EFFECT OF BORON ON GROWTH AND YIELD OF FIELD-PEA

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ABSTRACT

A field experiment was carried out to find out the effect of boron on growth and yield of field pea (BARI Motor-3) at the farm of Bangladesh Agricultural Research Institute, Joydebpur, Gazipur, Bangladesh during the period from November, 2019 to March 2020. Seven doses of boron including control was considered as treatments *viz*. T_0 (0 kg B ha^{-1}; control), T_1 (0.5 kg B ha^{-1}), T_2 (1.0 kg B ha^{-1}), T_3 (1.5 kg B ha^{-1}), T_4 (2.0 kg B ha^{-1}), T_5 (2.5 kg B ha^{-1}) and T_6 (3.0 kg B ha^{-1}). This experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. All the parameters studied on growth, yield attributes and yield parameters were significantly affected due to boron doses. The maximum plant height (107.80 cm) was registered from the treatment T_6 (3.0 kg B ha^{-1}) but the T_3 (1.5 kg B ha^{-1}) showed maximum number of branch plant^{-1} (4.27), number of pods plant^{-1} (20.53), number of seeds pod^{-1} (6.60), 100 seed weight (13.08 g), seed yield (1732 kg ha^{-1}), stover yield (1862 kg ha^{-1}), biological yield (3594 kg ha^{-1}) and harvest index (48.27%) whereas the lowest result was obtained from control treatment T_0 (0 kg B ha^{-1}). In terms of nutrients content in field pea seed, significantly highest B content (33.33 ppm) was recorded from T_5 but the highest N content (4.81) and Mn content (102.50 ppm) were achieved from T_4. Similarly, significantly the highest Zn content (60.12 ppm) and Fe content (164.30 ppm) was recorded from T_3 whereas the lowest N, B, Zn, Fe and Mn content were recorded from control treatment (0 kg B ha^{-1}). Regarding P, K, S, Ca and Mg content in field pea seed, non-significant variation was found among the treatments. So, from the above results, it can be concluded that application of 1.5 kg B ha^{-1} (T_3) can be treated as best treatment followed by T_2 (1.0 kg B ha^{-1}) regarding yield performance of field pea (BARI Motor-3).

CHAPTER I

INTRODUCTION

Motor or field pea (*Pisum sativum* L. 2n=2x=14) is an important field crop, which belongs to the family Leguminosae (Fabaceae). It is widely cultivated throughout the world. As a cool season crop, it is extensively grown in temperate zone but restricted to cooler altitudes in the tropic and winter season in the subtropics. Globally, field pea covers an area of about 2.58 million hectares with a production of 19.87 million tons and productivity of 7.67 tons per hectare (Anonymous, 2016). It is a cool season crop now grown in many parts of the world. At present in Bangladesh pea is being cultivated in an area of 17746 acres with a production of 8139 metric tons (BBS, 2018).

Field pea is an annual herbaceous plant. The plants are succulent and they have a tendency to climb when provided support. Plants exhibit a tap root system with nodules in surface. Stem is hollow, slender, succulent and ridged. It has pinnate compound leaves with six leaf-lets and a terminal modified branched tendril. At the below of the stem, two large stipules on bracts are found and they cover the stems in such a way that leaves look like sessile (Khanna and Gupta, 2005).

The green pods and immature seeds are rich in vitamin and a balanced amino acid. In addition, calcium, phosphorus, iron are present in abundant quantities in peas. Due to its high nutritive value and good taste, the pea becomes popular. Besides, being rich in health building substances such as protein, carbohydrates, vitamins, minerals, sugars and starch. It is an important source of lysine, the limited amino acid in cereals. Pea is an important protein contributing factor in human diet as its protein level reaches up to 40 percent on dry weight basis. Fresh green pea per 100 g contain about 93 calories energy, 72.0 percent moisture, 7.2 g protein, 15.8 g carbohydrates, vitamin A 139 IU, vitamin C 9 mg (Choudhury, 2000). It contains

15-35% protein, 20-50% starch, 4- 10% sugar, 0.6-1.5% fat and 2-4% minerals (Makasheva, 1983). In Bangladesh people consumes 23 g vegetables per head per day but the minimum requirement is 200 g per head per day (Rashid, 1993).

Boron is required for infection thread development and nodule cell invasion, probably due to a B-mediated inhibition of the binding of infection thread matrix material to the cell surface of Rhizobium that promotes endocytosis of bacteria (Bolanos *et al*., 1996). The availability of B in plants is affected by numerous soil factors including soil solution. pH, texture, moisture, temperature, oxide content, carbonate compost, organic matter content and clay mineralogy (Goldberg *et al*., 2000). Boron is generally less available in clay soil and availability increases with increasing temperature (Fleming, 1980). When boron is added to soil, it is utilized by plants and currently it is consumed by soil microorganisms, fixed or absorbed by soil solids, post throughout surface runoff and leach out from soil. Zhu *et al*. (1994) reported that 80% of boron was transformed into unavailable form during a cropping season, and only 20-60% of B could be extracted by hot weather.

Lesser use of organic manures and boron fertilizers has resulted in deficiency of boron in soils which limits the growth, yield and nodulation of various legume crops including pea, indicating the need of its application. Boron toxicity levels in soils due to add of B in irrigation water in arid and semi-arid areas (Nable *et al*., 1997). Keeping these facts in view an experiment was conducted with the following objectives.

1. To find out the optimum dose of B on the growth and yield of field pea.
2. To find out the nutrient accumulation on the growth and yield of field pea.
3. To assess the concentration of different nutrients of seeds for different levels of B.

CHAPTER II

REVIEW OF LITERATURE

El-Waraky *et al.* (2013) carried out two field experiments during the winter seasons of 2008-09 and 2009-10 to investigate the response of pea plants, cv. Master B, to inoculation with bio-fertilizer (Halex-2) and different concentrations with boron (0, 5, 10 and 15ppm) as a foliar application. The results indicated that inoculation of pea seeds with bio-fertilizer (Halex-2), improved the most vegetative characters, as well as green pods yield and its components, shelling ratio, seed yield and its components, seed germination percentage, leaf contents of chlorophyll and seed content of protein. Increasing boron concentration up to 10ppm was accompanied with significant increases in vegetative growth characters, as well as green pods yield and its components, shelling ratio, seed yield and its components, seed germination percentage, leaf contents of chlorophyll and seed content of protein. The highest boron concentration at 10ppm combined with Halex-2 bio-fertilizer appeared to be the most efficient treatment for more vigorous growth, green pods yield and its components, shelling ratio, seed yield and its components and seed germination percentage, as well as chlorophyll content in leaves and protein content in seeds.

Vyas and Khadwe (2013) conducted a field experiment at Madhya Pradesh, during *kharif* seasons of 2007 and 2008, to study the effect of sulphur and boron levels on productivity of soybean. Results showed that no. of pods/plant and seed yield of soybean were increased up to the level of boron @ 0.5 kg ha^{-1}.

Salih (2013) carried out pot experiment under greenhouse conditions during 2011 and 2012 growth season to investigate Fe, B and Zn foliar application effects on nutrient concentration and seed protein of cowpea *(Vigna unguiculata).* Three concentrations (0, 1 and 2ppm) of micro-nutrient solutions were applied. Fe, B and Zn were sprayed every 15 days. Parameters measured were values of each nutrients and protein%, also, P, K, Ca, Mg, Na and Cl. The results showed that the effect of different treatments on nutrient concentration and seed protein were significant. Iron treatment has a greater effect on the nutrient uptake and protein percentage of seed than other treatments. The study results explain that foliar fertilization with micronutrient may have a possibility role for increasing cowpea yield.

Samet *et al*. (2013) conducted an experiment to study the, jointly effects of three potassium (K) levels (0, 200, and 400 mg kg^{-1} as K_2SO_4) and four boron (B) levels (0, 5, 10, and 20 mg kg^{-1} as H_3BO_3) on shoot and root dry weights and some macro and micronutrient contents of bean *(Phaseolus vulgaris* L.) were investigated. According to the results, the interactions of K and B on shoot and root dry weights, macro and micronutrient contents of shoots, and B and K uptakes were found statistically significant. In all treatments, shoot and root dry weights were negatively affected by increasing B levels.

Pandey and Gupta (2012) reported that foliar application of boron at 0.1% increase the yield attributing parameter like number of pods, pod size, number of seed pod^{-1} and yield in black gram..

Shekhawat and Shivay (2012) conducted an experiment and concluded that the application of sulphur at 50 kg ha^{-} and boron at 1.50 kg ha^{-1} significantly increase the plant height and number of branches $plant^{-1}$ in mung bean.

Mondal *et al*. (2012) reported that treatment combination involving three irrigations at branching, pre-flowering and pod filling stages along with foliar application of 0.2% borax at flowering stage recorded maximum mung bean seed yield (898 kg ha^{-1}) which was comparatively higher over other treatment combinations.

CHAPTER III

MATERIALS AND METHODS

3.4 Planting material

The variety BARI Motor-3 was used as the test crop. The seeds were collected from the Pulses Research Center of Bangladesh Agricultural Research Institute, Joydebpur, Gazipur which was recommended by the national seed board.

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 8^{th} to 10^{th} November, 2019, respectively.

Experimental land was divided into unit plots following the design of experiment.

3.6 Treatments of the experiment

Seven treatments on boron application

1. T_0: 0 kg B ha^{-1} (control)
2. T_1: 0.5 kg B ha^{-1}
3. T_2: 1.0 kg B ha^{-1}
4. T_3: 1.5 kg B ha^{-1}
5. T_4: 2.0 kg B ha^{-1}
6. T_5: 2.5 kg B ha^{-1}
7. T_6: 3.0 kg B ha^{-1}

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), zinc and gypsum were applied at the rate of 20, 20, 20, 10 and 2 kg hectare^{-1}, respectively following the Bangladesh Agricultural Research Institute (BARI) recommendation and boron were applied as per treatment. All of the fertilizers were applied during final land preparation.

3.8 Experimental design and layout

The single factors experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The experimental plot was divided into 3 equal blocks. The treatments were assigned in each block as replication according to the design adopt. The size of the each unit plot was 4.0 m × 3.0 m. The space between two blocks and two plots were 1.5 m and 0.75 m, respectively. The layout of the experiment is shown in Figure 1.

3.9 Sowing of seeds in the field

The seeds of Field pea (BARI Motor-3) were sown on November 11, 2019 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.

3.11 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.

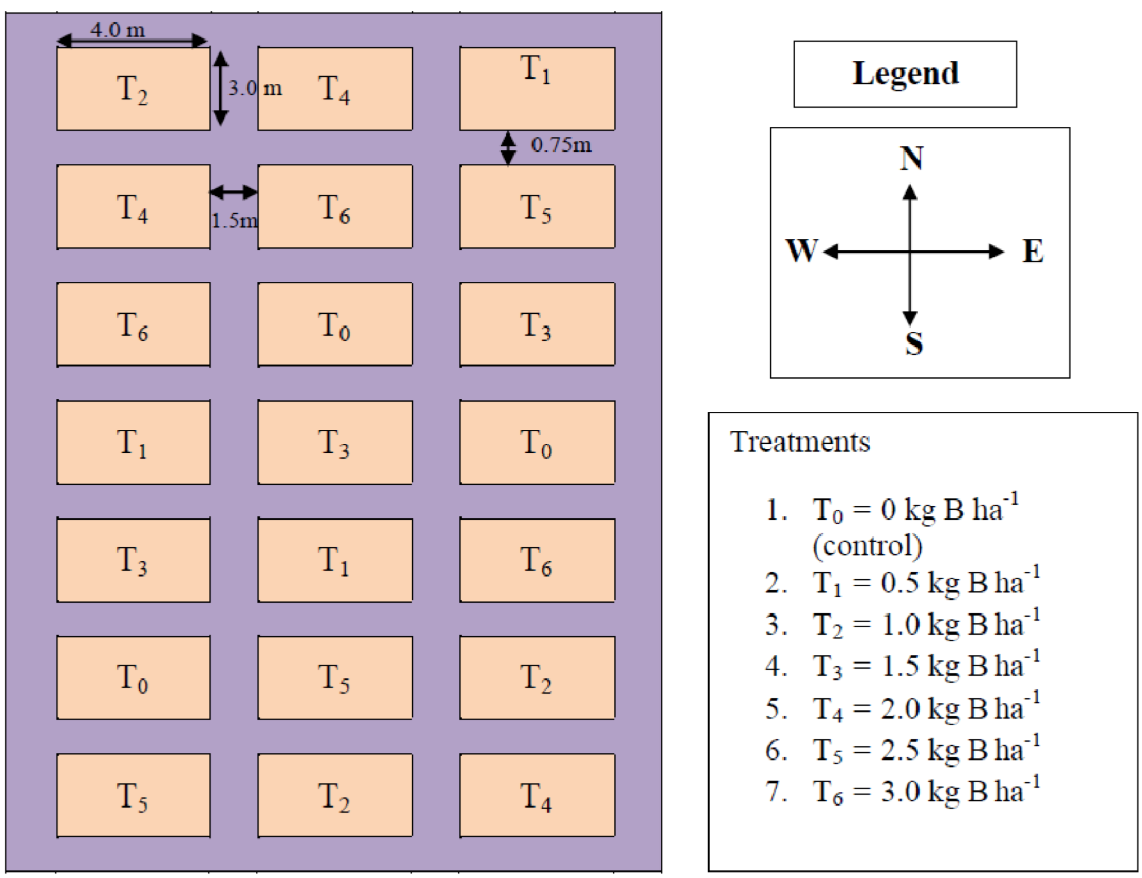

Figure 1. Layout of the experimental field

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 3.75 m^2 at the center of each plot.

3.13 Data collection

The following data were recorded

1. Plant height
2. Pod length (cm)
3. Number of pods $plant^{-1}$
4. Number of seeds pod^{-1}
5. Weight of 1000 seeds (g)
6. Seed yield $plot^{-1}$
7. Stover yield $plant^{-1}$
8. Seed yield $hectare^{-1}$
9. Stover yield $hectare^{-1}$
10. N, P, K, S, Ca, Mg, B, Zn, Fe and Mn concentration in seeds

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 Number of branches plant^{-1}

The total number of branches plant^{-1} was counted from each selected plant. Data were recorded as the average of 5 plants selected at random of each plot at the time of harvest.

3.14.3 Pod length

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

3.14.4 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.

3.14.5 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.

3.14.10 Harvest index

Harvest index is the ratio of economic (grain) yield and biological yield. It was calculated by dividing the grain yield from the harvested area by the biological yield of the same area and multiplying by 100.

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

3.15 Chemical analysis

3.15.1 Soil sampling and preparation

Before land preparation initial soil samples were collected at 0-15 cm depth from different parts of the experimental field. The composite soil sample was brought to the laboratory and spread on a brown paper for air-drying. The air-dried soil sample was grounded and passed through a 2 mm sieve. After sieving, the soil samples were kept in plastic bottle for physical and chemical analysis. The soil samples in duplicate were analyzed for available status of different nutrients along with the texture, pH and organic matter compounds.

3.15.2 Preparation of seed samples for chemical analysis

Seed samples were collected at the time of threshing. The samples were dried in an oven at 70°C for 72 hours and finally grounded by using a Wiley-Mill with stainless contact points to pass through a 60-mesh sieve. The samples were stored in plastic vials.

3.15.3 Analysis of N, P, K, S, Ca, Mg, Fe, Mn, Zn and B

Determination of N, P, K, S, Ca, Mg, Fe, Mn, Zn and B were done using the prepared seed samples followed by different prdoucedures.

3.16 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 study was conducted to find out effect of boron on growth and yield of field pea. Analyses of variance (ANOVA) of the data on different growth, yield parameters, yield and nutrients content of field pea are presented in Appendix IIIVII. The results have been presented and discusses with the help of table and graphs and possible interpretations given under the following headings:

4.1 Growth parameters

4.1.1 Plant height (cm)

Plant height of field pea was varied significantly due to different doses of boron application (Figure 2 and Appendix III). Results indicated that the maximum plant height (107.80 cm) was found from the treatment T_6 (3.0 kg B ha^{-1}) that was not significantly different to T_2 (1.0 kg B ha^{-1}) (105.90 cm), T_3 (1.5 kg B ha^{-1}) (106.20 cm), T_4 (2.0 kg B ha^{-1}) (107.50 cm) and T_5 (2.5 kg B ha^{-1}) (107.30 cm). Likewise, the minimum plant height (102.50 cm) was recorded from the control treatment T_0 (0 kg B ha^{-1}) which was statistically similar to T_1 (0.5 kg B ha^{-1}) (103.00 cm). Boron is a micro nutrient that plays an important role in increasing growth of pulses with making availability of other nutrients for the plant. The present study revealed that with the increase of boron fertilizer, plant height of field pea significantly increased upto the 1.0 kg of boron ha^{-1} that was applied under the present study. Parry *et al*. (2015) reported that increasing dose of up to 3 kg ha^{-1} resulted marked improvement in growth of garden pea. Boron is essential for cell wall synthesis, cell differentiation ribonucleic acid (RNA) metabolism thereby its increased availability might have enhanced the plant height. These results are in agreement to the findings obtained by Singh *et al*. (2012a), Moghazy *et al*. (2014), Parry *et al*. (2016) and Sharma and Sharma (2016). Kalyani *et al*. (1993) reported that application of boron resulted increase in the plant height. Moghazy *et al*.

(2014) reported that foliar spraying of boron had significant high influence on plant length. Parry *et al*. (2016) also reported that increasing dose of boron up to 3kg ha^{-1} resulted marked improvement in growth and higher plant height was achieved. Das *et al*. (2020) also found supported result with the present study in case of garden pea.

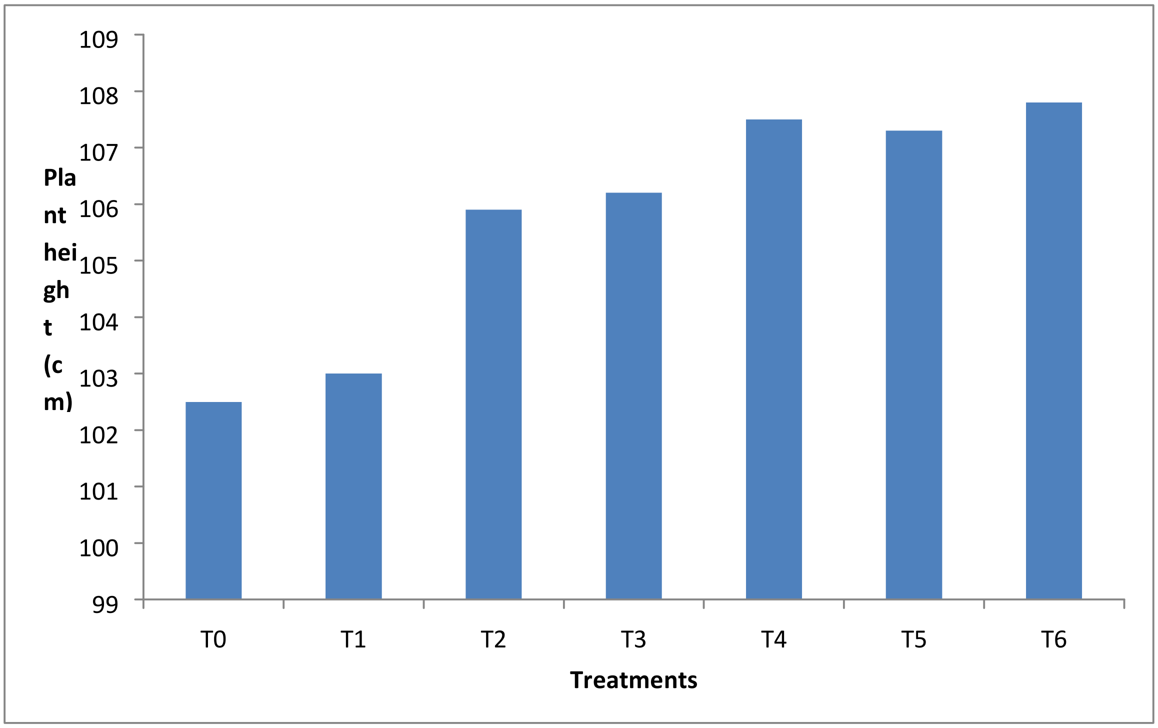

Figure 2. Plant height of field pea as influenced by different levels of boron application ($LSD_{0.05}$ = 2.243)

4.1.2 Number of branches plant^{-1}

Significant variation was observed for number of branches plant^{-1} influenced by different levels of boron application (Figure 3 and Appendix III). The treatment T_3 (1.5 kg B ha^{-1}) showed the maximum number of branches plant^{-1} (4.27) that was significantly similar with the treatments of T_2 (1.0 kg B ha^{-1}), T_4 (2.0 kg B ha^{-1}), T_5 (2.5 kg B ha^{-1}) and T_6 (3.0 kg B ha^{-1}) whereas the control treatment T_0 (0 kg B ha^{-1}) gave the minimum number of branches plant^{-1} (3.00) which was statistically similar with the treatments of T_1 (0.5 kg B ha^{-1}). Similar results have been reported by Kaisher *et al*. (2010), Moghazy *et al*. (2014) and Parry *et al*. (2016). Moghazy *et al*. (2014) reported that the vegetative growth traits of green pea e.g. number of branches per plant had high significant values by foliar spraying of boron. Kaisher *et al*. (2010) reported that boron at 5 kg ha^{-1} significantly increased number of branches $plant^{-1}$. Parry *et al*. (2016) reported that increasing dose of boron up to 3kg ha^{-1} resulted marked improvement in number of branches $plant^{-1}$**.**

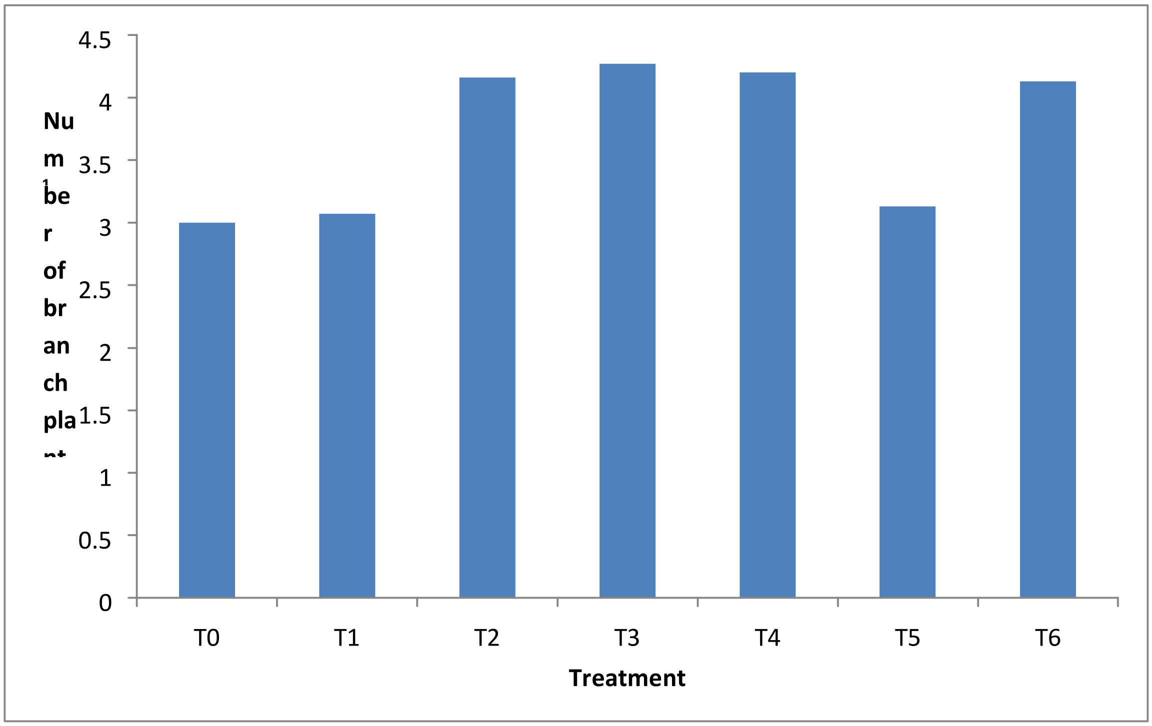

Figure 3. Number of branch $plant^{-1}$ of field pea as influenced by different levels of boron application ($LSD_{0.05}$ = 0.455)

Table 1. Yield contributing parameters in respect of number of pods $plant^{-1}$, number of seeds pod^{-1} and 100 seed weight of field pea as influenced by different levels of boron

Treatment	Yield contributing parameters

	Number of pods plant^{-1}	Number of seeds pod^{-1}	100 seed weight (g)
T_0	17.53 cd	6.00 b	9.99 d
T_1	17.73 c	6.40 ab	10.76 cd
T_2	20.33 a	6.53 ab	12.93 a
T_3	20.53 a	6.60 a	13.08 a
T_4	18.90 b	6.47 ab	11.76 b
T_5	18.10 c	6.13 ab	11.64 bc
T_6	17.00 d	6.33 ab	11.25 bc
$LSD_{0.05}$	0.603	0.593	0.985
CV(%)	11.80	5.25	4.76

Same or similar letter or letters in column is/are statistically same or similar and different letter or letters is/are different among treatments at 5% level of significance.

The recorded data on 100 seed weight of field pea was significant for the application of different boron doses (Table 1 and Appendix IV). It was noted that the highest 100 seed weight (13.08 g) was recorded from the treatment T_3 (1.5 kg B ha^{-1}) which was statistically similar to the treatment T_2 (1.0 kg B ha^{-1}) (12.93 g) followed by T_4 (2.0 kg B ha^{-1}) (11.76 g). Reversely, the lowest 100 seed weight (9.99 g) was recorded from the control treatment T_0 (0 kg B ha^{-1}) that was significantly similar to the treatment T_1 (0.5 kg B ha^{-1}) (10.76 g). Weight of 100 seeds is an important indicator for higher seed yield of crops. The present study showed that highest 100-seed weight was achieved with higher B doses till to at certain limit and after that 100-seed weight was decreased with increasing B doses. Kaisher *et al*. (2010) reported that application of boron had significant effect on 1000-seed weight and increased 1000-seed weight was found with higher boron doses.

4.3 Yield parameters

4.3.1 Seed yield

Seed yield ha^{-1} of field pea varied significantly due to different levels of boron (Figure 4 and Appendix V). Results exhibited that the treatment T_3 (1.5 kg B ha^{-1}) gave the maximum seed yield (1732 kg ha^{-1}) and similar yield (1703 kg ha^{-1}) was achieved from the treatment T_2 (1.0 kg B ha^{-1}) followed by T_4 (2.0 kg B ha^{-1}) (1635 kg ha^{-1}). Again, the lowest seed yield (1322 kg ha^{-1}) was recorded from the control treatment T_0 (0 kg B ha^{-1}) that was significantly different from other treatments. The present study revealed that the treatment T_3 (1.5 kg B ha^{-1}) gave the maximum seed yield (1732 kg ha^{-1}) which might be due to cause of better performance on yield attributes achieved from this treatment also. Higher boron doses showed higher yield of field pea.

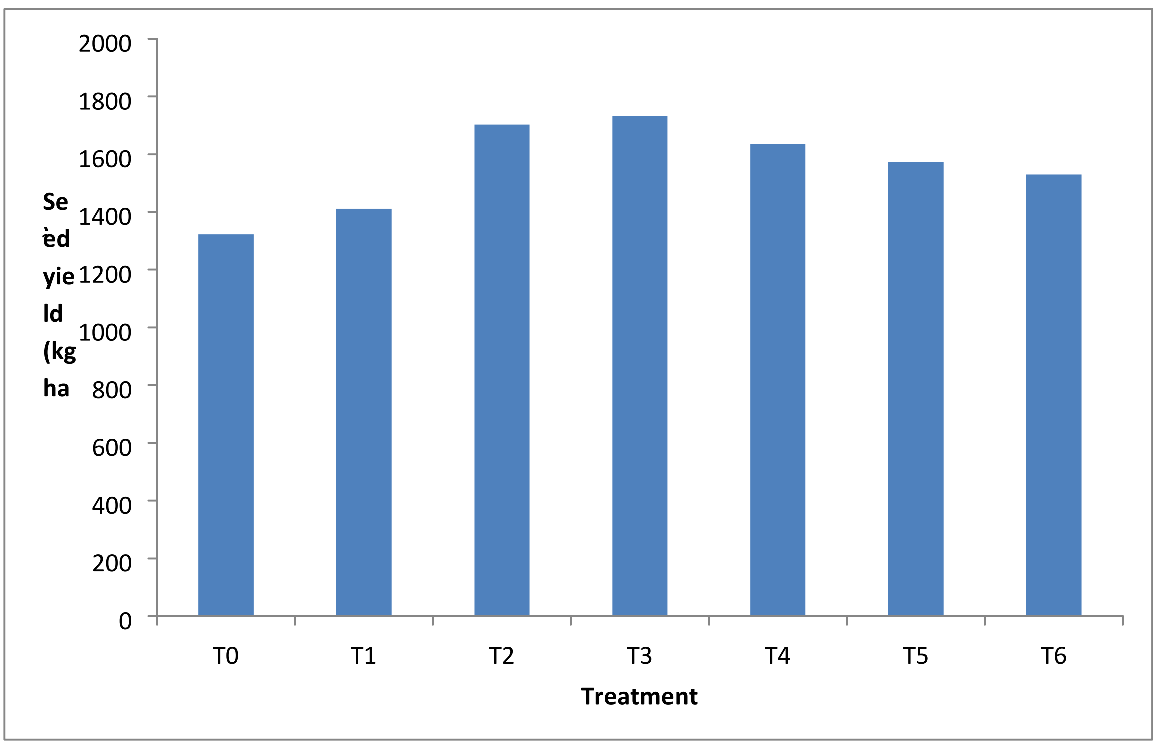

Figure 4. Seed yield of field pea as influenced by different levels of boron application ($LSD_{0.05}$ = 35.39)

The result obtained from the present study on seed yield ha^{-1} was in agreement with the findings of Moghazy *et al*. (2014) and they reported that pea yields and its components had high significant values by foliar spraying of boron. Shamsuddoha *et al*. (2011) reported that higher doses of B at 2 kg ha^{-1} gave highest seed yield of mungbean.

4.3.2 Stover yield

Results showed that the maximum stover yield (1862 kg ha^{-1}) was recorded from the treatment T_3 (1.5 kg B ha^{-1}) that was significantly similar to the treatment T_2 (1.0 kg B ha^{-1}) (1860 kg ha^{-1}) and T_5 (2.5 kg B ha^{-1}) (1838 kg ha^{-1}). The minimum stover yield (1678 kg ha^{-1}) was recorded from the control treatment T_0 (0 kg B ha^{1}) which was statistically similar (1679 kg ha^{-1}) to the treatment T_1 (0.5 kg B ha^{-1}). Boron has an important function in increasing growth of pulses with making availability of other nutrients for the plant (Table 2 and Appendix V. Data presented in Table 3 indicated that different doses of B had significant effect on stover yield and increasing levels of boron significantly increased stover yield. Again, it was evident that B is essential for cell wall synthesis, cell differentiation ribonucleic acid (RNA) metabolism thereby its increased availability might have resulted higher stover yield. These results are in agreement to the findings obtained by Shamsuddoha *et al*. (2011) who observed significant variation on stover yield and obtained higher stover yield with higher doses of B application.

Table 2. Yield parameters regarding seed yield, stover yield, biological yield and harvest index of field pea as influenced by different levels of boron

Treatment	Yield parameters		
	Stover yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest index (%)

T_0	1678.00 c	3000.00 e	44.03 d
T_1	1679.00 c	3090.00 d	45.63 c
T_2	1860.00 a	3563.00 a	47.80 a
T_3	1862.00 a	3594.00 a	48.27 a
T_4	1823.00 b	3458.00 b	47.30 ab
T_5	1838.00 ab	3412.00 b	46.16 bc
T_6	1815.00 b	3345.00 c	45.83 bc
$LSD_{0.05}$	35.92	48.21	1.540
CV(%)	5.01	9.94	2.85

Same or similar letter or letters in column is/are statistically same or similar and different letter or letters is/are different among treatments at 5% level of significance.

Nitrogen (N) content in seeds of field pea was varied significantly by the effect of boron application at different doses (Table 3 and Appendix VI). Results revealed that the maximum nitrogen content (4.81%) in seeds of field pea was observed from the treatment T_4 (2.0 kg B ha^{-1}) which was statistically similar to the treatment T_2 (1.0 kg B ha^{-1}), T_3 (1.5 kg B ha^{-1}), T_5 (2.5 kg B ha^{-1}) and T_6 (3.0 kg B ha^{-1}) whereas the minimum nitrogen content (3.99%) was recorded from the control treatment T_0 (0 kg B ha^{-1}) that was significantly similar to the treatment T_1 (0.5 kg B ha^{-1}). Boron affected nodule development and nitrogenase activity in the pea plants reported by Azevedo *et al*. (2002) which might be resulted higher nitrogen content in seeds with higher doses of boron.

Table 3. Nutrients content of field pea seeds regarding macro nutrients (N, P, K, S, Ca, Mg) as influenced by different levels of boron

Treatment	Nutrients content (macro nutrients) in seeds					
	Percent nitrogen (%N)	Percent phosphorus (%P)	Percent potassium (%K)	Percent sulphur (%S)	Percent calcium (%Ca)	Percent magnesium (%Mg)
T_0	3.99 b	0.61	0.71	0.25	0.55	0.56
T_1	4.16 b	0.67	0.75	0.27	0.59	0.56

T_2	4.62 a	0.72	0.76	0.31	0.66	0.63
T_3	4.72 a	0.73	0.79	0.31	0.67	0.64
T_4	4.81 a	0.74	0.78	0.32	0.66	0.63
T_5	4.70 a	0.73	0.78	0.31	0.64	0.62
T_6	4.64 a	0.72	0.77	0.31	0.65	0.61
$LSD_{0.05}$	0.303	0.149^{NS}	0.169^{NS}	0.195^{NS}	0.159^{NS}	0.113^{NS}
CV(%)	3.80	3.14	2.87	3.19	2.69	4.14

Same or similar letter or letters in column is/are statistically same or similar and different letter or letters is/are different among treatments at 5% level of significance.

4.4.1.2 Percent phosphorus

Non-significant variation was found among the treatments of different boron doses in field pea on phosphorus content in seeds (Table 3 and Appendix VI). However, the maximum phosphorus content (0.74%) in seeds of field pea was recorded from the treatment T_4 (2.0 kg B ha^{-1}) whereas the minimum phosphorus content (0.61%) was recorded from the control treatment T_0 (0 kg B ha^{-1}). This result suggested that B application at different doses had no significant effect on P content in field pea seeds. However, Hassanein *et al*. (1999) reported that application of boron increased the contents of P in cowpea seeds. Shamsuddoha *et al*. (2011) reported that 2 kg B ha^{-1} gave the maximum available P in mungbean seeds.

4.4.1.3 Percent potassium

Potassium content in seeds of field pea was not varied significantly due to different doses of boron application (Table 3 and Appendix VI). However, the treatment T_3 (1.5 kg B ha^{-1}) gave the maximum potassium content (0.79%) in seeds of field pea whereas the minimum potassium content (0.71%) was observed from the control treatment T_0 (0 kg B ha^{-1}). This result indicated that B application had no significant effect on K content in field pea seeds but the highest K content was found from higher B doses that was supported by Hassanein *et al*.

(1999).

4.4.1.4 Percent sulphur

Non-significant variation was found for sulphur content in seeds of field pea influenced by different levels boron (Table 3 and Appendix VI). However, the maximum sulphur content (0.32%) in seeds of field pea was recorded from the treatment T_4 (2.0 kg B ha^{-1}) whereas the minimum sulphur content (0.25%) was recorded from the control treatment T_0 (0 kg B ha^{-1}).

4.4.1.5 Percent calcium

Statistically non-significant variation was recorded due to the effect of boron at different doses in terms of calcium content in seeds of field pea (Table 3 and Appendix VI). However, the maximum calcium content (0.67%) in seeds of field pea was given by the treatment T_3 (1.5 kg B ha^{-1}) whereas the minimum calcium content (0.55%) was recorded from the control treatment T_0 (0 kg B ha^{-1})

4.4.1.6 Percent magnesium

Magnesium content in seeds of field pea was not varied significantly affected by boron application at different doses (Table 3 and Appendix VI). However, the treatment T_3 (1.5 kg B ha^{-1}) registered the maximum magnesium content (0.64%) whereas the control treatment T_0 (0 kg B ha^{-1}) registered the minimum magnesium content (0.56%) in seeds of field pea.

4.4.2 Micro nutrients

4.4.2.1 Boron content (ppm)

Boron content in field pea seeds varied significantly due to different doses of boron application to field pea cultivation (Table 4 and Appendix VII). Results indicated that the treatment T_5 (2.5 kg B ha^{-1}) exposed the maximum boron content (33.33 ppm) in seeds of field pea that was significantly similar to the treatment T_6 (3.0 kg B ha^{-1}) (33.32 ppm), T_4 (2.0 kg B ha^{-1}) (33.09 ppm), T_3 (1.5 kg B ha^{-1}) (32.63 ppm) and T_2 (1.0 kg B ha^{-1}) (32.10 ppm). Likewise, the minimum boron content (26.25 ppm) was recorded from the control treatment T_0 (0 kg B ha^{-1}) that was significantly different from other treatments. It was reported by Hassanein *et al*. (1999) that application of boron increased the contents of B in cowpea seeds. Boron content in different parts of pea plants increased with increasing boron concentration. Patel and Golakiya (1986) reported that boron application upto 2 μg g^{-1} soil increased the uptake of N, P, K, Fe, Cu and B. Application of 1.0 kg B ha^{-1} in gram increased B uptake while as 2.0 kg B ha^{-1} markedly enhanced the B availability in soil at harvest (Singh *et al*., 2004). Increasing levels of boron application in lentil significantly increased B uptake and improved available nutrients – N, P, S and B (Kushwaha *et al*., 2009). Singh *et al*. (2004) reported that application of boron 1 kg ha^{-1} increased the B content, boron uptake and soil available boron in groundnuts and pigeon pea. Boron content in different parts of pea plants increased with increasing boron concentration (Zhang *et al*., 1997).

Table 4. Nutrients content of field pea seeds regarding micro nutrients (B, Zn, Fe, Mn) as influenced by different levels of boron

Treatment	Nutrients content (micro nutrients) in seeds			
	Boron (B) content (ppm)	Zinc (Zn) content (ppm)	Iron (Fe) content (ppm)	Manganese (Mn) content (ppm)

T_0	26.25 c	50.92 c	151.60 c	89.22 c
T_1	31.72 b	54.57 b	154.50 b	96.57 b
T_2	32.10 ab	58.92 a	163.40 a	102.30 a
T_3	32.63 ab	60.12 a	164.30 a	101.90 a
T_4	33.09 a	59.71 a	164.00 a	102.50 a
T_5	33.33 a	59.61 a	163.80 a	102.40 a
T_6	33.32 a	59.88 a	163.00 a	102.10 a
$LSD_{0.05}$	1.275	1.741	2.532	2.433
CV(%)	6.38	5.68	4.89	6.37

Same or similar letter or letters in column is/are statistically same or similar and different letter or letters is/are different among treatments at 5% level of significance.

4.4.2.2 Zinc content (ppm)

Different doses of boron application for field pea cultivation showed statistically significant variation on zinc content in seeds (Table 4 and Appendix VII). Results revealed that the maximum zinc content (60.12 ppm) in seeds of field pea was given by the treatment T_3 (1.5 kg B ha^{-1}) that was significantly similar to the treatment T_2 (1.0 kg B ha^{-1}) (58.92 ppm), T_4 (2.0 kg B ha^{-1}) (59.71 ppm), T_5 (2.5 kg B ha^{-1}) (59.61 ppm) and T_6 (3.0 kg B ha^{-1}) (59.88 ppm). The minimum zinc content (50.92 ppm) in seeds of field pea was given by the control treatment T_0 (0 kg B ha^{-1}) that was significantly different from other treatments. Similar result with the present study was found from several authors. Boron content in different parts of pea plants increased with increasing boron concentration (Zhang *et al*., 1997). Hassanein *et al*. (1999) reported that application of boron increased the contents of Zn in cowpea seeds.

4.4.2.3 Iron content (ppm)

Iron content in field pea seeds varied significantly by the effect of boron application at different doses for field pea cultivation (Table 4 and Appendix VII). It was exhibited that the maximum iron content (164.30 ppm) in seeds of field pea was recorded from the treatment T_3 (1.5 kg B ha^{-1}) which was statistically similar to the treatment T_2 (1.0 kg B ha^{-1}) (163.40 ppm), T_4 (2.0 kg B ha^{-1}) (164.00 ppm), T_5 (2.5 kg B ha^{-1}) (163.80 ppm) and T_6 (3.0 kg B ha^{-1}) (163.00 ppm) whereas the minimum iron content (151.60 ppm) was recorded from the control treatment T_0 (0 kg B ha^{-1}) that was significantly different from other treatments. Similar result was also observed by Hassanein *et al*. (1999) and they reported that application of boron increased the contents of Fe in cowpea seeds. Boron content in different parts of pea plants increased with increasing boron concentration (Zhang *et al*., 1997). Nutrient content, nutrient uptake and available nutrients increased with boron application in cauliflower (Chander *et al*., 2010).

4.4.2.4 Manganese content (ppm)

Different doses of boron application for field pea cultivation showed statistically significant variation on manganese content in seeds (Table 4 and Appendix VII). Results showed that the treatment T_4 (2.0 kg B ha^{-1}) gave the maximum manganese content (102.50 ppm) in seeds of field pea which was statistically similar to the treatment T_2 (1.0 kg B ha^{-1}) (102.30 ppm), T_4 (2.0 kg B ha^{-1}) (101.90 ppm), T_5 (2.5 kg B ha^{-1}) (102.40 ppm) and T_6 (3.0 kg B ha^{-1}) (102.10 ppm). The control treatment T_0 (0 kg B ha^{-1}) gave the minimum manganese content (89.22 ppm) that was significantly different from other treatments. The present finding was similar with the findings of Hassanein *et al*. (1999) and was reported that Mn content in cowpea seeds increased with boron application. Boron content in different parts of pea plants increased with increasing boron concentration (Zhang *et al*., 1997). Chander *et al*. (2010) reported that nutrient content, nutrient uptake and available nutrients increased with boron application.

CHAPTER V

SUMMARY AND CONCLUSION

In terms of growth, the treatment T_6 (3.0 kg B ha^{-1}) gave the highest plant height (107.80 cm) whereas control treatment T_0 (0 kg B ha^{-1}) showed the lowest plant height (102.50 cm). Again, the highest number of branches $plant^{-1}$ (3.27) was given by the treatment T_3 (1.5 kg B ha^{-1}) whereas the control treatment T_0 (0 kg B ha^{-1}) gave the lowest number of branches $plant^{-1}$ (3.00)

In case of yield, number of seeds pod^{-1} and 100 seed weight by the different boron treatments. It was observed that the highest number of pods $plant^{-1}$ (20.53), number of seeds pod^{-1} (6.60) and 100 seed weight (13.08 g) were given by the treatment T_3 (1.5 kg B ha^{-1}) but the lowest number of pods plant^{-1} (17.00) was recorded from the treatmentT_6 (3.0 kg B ha^{-1}) whereas the lowest number of seeds pod^{-1} (6.00) and 100 seed weight (9.99 g) were recorded from control treatment T_0 (0 kg B ha^{-1}).The treatment T_3 (1.5 kg B ha^{-1}) registered the highest seed yield (1732 kg ha^{-1}), stover yield (1862 kg ha^{-1}), biological yield (3594 kg ha^{-1}) and harvest index (48.27%) that were similar to T_2 (1.0 kg B ha^{-1}) (1703 kg ha^{-1}, 1860 kg ha^{-1}, 3563 kg ha^{-1} and 47.80%, respectively) whereas the control treatment T_0 (0 kg B ha^{-1}) showed the lowest seed yield (1322 kg ha^{-1}), stover yield (1678 kg ha^{-1}), biological yield (3000 kg ha^{-1}) and harvest index (44.03%).

In terms of nutrients content in field pea seed, macro nutrients content (N, P, K, S, Ca and Mg), all the parameters was not varied significantly among the boron treatments except N content. The treatment T_4 (2.0 kg B ha^{-1}) registered the highest nitrogen content (4.81%) whereas the lowest nitrogen content (3.99%) was given by control treatment T_0 (0 kg B ha^{-1}). Similarly, the highest phosphorus content (0.74%) and sulphur content (0.32%) in seeds of field pea was recorded from the treatment T_4 (2.0 kg B ha^{-1}) but the highest potassium content (0.79%), calcium content (0.67%) and magnesium content (0.64%) in field pea seeds were recorded from the treatment T_3 (1.5 kg B ha^{-1}) whereas the lowest phosphorus content (0.61%), potassium content (0.71%), sulphur content (0.25%), calcium content (0.55%) and magnesium content (0.56%) were recorded from the control treatment T_0 (0 kg B ha^{-1}). Likewise, micro nutrients (B, Zn, Fe and Mn) content in field pea seeds, all were affected significantly by boron treatments. The treatment T_5 (2.5 kg B ha^{-1}) and T_4 (2.0 kg B ha^{-1}) showed the highest boron content (33.33 ppm) and manganese content (102.50 ppm) in field pea seeds, respectively but the highest zinc content (60.12 ppm) and iron content (164.30 ppm) was given by the treatment T_3 (1.5 kg B ha^{-1}) whereas the lowest boron content (26.25 ppm), zinc content (50.92 ppm), iron content (151.60 ppm) and manganese content (89.22 ppm) were registered from the control treatment T_0 (0 kg B ha^{-1}). It was also observed that treatment T_3 (1.5 kg B ha^{-1}), T_4 (2.0 kg B ha^{1}), T_5 (2.5 kg B ha^{-1}) and T_6 (3.0 kg B ha^{-1}) showed comparatively higher results on nutrients content of seeds while T_1 (0.5 kg B ha^{-1}) and control treatment (T_0) showed lower performance. From the above result, it may be concluded that application of 1.5 kg B ha^{-1} (T_3) showed best performance on yield parameters of field pea and that was similar to the treatment of 1.0 kg B ha^{-1} (T_2) whereas the control treatment T_0 (0 kg B ha^{-1}) gave statistically lower performance. So, it can be stated that 1.5 kg B ha^{-1} (T_3) can be more beneficial for the farmers to get maximum yield from the cultivation of field pea (BARI Motor-3).

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