zn_0B_0 (0 kg Zn ha^{-1} and 0 kg B ha^{-1}) treatment combination (Figure 9). El Sayed Hameda *et al*. (2012) reported that foliar spraying pea plants with a mixture of microelements significantly increased yield components expressed as weight of 100-green seed.

4.1.6 Seed yield plant^{-1}

Different levels of zinc showed statistically significant variation on seed yield plant^{-1} of BARI motorshuti-1 (Appendix III). The highest seed yield plant^{-1} (7.73 g) was recorded from Zn_3 (3.5 kg Zn ha^{-1}), which were statistically identical (7.66 g) with Zn_2 (2.5 kg Zn ha^{-1}) and closely followed (7.31 g) by Zn_1 (1.5 kg Zn ha^{-1}). On the other hand, the lowest seeds yield plant^{-1} (6.07 g) was found from Zn_0 (0 kg Zn ha^{-1}) (Table 3). Sakal *et al*. (1988) reported that application of 2.0 and 2.5 kg B ha^{-1} increased grain yields pea by 63 and 38%.

Seed yield plant^{-1} of BARI motorshuti-1 varied significantly due to different levels of boron (Appendix III). The highest seed yield plant^{-1} (7.79 g) was found from B_2 (2.5 kg B ha^{-1}) which were statistically similar (7.73 g) with B_1 (1.5 kg B ha^{-1}), whereas the lowest seed yield plant^{-1} (6.05 g) from B_0 (0 kg B ha^{-1}) (Table 3). Verma and Mishra (1999) reported best results in terms of seed yield/plant when the equivalent of 5 kg borax/ha was applied at flowering stage.

Statistically significant variation was recorded due to the interaction effect of different levels of zinc and born on seed yield plant^{-1} of BARI motorshuti-1 (Appendix III). The highest seed yield plant^{-1} (8.53 g) was obtained from Zn_3B_2 (3.5 kg Zn ha^{-1} and 2.5 kg B ha^{-1}), while the lowest seed yield plant^{-1} (5.47 g) was found from Zn_0B_0 (0 kg Zn ha^{-1} and 0 kg B ha^{-1}) treatment combination (Table 4).

4.1.7 Stover yield plant^{-1}

Stover yield plant^{-1} of BARI motorshuti-1 showed statistically significant variation due to different levels of zinc (Appendix III). Data revealed that the highest stover yield plant^{-1} (12.51 g) was observed from Zn_3 (3.5 kg Zn ha^{-1}), which were statistically identical (12.19 g) with Zn_2 (2.5 kg Zn ha^{-1}) and closely followed (11.75 g) by Zn_1 (1.5 kg Zn ha^{-1}), while the lowest stover yield plant^{-1} (10.10 g) was observed from Zn_0 (0 kg Zn ha^{-1}) (Table 3).

Statistically significant variation was recorded in term of stover yield plant^{-1} of BARI motorshuti-1 due to different levels of boron (Appendix III). The highest stover yield plant^{-1} (12.28 g) was recorded from B_2 (2.5 kg B ha^{-1}) which were statistically similar (12.05 g) with B_1 (1.5 kg B ha^{-1}) and the lowest stover yield plant^{-1} (10.58 g) from B_0 (0 kg B ha^{-1}) (Table 3).

Interaction effect of different levels of zinc and born showed statistically significant variation in terms of stover yield plant^{-1} of BARI motorshuti-1 (Appendix III). The highest stover yield plant^{-1} (13.52 g) was observed from Zn_3B_2 (3.5 kg Zn ha^{-1} and 2.5 kg B ha^{-1}), while the lowest stover yield plant^{-1} (10.03 g) was found from Zn_0B_0 (0 kg Zn ha^{-1} and 0 kg B ha^{-1}) treatment combination (Table 4). El Sayed Hameda *et al*. (2012) reported that foliar spraying pea plants with a mixture of microelements significantly increased yield components expressed as pod weight.

4.1.8 Seed yield hectare^{-1}

Different levels of zinc showed statistically significant variation on seed yield hectare^{-1} of BARI motorshuti-1 (Appendix III). The highest seed yield hectare^{-1} (7.98 ton) was recorded from Zn_3 (3.5 kg Zn ha^{-1}), which were statistically identical (7.72 ton) with Zn_2 (2.5 kg Zn ha^{-1}) and closely followed (7.16 ton) by Zn_1 (1.5 kg Zn ha^{-1}), whereas the lowest seed yield hectare^{-1} (6.00 ton) was found from Zn_0 (0 kg Zn ha^{-1}) (Table 3). Alam *et al*. (2010) reported that 2.5 kg ha^{-1} of each Zn produced the highest seeds yield of 8.51 t ha^{-1} during 2007-08. Kumar *et al*. (2014) reported that seed inoculation with zinc @ 5 kg ha^{-1} gave the significantly higher seed yield (11.97 q ha^{-1}).

Seed yield hectare^{-1} of BARI motorshuti-1 varied significantly due to different levels of boron (Appendix III). The highest seed yield hectare^{-1} (7.86 ton) was observed from B_2 (2.5 kg B ha^{-1}) which were statistically similar (7.64 ton) with B_1 (1.5 kg B ha^{-1}), while the lowest seed yield hectare^{-1} (6.15 ton) was observed from B_0 (0 kg B ha^{-1}) (Table 3). Moghazy *et al*. (2014) reported that foliar spray with boron (boric acid 17% B) at 50 ppm with application of nitrogen fertilizer in compost form at 2.5 ton fed^{-1} and inorganic N-fertilizer at 60 kg fed^{-1} in pea field were the most effective treatment for increasing yield. Srivastava *et al*. (1999) observed that the average grain yield of legume crops was 0.1 t ha^{-1} when B was not applied while the yield was 1.4 t ha^{-1} by the application of B 0.5 kg ha^{-1}.

Statistically significant variation was recorded due to the interaction effect of different levels of zinc and born on seed yield hectare^{-1} of BARI motorshuti-1 (Appendix III). The highest seed yield hectare^{-1} (8.85 ton) was found from Zn_3B_2 (3.5 kg Zn ha^{-1} and 2.5 kg B ha^{-1}) and the lowest seed yield hectare^{-1} (5.34 ton) was recorded from Zn_0B_0 (0 kg Zn ha^{-1} and 0 kg B ha^{-1}) treatment combination (Table 4).

4.1.9 Stover yield hectare^{-1}

Stover yield plant^{-1} of BARI motorshuti-1 varied significantly due to different levels of zinc (Appendix III). The highest stover yield hectare^{-1} (13.96 ton) was attained from Zn_3 (3.5 kg Zn ha^{-1}), which were statistically identical (13.74 ton) with Zn_2 (2.5 kg Zn ha^{-1}) and closely followed (12.95 ton) by Zn_1 (1.5 kg Zn ha^{-1}), while the lowest stover yield hectare^{-1} (10.65 ton) was found from Zn_0 (0 kg Zn ha^{-1}) (Table 3). Kumar *et al*. (2014) reported that seed inoculation with zinc @ 5 kg ha^{-1} gave the significantly higher straw yield (21.15 q ha^{-1}).

Statistically significant variation was recorded in terms of stover yield hectare^{-1} of BARI motorshuti-1 due to different levels of boron (Appendix III). The highest stover yield hectare^{-1} (13.42 ton) was observed from B_2 (2.5 kg B ha^{-1}) which were statistically similar (13.15 ton) with B_1 (1.5 kg B ha^{-1}), whereas the lowest stover yield hectare^{-1} (11.89 ton) was found from B_0 (0 kg B ha^{-1}) (Table 3).

Interaction effect of different levels of zinc and born showed statistically significant variation in terms of stover yield hectare^{-1} of BARI motorshuti-1 (Appendix III). The highest stover yield plant^{-1} (14.72 ton) was obtained from Zn_3B_2 (3.5 kg Zn ha^{-1} and 2.5 kg B ha^{-1}), while the lowest stover yield hectare^{-1} (10.48 ton) was recorded from Zn_0B_0 (0 kg Zn ha^{-1} and 0 kg B ha^{-1}) treatment combination (Table 4).

4.2 N, P, K, S, Zn and B concentration in seed and stover

4.2.1 N, P, K, S, Zn and B concentration in seed

Statistically significant variation was recorded for N, P, K, S, Zn and B concentration in seed due different levels of zinc (Appendix IV). The maximum concentration in seed for N (0.446%), P (0.212%), K (0.283%), S (0.160%), Zn (0.0184%) and B (0.0150%) were observed from Zn_3 (3.5 kg Zn ha^{-1}), whereas the minimum concentration in seed for N (0.318%), P (0.163%), K (0.203%), S (0.132%), Zn (0.0116%) and B (0.0115%) were found from Zn_0 (0 kg Zn ha^{-1}) (Table 5).

Table 5. Effect of zinc and boron on N, P, K, S, Zn and B concentrations in seeds of BARI motorshuti-1

Treatment	Concentration (%) in seeds					
	N	P	K	S	Zn	B
Levels of zinc						
Zn_0	0.318 c	0.163 c	0.203 c	0.132 c	0.0116 b	0.0115 b
Zn_1	0.388 b	0.180 b	0.245 b	0.144 b	0.0137 b	0.0134 ab
Zn_2	0.425 a	0.207 a	0.274 a	0.154 a	0.0170 a	0.0138 ab
Zn_3	0.446 a	0.212 a	0.283 a	0.160 a	0.0184 a	0.0150 a
$LSD_{(0.05)}$	**0.031**	**0.010**	**0.010**	**0.010**	**0.003**	**0.003**
Level of Significance	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**
Levels of boron						
B_0	0.351 c	0.180 b	0.210 c	0.128 b	0.0132 b	0.0114 b
B_1	0.401 b	0.194 a	0.267 b	0.155 a	0.0157 ab	0.0141 a
B_2	0.431 a	0.197 a	0.276 a	0.159 a	0.0166 a	0.0148 a
$LSD_{(0.05)}$	**0.027**	**0.008**	**0.008**	**0.008**	**0.003**	**0.003**
Level of Significance	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**
CV(%)	**8.61**	**4.73**	**7.90**	**5.05**	**5.75**	**5.50**

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

Zn_0: 0 kg Zn ha^{-1} (control)
Zn_1: 1.5 kg Zn ha^{-1}
Zn_2: 2.5 kg Zn ha^{-1}
Zn_3: 3.5 kg Zn ha^{-1}

B_0: 0 kg B ha^{-1} (control)
B_1: 1.5 kg B ha^{-1}
B_2: 2.5 kg B ha^{-1}

N, P, K, S, Zn and B concentration in seed showed statistically significant variation due to different levels of boron (Appendix IV). The maximum concentration in seeds for N (0.431%), P (0.197%), K (0.276%), S (0.159%), Zn (0.0166%) and B (0.0148%) were recorded from B_2 (2.5 kg B ha^{-1}) and the minimum concentration in seeds for N (0.351%), P (0.180%), K (0.210%), S (0.128%), Zn (0.0132%) and B (0.0114%) from B_0 (0 kg B ha^{-1} (Table 5).

Interaction effect of zinc and boron showed statistically significant variation in terms of N, P, K, S, Zn and B concentration in seeds (Appendix IV). The maximum concentration in seeds for N (0.497%), P (0.216%), K (0.320%), S (0.175%), Zn (0.0206%) and B (0.0160%) were observed from Zn_3B_2 (3.5 kg Zn ha^{-1} and 2.5 kg B ha^{-1}), while the minimum concentration in seeds for N (0.300%), P (0.162%), K (0.193%), S (0.121%), Zn (0.0103%) and B (0.0093%) were found from Zn_0B_0 (0 kg Zn ha^{-1} and 0 kg B ha^{-1}) treatment combination (Table 6). El Sayed Hameda *et al*. (2012) reported that foliar spraying pea plants with a mixture of microelements significantly increased chemical constituents such as NPK.

4.2.2 N, P, K, S, Zn and B concentration in stover

Different levels of zinc showed significant variation in terms of N, P, K, S, Zn and B concentration in stover (Appendix V). The maximum concentration in stover for N (0.376%), P (0.064%), K (1.419%), S (0.063%), Zn (0.0042%) and B (0.0026%) were found from Zn_3 (3.5 kg Zn ha^{-1}), while the minimum concentration in stover for N (0.279%), P (0.054%), K (1.084%), S (0.047%), Zn (0.0031%) and B (0.0015%) was recorded from Zn_0 (0 kg Zn ha^{-1}) (Table 7).

Statistically significant variation was found in terms of N, P, K, S, Zn and B concentration in stover due to different levels of boron (Appendix V). The maximum concentration in stover for N (0.368%), P (0.063%), K (1.327%), S (0.062%), Zn (0.0041%) and B (0.0026%) were found from B_2 (2.5 kg B ha^{-1}). On the other hand, the minimum concentration for N (0.274%), P (0.053%), K (1.192%), S (0.047%), Zn (0.0032%) and B (0.0017%) was recorded from B_0 (0 kg B ha^{-1} (Table 7).

Table 6. Interaction effect of zinc and boron on N, P, K, S, Zn and B concentrations in seeds of BARI motorshuti-1

Treatment	Concentration (%) in seeds					
	N	**P**	**K**	**S**	**Zn**	**B**
Zn_0B_0	0.300 e	0.162 c	0.193 e	0.121 e	0.0103 e	0.0093 b
Zn_0B_1	0.326 de	0.164 c	0.211 d	0.138 de	0.0127 c-e	0.0123 ab
Zn_0B_2	0.329 de	0.163 c	0.205 de	0.135 de	0.0116 de	0.0130 ab
Zn_1B_0	0.368 cd	0.165 c	0.216 d	0.127 e	0.0121 c-e	0.0116 ab
Zn_1B_1	0.391 bc	0.185 b	0.255 c	0.151 cd	0.0141 b-e	0.0139 ab
Zn_1B_2	0.404 bc	0.189 b	0.264 c	0.153 b-d	0.0147 a-e	0.0146 ab
Zn_2B_0	0.335 de	0.186 b	0.215 d	0.128 e	0.0137 b-e	0.0109 ab
Zn_2B_1	0.448 ab	0.214a	0.293 b	0.164 a-c	0.0180 a-c	0.0151 ab
Zn_2B_2	0.492 a	0.219 a	0.315 a	0.171 ab	0.0193 ab	0.0155 ab
Zn_3B_0	0.401 bc	0.207 a	0.217 d	0.137 de	0.0167 a-d	0.0137 ab
Zn_3B_1	0.440 ab	0.214 a	0.311 a	0.169 a-c	0.0179 a-c	0.0152 ab
Zn_3B_2	0.497 a	0.216 a	0.320 a	0.175 a	0.0206 a	0.0160 a
$LSD_{(0.05)}$	**0.054**	**0.017**	**0.017**	**0.017**	**0.005**	**0.005**
Level of Significance	**0.05**	**0.05**	**0.01**	**0.05**	**0.01**	**0.05**
CV(%)	**8.61**	**4.73**	**7.90**	**5.05**	**5.75**	**5.50**

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

Zn_0: 0 kg Zn ha^{-1} (control)
Zn_1: 1.5 kg Zn ha^{-1}
Zn_2: 2.5 kg Zn ha^{-1}
Zn_3: 3.5 kg Zn ha^{-1}

B_0: 0 kg B ha^{-1} (control)
B_1: 1.5 kg B ha^{-1}
B_2: 2.5 kg B ha^{-1}

Table 7. Effect of zinc and boron on N, P, K, S, Zn and B concentrations in stover of BARI motorshuti-1

Treatment	Concentration (%) in stover					
	N	P	K	S	Zn	B
Levels of zinc						
Zn_0	0.279 c	0.054 c	1.084 d	0.047 b	0.0031 b	0.0015 b
Zn_1	0.334 b	0.058 b	1.249 c	0.055 ab	0.0038 a	0.0024 a
Zn_2	0.354 ab	0.062 a	1.348 b	0.060 a	0.0039 a	0.0025 a
Zn_3	0.376 a	0.064 a	1.419 a	0.063 a	0.0042 a	0.0026 a
$LSD_{(0.05)}$	**0.031**	**0.003**	**0.044**	**0.010**	**0.0010**	**0.0010**
Level of Significance	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**
Levels of boron						
B_0	0.274 b	0.053 b	1.192 b	0.047 b	0.0032 b	0.0017 b
B_1	0.364 a	0.062 a	1.306 a	0.059 a	0.0040 a	0.0025 a
B_2	0.368 a	0.063 a	1.327 a	0.062 a	0.0041 a	0.0026 a
$LSD_{(0.05)}$	**0.027**	**0.003**	**0.038**	**0.008**	**0.0008**	**0.0008**
Level of Significance	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**
CV(%)	**7.34**	**4.30**	**6.27**	**8.35**	**5.77**	**5.54**

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

Zn_0: 0 kg Zn ha^{-1} (control) B_0: 0 kg B ha^{-1} (control)

Zn_1: 1.5 kg Zn ha^{-1} B_1: 1.5 kg B ha^{-1}

Zn_2: 2.5 kg Zn ha^{-1} B_2: 2.5 kg B ha^{-1}

Zn_3: 3.5 kg Zn ha^{-1}

N, P, K, S, Zn and B concentration in stover showed statistically significant differences due to the interaction effect of zinc and boron (Appendix V). The maximum concentration in stover for N (0.409%), P (0.068%), K (1.465%), S (0.071%), Zn (0.0046%) and B (0.0031%) were recorded from Zn_3B_2 (3.5 kg Zn ha^{-1} and 2.5 kg B ha^{-1}), while the minimum concentration in stover for N (0.239%), P (0.051%), K (1.025%), S (0.041%), Zn (0.0025%) and B (0.0011%) were observed from Zn_0B_0 (0 kg Zn ha^{-1} and 0 kg B ha^{-1}) treatment combination (Table 8). El Sayed Hameda *et al*. (2012) reported that foliar spraying pea plants with a mixture of microelements significantly increased chemical constituents such as NPK.

4.3 pH, organic matter, Zn and B in post harvest soil

4.3.1 pH

Different levels of zinc showed statistically significant variation in terms of pH in post harvest soil (Appendix VI). The highest pH in post harvest soil (6.72) was observed from Zn_3 (3.5 kg Zn ha^{-1}), which was statistically identical (6.60) with Zn_2 (2.5 kg Zn ha^{-1}) and closely followed (6.39) by Zn_1 (1.5 kg Zn ha^{-1}), while the lowest pH (6.12) was found from Zn_0 (0 kg Zn ha^{-1}) (Table 9).

Statistically significant variation was recorded for pH in post harvest soil due to different levels of boron (Appendix VI). The highest pH in post harvest soil (6.62) was recorded from B_2 (2.5 kg B ha^{-1}) which was statistically similar (6.52) with B_1 (1.5 kg B ha^{-1}), whereas the lowest pH (6.23) from B_0 (0 kg B ha^{-1}) (Table 9).

Interaction effect of different levels of zinc and boron showed significant variation on pH in post harvest soil (Appendix VI). The highest pH in post harvest soil (6.92) was observed from Zn_3B_2 (3.5 kg Zn ha^{-1} and 2.5 kg B ha^{-1}) and the lowest pH in post harvest soil (6.02) was found from Zn_0B_0 (0 kg Zn ha^{-1} and 0 kg B ha^{-1}) treatment combination (Table 10).

Table 8. Interaction effect of zinc and boron on N, P, K, S, Zn and B concentrations in stover of BARI motorshuti-1

Treatment	Concentration (%) in stover					
	N	**P**	**K**	**S**	**Zn**	**B**
Zn_0B_0	0.239 d	0.051 f	1.025 f	0.041 e	0.0025 b	0.0011 b
Zn_0B_1	0.303 c	0.056 c-f	1.131 de	0.050 b-e	0.0036 a	0.0022 a
Zn_0B_2	0.296 cd	0.054 d-f	1.097 ef	0.049 c-e	0.0034 a	0.0021 a
Zn_1B_0	0.268 cd	0.052 ef	1.177 d	0.046 de	0.0033 a	0.0021 a
Zn_1B_1	0.364 ab	0.060 bc	1.273 c	0.059 a-e	0.0040 a	0.0025 a
Zn_1B_2	0.369 ab	0.060 b-d	1.296 c	0.060 a-e	0.0041 a	0.0025 a
Zn_2B_0	0.267 cd	0.053 ef	1.186 d	0.044 de	0.0029 a	0.0020 a
Zn_2B_1	0.396 a	0.064 ab	1.410 ab	0.067 a-c	0.0043 a	0.0027 a
Zn_2B_2	0.398 a	0.067 a	1.449 ab	0.069 ab	0.0045 a	0.0029 a
Zn_3B_0	0.324 bc	0.058 c-e	1.380 b	0.057 a-e	0.0036 a	0.0022 a
Zn_3B_1	0.395 a	0.066 ab	1.411 ab	0.061 a-d	0.0043 a	0.0027 a
Zn_3B_2	0.409 a	0.068 a	1.465 a	0.071 a	0.0046 a	0.0031 a
$LSD_{(0.05)}$	**0.054**	**0.005**	**0.076**	**0.017**	**0.002**	**0.002**
Level of Significance	**0.05**	**0.05**	**0.01**	**0.05**	**0.01**	**0.01**
CV(%)	**7.34**	**4.30**	**6.27**	**8.35**	**5.77**	**5.54**

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

Zn_0: 0 kg Zn ha^{-1} (control)
Zn_1: 1.5 kg Zn ha^{-1}
Zn_2: 2.5 kg Zn ha^{-1}
Zn_3: 3.5 kg Zn ha^{-1}

B_0: 0 kg B ha^{-1} (control)
B_1: 1.5 kg B ha^{-1}
B_2: 2.5 kg B ha^{-1}

Table 9. Effect of zinc and boron on pH, organic matter, available Zn and B of post harvest soil of BARI motorshuti-1

Treatment	pH	Organic matter (%)	Available Zn (ppm)	Available B (ppm)
Levels of zinc				
Zn_0	6.12 c	1.33 d	0.168 c	0.191 b
Zn_1	6.39 b	1.40 c	0.522 b	0.279 a
Zn_2	6.60 ab	1.49 b	0.557 ab	0.296 a
Zn_3	6.72 a	1.58 a	0.570 a	0.310 a
$LSD_{(0.05)}$	**0.210**	**0.054**	**0.044**	**0.031**
Level of Significance	**0.01**	**0.01**	**0.01**	**0.01**
Levels of boron				
B_0	6.23 b	1.38 b	0.381 c	0.166 c
B_1	6.52 a	1.48 a	0.454 b	0.305 b
B_2	6.62 a	1.49 a	0.528 a	0.335 a
$LSD_{(0.05)}$	**0.182**	**0.046**	**0.038**	**0.027**
Level of Significance	**0.01**	**0.01**	**0.01**	**0.01**
CV(%)	**6.30**	**4.55**	**8.72**	**9.52**

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

Zn_0: 0 kg Zn ha^{-1} (control)

Zn_1: 1.5 kg Zn ha^{-1}

Zn_2: 2.5 kg Zn ha^{-1}

Zn_3: 3.5 kg Zn ha^{-1}

B_0: 0 kg B ha^{-1} (control)

B_1: 1.5 kg B ha^{-1}

B_2: 2.5 kg B ha^{-1}

Table 10. Interaction effect of zinc and boron on pH, organic matter, available Zn and B of post harvest soil of BARI motorshuti-1

Treatment	pH	Organic matter (%)	Available Zn (ppm)	Available B (ppm)
Zn_0B_0	6.02 e	1.30 f	0.148 e	0.134 d
Zn_0B_1	6.34 c-e	1.38 ef	0.172 e	0.209 bc
Zn_0B_2	6.00 e	1.31 f	0.183 e	0.232 b
Zn_1B_0	6.11 de	1.36 f	0.437 d	0.155 cd
Zn_1B_1	6.31 c-e	1.39 ef	0.533 bc	0.332 a
Zn_1B_2	6.76 ab	1.46 de	0.598 ab	0.350 a
Zn_2B_0	6.34 c-e	1.37 ef	0.471 cd	0.185 b-d
Zn_2B_1	6.67 a-c	1.53 b-d	0.545 bc	0.330 a
Zn_2B_2	6.78 ab	1.57 a-c	0.655 a	0.373 a
Zn_3B_0	6.44 b-d	1.49 cd	0.469 cd	0.191 b-d
Zn_3B_1	6.78 ab	1.62 ab	0.566 b	0.351 a
Zn_3B_2	6.92 a	1.63 a	0.675 a	0.387 a
$LSD_{(0.05)}$	**0.363**	**0.093**	**0.076**	**0.054**
Level of Significance	**0.05**	**0.05**	**0.05**	**0.01**
CV(%)	**6.30**	**4.55**	**8.72**	**9.52**

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

Zn_0: 0 kg Zn ha^{-1} (control) — B_0: 0 kg B ha^{-1} (control)

Zn_1: 1.5 kg Zn ha^{-1} — B_1: 1.5 kg B ha^{-1}

Zn_2: 2.5 kg Zn ha^{-1} — B_2: 2.5 kg B ha^{-1}

Zn_3: 3.5 kg Zn ha^{-1}

4.3.2 Organic matter

Organic matter in post harvest soil showed statistically significant variation due to different levels of zinc (Appendix VI). The highest organic matter in post harvest soil (1.58%) was found from Zn_3 (3.5 kg Zn ha^{-1}), which was closely followed (1.49%) by Zn_1 (1.5 kg Zn ha^{-1}), whereas the lowest organic matter (1.33%) was recorded from Zn_0 (0 kg Zn ha^{-1}) (Table 9).

Different levels of boron varied significantly in terms of organic matter in post harvest soil under that present trial (Appendix VI). Data revealed that the highest organic matter in post harvest soil (1.49%) was found from B_2 (2.5 kg B ha^{-1}) which was statistically similar (1.48%) with B_1 (1.5 kg B ha^{-1}) and the lowest organic matter (1.38%) from B_0 (0 kg B ha^{-1}) (Table 9).

Statistically significant variation was recorded due to the interaction effect of different levels of zinc and boron in terms of organic matter in post harvest soil (Appendix VI). The highest organic matter in post harvest soil (1.63%) was obtained from Zn_3B_2 (3.5 kg Zn ha^{-1} and 2.5 kg B ha^{-1}), while the lowest organic matter in post harvest soil (1.30%) was found from Zn_0B_0 (0 kg Zn ha^{-1} and 0 kg B ha^{-1}) treatment combination (Table 10).

4.3.3 Available zinc

Available zinc in post harvest soil showed statistically significant variation due to different levels of zinc (Appendix VI). The highest available zinc in post harvest soil (0.570 ppm) was observed from Zn_3 (3.5 kg Zn ha^{-1}), which was statistically similar (0.557 ppm) with Zn_2 (2.5 kg Zn ha^{-1}) and closely followed (0.522 ppm) by Zn_1 (1.5 kg Zn ha^{-1}), while the lowest available zinc (0.168 ppm) was found from Zn_0 (0 kg Zn ha^{-1}) (Table 9).

Significant variation was recorded for available zinc in post harvest soil due to different levels of boron (Appendix VI). The highest available zinc in post harvest soil (0.528 ppm) was recorded from B_2 (2.5 kg B ha^{-1}) which was statistically similar (0.454 ppm) with B_1 (1.5 kg B ha^{-1}), whereas the lowest available zinc (0.381 ppm) from B_0 (0 kg B ha^{-1}) (Table 9).

Interaction effect of different levels of zinc and boron showed significant variation on available zinc in post harvest soil (Appendix VI). The highest available zinc in post harvest soil (0.675 ppm) was observed from Zn_3B_2 (3.5 kg Zn ha^{-1} and 2.5 kg B ha^{-1}) and the lowest available zinc in post harvest soil (0.148 ppm) was found from Zn_0B_0 (0 kg Zn ha^{-1} and 0 kg B ha^{-1}) treatment combination (Table 10).

4.3.4 Available boron

Different levels of zinc showed statistically significant variation in terms of available boron in post harvest soil (Appendix VI). The highest available boron in post harvest soil (0.310 ppm) was found from Zn_3 (3.5 kg Zn ha^{-1}), which was statistically similar (0.296 ppm and 0.279 ppm) with Zn_2 (2.5 kg Zn ha^{-1}) and Zn_1 (1.5 kg Zn ha^{-1}), whereas the lowest available boron (0.191 ppm) was observed from Zn_0 (0 kg Zn ha^{-1}) (Table 9).

Available boron in post harvest varied significantly due to different levels of boron (Appendix VI). The highest available boron in post harvest soil (0.335 ppm) was obtained from B_2 (2.5 kg B ha^{-1}) which was closely followed (0.305 ppm) by B_1 (1.5 kg B ha^{-1}), while the lowest available boron (0.166 ppm) was recorded from B_0 (0 kg B ha^{-1}) (Table 9).

Interaction effect of different levels of zinc and boron showed significant variation on available boron in post harvest soil (Appendix VI). The highest available boron in post harvest soil (0.387 ppm) was found from Zn_3B_2 (3.5 kg Zn ha^{-1} and 2.5 kg B ha^{-1}). On the other ahnd, the lowest available boron in post harvest soil (0.134 ppm) was recorded from Zn_0B_0 (0 kg Zn ha^{-1} and 0 kg B ha^{-1}) treatment combination (Table 10).

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted during the period from November, 2013 to March 2014 at the farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh to study the effect of zinc and boron on growth and yield of BARI motorshuti-1. The variety BARI Motorshuti-1 was used as the test crop. The experiment comprised of two factors; Factor A: Levels of zinc (4 levels)- Zn_0: 0 kg Zn ha^{-1} (control), Zn_1: 1.5 kg Zn ha^{-1}, Zn_2: 2.5 kg Zn ha^{-1}, Zn_3: 3.5 kg Zn ha^{-1} and Factors B: Levels of boron (3 levels)- B_0: 0 kg B ha^{-1} (control), B_1: 1.5 kg B ha^{-1} and B_2: 2.5 kg B ha^{-1}. The two factors experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Data on different growth parameters, yield, nutrient concentration in pods and stover and nutrient of post harvest soil was recorded and statistically significant variation was observed different level of zinc and boron.

For different levels of zinc, at 20, 30, 40, 50, 60 DAT and at harvest, the tallest plant (15.75, 36.15, 55.60, 69.29, 81.67 and 86.76 cm, respectively) was recorded from Zn_3, whereas the shortest plant (12.23, 26.59, 37.50, 52.60, 65.96 and 72.94 cm, respectively) was found from Zn_0. The longest pod (7.27 cm) was recorded from Zn_3, while the shortest pod (5.61 cm) from Zn_0. The maximum number of pod $plant^{-1}$ (26.19) was found from Zn_3 and the minimum number (21.60) from Zn_0. The maximum number of seeds pod^{-1} (7.80) was recorded from Zn_3, while the minimum number of seeds pod^{-1} (5.23) was observed from Zn_0. The highest weight of 1000 seeds (230.07 g) was observed from Zn_3, whereas the lowest weight (161.15 g) from Zn_0. The highest seed yield $plant^{-1}$ (7.73 g) was recorded from Zn_3 and the lowest seed yield $plant^{-1}$ (6.07 g) from Zn_0. The highest stover yield $plant^{-1}$ (12.51 g) was observed from Zn_3, while the lowest (10.10 g) from Zn_0. The highest seed yield $hectare^{-1}$ (7.98 ton) was recorded from Zn_3, whereas the lowest (6.00 ton) from Zn_0. The highest stover yield $hectare^{-1}$ (13.96 ton) was attained from Zn_3, while the lowest ^{1} (10.65 ton) was found from Zn_0.

The maximum concentration in seed for N (0.446%), P (0.212%), K (0.283%), S (0.160%), Zn (0.0184%) and B (0.0150%) were observed from Zn_3, whereas the minimum concentration in seed for N (0.318%), P (0.163%), K (0.203%), S (0.132%), Zn (0.0116%) and B (0.0115%) from Zn_0. The maximum concentration in stover for N (0.376%), P (0.064%), K (1.419%), S (0.063%), Zn (0.0042%) and B (0.0026%) were found from Zn_3, while the minimum concentration in stover for N (0.279%), P (0.054%), K (1.084%), S (0.047%), Zn (0.0031%) and B (0.0015%) from Zn_0. The highest pH in post harvest soil (6.72) was observed from Zn_3, while the lowest pH (6.12) from Zn_0. The highest organic matter in post harvest soil (1.58%) was found from Zn_3, whereas the lowest organic matter (1.33%) from Zn_0. The highest available zinc in post harvest soil (0.570 ppm) was observed from Zn_3, while the lowest available zinc (0.168 ppm) from Zn_0. The highest available boron in post harvest soil (0.310 ppm) was found from Zn_3, whereas the lowest available boron (0.191 ppm) from Zn_0.

In consideration of different level of boron, at 20, 30, 40, 50, 60 DAS and at harvest, the tallest plant (15.76, 34.99, 52.89, 65.93, 78.89 and 85.69 cm, respectively) were recorded from B_2, while the shortest plant (12.32, 29.90, 45.21, 60.11, 69.62 and 77.04 cm, respectively) from B_0. The longest pod (7.16 cm) was obtained from B_2 and the shortest pod (5.72 cm) from B_0. The maximum number of pods plant^{-1} (26.58) was found from B_2, whereas the minimum number (21.18) from B_0. The maximum number of seeds pod^{-1} (7.41) was found from B_2 and the minimum number of seeds pod^{-1} (5.79) from B_0. The highest weight of 1000 seeds (212.68 g) was recorded from B_2, while the lowest weight of 1000 seeds (186.25 g) from B_0. The highest seed yield plant^{-1} (7.79 g) was found from B_2, whereas the lowest seed yield plant^{-1} (6.05 g) from B_0. The highest stover yield plant^{-1} (12.28 g) was recorded from B_2 and the lowest stover yield plant^{-1} (10.58 g) from B_0. The highest seed yield hectare^{-1} (7.86 ton) from B_2, while the lowest seed yield hectare^{-1} (6.15 ton) from B_0. The highest stover yield hectare^{-1} (13.42 ton) was observed from B_2, whereas the lowest stover yield hectare^{-1} (11.89 ton) from B_0.

The maximum concentration in seed for N (0.431%), P (0.197%), K (0.276%), S (0.159%), Zn (0.0166%) and B (0.0148%) were recorded from B_2 and the minimum concentration in seed for N (0.351%), P (0.180%), K (0.210%), S (0.128%), Zn (0.0132%) and B (0.0114%) from B_0. The maximum concentration in stover for N (0.368%), P (0.063%), K (1.327%), S (0.062%), Zn (0.0041%) and B (0.0026%) were found from B_2 and the minimum concentration in stover for N (0.274%), P (0.053%), K (1.192%), S (0.047%), Zn (0.0032%) and B (0.0017%) from B_0. The highest pH in post harvest soil (6.62) was recorded from B_2, whereas the lowest pH (6.23) from B_0. The highest organic matter in post harvest soil (1.49%) was found from B_2 and the lowest organic matter (1.38%) from B_0. The highest available zinc in post harvest soil (0.528 ppm) was recorded from B_2, whereas the lowest available zinc (0.381 ppm) from B_0. The highest available boron in post harvest soil (0.335 ppm) was obtained from B_2, while the lowest available boron (0.166 ppm) from B_0.

At 20, 30, 40, 50, 60 DAS and at harvest, the tallest plant (17.72, 39.29, 60.46, 73.75, 86.60 and 91.50 cm, respectively) were observed from Zn_3B_2 and the shortest plant (10.37, 25.18, 35.38, 51.36, 60.19 and 69.40 cm, respectively) from Zn_0B_0. The longest pod (8.04 cm) was recorded from Zn_3B_2, whereas the shortest pod (4.57 cm) was observed from Zn_0B_0. The maximum number of pods plant^{-1} (28.60) was found from Zn_3B_2, while the minimum number (19.50) from Zn_0B_0. The maximum number of seeds pod^{-1} (8.90) was recorded from Zn_3B_2, again the minimum number (4.97) from Zn_0B_0. The highest weight of 1000 seeds (247.62 g) was observed from Zn_3B_2 and the lowest weight (158.59 g) from Zn_0B_0. The highest seed yield plant^{-1} (8.53 g) was obtained from Zn_3B_2, while the lowest seed yield plant^{-1} (5.47 g) from Zn_0B_0. The highest stover yield plant^{-1} (13.52 g) was observed from Zn_3B_2, while the lowest stover yield plant^{-1} (10.03 g) from Zn_0B_0. The highest seed yield hectare^{-1} (8.85 ton) was found from Zn_3B_2 and the lowest seed yield hectare^{-1} (5.34 ton) from Zn_0B_0. The highest stover yield plant^{-1} (14.72 ton) was obtained from Zn_3B_2, while the lowest stover yield hectare^{-1} (10.48 ton) was recorded from Zn_0B_0.

The maximum concentration in seed for N (0.497%), P (0.216%), K (0.320%), S (0.175%), Zn (0.0206%) and B (0.0160%) were observed from Zn_3B_2, while the minimum concentration in seed for N (0.300%), P (0.162%), K (0.193%), S (0.121%), Zn (0.0103%) and B (0.0093%) from Zn_0B_0. The maximum concentration in stover for N (0.409%), P (0.068%), K (1.465%), S (0.071%), Zn (0.0046%) and B (0.0031%) were recorded from Zn_3B_2, while the minimum concentration in stover for N (0.239%), P (0.051%), K (1.025%), S (0.041%), Zn (0.0025%) and B (0.0011%) from Zn_0B_0. The highest pH in post harvest soil (6.92) was observed from Zn_3B_2 and the lowest pH in post harvest soil (6.02) from Zn_0B_0. The highest organic matter in post harvest soil (1.63%) was obtained from Zn_3B_2, while the lowest organic matter in post harvest soil (1.30%) from Zn_0B_0. The highest available zinc in post harvest soil (0.675 ppm) was observed from Zn_3B_2 and the lowest (0.148 ppm) from Zn_0B_0. The highest available boron in post harvest soil (0.387 ppm) was found from Zn_3B_2 and, the lowest (0.134 ppm) from Zn_0B_0.

Conclusion

From the findings it was found that application of 3.5 kg Zn ha^{-1} & 2.5 kg B ha^{-1} and 2.5 kg Zn ha^{-1} & 1.5 kg B ha^{-1} showed statistically same seed yield. So, it can be concluded that combination of 2.5 kg Zn ha^{-1} & 1.5 kg B ha^{-1} can be more beneficial for the farmers to get better yield from the cultivation of BARI Motorshuti-1.

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

1. Such study is needed in different agro-ecological zones (AEZ) of Bangladesh for regional compliance and other performances.

2. More experiments may be carried out with other organic and also macro nutrients.

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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 2013 to March 2014

Month	*Air temperature (ºc)		*Relative humidity (%)	Total Rainfall (mm)	*Sunshine (hr)
	Maximum	Minimum			
November, 2013	25.8	16.0	78	00	6.8
December, 2013	22.4	13.5	74	00	6.3
January, 2014	24.5	12.4	68	00	5.7
February, 2014	27.1	16.7	67	30	6.7
March, 2014	31.4	19.6	54	11	8.2

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

Appendix II. Analysis of variance of the data on plant height of BARI motorshuti-1 as influenced by different levels of zinc and boron

Source of variation	Degrees of freedom	Mean square					
		Plant height (cm) at					
		20 DAS	30 DAS	40 DAS	50 DAS	60 DAS	Harvest (70 DAS)
Replication	2	0.516	1.417	0.617	11.453	6.764	3.722
Level of zinc (A)	3	22.631**	178.527**	639.517**	541.692**	486.061**	366.086**
Level of boron (B)	2	40.569**	92.973**	204.629**	124.728**	309.538**	253.296**
Interaction (A×B)	6	2.091*	5.377*	13.018*	18.522*	8.833*	11.269*
Error	22	0.726	3.353	5.937	6.386	7.531	10.559

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

Appendix III. Analysis of variance of the data on yield contributing characters and yield of BARI motorshuti-1 as influenced by different levels of zinc and boron

Source of variation	Degrees of freedom								
		Pod length (cm)	Pods plant^{-1} (No.)	Seeds pod^{-1} (No.)	Weight of 1000 seeds (g)	Seed yield plant^{-1} (g)	Weight of stover plant^{-1} (g)	Seed yield hectare^{-1} (ton)	Weight of stover hectare^{-1} (ton)
Replication	2	0.054	0.454	0.026	12.518	0.007	0.166	0.063	0.102
Level of zinc (A)	3	5.105**	40.448**	13.017**	9093.11**	5.351**	10.290**	6.982**	20.580**
Level of boron (B)	2	7.366**	109.884**	9.051**	2384.56**	11.663**	10.286**	10.370**	7.981**
Interaction (A×B)	6	0.641*	2.302*	0.917*	281.591*	0.354*	1.179*	0.482*	1.208*
Error	22	0.202	0.748	0.307	109.180	0.118	0.429	0.183	0.436

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

Appendix IV. Analysis of variance of the data on N, P, K, S, Zn and B concentrations in seeds of BARI motorshuti-1 as influenced by different levels of zinc and boron

Source of variation	Degrees of freedom	Mean square					
		Concentration (%) in seeds					
		N	P	K	S	Zn	B
Replication	2	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Level of zinc (A)	3	0.028**	0.005**	0.012**	0.001**	0.0001**	0.0001**
Level of boron (B)	2	0.019**	0.001**	0.015**	0.003**	0.0001**	0.0001**
Interaction (A×B)	6	0.003	0.0001*	0.002**	0.0001*	0.0001**	0.0001*
Error	22	0.001	0.0001	0.000	0.000	0.00001	0.0001

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

Appendix V. Analysis of variance of the data on N, P, K, S, Zn and B concentrations in stover of BARI motorshuti-1 as influenced by different levels of zinc and boron

Source of variation	Degrees of freedom	Mean square					
		Concentration (%) in stover					
		N	P	K	S	Zn	B
Replication	2	0.0001	0.0001	0.001	0.0001	0.0001	0.0001
Level of zinc (A)	3	0.015**	0.0001**	0.189**	0.0001**	0.0001**	0.0001**
Level of boron (B)	2	0.034**	0.0001**	0.063**	0.001**	0.0001**	0.0001**
Interaction (A×B)	6	0.001*	0.0001*	0.008**	0.0001*	0.0001**	0.0001**
Error	22	0.001	0.00001	0.002	0.0001	0.000001	0.000001

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

Appendix VI. Analysis of variance of the data on pH, organic matter, available Zn and B of post harvest soil of BARI motorshuti-1 as influenced by different levels of zinc and boron

Source of variation	Degrees of freedom	Mean square			
		pH	Organic matter (%)	Available Zn (ppm)	Available B (ppm)
Replication	2	0.001	0.0001	0.0001	0.0001
Level of zinc (A)	3	0.617**	0.104**	0.332**	0.025**
Level of boron (B)	2	0.494**	0.048**	0.064**	0.098**
Interaction (A×B)	6	0.097*	0.006*	0.005*	0.002**
Error	22	0.046	0.003	0.002	0.001

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