EFFECT OF BORON AND ZINC ON THE GROWTH AND YIELD RESPONSE OF MUNGBEAN

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CERTIFICATE

This is to certify that the thesis entitled **"EFFECT OF BORON AND ZINC ON THE GROWTH AND YIELD RESPONSE OF MUNGBEAN"** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **Master of Science** in **AGRONOMY**, embodies the result of a piece of *bonafide* research work carried out by **MEGHDUT KUMAR ROY**, Registration No. **Reg No. 11-04470** 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 been duly acknowledged.

Dated:

Dhaka, Bangladesh

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Dedicated To

My Beloved Parents

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The Author

EFFECT OF BORON AND ZINC ON THE GROWTH AND YIELD RESPONSE OF MUNGBEAN

ABSTRACT

The experiment was carried out during the period from March 2017 to June 2017 at the Agronomy farm of Sher-e-Bangla Agricultural University, Dhaka to evaluate the effect of boron and zinc on the growth and yield performance of mungbean (var:BARI Mung-6). The experiment comprised of two factors; Factor A: Three levels of boron - (i) B_R = Recommended dose of B, (ii) B_{R-20} = 20% less than recommended dose of B and (iii) B_{R+20} = 20% higher than recommended dose of B and Factors B: Three levels of zinc - (i) Zn_R = Recommended dose of Zn, (ii) Zn_{R-20} = 20% less than recommended dose of Zn and (iii) Zn_{R+20} = 20% higher than recommended dose of Zn. The experiment was laid out in a randomized complete block design using three replications. Data on different growth parameters, yield contributing parameters and yield were recorded. Results showed significant variations in the growth and yield parameters due to the application of varying levels of boron and zinc; and also applying them combined. Higher values of almost all the parameters were observed with the interaction treatments B_RZn_R and also with other interaction treatments having 20% higher amount of boron and zinc over the recommended dose. Significantly the highest dry weight per plant was obtained with $B_{R+20}Zn_{R+20}$ (68.07 g). However the higher seed yields (1362-1371 kg/ha) were obtained with B_RZn_R and B_RZn_{R+20} combination of treatments which were attributed to the higher values of number of pods per plant (23.45-24.25), number of seeds per pod (12.72-12.87) and 1000 seed weight (over 47 g) of these two interaction treatments.

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ABBREVIATIONS AND ACRONYMS

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

CHAPTER I

INTRODUCTION

Pulse crops are important component of profitable agriculture as pulses are cheap source of protein as of poor man's meat. Among pulses mungbean (*Vigna radiata* L.) enjoys special place in people's diet due to its high nutritional value, owing to its quick cooking, easy digestibility and anti-flatulent properties (Usman *et al*. 2007). Mungbean contains 24.5% crude protein, 60% carbohydrate, 1-3% fat, 3.5-4.5% crude fiber, 4.5-5.5% ash, 75 mg calcium, 8.5 mg iron, and 49 mg β-carotene per 100g of grain (Afzal *et al*. 2004).

To meet up the basic demand of food, farmers are growing more cereal crops. So, at present the cultivation of pulse has gone to marginal land because farmers do not want to use their fertile land in pulse cultivation. The farmers of Bangladesh generally produce mungbean by one ploughing and hardly use minimum fertilizers and irrigations due to its lower productivity and also to their poor socio-economic condition and lack of proper knowledge. There is an ample scope for increasing the yield of mungbean with improved management practices.

Pulse crop belongs to seed legume under the family of Fabaceae. According to FAO (2013) recommendation, a minimum per capita intake of pulse should be 80 g day^{-1}, where as it is 7.92 g day^{-1} in Bangladesh (BBS, 2011). This is because of fact that national production of the pulses is not adequate to meet our national demand. Both the area and production of the pulses are decreasing in Bangladesh day by day due cultivating wheat, boro rice and maize in our cropping pattern with irrigation facilities.

Mungbean is one of the most important pulse crops in Bangladesh. It holds the 3rd in protein content and 4th in both acreage and production in Bangladesh (Sarkar*et al*., 2012). In Bangladesh, total production of pulses is only 0.65 million ton against 2.7 million tons requirement. This means the shortage is almost 80% of the total requirement (Rahman and Ali, 2007). This is mostly due to low yield (MoA, 2013). At present, the area under pulse crop is 0.406 million hectare with a production of 0.322 million tons (BBS, 2013), where mungbean is cultivated in the area of 0.108 million ha with production of 0.03 million tons (BBS, 2014).

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). 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 of mungbean and other pulse crops. Fageria *et al*. (2007) found that boron application significantly increased common bean yield. The response of pulse 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 is a micronutrient essential for normal growth of pollen grains, sugar translocation and movement of growth regulators within the plant (Hamasa and Putaiah, 2012). 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). 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 (Tanaka and Fujiwar, 2008).

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 (Stoyanova and Doncheva, 2002) and membrane integrity (De Vos*et al*., 1991). Within plants Zn seems to affect the capacity for water uptake and transport (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 (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 of mungbean cultivation and like other pulse crop in several Asian countries (Rehman *et al*., 2012).

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

1. To find out the optimum dose of B on the growth and yield of mungbean
2. To find out the optimum dose of Zn on the growth and yield of mungbean
3. To find out the interaction effect of B and Zn on the growth and yield of mungbean

CHAPTER II

REVIEW OF LITERATURE

Mungbean (*Vigna radiata L.*) is considered to be a very important leguminous pulse seed crop in the world. Much attention has been received by a large number of researchers on various aspects of mungban production, processing and utilization. Since review of literature forms a bridge between the past and present research works related to problem, which helps an investigator to draw a satisfactory conclusion, an effort was thus made to present some research works related to the present study in this section.

2.1 Effect of boron

Maqbool *et al*. (2018) conducted two years of field experiment to evaluate the effect of boron application and water stress given at vegetative and flowering stages on growth, yield and protein contents of mungbean. The experiment comprised three water stress levels (normal irrigation, water stress at vegetative stage and water stress at reproductive phase) and four boron levels (0, 2, 4 and 6 kg ha^{-1}). The increase in yield was mainly due to greater plant height, number of pods bearing branches, number of pods per plant, number of seeds per pod and 1000-grain weight. Boron application at 4 kg ha^{-1} caused 17%, 10% and 4% increase in grain yield under normal irrigation, stress at vegetative stage and water stress at reproductive phase, respectively. Protein contents were also increased (9-16%) at same boron treatment. Most parameters showed a marked decrease at higher dose (6 kg ha^{-1}) of boron. In conclusion, the boron application at rate of 4 kg ha^{-1} in clay-loam soil performed the best to enhance mungbean growth, yield and seed protein both under normal and water stressed conditions. So, boron is considered important to improve the drought resistance, yield and protein contents of pulses.

Vimalan *et al*. (2017) conducted a pot experiment to assess the response of green gram (CO 8) to the soil application of different levels of boron in a boron deficient soil. It appeared that 1.5 kg of B ha^{-1} significantly increased plant height, number of leaves and branches plant^{-1}, number of pods plant^{-1}, number of seeds pod^{-1}, 1000 seed weight, seed yield and protein content (%). The control (0 kg of B ha^{-1}) had the poorest performance in respect of yield and protein content of green gram seed.

Hamza *et al*. (2016) conducted a field experiment to investigate the effect of levels of phosphorus (0, 20, 40 and 60 kg ha^{-1}) and boron (0, 1.0, 1.5 and 2.0 kg ha^{-1}) on growth and yield of summer mungbean cv. BINAmung-8. The results indicated that the crop responded significantly to boron in respect of growth and yield such as plant height, number of branches plant^{-1}, pods plant^{-1}, pod length, number of seeds pod^{-1}, 1000 seed weight, seed yield, stover yield, biological yield and harvest index. The highest seed yield (1.16 t ha^{-1}) was obtained from 1.5 kg B ha^{-1} followed by 2.0 kg B ha^{-1} (1.14 t ha^{-}1) and 1.0 kg B ha^{-1} (1.09 t ha^{-1}) whereas the lowest seed yield (1.04 t ha^{-1}) was obtained from the control plot.

Padbhushan and Kumar (2014) conducted a greenhouse experiment with green gram grown on boron (B) deficient calcareous soils for two years to study the influence of soil and foliar applied boron. The treatments comprised of four levels of soil applied boron *viz*. 0.5, 0.75, 1.0 and 1.5 mg B kg^{-1} and two levels of foliar applied boron *viz*. 0.1 and 0.2 percent borax solution with common control. Soil applied boron has more influence on mean dry matter yield while foliar applied boron has on mean grain yield. Among all soil applied boron 0.5 mg kg^{-1} is best treatment while 0.1% is best foliar treatment. Soil applied boron was at the par with foliar applied boron. Among all three calcareous soils, Soil-I with lower calcium carbonate was best soil in respect of mean yield and yield components in comparison to Soil-II and Soil-III. Combined effect of boron level and soils had a significant effect on yield and yield attributing characters. Total seed weight and leaf boron content are highly correlated with one another.

Patra and Bhattacharya (2009) conducted a field experiment to investigate the effect of four levels of boron and three levels of molybdenum on growth and yield of Mung Bean (*Vigna radiata* L. Wilczek cv. Baisakhi Mung). Boron, molybdenum and their combined application significantly improved all the growth and yield attributing characters of Mungbean. The synergistic influence of these two micronutrients helped augmenting growth and yield of the crop.

Srivastava *et al.* (2005) observed that in absence of B application no pod and grain yield were formed, in comparison to a yield of 2.06t ha^{-1} in the full nutrient treatment. There was yellowing of younger leaves and typical 'little leaf' symptoms when B was omitted. A critical concentration range of 15-20 ppm B was found for the shoot tips of mungbean.

Ali *et al.* (2002) reported that yield losses of varying magnitude in chickpea, e.g., 22-50% due to Zinc (Zn), up to 100% due to boron (B) and 16-30% due to sulphur (S). Genotypic differences in response to application of Fe, B and Zn have also been found among mungbean genotypes.

Bharti *et al.* (2002) carried out a field experiment in Bihar, India during the winter of 1997-98 to observe the effect of B (0, 1.5 and 2.5 kg ha^{-1}) application on the yield and nutrition of mungbean (cv. BG256). They reported that the mean seed yield increased when Zn and B content increased, whereas stover yield decreased with the increasing B and Zn rate.

Verma and Mishra (1999) carried out a pot experiment with mungbean cv. PDM 54; boron was applied by seed treatment, soil application or foliar spraying. Boron increased yield and growth parameters with the best results in terms of seed yield $plant^{-1}$ when the equivalent of 5 kg boron ha^{-1} was applied at flowering.

Wang *et al.* (1999) reported that there is limited risk of B toxicity due to the of boron fertilizer at up to 4 to 8 times recommended rates in rape-rice cropping rotations in southeast china. The low risk of B toxicity can be attributed to relatively high B removal in harvested seed, grain and stubble, the redistribution of fertilizer B by leaching in the 0 to 60 cm layer and to boron sorption.

Verma *et al.* (1988) in a pot experiment with mungbean cv. PDM 54, boron was applied by seed treatment, soil application or foliar spraying. Boron increased yield and growth parameters with the best results in terms in terms of seed yield/plant given when the equivalent of 5 kg borax ha^{-1} was applied at flowering.

Mandal *et al.* (1998) noted that most of alluvial acidic soils in North Bengal, India may response to the application of B fertilizer thus increasing the yield of pulse crops in the area.

Bonilla *et al.* (1997) suggested that B is an obligatory requirement for normal determinate nodule development and functioning in case of bean. Boron deficiency in pea caused a decrease in the number of nodules and an alteration of indeterminate nodule development. Moreover, B plays an important role in mediating cell surface interactions that lead to endocytosis of rhizobia by hoist cells and hence to the correct establishment of the symbiosis between pea and rhizobium (Bolanos *et al.*, 1994) .

Zaman *et al.* (1996a) conducted an experiment on mungbean and observed that application of B (2.0 kg ha^{-1}) produced 23.37% higher 1000 seed weight over control.

Zaman *et al.* (1996b) conducted an experiment on mungbean and observed that the application of Zn (1 kg ha^{-1}) with B (2 kg ha^{-1}) produced maximum plant height (35.03 cm) compared to control (21.53 cm). They also reported that the application of Zn (1 kg ha^{-1}) either alone or in combination with B (1 or 2 kg ha^{-1}) appreciable increased root length of mungbean over the control. They also reported that plant received 1 kg Mo ha^{-1} with 2 kg B ha^{-1} produced 50.31 and 40.21% higher root length of mungbean over control.

Zaman *et al.* (1996c) observed that application of B (2 kg ha^{-1}) significant increased 23.57% higher plant height of mungbean over control. They also observed that application of B (2 kg ha^{-1}) produced 23.18% and 20.49% higher root length over control in 1989 and 1990, respectively.

Marschner (1990) reported that the deficiency symptoms of some boron sensitive crops like legumes, Brassica, beets, celery, grapes and fruit trees showed chlorosis and browning of young leaves, killed growing points, distorted blossom development, lesions in pit and roots and plants, burning of the tips of the leaves and restricted root growth are the boron toxicity symptoms in most crops.

Sakal and Sinha (1990) carried out field trails at 7 sites in North Bihar, India. They observed the seed yield of chickpea increased from 1.4 t/ha with no B to 1.76 t/ha with 3 kg B/ha. The yield response to B application was grater on low B soils. It was conclude the on soils <0.35 ppm B, 3 kg B/ha was optimum and on soils >0.35 ppm B, 2kg B/ha was optimum.

2.2 Effect of zinc

Rahman *et al*. (2015) conducted a field experiment to study the effects of Phosphorus and Zinc on the growth and yield of Mungbean (BARI Mug 6). Four levels of phosphorus (P) (0, 15, 20 and 25 kg P ha^{-1}) and three levels of zinc (Zn) (0, 1.5 and 3 kg Zn ha^{-1}) were used in the study. The results revealed that seed and stover yield of mungbean increased with increasing levels of phosphorus and zinc up to certain level. In case of Zn the maximum significant seed yield (1.45 t ha^{-1}) and stover yield (2.42 t ha^{-1}) were obtained with the treatment Zn_2 (3 kg Zn ha^{-1}) and the minimum significant seed yield (1.27 t ha^{-1}) and stover yield (2.21 t ha^{-1}) were obtained with the treatment Zn_0 (0 kg Zn ha^{-1}). The maximum significant plant height (52.05 cm), number of branch plant^{-1} (2.87), number of pods plant^{-}

^{1}(20.86), number of seeds pod^{-1} (12.65) and weight of 1000-seeds (45.11 g) were also obtained with the treatment of Zn_2 (3 kg Zn ha^{-1}).

Karmakar *et al*. (2015) conducted a field experiment during the kharif season of 2014 to study the effects of Zinc on the concentrations of N, P, K, S and Zn in Mungbean stover and seed (BARI mug 6). Three levels of zinc (Zn) (0, 1.5 and 3 kg Zn ha$_{-1}$) were used in the study. The results revealed that The N, P, K and S concentration of mungbean plant increased significantly from control to Zn_2 (3 kg Zn ha^{-1}) treatment. Application of zinc increase organic carbon, N, P, K and S status of postharvest soil significantly. Zn_2 (3 kg Zn ha^{-1}) treatment also produced highest pods plant^{-1}, seeds pod^{-1} and seed yield ha^{-1}.

Malik *et al*. (2015) conducted an experiment during the years 2011-2012 to study the effect of zinc on plant height (cm), number of productive branches, number of leaves, leaf area (sq.cm.), fresh weight (g), dry weight (g), number of pods per plant, seed yield per plant and 1000 seeds weight (g) (Test weight) of mungbean (*Vigna radiata* L.) var. Pant Mung-4 and Narendra-1. The doses of zinc were 5, 10, 15 and 20 ppm. The results were found significant of both varieties of mungbean with Zn application of different rates. All the parameters were significantly influenced by Zn and highest seed yield per plant was from 10 ppm Zn.

Ram and Katiyar (2013) conducted a field experiment to evaluate the influence of sulphur and zinc on mungbean for two consecutive summer seasons i.e. 2008-09 and 2009-10. The experiment with four levels of sulphur (0, 20, 40 and 60 Kg S ha-1) and four levels of zinc (0, 5, 7.5 and 10 Kg Zn ha^{-1}). The summer mungbean variety “Narendra Moong-1” was used. The results revealed that application of 10 Kg Zn ha^{-1} significantly increased the plant height, number of branches plant^{-1}, number of nodules plant^{-1}, number of pods plant^{-1}, pod length, number of seeds pod^{-1}, seed yield, protein content (%) and test weight was non-significant. The control (0 Kg Zn ha^{-1}) had the poorest performance in respect of yield and protein content of mungbean seed during both the years, respectively. The highest seed yield (14.40 q ha^{-1}) was observed in 10 Kg Zn ha^{-1} which was significantly superior over rest of the treatments during 2008-09 and 2009-10, respectively. The minimum seed yield (9.56 and 10.06 q ha^{-1}) was achieved with 5 Kg Zn ha^{-1} and least was in control during both the years.

Samreen *et al*. (2013) conducted an experiment using four varieties of mungbeans (Ramazan, Swat mungI, NM92 and KMI) with nutrient solutions with and without Zn. Each variety was applied with Zn solutions at three levels i.e. 0, 1 and 2 µM concentrations. Plant growth, chlorophyll contents, crude proteins and Zn contents were noted to be higher when greater supply of zinc doses was applied. Plant phosphorous contents declined with supply of Zn from 1 µM to 2 µM compared to the control signifying a Zn/P complex foundation possibly in roots of plant, preventing the movement of P to plant. Zinc application at 2 µM concentrations in solution culture turned out to be the best treatment for improving the growth and quality parameters of mungbean.

Biswas *et al.* (2010) conducted a two-year field experiment during kharif season of 2005 and 2006 at the Pulse and Oilseeds Research Sub-station, Beldabga, Murshidabad, West Bengal, India to study the effect of zinc spray and seed inoculation on nodulation, growth and seed yield of mungbean. The results revealed that two rounds of foliar spray of 0.05% $ZnSO_4$ solution at 25 and 40 days after sowing (DAS) increased seed yield by 9.02% (1236.50 kg ha^{-1}) over water spray (1164.50 kg ha^{-1}). Combined inoculation of seed with *Rhizobium* + *Azotobacter* + PSB (1629.00 kg ha^{-1}) and *Rhizobium* + PSB remarkably increased the seed yield due to better nodulation along with improvement in growth and yield. The effect of interaction between foliar spray and inoculation on seed yield was found significant.

Mishra and Masood (1998) in a field study at Kanpur, Uttar Pradesh, mungbean *(Vigna radiata)* cv. K-851 were given 0, 25 or 50 kg P_2O_5 ha^{-1} and 0, 2, 4 or 6 g $Znha^{-1}$ seed by seed pelleting. Seed yields were 422, 624 and 714 kg ha^{-1} with the P rates as listed and 486, 583, 649 and 628 kg from seed pelleting with increasing Zn rates. Nodule numbers were not significantly affected by treatment. Yang and Zhang (1998) observed that the addition of Zn promoted elongation of epicotyle and hypocotyle of mungbean and increased seedling height and dry weight. High concentration of Zn decreased soluble protein.

Bolanos *et al.* (1994) suggested that Zn is required for normal development and function of nodules in case of pea. In the absence of Zn, the number, size and weight of nodules decreased and nodules development changed leading to an inhibition of nitrogenous activity.

Agarwal *et al.* (1981) found that direct effects of Zn are reflected by the close relationship between Zn supply and pollen production capacity of the anthers as well as the viability of the pollen grains of chickpea.

Gupta (1979) reported that Zn is a micronutrient requiring for plant growth relatively to a smaller amount. The total Zn content of soils lies between 20 and 200 ppm with the available Zn fraction ranging from 0.4 to 0.5 ppm.

2.3 Combined effect of boron and zinc

Alam and Islam (2016) conducted an experiment to observe the effect of zinc (Zn) and boron (B) on the seed yield and yield contributing characters of mungbean. There were four levels of zinc (0, 1.0, 2.0, and 4.0 kg/ha) and boron (0, 0.75, 1.5, and 3.0 kg/ha) along with a blanket dose of N24, P20, K30, S15, kg/ha. In case of zinc application, highest seed yield (1.418 ton/ha) was obtained from 1.0 kg Zn/ha which was statistically similar (1.358 t/ha) with dose 1.0 kg Zn/ha and but significantly higher (1.034 t/ha) than the control. Again for boron application, the highest seed yield (1.550 t/ha) was found from the treatment 1.50 kg B/ha which was statistically identical with 3.0 kg B/ha and the lowest (0.927 t/ha) for control. The combined application of zinc and boron showed significant effect on mungbean yield than the single application of zinc and boron. Results showed that the combination of Zn_1.0B1.5 produced significantly higher yield (1.677ton/ha) than the control (Zn_0B_0) combination (0.64 ton/ha). Combined application of zinc and boron were observed superior to their single application. Therefore, the combination of 1.0 kg zinc per hectare and 1.5 kg boron per hectare might be considered as suitable dose for mungbean cultivation in acidic soil of Sylhet region of Bangladesh.

Quddus *et al*. (2011) carried out an experiment in AEZ 12, during Kharif 12008 and 2009. The objectives were to evaluate the effect of zinc (Zn) and boron (B) on the yield and yield contributing characters of mungbean (*Vigna radiata* L. Wilczek). There were four levels of zinc (0, 0.75, 1.5, and 3.0 kg/ha and boron (0, 0.5, 1.0, and 2 kg/ha). Results showed that the combination of Zn1.5B1.0 produced significantly higher yield (3058 kg/ha) and (2631 kg/ha, in the year 2008 and 2009, respectively. The lowest yield (2173 kg/ha) and (1573 kg/ha, were found in control (Zn_0B_0) combination. The combined application of zinc and boron were observed superior to their single application in both the years.

Liu Peng *et al.,* (2005) conducted an experiment with three cultivars (Zhechum no. 3, Zhechum no. 2 and 3811) of soybean at four growth stages. The proper -1) and (2631 kg ha^{-1}), in the year 2008 and 2009, respectively. The lowest yield (2173 kg ha^{-1}) and (1573 kg ha^{-1}) were found in control (Zn_0B_0) combination. The combined application of zinc and boron were observed superior to their single application in both the years. Therefore, the combination of Zn1.5B1.0 might be considered as suitable dose for mungbean cultivation in Bangladesh. But from regression analysis, the optimum treatment combination was Zn1.87 and B1.24 kg ha^{-1} supply of Mo and/or B sufficiently increased the absorption of Mo and B by soybean. High supply of B decreased B absorption but increased B content. The absorption of B was the highest in all the treatment at early stage and the B content was lower than single B supply at maturity stage. The B absorbed by soybean mainly accumulated in leaf.

Abdo (2001) conducted two field experiments at Giza experimental Station, ARC, Egypt, during the 1998 and 1999 seasons to study the effect of foliar spray with micronutrients (Zn, Mn or B) on morphological, physiological and anatomical parameters of two mungbean*(Vigna radiata)* cultivars V- 2010 (Giza-1) and VC-1000. 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 DAS. The results showed that foliar spray with the adopted conc. of Zn, Mn or B alone or in a mixture, increased significantly most of the growth parameters over the control in both seasons. Application of Zn (0.2 g/l) along followed by a mixture of micronutrients results in better morphological and physiological parameters. It was observed that mungbean cv. VC-1000 surpassed cv. V- 2010 in all parameters under investigation in both seasons. The effect of spraying with lower level of Zn, Mn, B and their mixture on the internal structure of the vegetative growth of mungbean cv. VC-1000 was investigated.

Rizk and Adbo (2001) carried out two field experiments at Giza Experimental Station, ARC, Egypt, during the 1998 and 1999 seasons to investigate the response of mungbean*(Vigna radiata)* to treatment with some micronutrients. Two cultivars of mungbean (V-2010 and VC-1000) were used in this investigation. Zn (0.2 or 0.4g/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 DAS. The obtained results could be summarized in the following: Generally, cultivar VC-100 surpassed cultivar V-1000 in yield and its components as well as in the chemical composition of seeds with exception in 1000-seed weight and phosphorus percentage in seeds. All treatments increased significant 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 all treatments of micronutrients, B gave the highest percentage of crude protein. Seeds mungbean cv. VC-1000 exceeded those in both seasons.

Chowdhury and Narayanan (1992) observed that the tallest plant height of mungbean (64.9 cm) was found in plant receiving inoculums alone with Zn and B (both 1 kg ha^{-1}) as compared to all other treatments. They also reported that plant height increased 123% higher in plants receiving inoculums along with Zn (1 kg ha^{-1}) and B (1 kg ha^{-1}) over control.

Saha *et al.* (1996) conducted a field experiment in pre-khraif seasons of 1993-94 at Pundibari, India, Yellow season was given 0, 2.5or 5.0 kg borax and 0, 1 or 2 kg $ZnSO_4$ ha^{-1} applied as soil, 66% soil + 33% foliar or foliar applications and the residual effects were studied on summer mungbean. In both years green gram seed yield was highest with a combination of 5 kg borax + 2 kg $ZnSO_4$. Soil application gave higher yields than foliar or soil + foliar application.

Yang *et al.* (1989) reported that combined application of N, K, Zn and B increased seed yield in rapeseed. Application of B along with N, K and Zn promoted CO_2 assimilation, nitrate reduced activity in leaves and dry matter accumulation. Seed glucosinolate and erucic acid content varies among cultivars and generally decreased with increasing K, Zn and B while seed oil content increased.

CHAPTER III

MATERIALS AND METHODS

The experiment was carried out at the Sher-e-Bangla Agricultural University farm, Dhaka, during the period from March 2017 to June 2017 to study the effect of boron and zinc on the growth and yield response of mungbean. The details of the materials and methods have been presented below:

3.1 Description of the experimental site

3.1.1 Location

The location of the experimental field was in Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka. The location of the site is 90°33´E longitude and 23°77´N latitude with an elevation of 8.2 m from sea level. Location of the experimental site presented in Appendix I.

3.1.2 Soil

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

3.1.3 Climate

The geographical location of the experimental site was under the subtropical climate, characterized by 3 distinct seasons, Robi season from November to February and the kharif-1 season from March to April and kharif-2 from May to October. Details on the meteorological data of air temperature, relative humidity, rainfall and sunshine hour during the period of the experiment was collected from the Weather Station of Bangladesh, Sher-e-Bangla Nagar, presented in Appendix III.

3.2 Test crop and its characteristics

The test crop was BARI Mung-6 and seeds were collected from Bangladesh Agricultural Research Institute (BARI), Joydevpur, Gazipur. After multi location trials BARI released this variety for general cultivation named BARI Mung-6 in the year 2003. The plant attains a height of 35-40 cm, the leaves look light green and its life duration is about 75-80 days. Seeds are larger than local variety and light brown yellow in color. Seed contains 20-25 % protein. 1000 seeds weight is 35-40g. Under proper management practices it may give 1.6-2.0 t ha^{-1} seed yield.

3.3 Experimental details

3.3.1 Treatments

The experiment comprised of two factors.

Factor A: Boron (B) – Three levels of boron are:

1. B_R = Recommended dose of B
2. B_{R-20} = 20% less than recommended dose of B
3. B_{R+20} = 20% higher than recommended dose of B

Factor B: Zinc (Zn) – Three levels of Zn are:

1. Zn_R = Recommended dose of Zn
2. Zn_{R-20} = 20% less than recommended dose of Zn
3. Zn_{R+20} = 20% higher than recommended dose of Zn

According to BARI (2011) the experimental area was fertilized @ 50, 100 and 55 of Urea, TSP, MoP, and 10 t ha^{-1} cowdung respectively. The entire amounts of triple super phosphate (TSP), muriate of potash (MoP), and cowdung along with urea were applied as basal dose at final land preparation. Boron and zinc were applied according to treatments.

3.3.2 Experimental design and layout

The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The layout of the experiment was prepared for distributing the combination of doses of Boron (B) and Zinc (Zn). The 9 treatment combinations of the experiment were assigned at random into 27 plots. The size of each unit plot was 3.0 m× 2.0 m. The distance between blocks and plots were 0.5 m and 0.25 m respectively. The layout of the experiment field is shown in Appendix IV.

3.4 Growing of crops

3.4.1 Seed collection

The seeds of the test crop i.e., BARI Mung-6 were collected from Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur.

3.4.2 Preparation of the main field

The plot selected for the experiment was opened in the first week of March, 2017 with a power tiller, and was exposed to the sun for a week, after, which the land was harrowed, ploughed and cross-ploughed several times followed by laddering to obtain a good tilth. Weeds and stubble were removed and finally obtained a desirable tilth of soil for sowing.

3.4.3 Seed Sowing

Seeds are sown in well prepared land on according to the layout and treatments selected.

3.4.4 Fertilizers and manure application

The fertilizer N, P and K were applied @ 20.7 kg N/ha, 48 kg P_2O_5/ha, 34.8 kg K_2O/ha in the form of urea, TSP and MOP respectively during final land preparation as basal dose. B and Zn were applied respectively from borax and $ZnSO_4$ as per treatment during final land preparation. According to BARC the recommended doses of B and Zn are 0.5 and 1.0 kg ha^{-1} respectively and were applied as borax and $ZnSO_4$ respectively.

3.4.5 Intercultural Operation

After establishment of seedlings, various intercultural operations were accomplished for better growth and development of the mungbean.

3.4.5.1 Irrigation and drainage

Over-head irrigation was provided with a watering can to the plots once immediately after germination in every alternate day in the evening. Further irrigation was done when needed. Stagnant water was effectively drained out at the time of heavy rains.

3.4.5.2 Weeding

Several weedings were done to keep the plots free from weeds, which ultimately ensured better growth and development. First weeding was done at 20 days after sowing (DAS), 2^{nd} and 3^{rd} weeding was done at 35 and 50 DAS, respectively.

3.4.5.3 Plant protection

At early stage of growth few hairy caterpillar and virus vectors (Jassid) attacked the young plants and at later stage of growth pod borer attacked the plant. Hairy caterpillar and pod borer were successfully controlled by the application of Diazinon 50 EC and Ripcord @ 1 L ha^{-1} on the time of 50% pod formation stage.

3.5 Harvesting, threshing and cleaning

The crop was harvested at full maturity on the 21^{st} June, 2017. Harvesting was done manually from each plot. The harvested crop of each plot was bundled separately, properly tagged and brought to threshing floor. Enough care was taken for harvesting, threshing and also cleaning of mungbean seed. Fresh weight of seed and stover were recorded plot wise. The grains were cleaned and finally the weight was adjusted to a moisture content of 12%. The stover was sun dried and the yields of seed and stover plot^{-1} were recorded and converted to t ha^{-1}.

3.6 Data Collection and Recording

Ten plants were selected randomly from each unit plot for recording data on crop parameters and the yield of grain and straw were taken plot wise.

The following parameters were recorded during the study:

1. Plant height (cm)
2. Number of leaves plant^{-1}
3. Number of branches plant^{-1}
4. Dry weight plant^{-1} (g)
5. Days to first flowering
6. Days to maturity
7. Number of pods plant^{-1}
8. Number of seeds pod^{-1}
9. Pod length (cm)
10. 1000 seed weight (g)
11. Seed yield (kg ha^{-1})
12. Stover yield (kg ha^{-1})
13. Biological yield (kg ha^{-1})
14. Harvest index (%)

3.7 Procedure of recording data

3.7.1 Plant height (cm)

The height of plant was recorded in centimeter (cm) at different days after sowing (DAS). Data were recorded as the average of 10 plants selected at random from the inner rows of each plot. The height was measured from the ground level to the tip of the leaves.

3.7.2 Number of leaves plant^{-1}

Number of leaves plant^{-1} was counted at different days after sowing of crop duration. Leaves number plant^{-1} were counted from pre selected 10 plants samples from each plot and mean was calculated.

3.7.3 Number of branches plant^{-1}

The branches were counted from the 10 randomly selected plant at harvest time and mean value was determined.

3.7.4 Dry weight plant^{-1} (g)

Five sample plants in each plot were selected at random in the sample rows outside the central 1 m^2 of effective harvesting area and cut close to the ground surface at different days of crop duration. They were first air dried for one hour, then oven dried at 80±5°C till a constant weight was attained. Mean dry weight was expressed as per plant basis.

3.7.5 Days to first flowering

Days to 1st flowering was measured from the date of sowing when 1st of the mungbean plants flowered.

3.7.6 Days to maturity

Days to maturity was calculated from the date of sowing when at least 90% of the mungbean pods were matured.

3.7.7 Number of pods plant^{-1}

Total Number of pods of 10 plants plot was noted and the mean number was expressed per plant basis.

3.7.8 Number of seeds pod^{-1}

Total number of seeds of ten pods selected at random from each sampled plants was noted and the mean number was expressed per pod basis.

3.7.9 Pod length (cm)

Length of 10 pods selected from(10) selected plants from each plot was noted and the mean number was expressed per pod basis.

3.7.10 Weight of 1000 seeds (g)

One thousand cleaned and dried seeds were counted randomly form 1m^{2}area and weight by using a digital electric balance and the weight was expressed in gram.

3.7.11 Seed yield (kg ha^{-1})

The plants of the central 1.0 m^2 area plot were harvested for measuring seed yield. The seed were threshed from the plants, cleaned, dried and then weighed. The seed yield (kg)plot^{-1} was converted to t ha^{-1}.

3.7.12 Stover yield (kg ha^{-1})

The stover of the harvested crop in each plot was sun dried to a constant weight. Then the stovers were weighted and thus the stover yield plot^{-1} was determined. The yield of stover in kg plot^{-1} was converted to kg ha^{-1}.

3.7.13 Biological yield (kg ha^{-1})

Grain yield and stover yield together were regarded as biological yield. The biological yield was calculated and recorded as kg ha^{-1}.

3.7.14 Harvest index (%)

Harvest index was calculated from the ratio of grain yield to biological yield and expressed in percentage. It was calculated by using the following formula.

$$\text{HI (\%)} = \frac{\text{Seed yield}}{\text{Biological yield (Seed yield + Stover yield)}} \times 100$$

3.8 Statistical Analysis

The data obtained on different characters were statistically analyzed to observe the significant difference among the treatment by using the MSTAT-C computer package program. The mean values of all the characters were calculated and analysis of variance was performed. The significant differences among the treatment means were estimated by the Least Significant Deferent Test (LSD) at 5% level of probability (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSIN

The experiment was conducted to evaluate the effect of boron and zinc on the growth and yield response of mungbean. The results obtained from the study have been presented, discussed and compared in this chapter through different tables, figures and appendices.

4.1 Growth parameters

4.1.1 Plant height(cm)

Effect of B

Plant height of mungbean at different growth stages varied significantly due to different boron treatments (Figure 1 and Appendix V). Results signified that the highest plant height (34.31, 62.26 and 65.18 cm at 30, 45 DAS and at harvest respectively) was found from B_{R+20} which was significantly different from other treatments followed by B_R (Recommended dose of B) where the lowest plant height (30.62, 55.54 and 57.06 cm at 30, 45 DAS and at harvest respectively) was found from B_{R-20}. Similar results on plant height were also observed from the findings of Vimalan *et al*. (2017), Hamza *et al*. (2016) and Zaman *et al.* (1996b).

Effect of Zn

Different Zn treatment showed significant variation on plant height of mungbean at different growth stages (Figure 2 and Appendix V). It was found that higher Zn rate gave higher plant height. The highest plant height (34.31, 62.26 and 65.18 cm at 30, 45 DAS and at harvest respectively) was found from Zn_{R+20} which was statistically identical with Zn_R(Recommended dose of Zn) where the lowest plant height (30.91, 56.42 and 58.08 cm at 30, 45 DAS and at harvest respectively) was found from Zn_{R-20}. The results obtained from the present findings was similar with the findings of Rahman*et al*. (2015), Malik *et al*. (2015) and Ram and Katiyar (2013).

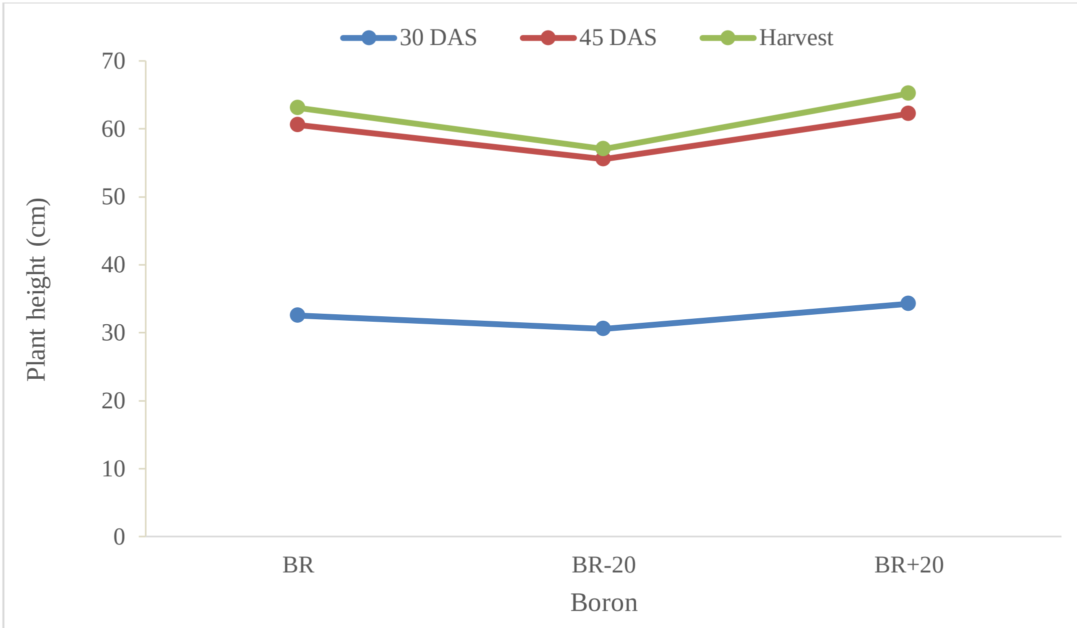

Fig. 1. Plant height of mungbean as influenced by boron (B)

B_R = Recommended dose of B
B_{R-20} = 20% less than recommended dose of B
B_{R+20} = 20% higher than recommended dose of B

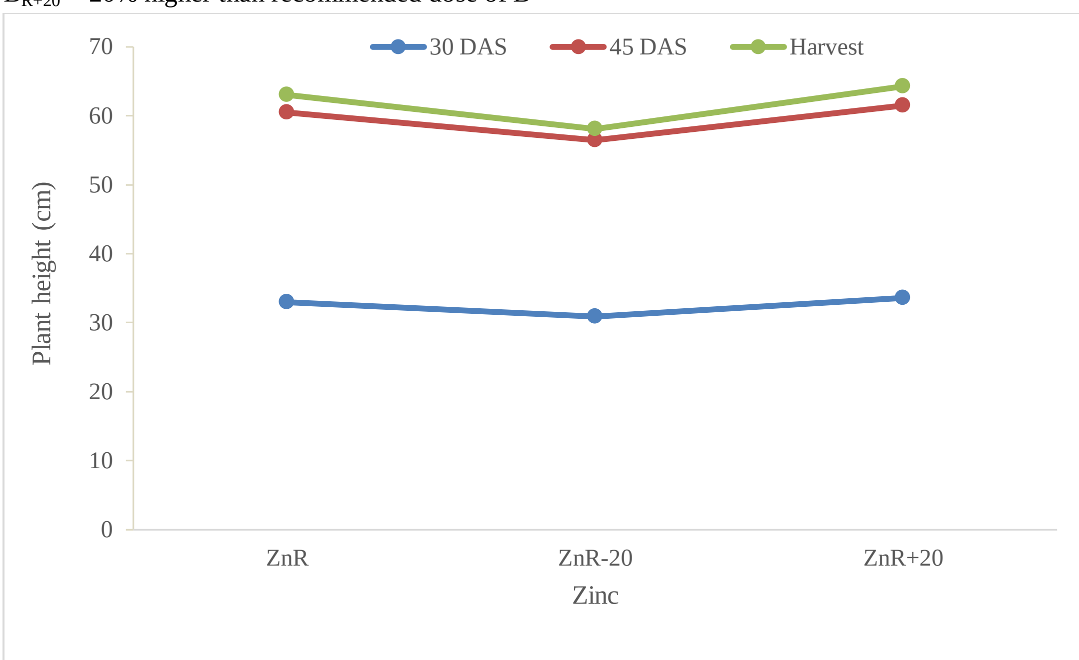

Fig. 2. Plant height of mungbean as influenced by zinc (Zn)

Zn_R = Recommended dose of Zn
Zn_{R-20} = 20% less than recommended dose of Zn
Zn_{R+20} = 20% higher than recommended dose of Zn

Combined effect of B and Zn

Significant influence was found on plant height of mungbean at different growth stages affected by combined effect of B and Zn (Table 1 and Appendix V). results indicated that the highest plant heights (35.20, 64.67 and 68.07 cm at 30, 45 DAS and at harvest respectively) were found from the treatment combination of $B_{R+20}Zn_{R+20}$ which were statistically identical with $B_{R+20}Zn_R$ at 30 DAS but at 50 DAS showed significantly similar results with each other. The lowest plant height (28.77, 51.83 and cm at 30, 45 DAS and at harvest respectively) were found from the treatment combination of $B_{R-20}Zn_{R-20}$. The treatment combination of $Zn_{R-20}Zn_R$ also showed comparatively lower plant height but significantly different from $B_{R-20}Zn_{R-20}$.

Table 1. Plant height of mungbean as influenced by combination treatment of boron (B) and zinc (Zn)

Treatment combination	Plant height (cm)		
	30 DAS	45 DAS	At harvest
B_RZn_R	33.00 bc	61.37 c	64.24 c
B_RZn_{R-20}	31.17 de	58.40 de	60.03 de
B_RZn_{R+20}	33.47 b	61.97 bc	65.09 bc
$B_{R-20}Zn_R$	30.90 e	56.97 e	58.49 e
$B_{R-20}Zn_{R-20}$	28.77 f	51.83 f	53.09 f
$B_{R-20}Zn_{R+20}$	32.20 cd	57.83 de	59.61 de
$B_{R+20}Zn_R$	34.93 a	63.10 ab	66.36 b
$B_{R+20}Zn_{R-20}$	32.80 bc	59.02 d	61.12 d
$B_{R+20}Zn_{R+20}$	35.20 a	64.67 a	68.07 a
$LSD_{0.05}$	1.038	1.581	1.630
CV (%)	6.274	9.632	10.319

In a column figures having similar letter(s) do not differ significantly whereas figures with dissimilar letter(s) differ significantly

B_R = Recommended dose of B
B_{R-20} = 20% less than recommended dose of B
B_{R+20} = 20% higher than recommended dose of B

Zn_R = Recommended dose of Zn
Zn_{R-20} = 20% less than recommended dose of Zn
Zn_{R+20} = 20% higher than recommended dose of Zn

4.1.2 Number of leaves plant^{-1}

Effect of B

Significant influence was noted for number of leaves plant^{-1} at different growth stages influenced by B treatment (Figure 3 and Appendix VI). Results exposed that the highest numbers of leaves plant^{-1} (6.04, 10.71 and 16.92 at 30, 45 DAS and at harvest respectively) were found from B_R which were significantly different from other treatments followed by $B_{R+20.}$ The lowest number of leaves plant^{-1} (4.97, 8.26 and 13.53 at 30, 45 DAS and at harvest respectively) was found from B_{R-20}. Vimalan *et al*. (2017) also obtained similar results which supported the present finding on number of leaves plant^{-1}.

Effect of Zn

Remarkable variation was detected on number of leaves plant^{-1} at different growth stages of mungbean affected by Zn application (Figure 4 and Appendix VI). It was found that the highest number of leaves plant^{-1} (5.93, 10.59 and 16.38 at 30, 45 DAS and at harvest respectively) were found from Zn_{R+20} which were statistically similar with Zn_R at 30 DAS but significantly different at 45 DAS and at harvest. The lowest number of leaves plant^{-1} (4.98, 8.63 and 14.30 at 30, 45 DAS and at harvest respectively) was found from Zn_{R-20}. Malik *et al*. (2015) also found similar results with the present study.

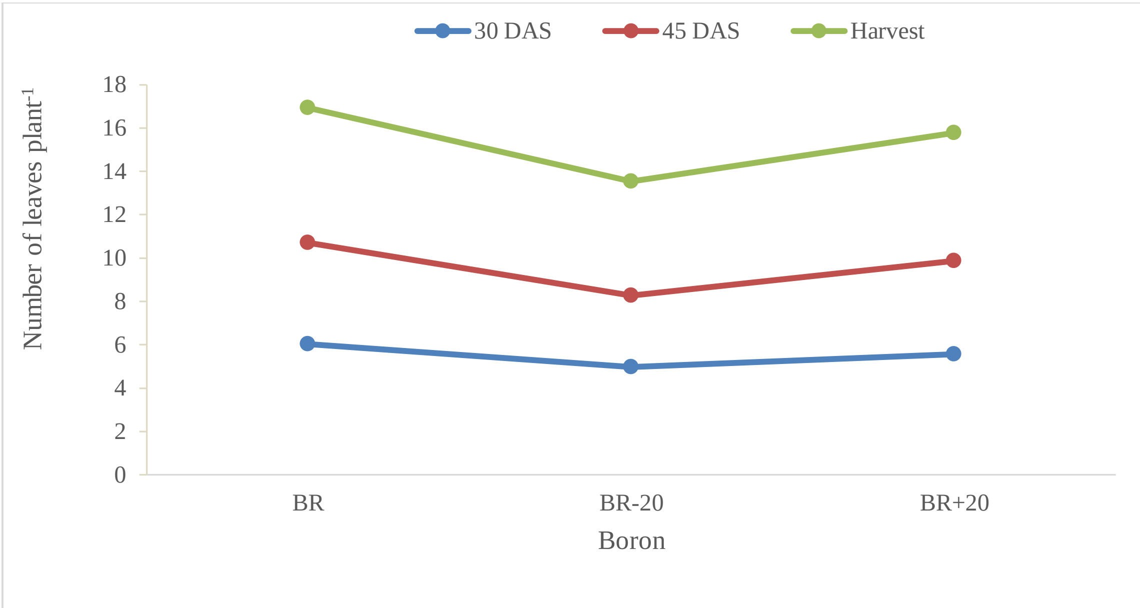

Fig. 3. Number of leaves plant^{-1} of mungbean as influenced by boron (B)

B_R = Recommended dose of B
B_{R-20} = 20% less than recommended dose of B
B_{R+20} = 20% higher than recommended dose of B

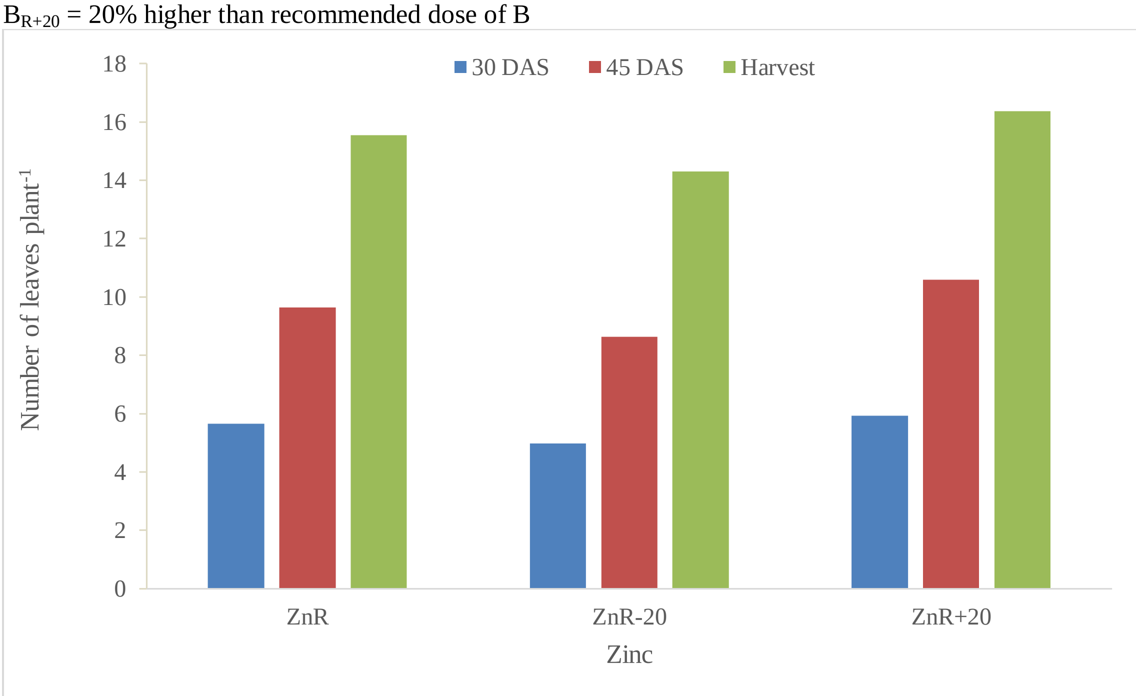

Fig. 4. Number of leaves plant^{-1} of mungbean as influenced by zinc (Zn)

Zn_R = Recommended dose of Zn
Zn_{R-20} = 20% less than recommended dose of Zn
Zn_{R+20} = 20% higher than recommended dose of Zn

Combined effect of B and Zn

Variation on number of leaves plant^{-1} was significant due to the combined effect of B and Zn (Table 2 and Appendix VI). Results revealed that the highest numbers of leaves plant^{-1} (6.52, 12.40 and 18.50 at 30, 45 DAS and at harvest respectively) were found from the combination of B_RZn_{R+20} which was nearest to the treatment combination of B_RZn_R but significantly different. The lowest numbers of leaves plant^{-1} (4.50, 7.85 and 12.80 at 30, 45 DAS and at harvest respectively) were found from the treatment combination of $B_{R-20}Zn_{R-20}$ which were statistically similar with $B_{R-20}Zn_R$ at 45(DAS) and harvest only.

Table 2. Number of leaves plant^{-1} of mungbean as influenced by the combined treatments of boron (B) and zinc (Zn)

Treatment combination	Number of leaves plant^{-1}		
	30 DAS	45 DAS	At harvest
B_RZn_R	6.45 ab	11.10 b	17.50 b
B_RZn_{R-20}	5.15 d	8.670 ef	14.77 de
B_RZn_{R+20}	6.52 a	12.40 a	18.50 a
$B_{R-20}Zn_R$	5.05 d	8.040 fg	13.48 fg
$B_{R-20}Zn_{R-20}$	4.50 e	7.850 g	12.80 g
$B_{R-20}Zn_{R+20}$	5.35 d	8.900 de	14.32 ef
$B_{R+20}Zn_R$	5.48 cd	9.800 c	15.67 cd
$B_{R+20}Zn_{R-20}$	5.28 d	9.370 cd	15.33 d
$B_{R+20}Zn_{R+20}$	5.92 bc	10.50 b	16.33 c
$LSD_{0.05}$	0.532	0.6509	0.9489
CV (%)	5.253	7.138	8.522

In a column figures having similar letter(s) do not differ significantly whereas figures with dissimilar letter(s) differ significantly

B_R = Recommended dose of B
B_{R-20} = 20% less than recommended dose of B
B_{R+20} = 20% higher than recommended dose of B

Zn_R = Recommended dose of Zn
Zn_{R-20} = 20% less than recommended dose of Zn
Zn_{R+20} = 20% higher than recommended dose of Zn

4.1.3 Number of branches plant^{-1}

Effect of B

Number of branches plant^{-1} of mungbean at different growth stages varied significantly due to different boron treatments (Figure 5 and Appendix VII). It was found that the highest numbers of branches plant^{-1} (1.12, 4.37 and 4.62 at 30, 45 DAS and at harvest respectively) were found from B_R which was statistically identical with B_{R+20} at all growth stages where the lowest number of branches plant^{-1} (0.85, 3.45 and 3.49 at 30, 45 DAS and at harvest respectively) were found from B_{R-20}. The results found from the present findings was similar with the findings of Vimalan *et al*. (2017), Hamza *et al*. (2016) and Rahman *et al*. (2015).

Effect of Zn

Level of Zn showed significant variation on number of branches plant^{-1} of mungbean at different growth stages (Figure 6 and Appendix VII). It was identified that the highest numbers of branches plant^{-1} (1.10, 4.23 and 4.38 at 30, 45 DAS and at harvest respectively) were found from Zn_R which were statistically identical with Zn_{R+20} at 45 DAS and at harvest. The lowest numbers of branches plant^{-1} (0.88, 3.59 and 3.68 at 30, 45 DAS and at harvest respectively) were found from Zn_{R-20}. The results obtained from the present findings were similar with the findings of Rahman *et al*. (2015) and Malik *et al*. (2015).

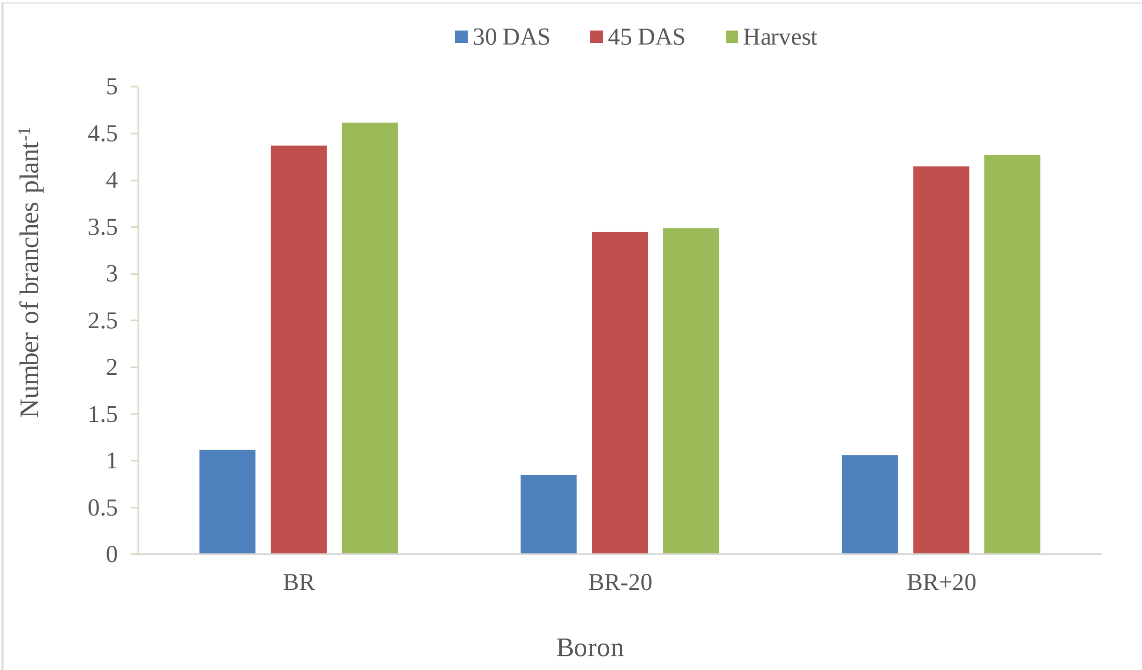

Fig. 5. Number of branches plant^{-1} of mungbean as influenced by boron (B)

B_R = Recommended dose of B
B_{R-20} = 20% less than recommended dose of B
B_{R+20} = 20% higher than recommended dose of B

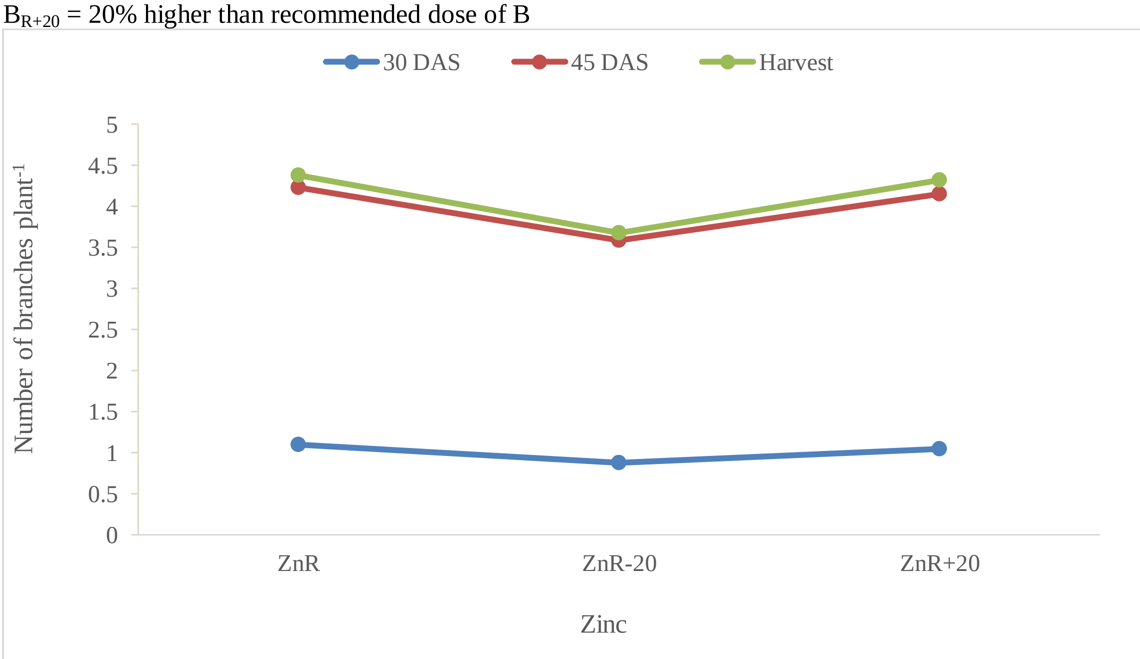

Fig. 6. Number of branches plant^{-1} of mungbean as influenced by zinc (Zn)

Zn_R = Recommended dose of Zn
Zn_{R-20} = 20% less than recommended dose of Zn
Zn_{R+20} = 20% higher than recommended dose of Zn

Combined effect of B and Zn

Significant influence was detected on number of branches plant^{-1} of mungbean at different growth stages affected by combined effect of B and Zn (Table 3 and Appendix VII). It was noted that the highest numbers of branches plant^{-1} (1.25, 4.75 and 5.12 at 30, 45 DAS and at harvest respectively) were found from the treatment combination of B_RZn_R which were statistically identical with B_RZn_{R+20} at all growth stages. The treatment combination of $B_{R+20}Zn_R$ also showed identical result with B_RZn_R at 30 and 45 DAS. The lowest numbers of branches plant^{-1} (0.75, 3.10 and 3.20 at 30, 45 DAS and at harvest respectively) were found from the treatment combination of $B_{R-20}Zn_{R-20}$.

Table 3. Number of branches plant^{-1} of mungbean as influenced by combined treatments of boron (B) and zinc (Zn)

Treatment combination	Number of branches plant^{-1}		
	30 DAS	45 DAS	At harvest
B_RZn_R	1.25 a	4.75 a	5.12 a
B_RZn_{R-20}	0.90 bc	3.67 bc	3.75 de
B_RZn_{R+20}	1.22 a	4.70 a	5.00 a
$B_{R-20}Zn_R$	0.87 bc	3.50 c	3.63 e
$B_{R-20}Zn_{R-20}$	0.75 c	3.10 d	3.20 f
$B_{R-20}Zn_{R+20}$	0.92 bc	3.75 bc	3.93 c-e
$B_{R+20}Zn_R$	1.18 a	4.45 a	4.50 b
$B_{R+20}Zn_{R-20}$	1.00 b	4.00 b	4.10 cd
$B_{R+20}Zn_{R+20}$	1.00 b	4.03 b	4.22 bc
$LSD_{0.05}$	0.163	0.339	0.376
CV (%)	3.274	5.137	5.314

In a column figures having similar letter(s) do not differ significantly whereas figures with dissimilar letter(s) differ significantly

B_R = Recommended dose of B
B_{R-20} = 20% less than recommended dose of B
B_{R+20} = 20% higher than recommended dose of B

Zn_R = Recommended dose of Zn
Zn_{R-20} = 20% less than recommended dose of Zn
Zn_{R+20} = % higher than recommended dose of Zn

4.1.4 Dry weight plant^{-1}

Effect of B

Significant influence was noted on dry weight plant^{-1} (Figure 7 and Appendix VIII). It was observed that the highest dry weight plant^{-1} (7.75, 17.23 and 23.71 g at 30, 45 DAS and at harvest respectively) were found from B_R which was statistically identical with $B_{R+20.}$ The lowest dry weight plant^{-1} (5.98, 12.75 and 18.62 g at 30, 45 DAS and at harvest respectively) were found from B_{R-20}. Similar finding were also observed by Padbhushan and Kumar (2014).

Effect of Zn

Remarkable variation was dected on dry weight plant^{-1} due to Zn levels on growth of mungbean (Figure 8 and Appendix VIII). Results showed that the highest dry weight plant^{-1} (7.73, 17.32 and 23.93 g at 30, 45 DAS and at harvest respectively) were found from Zn_{R+20} which was statistically identical with Zn_R at 45 DAS and at harvest where as the lowest dry weight plant^{-1} (6.28, 13.61 and 19.51 g at 30, 45 DAS and at harvest respectively) were found from Zn_{R-20}. Supported results was also observed from Malik *et al*. (2015) and Yang and Zhang (1998).

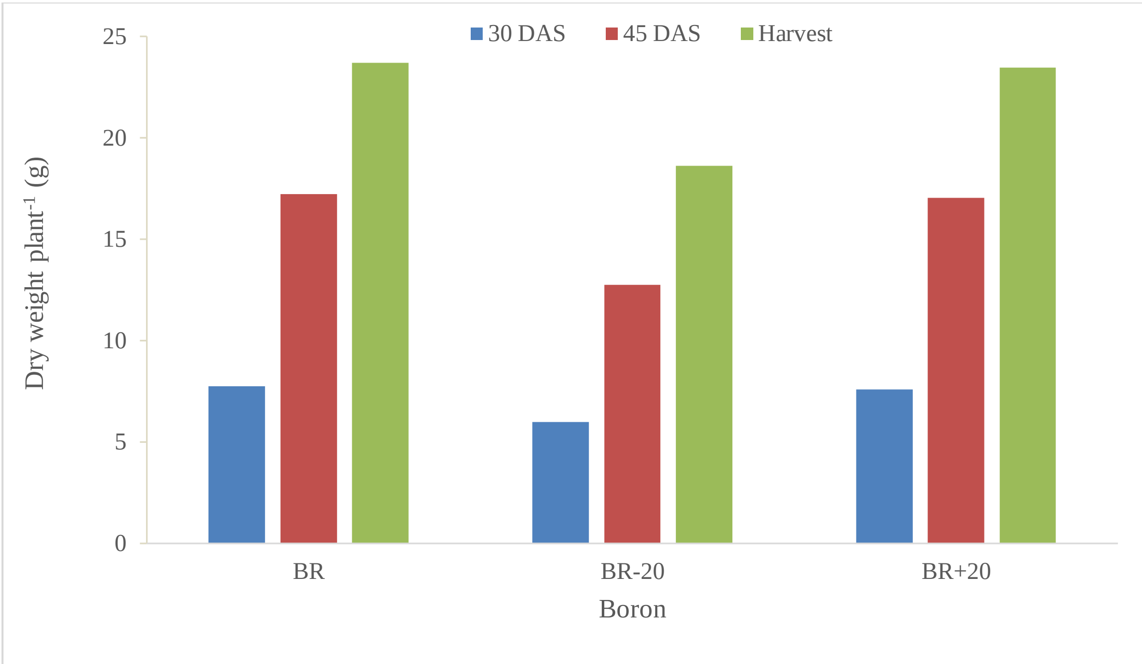

Fig. 7. Dry weight plant^{-1} of mungbean as influenced by boron (B)

B_R = Recommended dose of B
B_{R-20} = 20% less than recommended dose of B
B_{R+20} = 20% higher than recommended dose of B

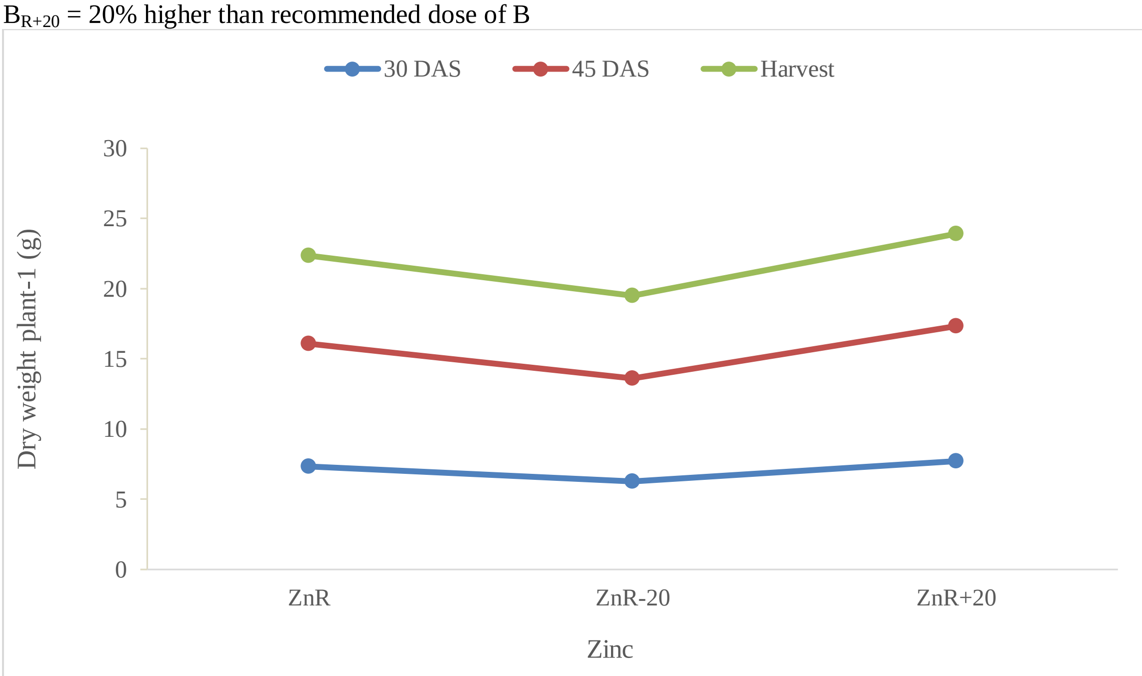

Fig. 8. Dry weight plant^{-1} of mungbean as influenced by zinc (Zn)

Zn_R = Recommended dose of Zn
Zn_{R-20} = 20% less than recommended dose of Zn
Zn_{R+20} = 20% higher than recommended dose of Zn

Combined effect of B and Zn

Variation on dry weight plant^{-1} was significant at different growth stages as affected by combined effect of B and Zn (Table 4 and Appendix VIII). Results exhibited that the highest dry weight plant^{-1} (8.85, 18.91 and 26.33 g at 30, 45 DAS and at harvest respectively) were found from the combination of B_RZn_{R+20} which were statistically similar with B_RZn_R at 45 DAS and at harvest followed by $B_{R+20}Zn_R$ and $B_{R+20}Zn_{R-20}$. The lowest dry weights plant^{-1} (5.58, 10.48 and 16.48 g at 30, 45 DAS and at harvest respectively) were found from the treatment combination of $B_{R-20}Zn_{R-20}$ which were close to the treatment combination of $B_{R-20}Zn_R$ at harvest.

Table 4. Dry weight plant^{-1}of mungbean as influenced by combined treatments of boron (B) and zinc (Zn)

Treatment combination	Dry weight plant^{-1} (g)		
	30 DAS	45 DAS	At harvest
B_RZn_R	8.27 b	18.24 ab	24.98 ab
B_RZn_{R-20}	6.14 e	13.98 e	19.81 de
B_RZn_{R+20}	8.85 a	18.91 a	26.33 a
$B_{R-20}Zn_R$	6.03 ef	12.54 f	18.29 e
$B_{R-20}Zn_{R-20}$	5.58 f	10.48 g	16.48 f
$B_{R-20}Zn_{R+20}$	6.33 e	15.24 d	21.10 cd
$B_{R+20}Zn_R$	7.65 c	17.49 bc	23.84 b
$B_{R+20}Zn_{R-20}$	7.11 d	16.38 cd	22.24 c
$B_{R+20}Zn_{R+20}$	8.01 bc	17.82 ab	24.36 b
$LSD_{0.05}$	0.463	1.211	1.532
CV (%)	4.385	6.229	9.212

In a column figures having similar letter(s) do not differ significantly whereas figures with dissimilar letter(s) differ significantly

B_R = Recommended dose of B
B_{R-20} = 20% less than recommended dose of B
B_{R+20} = 20% higher than recommended dose of B

Zn_R = Recommended dose of Zn
Zn_{R-20} = 20% less than recommended dose of Zn
Zn_{R+20} = 20% higher than recommended dose of Zn

4.2 Yield contributing parameters

4.2.1 Days to 1st flowering

Effect of B

Days to 1st flowering of mungbean varied significantly due to different boron treatments (Table 5 and Appendix IX). It was observed that the highest days to 1st flowering (37.22) was found from B_{R-20} followed by B_R where the lowest days to 1stflowering (535.44) was found from B_{R+20}. Maqbool *et al*. (2018) and Vrema and Mishra (1999) also found that B had significant influence on flowering habit of mungbean.

Effect of Zn

Different Zn treatment showed significant variation on days to 1st flowering of mungbean (Table 5 and Appendix IX). It was observed that the highest days to 1st flowering (37.11) was found from Zn_{R-20} followed by Zn_R where the lowest days to 1stflowering (35.78) was found from Zn_{R+20}.

Combined effect of B and Zn

Significant influence was examined on days to 1st flowering of mungbean affected by combined effect of B and Zn (Table 5 and Appendix IX). Results revealed that the highest days to 1st flowering (38.00) was found from the treatment combination of $B_{R-20}Zn_{R-20}$ which was statistically similar with the treatment combination of B_RZn_{R-20} followed by $B_{R-20}Zn_R$. The lowest days to 1st flowering (35.00) was found from the treatment combination of $B_{R+20}Zn_{R-20}$ which was statistically similar with $B_{R+20}Zn_R$.

4.2.2 Days to maturity

Effect of B

Significant influence was noted for days to maturity affected by B application (Table 5 and Appendix IX). Results indicated that the highest days to maturity (59.55) was found from B_{R+20} followed by B_R where the lowest days to maturity (56.67) was found from B_{R-20}.

Effect of Zn

Remarkable variation was observed in terms of days to maturity of mungbean influenced by Zn application (Table 5 and Appendix IX). Results showed that the highest days to maturity (59.11) was found from B_{R+20} which was statistically identical with Zn_R where the lowest days to maturity (56.78) was found from B_{R-20}. Liu Peng *et al.,* (2005) also found boron effect on maturity of mungbean.

Combined effect of B and Zn

Variation on days to maturity was significant affected by combined effect o B and Zn (Table 5 and Appendix IX). Results exposed that the highest days to maturity (60.33) was found from the treatment combination of $B_{R+20}Zn_{R+20}$ which was statistically similar with the treatment combination of B_RZn_R and $B_{R+20}Zn_R$. The lowest days to maturity (55.67) was found from the treatment combination of B_{R-20} Zn_{R-20} which was statistically similar with the treatment combination of B_RZn_{R-20}.

4.2.3 Number of pods plant^{-1}

Effect of B

Number of pods plant^{-1} of mungbean varied significantly due to different boron treatments (Table 5 and Appendix IX). Results signified that the highest number of pods plant^{-1} (21.12) was found from B_R where the lowest number of pods plant^{-}

^{1}(14.58) was found from B_{R-20} followed by B_{R-20}. Similar results was also observed by Maqbool *et al*. (2018) and Vimalan *et al*. (2017).

Effect of Zn

Different Zn treatment showed significant variation on number of pods plant^{-1} of mungbean (Table 5 and Appendix IX). It was noted that the highest number of pods plant^{-1}(20.32) was found from Zn_{R+20} followed by Zn_R whereas the lowest number of pods plant^{-1} (15.72) was found from Zn_{R-20}. The results obtained from the present study was similar with the findings of Rahman *et al*. (2015), Karmakar *et al*. (2015) and Ram and Katiyar (2013).

Combined effect of B and Zn

Significant influence was examined on number of pods plant^{-1} of mungbean affected by combined effect of B and Zn (Table 5 and Appendix IX). It was indicated that the highest number of pods plant^{-1} (24.25) was found from the treatment combination of B_R Zn_{R+20} which was statistically similar with B_RZn_R followed by $B_{R+20}Zn_{R+20}$ and $B_{R+20}Zn_{R-20}$. The lowest number of pods plant^{-1} (13.70) was found from the treatment combination of $B_{R-20}Zn_{R-20}$ which was statistically identical with $B_{R-20}Zn_{R-20}$ and statistically similar with B_RZn_{R-20} and $B_{R-20}Zn_{R+20}$.

4.2.4 Number of seeds pods^{-1}

Effect of B

Significant influence was noted for number of seeds pods^{-1} affected by B treatment (Table 5 and Appendix IX). Results exhibited that the highest number of seeds pods^{-1} (21.13) was found from B_R which was statistically identical with B_{R+20} where the lowest number of seeds pods^{-1} (10.56) was found from B_{R-20}. Vimalan *et al*. (2017) and Hamza *et al*. (2016) also found similar results with the present study.

Effect of Zn

Remarkable variation was examined in terms of number of seeds pods^{-1} of mungbean influenced by Zn treatment (Table 5 and Appendix IX). It was examined that the highest number of seeds pods^{-1}(12.03) was found from Zn_{R+20} followed by Zn_R where the lowest number of seeds pods^{-1} (10.78) was found from Zn_{R-20}. The results obtained from the present study was similar with the findings of Rahman *et al*. (2015), Karmakar *et al*. (2015) and Ram and Katiyar (2013).

Combined effect of B and Zn

Variation on number of seeds pods^{-1} was significant affected by combined effect o B and Zn (Table 5 and Appendix IX). It was identified that the highest number of seeds pods^{-1} (12.87) was found from the treatment combination of B_R Zn_{R+20} which was statistically identical with the treatment combination of B_RZn_R followed by $B_{R+20}Zn_R$ and $B_{R+20}Zn_{R+20}$. The lowest number of seeds pods^{-1} (10.25) was found from the treatment combination of $B_{R-20}Zn_{R-20}$ which was statistically identical with $B_{R-20}Zn_R$.

4.2.5 Pod length

Effect of B

Pod length of mungbean varied significantly due to different boron treatments (Table 5 and Appendix IX). Results showed that the highest pod length (8.20 cm) was found from B_R which was statistically identical with B_{R+20} where the lowest pod length (7.33 cm) was found from B_{R-20}. Similar results was also observed by Hamza *et al*. (2016) and Zaman *et al.* (1996b)

Effect of Zn

Different Zn treatment showed significant variation on pod length of mungbean (Table 5 and Appendix IX). It was identified that the highest pod length (8.19

cm)was found from Zn_{R+20} which was statistically identical with Zn_R where the lowest pod length (7.52 cm) was found from Zn_{R-20}. Ram and Katiyar (2013) also found similar results with the present study.

Combined effect of B and Zn

Significant influence was examined on pod length of mungbean affected by combined effect of B and Zn (Table 5 and Appendix IX). Results indicated that the highest pod length (8.60 cm) was found from the treatment combination of B_RZn_{R+20} which was statistically similar with B_RZn_R and $B_{R+20}Zn_{R+20}$ followed by $B_{R+20}Zn_R$. The lowest pod length (7.15 cm) was found from the treatment combination of B_{R-20} Zn_{R-20} which was significantly same with $B_{R-20}Zn_R$.

4.2.6 Weight of 1000 seeds

Effect of B

Significant influence was noted for 1000 seed weight affected by B treatment (Table 5 and Appendix IX). Results revealed that the highest 1000 seed weight (46.32 g) was found from B_R which was significantly same with B_{R+20} where the lowest 1000 seed weight (43.90 g) was found from B_{R-20}. Similar results was also observed by Maqbool *et al*. (2018), Vimalan *et al*. (2017) and Hamza *et al*. (2016).

Effect of Zn

Remarkable variation was examined in terms of 1000 seed weight of mungbean influenced by Zn treatment (Table 5 and Appendix IX). It was found that the highest 1000 seed weight (45.95 g) was obtained from Zn_R which was statistically identical with Zn_{R+20} where the lowest 1000 seed weight (44.41 g) was found from Zn_{R-20}. The results obtained from the present study was similar with the findings of Rahman *et al*. (2015) and Malik *et al*. (2015).

Combined effect of B and Zn

Variation on 1000 seed weight was affected significantly due to combined effects of B and Zn (Table 5 and Appendix IX). It was found that the highest 1000 seed weight (47.50 g) was found from the combination of B_RZn_R which was significantly similar with that of B_RZn_{R+20} followed by $B_{R+20}Zn_R$. The lowest 1000 seed weight (43.33 g) was found from the treatment combination of $B_{R-20}Zn_{R-20}$ which was statistically identical with $B_{R-20}Zn_R$.

Table 5. Phenotypic and reproductive parameters of mungbean as influenced by boron (B), zinc (Zn) and their combinations

Treatment	Yield contributing parameters					
	Days to 1st flowering	Days to maturity	Number of pods plant^{-1}	Number of seeds pods^{-1}	Pod length (cm)	1000 seed weight (g)
Effect of B						
B_R	36.56 b	58.44 b	21.12 a	12.13 a	8.20 a	46.32 a
B_{R-20}	37.22 a	56.67 c	14.58 c	10.56 b	7.33 b	43.90 b
B_{R+20}	35.44 c	59.55 a	19.32 b	11.81 a	8.17 a	45.75 a
$LSD_{0.05}$	0.389	0.684	1.352	0.453	0.514	1.371
CV (%)	8.303	6.299	6.517	5.417	5.744	6.375
Effect of Zn						
Zn_R	36.33 b	58.78 a	18.97 b	11.68 b	7.99 a	45.95 a
Zn_{R-20}	37.11 a	56.78 b	15.72 c	10.78 c	7.52 b	44.41 b
Zn_{R+20}	35.78 c	59.11 a	20.32 a	12.03 a	8.19 a	45.61 a
$LSD_{0.05}$	0.414	1.237	2.076	0.285	0.224	1.012
CV (%)	8.303	6.299	6.517	5.417	5.744	6.375
Combined effect of B and Zn						
B_RZn_R	36.67 bc	59.67 ab	23.45 ab	12.72 a	8.520 ab	47.50 a
B_RZn_{R-20}	37.33 ab	56.33 de	15.67 de	10.80 d	7.480 d	44.33 de
B_RZn_{R+20}	35.67 de	59.33 b	24.25 a	12.87 a	8.600 a	47.12 ab
$B_{R-20}Zn_R$	37.00 b	56.67 d	13.80 e	10.33 e	7.200 e	43.50 e
$B_{R-20}Zn_{R-20}$	38.00 a	55.67 e	13.70 e	10.25 e	7.150 e	43.33 e
$B_{R-20}Zn_{R+20}$	36.67 bc	57.67 c	16.24 de	11.10 cd	7.640 d	44.87 cd
$B_{R+20}Zn_R$	35.33 de	60.00 ab	19.67 c	12.00 b	8.250 b	46.00 bc
$B_{R+20}Zn_{R-20}$	36.00 cd	58.33 c	17.80 cd	11.30 c	7.920 c	45.40 cd
$B_{R+20}Zn_{R+20}$	35.00 e	60.33 a	20.48 bc	12.14 b	8.330 ab	45.85 c
$LSD_{0.05}$	0.8298	0.8764	2.989	0.3255	0.2657	1.131
CV (%)	8.303	6.299	6.517	5.417	5.744	6.375

In a column figures having similar letter(s) do not differ significantly whereas figures with dissimilar letter(s) differ significantly

B_R = Recommended dose of B
B_{R-20} = 20% less than recommended dose of B
B_{R+20} = 20% higher than recommended dose of B

Zn_R = Recommended dose of Zn
Zn_{R-20} = 20% less than recommended dose of Zn
Zn_{R+20} = 20% higher than recommended dose of Zn

4.3 Yield parameters

4.3.1 Seed yield

Effect of B

Seed yield of mungbean varied significantly due to different boron treatments (Table 6 and Appendix X). Results showed that the highest seed yield (1258.67 kg ha^{-1}) was found from B_R which was significantly same with B_{R+20} where the lowest seed yield (1061.33 kg ha^{-1}) was found from B_{R-20}. The results obtained from the present study was similar with the findings of Vimalan *et al*. (2017), Hamza *et al*. (2016), Padbhushan and Kumar (2014), Patra and Bhattacharya (2009) and Srivastava *et al.* (2005).

Effect of Zn

Different Zn treatment showed significant variation on seed yieldof mungbean (Table 6 and Appendix X). It was identified that the highest seed yield (1263.67 kg ha^{-1}) was found from Zn_{R+20} which was close to the treatment of Zn_R but significantly different from Zn_{R+20} where the lowest seed yield (1067.33 kg ha^{-1}) was found from Zn_{R-20}. Similar results was also observed by Rahman *et al*. (2015), Karmakar *et al*. (2015), Malik *et al*. (2015), Ram and Katiyar (2013) and Biswas*et al.* (2010).

Combined effect of B and Zn

Significant influence was examined on seed yield of mungbean affected by combined effect of B and Zn (Table 6 and Appendix X). It was examined that the highest seed yield (1371.00 kg ha^{-1}) was found from the treatment combination of B_RZn_{R+20} which was significantly same with the combination of B_RZn_R followed by $B_{R+20}Zn_R$. The combination of $B_{R+20}Zn_{R+20}$ and also showed comparatively higher seed yield but significantly different from B_R Zn_{R+20}. The lowest seed yield (966.00 kg ha^{-1}) was found from the treatment combination of $B_{R-20}Zn_{R-20}$ which was nearest to the treatment combination of B_RZn_{R-20} and $B_{R-20}Zn_R$ but significantly different. Here, it also observed that the treatment combination of B_RZn_{R+20} showed best seed yield might be due to cause of higher number of pods plant^{-1}, number of seeds pods^{-1}, pod length and 1000 seed weight. Alam and Islam (2016), Quddus *et al*. (2011) and Liu peng *et al.,* (2005) also found similar results with the present study.

4.3.2 Stover yield

Effect of B

Significant influence was noted for stover yield affected by B treatment (Table 6 and Appendix X). It was monitored that the highest stover yield (1615.33 kg ha^{-1}) was found from B_R which was significantly same with the treatment combination of B_{R+20} where the lowest stover yield (1493 kg ha^{-1}) was found from B_{R-20}. Hamza *et al*. (2016) and Bharti *et al.* (2002) also found similar results with the present study.

Effect of Zn

Remarkable variation was found on stover yield of mungbean influenced by Zn treatment (Table 6 and Appendix X). Results revealed that the highest stover yield (1607.67 kg ha^{-1}) was found from Zn_{R+20} which was statistically identical with Zn_R where the lowest stover yield (1511.00 kg ha^{-1}) was found from Zn_{R-20}. Similar results was also observed by Rahman *et al*. (2015) and Karmakar *et al*. (2015)

Combined effect of B and Zn

Variation on stover yield was significant affected by combined effect o B and Zn (Table 6 and Appendix X). It was showed that the highest stover yield (1666.00 kg ha^{-1}) was found from the treatment combination of B_RZn_{R+20} which was significantly same with the treatment of B_RZn_R followed by $B_{R+20}Zn_R$. The lowest stover yield (1445.00 kg ha^{-1}) was found from the treatment combination of $B_{R-20}Zn_{R-20}$ which was close to the treatment combination of $B_{R-20}Zn_R$.

4.3.3 Biological yield

Effect of B

Significant influence was noted for biological yield affected by B treatment (Table 6 and Appendix X). Results revealed that the highest biological yield (2874.00 kg ha^{-1}) was found from B_R which was significantly same with the treatment of B_{R+20} where the lowest biological yield (2554.67 kg ha^{-1}) was found from B_{R-20}.

Effect of Zn

Remarkable variation was examined in terms of biological yield of mungbean influenced by Zn treatment (Table 6 and Appendix X). It was found that the highest biological yield (2871.33 kg ha^{-1}) was achieved from Zn_{R+20} followed by the treatment of Zn_R where the lowest biological yield (2578.22 kg ha^{-1}) was found from Zn_{R-20}.

Combined effect of B and Zn

Variation on biological yield was significant affected by combined effect o B and Zn (Table 6 and Appendix X). Results signified that the highest biological yield (3036.00 kg ha^{-1}) was found from the treatment combination of B_RZn_{R+20} which was statistically identical with the treatment combination of B_RZn_R followed by the treatment combination of $B_{R+20}Zn_R$. The lowest biological yield (2411.00 kg ha^{-1}) was obtained from the treatment combination of $B_{R-20}Zn_{R-20}$ which was nearest to the treatment combination of B_RZn_{R-20} and $B_{R-20}Zn_R$ which was significantly same with each other but significantly different from $B_{R-20}Zn_{R-20}$.

4.3.4 Harvest index

Effect of B

Significant influence was noted for harvest index affected by B treatment (Table 6 and Appendix X). It was shown that the highest harvest index (43.85%) was found from B_R which was statistically identical with the treatment of B_{R+20} where the lowest harvest index (41.50%) was found from B_{R-20}. Hamza *et al*. (2016) also found similar results with the present study.

Effect of Zn

Remarkable variation was examined in terms of harvest index of mungbean influenced by Zn treatment (Table 6 and Appendix X). It was observed that the highest harvest index (43.96%) was found from Zn_{R+20} which was significantly same with the treatment of Zn_R where the lowest harvest index (41.33%) was found from Zn_{R-20}.

Combined effect of B and Zn

Variation on harvest index was significant affected by combined effect of B and Zn (Table 6 and Appendix X). It was noted that the highest harvest index (45.13%) was found from the treatment combination of B_R Zn_{R+20} which was statistically identical with the treatment combination of B_RZn_R and $B_{R+20}Zn_R$ and significantly similar with $B_{R+20}Zn_{R+20}$. The lowest harvest index (40.07%) was found from the treatment combination of $B_{R-20}Zn_{R-20}$ which was significantly similar with the treatment combination of B_RZn_{R-20}.

Table 6.Yield and yield attributes of mungbean as influenced by boron (B), zinc (Zn) and their combinations

Treatment	Yield parameters			
	Seed yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest index (%)
Effect of B				
B_R	1258.67 a	1615.33 a	2874.00 a	43.85 a
B_{R-20}	1061.33 b	1493.33 b	2554.67 b	41.50 b
B_{R+20}	1256.33 a	1608.00 a	2864.33 a	43.64 a
$LSD_{0.05}$	10.395	12.426	13.229	1.012
CV (%)	12.529	14.276	13.937	10.244
Effect of Zn				
Zn_R	1245.33 b	1598.00 a	2843.33 b	43.70 a
Zn_{R-20}	1067.33 c	1511.00 b	2578.33 c	41.33 b
Zn_{R+20}	1263.67 a	1607.67 a	2871.33 a	43.96 a
$LSD_{0.05}$	9.852	12.527	11.671	1.053
CV (%)	12.529	14.276	13.937	10.244
Combined effect of B and Zn				
B_RZn_R	1362.00 a	1660.00 a	3022.00 a	45.07 a
B_RZn_{R-20}	1044.00 g	1520.00 f	2564.00 f	40.72 ef
B_RZn_{R+20}	1371.00 a	1666.00 a	3036.00 a	45.13 a
$B_{R-20}Zn_R$	1070.00 f	1496.00 g	2566.00 f	41.70 de
$B_{R-20}Zn_{R-20}$	966.00 h	1445.00 h	2411.00 g	40.07 f
$B_{R-20}Zn_{R+20}$	1148.00 e	1539.00 e	2687.00 e	42.72 cd
$B_{R+20}Zn_R$	1304.00 b	1638.00 b	2942.00 b	44.32 a
$B_{R+20}Zn_{R-20}$	1192.00 d	1568.00 d	2760.00 d	43.19 bc
$B_{R+20}Zn_{R+20}$	1273.00 c	1618.00 c	2891.00 c	44.03 ab
$LSD_{0.05}$	11.679	13.524	14.278	1.038
CV (%)	12.529	14.276	13.937	10.244

In a column figures having similar letter(s) do not differ significantly whereas figures with dissimilar letter(s) differ significantly

B_R = Recommended dose of B
B_{R-20} = 20% less than recommended dose of B
B_{R+20} = 20% higher than recommended dose of B

Zn_R = Recommended dose of Zn
Zn_{R-20} = 20% less than recommended dose of Zn
Zn_{R+20} = 20% higher than recommended dose of Zn

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was carried out during the period from March 2017 to June 2017 at the Agronomy farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh to study the effect of boron and zinc on the growth and yield response of munghean. The variety BARI Mung-6 was used as the test crop. The experiment comprised of two factors; Factor A: Three levels of boron - (i) B_R = Recommended dose of B, (ii) B_{R-20} = 20% less than recommended dose of B and (iii) B_{R+20} = 20% higher than recommended dose of B and Factors B: Three levels of zinc - (i) Zn_R = Recommended dose of Zn, (ii) Zn_{R-20} = 20% less than recommended dose of Zn and (iii) Zn_{R+20} = 20% higher than recommended dose of Zn. According to BARC the recommended doses of B and Zn are 0.5 and 1.0 kg ha^{-1} respectively. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Data on different growth parameters, yield, yield contributing parameters and yield were recorded and statistically and significant variation was observed due to different level of boron and zinc and their combination.

Due to different rates of B the highest plant height (34.31, 62.26 and 65.18 cm at 30, 45 DAS and at harvest respectively) was found from B_{R+20} but the highest number of leaves $plant^{-1}$ (6.04, 10.71 and 16.92 at 30, 45 DAS and at harvest respectively), number of branches $plant^{-1}$ (1.12, 4.37 and 4.62 at 30, 45 DAS and at harvest respectively) and dry weight $plant^{-1}$ (7.75, 17.23 and 23.71 g at 30, 45 DAS and at harvest respectively) were found from B_R. The highest days to 1st flowering (37.22) was found from $B_{R-20.}$ whereas the highest days to maturity (59.55) was found from B_{R+20}. Moreover the highest number of pods $plant^{-1}$ (21.12), number of seeds $pods^{-1}$ (21.13), pod length (8.20 cm), 1000 seed weight (46.32 g), seed yield (1258.67 kg ha^{-1}), stover yield (1615.33 kg ha^{-1}), biological yield (2874.00 kg ha^{-1}) and highest harvest index (43.85%) were also recorded from B_R. On the other hand, the lowest plant height (30.62, 55.54 and 57.06 cm at 30, 45 DAS and at harvest respectively), number of leaves plant^{-1} (4.97, 8.26 and 13.53 at 30, 45 DAS and at harvest respectively), number of branches plant^{-1} (0.85, 3.45 and 3.49 at 30, 45 DAS and at harvest respectively) and dry weight plant^{-1} (5.98, 12.75 and 18.62 g at 30, 45 DAS and at harvest respectively) were resulted from B_{R-20}. The lowest days to 1stflowering (535.44) was found from B_{R+20} but the lowest days to maturity (56.67) was found from B_{R-20}. Again, the lowest number of pods plant^{-1} (14.58), lowest number of seeds pods^{-1} (10.56), lowest pod length (7.33 cm), lowest 1000 seed weight (43.90 g), lowest seed yield (1061.33 kg ha^{-1}), lowest stover yield (1493 kg ha^{-1}), lowest biological yield (2554.67 kg ha^{-1}) and lowest harvest index (41.50%) were also found from B_{R-20}.

Due to different levels of Zn application, the highest plant height (34.31, 62.26 and 65.18 cm at 30, 45 DAS and at harvest respectively), number of leaves plant^{-1} (5.93, 10.59 and 16.38 at 30, 45 DAS and at harvest respectively) and dry weight plant^{-1} (7.73, 17.32 and 23.93 g at 30, 45 DAS and at harvest respectively) were found from Zn_{R+20} but the highest number of branches plant^{-1} (1.10, 4.23 and 4.38 at 30, 45 DAS and at harvest respectively) were found from Zn_R. Results also revealed that the highest days to 1st flowering (37.11) was found from Zn_{R-20} but the highest days to maturity (59.11) was found from B_{R+20} where the highest number of pods plant^{-1} (20.32), number of seeds pods^{-1} (12.03), pod length (8.19 cm), seed yield (1263.67 kg ha^{-1}), stover yield (1607.67 kg ha^{-1}), biological yield (2871.33 kg ha^{-1}) and harvest index (43.96%) were also found from Zn_{R+20} but the highest 1000 seed weight (45.95 g) was found from Zn_R. Again, the lowest plant height (30.91, 56.42 and 58.08 cm at 30, 45 DAS and at harvest respectively), number of leaves plant^{-1} (4.98, 8.63 and 14.30 at 30, 45 DAS and at harvest respectively), number of branches plant^{-1} (0.88, 3.59 and 3.68 at 30, 45 DAS and at harvest respectively) and dry weight plant^{-1} (6.28, 13.61 and 19.51 g at 30, 45

DAS and at harvest respectively) were obtained from Zn_{R-20}. The lowest days to 1^{st}flowering (35.78) was found from Zn_{R+20} but the lowest days to maturity (56.78) was found from B_{R-20}. The lowest number of pods plant^{-1} (15.72), number of seeds pods^{-1} (10.78), pod length (7.52 cm), 1000 seed weight (44.41 g), seed yield (1067.33 kg ha^{-1}), stover yield (1511.00 kg ha^{-1}), biological yield (2578.22 kg ha^{-1}) and harvest index (41.33%) were also found from Zn_{R-20}.

Regarding combined effect of B and Zn, the highest plant height (35.20, 64.67 and 68.07 cm at 30, 45 DAS and at harvest respectively) was found from the treatment combination of $B_{R+20}Zn_{R+20}$ but the highest number of branches plant^{-1} (1.25, 4.75 and 5.12 at 30, 45 DAS and at harvest respectively) was found from the treatment combination of B_RZn_R where the highest number of leaves plant^{-1} (6.52, 12.40 and 18.50 at 30, 45 DAS and at harvest respectively) and dry weight plant^{-1} (8.85, 18.91 and 26.33 g at 30, 45 DAS and at harvest respectively) were achieved from the treatment combination of B_RZn_{R+20}. The highest days to 1^{st} flowering (38.00) was found from the treatment combination of $B_{R-20}Zn_{R-20}$ but the highest days to maturity (60.33) was found from the treatment combination of $B_{R+20}Zn_{R+20}$. Again, the highest number of pods plant^{-1} (24.25), number of seeds pods^{-1} (12.87), pod length (8.60 cm), seed yield (1371.00 kg ha^{-1}), stover yield (1666.00 kg ha^{-1}), biological yield (3036.00 kg ha^{-1}) and harvest index (45.13%) was found from the treatment combination of B_RZn_{R+20} but the highest 1000 seed weight (47.50 g) was found from the treatment combination of B_RZn_R. Results also revealed that the lowest plant height (28.77, 51.83 and cm at 30, 45 DAS and at harvest respectively), number of leaves plant^{-1} (4.50, 7.85 and 12.80 at 30, 45 DAS and at harvest respectively), number of branches plant^{-1} (0.75, 3.10 and 3.20 at 30, 45 DAS and at harvest respectively) and dry weight plant^{-1} (5.58, 10.48 and 16.48 g at 30, 45 DAS and at harvest respectively) was found from the treatment combination of $B_{R-20}Zn_{R-20}$. The lowest days to 1^{st} flowering (35.00) was found from the treatment combination of $B_{R+20}Zn_{R-20}$ but the lowest days to maturity

(55.67) was found from the treatment combination of B_{R-20} Zn_{R-20}. The lowest number of pods plant^{-1}(13.70), number of seeds pods^{-1} (10.25), pod length (7.15 cm), 1000 seed weight (43.33 g), seed yield (966.00 kg ha^{-1}), stover yield (1445.00 kg ha^{-1}), biological yield (2411.00 kg ha^{-1}) and harvest index (40.07%) were found from the treatment combination of $B_{R-20}Zn_{R-20}$.

From the above findings it was found that application of B_R (Recommended dose of B) and Zn_{R+20} (20% higher than recommended dose of Zn) showed best mungbean seed yield which was significantly same with the treatment combination of B_RZn_R (Recommended dose of B and Zn). So, it can be concluded that combination of B_R (Recommended dose of B) and Zn_{R+20} (20% higher than recommended dose of Zn) and also combination of B_RZn_R (Recommended dose of B and Zn) can be more beneficial for the farmers to get better yield from the cultivation of BARI mung-6.

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 different doses of B and Zn.

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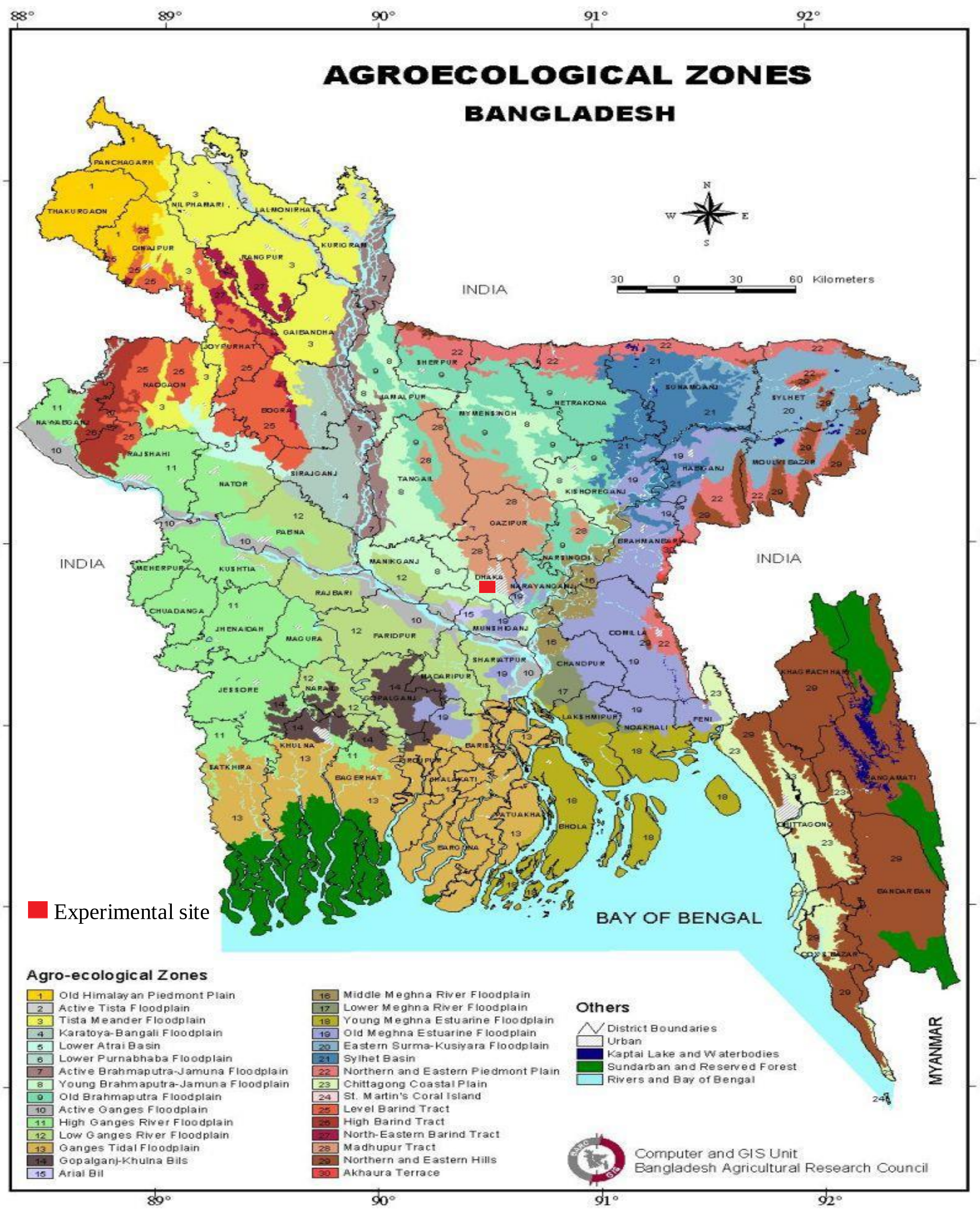
APPENDICES

Appendix I. Agro-Ecological Zone of Bangladesh showing the experimental location



Appendix II. Monthly records of air temperature, relative humidity, rainfall and sunshine hours during the period from March to June, 2017

Month	RH (%)	Air temperature (C)			Rainfall (mm)
		Max.	*Min.*	*Mean*	
March	52.44	35.20	21.00	28.10	0
April	65.40	34.70	24.60	29.65	165
May	68.30	32.64	23.85	28.25	182
June	71.28	27.40	23.44	25.42	190

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

Appendix III. Characteristics of experimental soil analyzed at Soil Resources Development Institute (SRDI), Farmgate, Dhaka.

A. Morphological characteristics of the experimental field

Morphological features	**Characteristics**
Location	Agronomy Farm, SAU, Dhaka
AEZ	Modhupur 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
Cropping pattern	Not Applicable

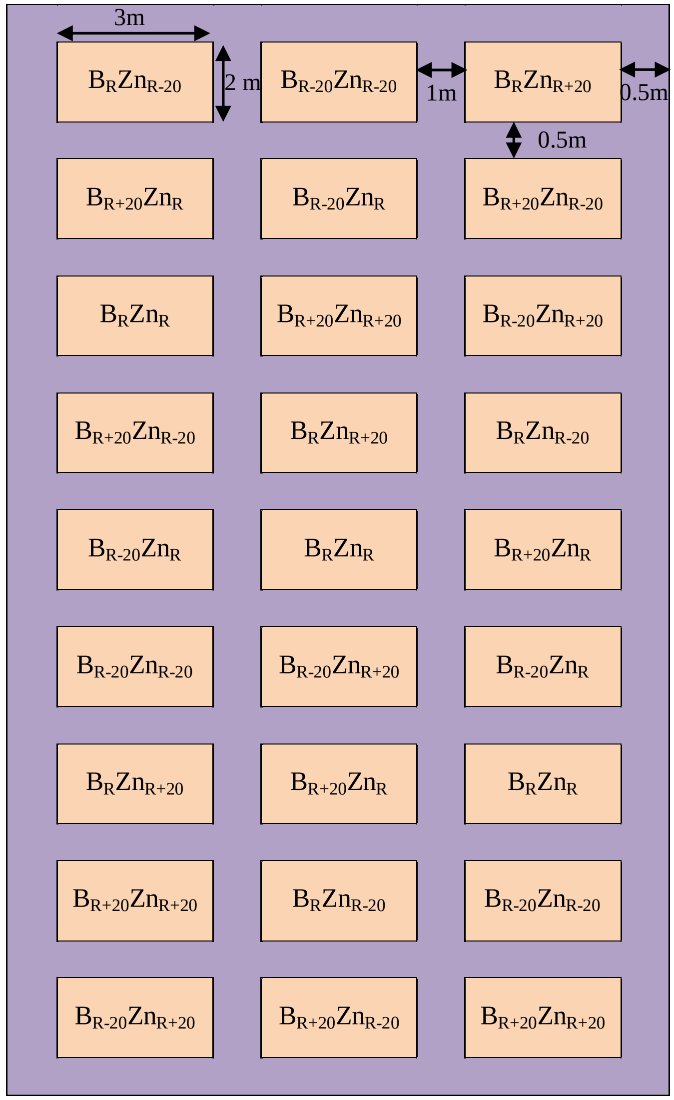
Source: Soil Resource Development Institute (SRDI)

B. Physical and chemical properties of the initial soil

Characteristics	**Value**
Partical size analysis % Sand	27
%Silt	43
% Clay	30
Textural class	Silty Clay Loam (ISSS)
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20
Exchangeable K (me/100 g soil)	0.1
Available S (ppm)	45

Source: Soil Resource Development Institute (SRDI)

Appendix IV. Layout of the experimental field



Appendix IV.Mean square of plant height of mungbean influenced by boron (B) and zinc (Zn) and their combination

Sources of variation	Degrees of freedom	Mean square of plant height (cm) at		
		30 DAS	45 DAS	At harvest
Replication	2	0.266	0.311	0.621
Factor A	2	6.214**	15.36*	19.27*
Factor B	2	11.329*	26.18*	33.52*
AB	4	4.117**	10.75**	11.76**
Error	18	1.059	2.214	2.334

Appendix V. Mean square of umber of leaves plant^{-1} of mungbean influenced by boron (B) and zinc (Zn) and their combination

Sources of variation	Degrees of freedom	Mean square of umber of leaves plant^{-1} at		
		30 DAS	45 DAS	At harvest
Replication	2	0.048	0.106	0.304
Factor A	2	6.186*	8.317**	12.036*
Factor B	2	4.439*	11.255*	18.527*
AB	4	2.286**	5.279**	7.298**
Error	18	0.259	0.386	1.073

Appendix VI.Mean square of number of branches plant^{-1} of mungbean influenced by boron (B) and zinc (Zn) and their combination

Sources of variation	Degrees of freedom	Mean square of number of branches plant^{-1} at		
		30 DAS	45 DAS	At harvest
Replication	2	0.002	0.032	0.064
Factor A	2	0.627**	3.227**	4.319**
Factor B	2	1.014**	4.086*	4.573*
AB	4	0.113**	1.272**	1.044**
Error	18	0.056	0.113	0.128

Appendix VIII. Mean square of dry weight plant^{-1} of mungbean influenced by boron (B) and zinc (Zn) and their combination

Sources of variation	Degrees of freedom	Mean square of dry weight plant^{-1} (g) at		
		30 DAS	45 DAS	At harvest
Replication	2	0.004	0.086	0.347
Factor A	2	5.241*	7.661*	8.863*
Factor B	2	6.368*	6.428*	10.28*
AB	4	2.117**	3.139**	4.318**
Error	18	0.083	1.014	1.037

Appendix VIII.Mean square of yield contributing parameters of mungbean influenced by boron (B) and zinc (Zn) and their combination

Sources of variation	Degrees of freedom	Mean square of yield contributing parameters			
		Number of pods plant^{-1}	Number of seeds pod^{-1}	Pod length (cm)	1000 seed weight (g)
Replication	2	0.688	0.318	0.512	0.018
Factor A	2	9.263*	6.569*	8.038	7.041**
Factor B	2	15.31*	13.74*	15.16*	9.117*
AB	4	7.841*	5.336**	6.714*	3.056*
Error	18	1.346	1.314	0.236	0.148

Appendix IX.Mean square of yield parameters of mungbean influenced by boron (B) and zinc (Zn) and their combination

Sources of variation	Degrees of freedom	Mean square of yield parameters			
		Seed yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest index (%)
Replication	2	5.510	6.217	6.783	0.704
Factor A	2	104.81*	147.42*	157.28*	11.783*
Factor B	2	305.52*	378.24*	386.47*	28.314*
AB	4	76.241*	81.58*	68.79**	7.418**
Error	18	10.011	14.752	14.217	0.933

PICTURES

Picture 1: Plot view of mungbean

Picture 2: Net was given to protect from birds in mungbean field