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EFFECTS OF ZINC AND BORON ON YIELD, NODULATION AND NUTRIENT CONTENTS OF FIELDPEA IN TERRACE SOILS

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Abstract

An experiment was conducted for two consecutive years (2014-15 and 2015-16) in the field of Pulses Research Sub-Station, BARI, Gazipur during *rabi* (winter) season to evaluate the effect of zinc (Zn) and boron (B) application on the yield, nodulation and nutrient content of fieldpea (*Pisum sativum* L.). There were 16 treatment combinations comprising four levels each of zinc (0, 1, 2 and 3 kg ha^{-1}) and boron (0, 1, 1.5 and 2 kg ha^{-1}) along with a blanket dose of N_{12} P_{18} K_{30} S_{10} kg ha^{-1} over the treatments. The experiment was laid out in a split-plot design with three replications. Zinc (Zn) as $ZnSO_4.7H_2O$ and boron (B) as H_3BO_3 were applied to the crop (cv. BARI Fieldpea-1). Results showed that the combination of $Zn_3B_{1.5}$ kg ha^{-1} produced the highest seed yield (1582 kg ha^{-1}) in the 1st year and the Zn_3B_2 kg ha^{-1} gave the highest yield (1702 kg ha^{-1}) in the 2nd year.The lowest seed yield was found in the control (Zn_0B_0). The Zn_3B_2 demonstrated the highest nodulation and nutrient and protein contents. The results suggest that the application of Zn_3B_2 kg ha^{-1} along with N_{12} P_{18} K_{30} S_{10} kg ha^{-1} can support the higher yield of fieldpea in terrace soils of Bangladesh.

Keywords: Zinc and boron, fieldpea, yield, nodulation, nutrient content

Introduction

Field pea (*Pisum sativum* L) is a popular legume crop worldwide. Fieldpea is rich in high-quality protein (20%), contains 4 mg pro-vitamin A, 300 mg vitamin C, 3 mg B_1, 1.5 mg B_2 and 1.2 mg pantothenic acid per 1000g fresh seed weight and also it contains 1.1% fat, 2.2% minerals, 4.5% fiber and 56.5% carbohydrate (Dixit, 2002). Besides, fieldpea improves soil health through biological nitrogen fixation (about 30-50 kg N ha^{-1}) and addition of organic matter to the soil (Erman *et al*., 2009).

The yield of pulses including fieldpea in Bangladesh is low as because it is usually cultivated in less fertile soil. As a micronutrient, Zn and B are deficient in this country's soil. This crop (fieldpea) is less tested in terrace soils which exist in the Barind and Madhupur tracts. They are acidic in reaction with low organic matter, moisture holding capacity and fertility level. The soils are mainly phosphate fixing, and low in P, K, S, Zn and B levels (Rashid, 2001; FRG, 2012).

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Zinc and B deficiency is widespread in the country; specifically B deficiency is more common in *rabi* crops (Jahiruddin, 2015). Zinc plays a vital role in metabolism and is known to be involved in N-fixation through nodule formation (Patel *et al*., 2011). Boron influences the absorption of N, P, K and its deficiency changed the equilibrium of optimum of those three macronutrients (Raj, 1985).

Hence, balance application of micronutrient along with macro nutrients may render good possibility to increase fieldpea production as well as improve soil fertility. The present study was therefore, undertaken (i) to evaluate the effect of Zn and B on yield, nodulation and nutrient content of fieldpea; and (ii) to find out the suitable combination of Zn and B for yield maximization of fieldpea.

Materials and Methods

A field experiment was conducted for two consecutive years (2014-15 and 2015-16 at winter) in the research field of Pulses Research Sub-Station (PRSS), Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur. The terrace soils of Gazipur is medium high land with fine-textured (clay loam) and belongs to Chhiata series (Soil taxonomy: Udic Rhodustalf) under the agroecological zone - Madhupur Tract (AEZ-28). Before beginning the experiment initial soil (0-15 cm) sample was collected from the field and analysed for chemical properties. The soil contains 6.6 pH, 1.26% organic matter, 0.057% N, 15.5 ppm P, 16 ppm S, 0.8 ppm Zn and 0.17 ppm B.

There were 16 treatment combinations comprising four levels each of Zn (0, 1, 2 and 3 kg ha^{-1}) and four levels of B (0, 1, 1.5 and 2 kg ha^{-1}). The blanket dose was N_{12} P_{18} K_{30} S_{10} kg ha^{-1}. The experiment was laid out in split-plot design with three replications. The unit plot size was 4 m × 3 m. Zinc and B were applied as zinc sulphate and boric acid, respectively. Every plot received an equal amount of fertilizers at N_{12} P_{18} K_{30} S_{10} kg ha^{-1} (FRG, 2012) as urea, TSP, MoP and gypsum during final plot preparation. Seeds of fieldpea cv BARI Fieldpea-1 were sown @ 30 kg ha^{-1} with a spacing of 40 cm × 05 cm on 12 November 2014 and 10 November 2015. Two hand weedings were done at 25 and 50 days after sowing. Diseases and insects were controlled properly. The crop was harvested after maturity. The data of nodule per plant was recorded from 5 randomly selected plants in each plot. Stover yield (kg ha^{-1}) was measured from two places in each plot over one square meter. Seed yield (kg ha^{-1}) was recorded from the whole plot technique.

Treatment-wise plant samples (stover and seed) against each treatment plot were oven-dried at 70° C for 48 h and finely ground.

The initial soil sample was analyzed for soil pH was measured by glass electrode pH meter using soil:water ratio of 1:2.5 (Page *et al.,* 1982) and organic matter by

Nelson and Sommers (1982) method; total N (Bremner and Mulvaney, 1982); exchangeable K by 1N NH_4OAc method (Jackson, 1973); available P by Bray and Kurtz (1945) method; available S by turbidity method using $BaCl_2$ (Fox *et al*., 1964); available Zn by DTPA method (Lindsay and Norvell, 1978); available B by azomethine-H method (Page *et al.*, 1982).

Ground plant sample (stover and seeds) was analysed for N using the Kjeldahl method FOSS (Persson *et al.,* 2008). Ground plant samples (seed and stover) were digested with di-acid mixture (HNO_3-$HClO_4$) (5: 1) as described by Piper (1966) for the determination- content of P (spectrophotometer method), K (atomic absorption spectrophotometer method), S (turbidity method using $BaCl_2$ by spectrophotometer), Zn (atomic absorption spectrophotometer method) and B (spectrophotometer following azomethine-H method).

Protein content in fieldpea seed was calculated on considering the pulses food factor 5.30 (FAO, 2018). Protein content was measured by multiplying the %N content of seed with pulses food factor 5.30 that means (%N × 5.30).

Analysis of variance (ANOVA) for the yield, nodulation, different nutrient and protein content was done following the Statistix 10 package (Statistix 10. 1985). The least significant difference (LSD) at 5% level was used to compare the treatments means.

Results and Discussion

Effects of zinc and boron on crop yields

The interaction effect of Zn and B on the yields of fieldpea was observed statistically significant during two consecutive years (Table 1). The crop responded to Zn and B application since the experimental soil was deficient zinc and boron. Similar findings were reported by Agrawal and Sharma (2005). Results showed that the mean seed yield varied from 920 kg ha^{-1} to 1631 kg ha^{-1} depending on the treatments. The highest seed yield of 1582 kg ha^{-1} in 1st year was obtained from $Zn_3B_{1.5}$ kg ha^{-1} and 1702 kg ha^{-1} in the 2nd year from Zn_3B_2 kg ha^{-1} treatment; however both the treatments were statistically similar to each other. The lowest seed yield was observed in control (Zn_0B_0) treatment. The stover yield (mean of two years) of fieldpea ranged from 2486 kg ha^{-1} to 4310 kg ha^{-1} over the treatments. The Zn_3B_2 treatment combination exhibited the highest stover yield in both years followed by the treatment of $Zn_3B_{1.5}$ kg ha^{-1} (Table 1). Micronutrient enhanced the survival and multiplication of microorganism, more nitrogen fixation, transport of sugars and better uptake and assimilation of available nutrients by the plants during the entire growth period for higher yields. Similar observations have been reported by Valenciano *et al.* (2010).

Table 1. Combined effect of zinc and boron on the yields of fieldpea

Treatment	Seed yield (kg ha^{-1})			Stover yield (kg ha^{-1})		
	1st yr	2nd yr	Mean	1st yr	2nd yr	Mean
Zn_0B_0	890e	949	920	2475	2497	2486
Zn_0B_1	1126	1187	1157	3263	2995	3129
$Zn_0B_{1.5}$	1196	1283	1240	3350	3224	3287
Zn_0B_2	1126	1384	1255	3021	3416	3219
Zn_1B_0	1085	1163	1124	2967	3011	2989
Zn_1B_1	1158	1421	1290	3249	3612	3431
$Zn_1B_{1.5}$	1248	1528	1388	3445	3745	3595
Zn_1B_2	1277	1544	1411	3491	3831	3661
Zn_2B_0	1126	1306	1216	3263	3323	3293
Zn_2B_1	1297	1468	1383	3578	3629	3629
$Zn_2B_{1.5}$	1417	1549	1483	3802	3756	3779
Zn_2B_2	1408	1607	1508	3778	4005	3892
Zn_3B_0	1155	1375	1265	3194	3511	3353
Zn_3B_1	1291	1597	1444	3544	3898	3721
$Zn_3B_{1.5}$	1582	1680	1631	4015	4253	4134
Zn_3B_2	1513	1702	1608	4233	4387	4310
CV (%)	4.61	3.66	-	5.71	4.39	-
LSD (0.05)	178	88	-	606	264	-

Effects of zinc and boron on nodulation

The Zn and B treatments along with macro nutrients promoted the nodule formation. Combined application of Zn and B influenced significantly to produce good numbers of active nodule per plant (Table 2). Similar observation made by Chatterjee and Bandyopadhyay (2015). The number of nodules per plant counted at 32 DAS ranged from 7.98 to 15.1 across the treatments. Nodulations per plant at 47 DAS varied from 19.8 to 30.2, at 62 DAS from 24.8 to 38.6 and 77 DAS, nodulations varied from 17.9 to 27.1. The maximum number of nodules per plant was counted on the treatment Zn_3B_2 in all the dates except 77 DAS. The minimum number of nodule per plant was counted in control treatment (Zn_0B_0) over the collection dates (Table 2). Nodule formation was less in 32 DAS and 77 DAS and was more at 47 and 62 DAS. It appears that the highest number of nodule formation occurred during early to mid flowering stage.

Table 2. Combined effect of zinc and boron on the number of nodules per plant of fieldpea at different dates (2-years pooled data)

Treatment	No. of nodules after 32 DAS	No. of nodules after 47 DAS	No. of nodules after 62 DAS	No. of nodules after 77 DAS
Zn_0B_0	7.98	19.8	24.8	17.9
Zn_0B_1	9.14	21.3	27.3	19.3
$Zn_0B_{1.5}$	9.25	22.4	27.1	20.5
Zn_0B_2	10.0	22.7	28.7	21.6
Zn_1B_0	9.39	21.6	27.1	22.1
Zn_1B_1	11.4	23.1	28.9	23.7
$Zn_1B_{1.5}$	12.1	23.9	30.1	25.6
Zn_1B_2	12.3	24.3	32.4	26.4
Zn_2B_0	10.6	23.7	29.8	23.3
Zn_2B_1	11.7	24.5	31.9	24.7
$Zn_2B_{1.5}$	12.4	25.7	33.7	27.1
Zn_2B_2	12.8	26.5	35.2	26.9
Zn_3B_0	11.4	23.4	31.6	25.7
Zn_3B_1	13.2	26.9	35.7	24.1
$Zn_3B_{1.5}$	14.3	28.7	37.9	25.1
Zn_3B_2	15.1	30.2	38.6	24.9
CV (%)	5.12	3.29	4.14	3.84
LSD (0.05)	0.99	1.35	2.18	1.53

Effects of zinc and boron on nutrient content

Application of Zn and B remarkedly influenced the N, protein, P, K, S, Zn and B contents of fieldpea seed (Table 3). The N content due to different treatments ranged from 3.85 to 4.56%, the highest N content being found in Zn_3B_2 which was statistically similar to $Zn_3B_{1.5}$, Zn_2B_2, $Zn_2B_{1.5}$, Zn_2B_1, and Zn_1B_2 treatments. Different combination of Zn and B had a significant effect on protein content (%) of fieldpea seed. The protein content varied between 20.4% and 24.1% over the treatments. The highest protein content (24.1%) was noted for the treatment Zn_3B_2 kg ha^{-1} which was significantly different with the others treatments. The lowest protein content in seed (20.4%) was calculated from Zn_0B_0 treatment (Table 3). Márquez-Quiroz *et al.* (2015) reported that micronutrient application may enhance nutrition security through improving the grain quality in addition its role in increasing productivity.The P content in seed varied from 0.22 to 0.29% with the highest record in Zn_3B_2 which was statistically identical to $Zn_3B_{1.5}$,

Zn_3B_1, Zn_2B_2, $Zn_2B_{1.5}$, Zn_3B_0 and Zn_1B_2 treatments. The K and S contents in different treatments ranged from 0.35 to 0.45% and 0.08 to 0.16%, respectively across the treatments. The maximum K content (0.45%) was recorded in Zn_3B_2 followed by $Zn_3B_{1.5}$, Zn_2B_2 and $Zn_2B_{1.5}$ and the lowest K content was in control. The highest S content (0.16%) was observed in Zn_3B_2 which was statistically similar at per $Zn_3B_{1.5}$, Zn_3B_1, Zn_2B_2, and $Zn_2B_{1.5}$ treatments. Regarding Zn and B contents in seed, it varied from 23.6 to 27.5 ppm and 25.9 to 31.2 ppm, respectively. The maximum Zn (27.5 ppm) and B (31.2 ppm) contents were observed in Zn_3B_2.The control (Zn_0B_0) gave the lowest nutrient contents (Table 3). Karim (2016) reported that combined application of Zn, B and Mo contributed to higher nutrient contens (5.04% N, 0.36% P, 0.86% K, 0.34% S, 72.4 ppm Zn and 41.5 ppm B) in lentil seed.

Table 3. Combined effects of zinc and boron on N, protein, P, K, S, Zn and B contents of fieldpea seed (2-years pooled data)

Treatment	Nutrient content in seed						
	N	Protein	P	K	S	Zn	B
	(%)					ppm	
Zn_0B_0	3.85	20.4	0.22	0.35	0.09	24.1	26.3
Zn_0B_1	3.93	20.8	0.23	0.36	0.08	24.3	26.2
$Zn_0B_{1.5}$	3.91	20.7	0.22	0.35	0.10	24.0	26.8
Zn_0B_2	3.98	21.1	0.24	0.34	0.09	24.5	27.1
Zn_1B_0	3.87	20.5	0.23	0.35	0.11	23.6	25.9
Zn_1B_1	4.03	21.4	0.24	0.38	0.12	25.1	27.3
$Zn_1B_{1.5}$	4.13	21.9	0.23	0.37	0.11	25.8	27.8
Zn_1B_2	4.25	22.5	0.26	0.39	0.13	26.1	27.9
Zn_2B_0	4.10	21.7	0.24	0.40	0.11	25.3	26.2
Zn_2B_1	4.31	22.8	0.25	0.41	0.13	24.9	26.9
$Zn_2B_{1.5}$	4.36	23.1	0.27	0.42	0.14	25.7	27.0
Zn_2B_2	4.41	23.4	0.28	0.43	0.15	26.1	25.9
Zn_3B_0	4.12	21.8	0.26	0.36	0.13	25.1	26.4
Zn_3B_1	4.06	21.5	0.27	0.37	0.14	25.5	28.3
$Zn_3B_{1.5}$	4.49	23.8	0.28	0.43	0.15	26.2	29.4
Zn_3B_2	4.56	24.1a	0.29	0.45	0.16	27.5	31.2
CV (%)	4.76	4.74	8.23	5.69	12.0	1.47	1.32
LSD (0.05)	0.33	1.75	0.04	0.04	0.025	0.62	0.61

Main effects of zinc

Different levels of zinc demonstrated significant variation in yields of fieldpea (Table 4). The seed yield increased with increasing Zn rates. The seed yields (mean of two years) in different Zn rates (0, 1, 2 and 3 kg ha^{-1}) were 1142, 1303, 1397 and 1488 kg ha^{-1}, respectively. Hence the seed yields due to 2 and 3 kg Zn ha^{-1} were found statistically similar particularly for the 1st year. The stover yields due to 2 and 3 kg Zn ha^{-1} were a similar trend of seed yield. It was observed that the yield increased with the increase of Zn level up to 3 kg ha^{-1}. Similar trend was also reported by Kasthurikrishna and Ahlawat (2000). The yield benefits in terms of percentage varied from 14.1 to 30.3% over the control treatment.

Table 4. Main effects of zinc on the yields of fieldpea

Zinc level (kg ha^{-1})	Seed yield (kg ha^{-1})			% Yield increment over control	Stover yield (kg ha^{-1})		
	1st yr	2nd yr	Mean		1st yr	2nd yr	Mean
Zn_0	1084	1200	1142	-	3028	3033	3031
Zn_1	1192	1414	1303	14.1	3288	3550	3419
Zn_2	1312	1482	1397	22.3	3605	3678	3642
Zn_3	1386	1589	1488	30.3	3747	4012	3880
CV (%)	5.58	3.82	-		6.94	4.52	-
LSD (0.05)	98	54	-		335	161	-

Zinc played encouraging role on nodulation of fieldpea. At 32 DAS, the number of active nodules per plant ranged from 9.09 to 13.5, at 47 DAS, 21.6 to 27.3 and at 62 DAS, it was 26.9 to 35.9, respectively. Furthermore, at 77 DAS, it varied from 19.8 to 25.5. The maximum number of nodules per plant was found with the application of Zn at 3 kg ha^{-1} for all the nodule collection dates. The minimumt number of nodules per plant was recorded from Zn control plot (Table 5).

Table 5. Main effect of zinc on nodulation of fieldpea (2- year's pooled data)

Zinc level (kg ha^{-1})	No. of nodules at 32 DAS	No. of nodules at 47 DAS	No. of nodules at 62 DAS	No. of nodules at 77 DAS
Zn_0	9.09	21.6	26.9	19.8
Zn_1	11.3	23.2	29.6	24.5
Zn_2	11.9	25.1	32.7	25.5
Zn_3	13.5	27.3	35.9	24.9
CV (%)	3.80	3.14	1.82	4.80
LSD (0.05)	0.44	0.76	0.57	1.13

In case of nutrients content, the highest N, protein, P, K, S, Zn and B contents 4.31%, 22.8%, 0.28%, 0.41%, 0.14%, 26.1 ppm and 28.8 ppm, respectively were recorded with 3 kg ha^{-1} Zn rate (Table 6). Proper doses of zinc application may enhance the synthesis of carbohydrates, nutrient and protein content and their transport to the site of seed formation (Mali *et al.*, 2003).

Table 6. Main effects of zinc and boron on N, protein, P, K, S, Zn and B contents of fieldpea seed (2-years pooled data)

Zinc levels (kg ha^{-1})	Nutrient content in seed						
	N	Protein	P	K	S	Zn	B
	(%)					ppm	
Zn_0	3.91	20.8	0.23	0.35	0.09	24.2	26.5
Zn_1	4.07	21.6	0.24	0.37	0.12	25.1	26.6
Zn_2	4.30	22.7	0.26	0.40	0.13	25.5	27.2
Zn_3	4.31	22.8	0.28	0.41	0.14	26.1	28.8
CV (%)	3.16	3.13	1.29	3.09	10	1.78	1.31
LSD (0.05)	0.13	0.69	3.22	0.02	0.02	0.45	0.36

Main effects of boron

The seed yield ranged from 1132 to 1446 kg ha^{-1}, the highest yield in the 2nd year being observed at 2 kg ha^{-1} B application. In the 1st year, the seed yield was found highest at B rate of 1.5 kg ha^{-1} was statistically similar to B rate of 2 kg ha^{-1}. The lowest yield was recorded in the control treatment (Table 7). The trend of stover yield showed the similar of seed yield. Boron influences reproductive growth of crop (Chatterjee and Bandyopadhyay, 2015).

Table 7. Main effects of boron on the yields of fieldpea

Boron level (kg ha^{-1})	Seed yield (kg ha^{-1})			% Yield increment over control	Stover yield (kg ha^{-1})		
	1st yr	2nd yr	Mean		1st yr	2nd yr	Mean
B_0	1065	1198	1132	-	2975	3086	3031
B_1	1218	1418	1318	16.4	3408	3533	3471
$B_{1.5}$	1361	1510	1436	26.6	3707	3744	3726
B_{2-}	1331	1560	1446	27.7	3577	3910	3744
CV (%)	5.58	3.82	-		6.94	4.52	-
LSD (0.05)	64.6	43.8	-		219	132	-

The number of nodules per plant increased with increasing the rates of B application. The number of nodules per plant at 32 DAS ranged from 9.84 to 14.6, at 47 DAS from 22.1 to 25.9, at 62 DAS from 28.3 to 33.7 and at 77 DAS, it varied from 22.2 to 24.9 over the treatments. The maximum number of nodules per plant was recorded from the application of 2 kg B ha^{-1} across the nodule collection dates (Table 8). Noor and Hossain (2007) reported that adequate boron application positively influenced effective nodulation and nitrogen fixation in legumes.

Table 8. Main effects of boron on nodulation of fieldpea (2- year's pooled data)

Boron level (kg ha^{-1})	No. of nodules at 32 DAS	No. of nodules at 47 DAS	No. of nodules at 62 DAS	No. of nodules at 77 DAS
B_0	9.84	22.1	28.3	22.2
B_1	11.4	23.9	30.9	22.9
$B_{1.5}$	12.0	25.2	32.2	24.5
B_2	12.6	25.9	33.7	24.9
CV (%)	3.80	3.14	1.82	4.80
LSD (0.05)	0.49	0.67	1.09	0.76

Different nutrient (N, P, K, S, Zn and B) and protein contents in seed of fieldpea was influenced significantly due to application of different rates of B (Table 9). The highest nutrient content (4.30% N, 0.27% P, 0.40% K, 0.13% S, 26 ppm Zn and 28 ppm B) in seed were obtained with application of 2 kg B ha^{-1} that was statistically identical to 1.5 kg B ha^{-1} except P and Zn contents. The lowest nutrient content in seed was noted for B control treatment (Table 9). Regarding protein content, the highest protein content in seed (22.8%) was obtained with 2 kg B ha^{-1} application that was statistically similar to application of 1.5 kg B ha^{-1}(Table 9).

Table 9. Main effects of zinc and boron on N, protein, P, K, S, Zn and B contents of fieldpea seed (2-years pooled data)

Boron levels (kg ha^{-1})	Nutrient content in seed						
	N	Protein	P	K	S	Zn	B
	(%)					ppm	
B_0	3.98	21.1	0.24	0.37	0.11	24.5	26.2
B_1	4.08	21.6	0.25	0.38	0.12	24.9	27.2
$B_{1.5}$	4.22	22.4	0.25	0.39	0.13	25.4	27.7
B_2	4.30	22.8	0.27	0.40	0.13	26.0	28.0
CV (%)	3.16	3.13	1.29	3.09	10	1.78	1.31
LSD (0.05)	0.17	0.87	0.02	0.02	0.02	0.31	0.30

Conclusion

This study indicates that application of Zn at 3 kg ha^{-1} and B at 1.5 or 2 kg ha^{-1} significantly increased the seed yield of fieldpea. The maximum nodulation and protein percentage was found in Zn_3B_2 treatment followed by $Zn_3B_{1.5}$ treatment. Similarly nutrient (N, P, K, S, Zn and B) contens were also higher in the treatment combination of Zn_3B_2 followed by $Zn_3B_{1.5.}$ Thus, results of the experiment suggest that the application of Zn_3B_2 along with N_{12} P_{18} K_{30} S_{10} kg ha^{-1} is needed for yield maximization of fieldpea.

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