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RESPONSE OF CHICKPEA VARIETIES TO BORON APPLICATION IN CALCAREOUS AND TERRACE SOILS OF BANGLADESH

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Abstract

An experiment was conducted at Madaripur and Gazipur during *rabi* (winter) season of 2012-13 and 2013-14 to determine the optimum dose of B for different varieties of chickpea (*Cicer arietinum* L.). There were 12 treatment combinations comprising three varieties (BARI Chola-5, BARI Chola-8 and BARI Chola-9) and four levels of boron (0, 1, 1.5 and 2 kg ha^{-1}) along with a blanket dose of $N_{20}P_{20}K_{25}S_{10}Zn_2$ kg ha^{-1}. Boron was applied as H_3BO_3. Results showed BARI Chola-9 with 1.5 kg B ha^{-1} produced the highest seed yield of 1338 kg ha^{-1} at Madaripur and 2218 kg ha^{-1} at Gazipur. Nodulation, nitrogen (N) and protein contents were also found highest for the same variety and B treatment. The other two varieties (BARI Chola-5 and BARI Chola-8) also performed higher yield in the plot receiving 1.5 kg B ha^{-1} compared to 1 kg B ha^{-1} or 2 kg B ha^{-1} at both locations. The results suggest that BARI Chola-9 and 1.5 kg B ha^{-1} along with $N_{20}P_{20}K_{25}S_{10}Zn_2$ kg ha^{-1} could be used for achieving higher yield of chickpea in calcareous and terrace soils of Bangladesh.

Keywords: Chickpea, boron, yield, nodulation, protein content

Introduction

Chickpea (*Cicer arietinum* L.) commonly known as gram, is the third most important pulse crop in the world and stands 5th in respect of area (8250 ha) and production (6488 tons) in Bangladesh, with an average yield of 786 kg ha^{-1} (BBS, 2012). It is an important source of protein and is rich in fiber, minerals (phosphorus, calcium, magnesium, iron and zinc) and β-carotene (Legesse Hidoto *et al.,* 2017). Chickpea as a legume crop plays a significant role in improving soil fertility by fixing the atmospheric nitrogen (Kuldeep Balai, 2017). It leaves substantial amount of residual nitrogen for subsequent crops and adds huge amount of organic matter to improve soil health. Due to deep tap root system, chickpea can withstand drought conditions by extracting water from deeper layers in the soil profile.

The soils of different parts of Bangladesh are deficient in B and nitrogen fixing bacteria (*Rhizobium* sp.) which causes low yield of crops (Quddus *et al.,* 2014).

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Boron deficiency is more common in winter crops (Jahiruddin, 2015). General fertility levels of calcareous soils are low to medium. Terrace soils 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 (FRG, 2012). Boron plays a vital role for chickpea growth especially flowering, fruit and seed set and yields (Ahlawat *et al.*, 2007). Boron influences the absorption of N, P, K and its deficiency affects the optimum levels of these three macronutrients (Raj, 1985). So, use of suitable variety and B dose can ensure higher yield of chickpea.

The present study was undertaken to evaluate the response of chickpea varieties to boron application and to find out the suitable dose of boron for yield maximization of chickpea in calcareous and terrace soils of Bangladesh.

Materials and Methods

Field experiments were conducted in two locations for two consecutive years (winter season of 2012-13 and 2013-14): (i) research field of Regional Pulses Research Station, Bangladesh Agricultural Research Institute (BARI), Madaripur and (ii) Pulses Research Sub-Station, BARI, Gazipur. Madaripur is medium high land with loamy textured calcareous soils. It belongs to Gopalpur series (Soil taxonomy: Aquic Eutrochrepts) under the agro-ecological zone of Low Ganges River Floodplain (AEZ-12). Gazipur is medium high land with fine-textured (clay loam) terrace soils. It belongs to Chhiata series (Soil taxonomy: Udic Rhodustalf) under the agro ecological zone - Madhupur Tract (AEZ-28). The Madaripur area got average rainfall from 7.6 to 80.2 mm during November to April. The mean minimum and maximum air temperatures during November to March of the experiment were 10.3 and 34.8°C, respectively. Gazipur area received average rainfall from 1.2 to 34.8 mm during November to April. The mean minimum and maximum air temperatures during November to March of the experiment were 9.23 and 34.2°C, respectively. Before starting the experiment initial soil (0-15 cm) samples of both locations were analyzed. The chemical properties are shown in Table 1.

There were 12 treatment combinations comprising three varieties of chickpea (V_1= BARI Chola-5, V_2= BARI Chola-8 and V_3= BARI Chola-9) and four levels of boron (0, 1, 1.5 and 2 kg ha^{-1}) along with a blanket dose of $N_{20}P_{20}K_{25}S_{10}Zn_2$ kg ha^{-1}. Treatment combinations were arranged as T_1= V_1B_0; T_2= V_1B_1; T_3= $V_1B_{1.5}$; T_4= V_1B_2; T_5= V_2B_0; T_6= V_2B_1; T_7= $V_2B_{1.5}$; T_8= V_2B_2; T_9= V_3B_0; T_{10}= V_3B_1; T_{11}= $V_3B_{1.5}$; and T_{12}= V_3B_2. The experiment was laid out in a split-plot design with three replicates. The main plot was considered as variety factor and sub-plot was as B factor. Each sub-plot size was 4 m × 3 m. The land was first opened by a tractor and prepared thoroughly by ploughing with a power tiller followed by laddering and leveling. Boron was applied as boric acid (17% B). Each plot received an equal amount of fertilizers $N_{20}P_{20}K_{25}S_{10}Zn_2$ kg ha^{-1} as urea, TSP,

Table 1. Soil fertility status of experimental field at Madaripur and Gazipur

Location	pH	OM (%)	Total N (%)	Ca	K	P	S	Zn	B
				meq. 100 g^{-1}		μg g^{-1}			
Madaripur (result)	7.3	1.22	0.058	11.4	0.13	16	14	0.50	0.12
Critical level	-	-	0.12	2.0	0.12	10	10	0.60	0.20
Interpretation	slightly alkaline	low	very low	high	low	medium	medium	low	low
Gazipur (result)	6.2	1.28	0.061	6.55	0.11	13	13.5	0.65	0.16
Critical level	-	-	0.12	2.0	0.12	7	10	0.60	0.20
Interpretation	acidic	low	very low	high	low	medium	medium	low	low

(Interpretation source: FRG 2012)

MoP, gypsum and zinc sulphate, respectively during final plot preparation. Two types of chickpea like Desi chickpea (brown to yellow brown seed coat with various shaped- generally small or medium small and angular with a rough surface) e.g. BARI Chola-5 and BARI Chola-9, and Kabuli chickpea (white thin seed coat with bigger round shape and smooth surface) e.g. BARI Chola-8 were used. Seeds of chickpeas were sown @ 40-45 kg ha^{-1} with a spacing of 50 cm × 10 cm in mid-November in both locations. Two hand weedings were done at 25 and 50 days after sowing. The disease (BGM) was controlled by spraying Secure fungicide @ 0.2% two times at an interval of 10 days. The first at flowering stage and insects (pod borer and aphid) were controlled by spraying Karate @ 0.2% two times at 10 day intervals during podding stage. Crop was harvested at maturity. Maturity refers to chickpea pods to be brown or yellow brown coloured as well as the seed become hard containing 12-16% moisture. The data of nodules per plant was recorded at flowering stage in each plot by selecting 5 plants randomly. The chickpea plants were smoothly uprooted and the soil was carefully removed from roots by water. Then the roots were washed with distilled water, blotted with tissue paper and the number of nodules was counted. For measuring yield attributes viz. plant height, pods per plant and seeds per pod, mature ten plants of chickpea were randomly selected and uprooted from each plot at the harvest time. Plant height was recorded from above ground part and averaged. Pods were detached from every plant and the number of pods per plant was counted and averaged. Ten pods were separated randomly from composite pods of 10 plants from each plot. The number of seeds per pod was counted on ten pods and averaged. For stover yield (kg ha^{-1}), mature plants were collected from 1-m^2 in each plot at harvest time. The harvested plants were sun dried and seeds were separated. The dry stovers were weighed and the weight was

converted to kg ha^{-1}. The seed yield (kg ha^{-1}) was measured based on whole plot (4 m× 3 m) technique. The 100- seed weight (g) was determined by randomly counting of 100- seed from the whole seeds from each plot and weighed. Initial soil samples (0-15 cm depth) of two locations were collected and brought to the laboratory and spread on a brown paper for air drying. The air-dry soil samples were ground and passed through a 2-mm sieve. After sieving, the prepared soil samples were kept into plastic containers with proper label for chemical analysis. 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 by Microkjeldahl method (Bremner and Mulvaney, 1982); exchangeable K by 1N NH_4OAc method (Jackson, 1973); exchangeable Ca by 1N NH_4OAc method (Gupta, 2004); available P by Olsen and Sommers (1982) method for calcareous soil and Bray and Kurtz (1945) method for terrace soil; 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). Plant samples (stover and seed) against each treatment were oven-dried at 70°C for 48 h and were finely ground using Cyclotec^{TM} 1093 sample Mill (Made in Sweden). An amount of 0.1 g ground sample (stover and seeds) was analyzed for N using the Kjeldahl method FOSS (Persson et al., 2008). Protein content in chickpea seed was calculated by considering the pulses food factor 5.30 (FAO, 2018). The protein content was estimated 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, yield attributes, nodulation and N and protein contents were done following the Statistix 10 package (Statistix 10., 1985). Data of yield attributes, nodules per plant, N and protein content were computed averaged of two study years in each location. Averaged data of all parameter were also statistical analyzed through ANOVA procedure using a split-plot design with three replicates considering main-plot factor variety and sub-plot for factor B. Then multiple comparisons like all-pairwise comparisons i.e. the means of treatment tested by LSD method at 5% (LSD 0.05) and level of significance (Statistix 10., 1985).

Results and Discussion

Effects of varieties and boron

The interaction between variety and boron showed significant variation in seed yield of chickpea over the years and locations (Table 2). The mean seed yield varied from 865 kg ha^{-1} to 1338 kg ha^{-1} at Madaripur and 1121 kg ha^{-1} to 2218 kg ha^{-1} at Gazipur across the treatments. The highest seed yield (1649 kg ha^{-1} in the 1st year and 1026 kg ha^{-1} in the 2nd year) at Madaripur was found in the treatment $V_3B_{1.5}$ which was statistically similar to $V_1B_{1.5}$ and V_1B_2 in the 1st year and V_3B_2 & V_3B_1 in the 2nd year. At Gazipur, the highest seed yield of 1965 kg ha^{-1} in the 1st year and 2471 kg ha^{-1} in the 2nd year was found in the treatment $V_3B_{1.5}$ followed by V_3B_2 in the 1st year. Positive response of pulse crops to B application

Table 2. Effects of boron rates on the seed and stover yields of chickpea varieties

Treatment	Seed yield (kg ha^{-1})						Stover yield (kg ha^{-1})					
	Madaripur			Gazipur			Madaripur			Gazipur		
	1st yr	2nd yr	Mean	1st yr	2nd yr	Mean	1st yr	2nd yr	Mean	1st yr	2nd yr	Mean
v_1B_0	1256cde	774c-f	1015	1172fg	1352cd	1262	2989de	1654c	2322	2850c	3114fg	2982
v_1B_1	1385bcd	777b-f	1081	1329def	1508c	1419	3125cd	1745bc	2435	3521a	3745d	3633
$v_1B_{1.5}$	1641a	792b-e	1217	1457de	1782b	1620	3468a	1812bc	2640	3656a	3824cd	3740
v_1B_2	1543ab	812bcd	1178	1404de	1766b	1585	3314abc	1964b	2639	3612a	3678de	3645
v_2B_0	1122e	608g	865	1034g	1208d	1121	2745f	1610c	2178	2910c	3045g	2978
v_2B_1	1181e	625fg	903	1158fg	1269d	1214	2879ef	1798bc	2339	3123bc	3258fg	3191
$v_2B_{1.5}$	1374bcd	657d-g	1016	1286def	1347cd	1317	3254bc	1800bc	2527	3489a	3415ef	3452
v_2B_2	1244cde	650efg	947	1275def	1319cd	1297	3124cd	1697c	2411	3425ab	3356fg	3391
v_3B_0	1223de	891abc	1057	1486cd	1800b	1643	2833ef	2702a	2723	3124bc	3845cd	3485
v_3B_1	1417bc	938ab	1178	1674bc	1874b	1774	2845ef	2789a	2817	3547a	4056bc	3802
$v_3B_{1.5}$	1649a	1026a	1338	1965a	2471a	2218	3421ab	2941a	3181	3614a	4456a	4035
v_3B_2	1454b	989a	1222	1788ab	1892b	1840	3310abc	2812a	3061	3589a	4267ab	3928
CV (%)	8.14	12.8	-	8.73	8.87	-	3.58	6.61	-	5.88	5.44	-
$LSD_{0.05}$	192	175	-	212	248	-	191	239	-	340	342	-

Values within the same column with a common letter do not differ significantly (P<0.05).

(0.5 to 2.5 kg B ha^{-1}) was reported by Ceyhan and Onder (2007). Among the treatments, the lowest seed yield was observed in V_2B_0 in both years and locations. The stover yield (mean of two years) of chickpea ranged from 2178 to 3181 kg ha^{-1} at Madaripur and 2978 to 4035 kg ha^{-1} at Gazipur. The $V_3B_{1.5}$ treatment showed the highest stover yield across the years and locations (Table 2). The results indicate that every variety at 1.5 kg ha^{-1} B rate demonstrated positive effect on the yields of chickpea. The seed yield of chickpea was found comparatively lower in the 2nd year at Madaripur. This variation might be due to infestation of chickpea plants by *Fusarium* wilt in the 2nd year.

Table 3. Effects boron rates on the yield attributes (pooled data of two years) of chickpea varieties

Treatment	Plant height (cm)		Pods $plant^{-1}$		Seeds pod^{-1}		100 seed weight (g)	
	Madaripur	Gazipur	Madaripur	Gazipur	Madaripur	Gazipur	Madaripur	Gazipur
v_1B_0	32.1e	43.6e	27.9de	37.1fg	1.12bcd	1.13	13.0e	13.2c
v_1B_1	33.0de	46.1de	29.1cd	42.2cd	1.15a-d	1.21	13.4e	13.6c
$v_1B_{1.5}$	35.7cde	49.4abc	31.7b	43.1cd	1.24ab	1.26	13.3e	13.8c
v_1B_2	34.7cde	47.9bcd	30.7bc	43.4c	1.21a-d	1.23	13.0e	13.4c
v_2B_0	34.9cde	45.4de	21.2i	36.5g	1.06d	1.09	24.5b	25.6a
v_2B_1	36.2cd	47.6bcd	22.2hi	38.0fg	1.08cd	1.11	25.0ab	26.2a
$v_2B_{1.5}$	37.4bc	49.5abc	25.0fg	39.3ef	1.17a-d	1.13	25.3a	26.8a
v_2B_2	36.7cd	46.7cd	24.0gh	38.4efg	1.12bcd	1.11	24.9ab	26.2a
v_3B_0	36.8c	47.2bcd	26.5ef	40.7de	1.19a-d	1.19	20.7cd	20.7b
v_3B_1	37.9bc	50.0ab	28.6d	48.5b	1.23abc	1.22	21.0cd	21.4b
$v_3B_{1.5}$	41.6a	51.0a	33.6a	51.9a	1.30a	1.27	21.2c	21.7b
v_3B_2	40.8ab	49.4abc	30.9bc	49.0b	1.24ab	1.23	20.6d	20.9b
CV (%)	5.79	3.86	4.38	3.00	7.26	10.8	1.51	4.31
$LSD_{0.05}$	3.6	3.2	2.1	2.2	0.15	ns	0.5	1.5

Values within the same column with a common letter do not differ significantly ($P<0.05$)

Yield attributes of chickpea viz. plant height, number of pods per plant, number of seeds per pod and 100-seed weight were influenced significantly by the treatments of varieties and B rates in both locations except number of seeds per pod at Gazipur. The tallest plant was found in the treatment $V_3B_{1.5}$ followed by V_3B_2 and dwarf plant was observed in the treatment V_1B_0 in both Madaripur and Gazipur (Table 3). The maximum number of pods per plant (33.6 at Madaripur and 51.9 at Gazipur) was recorded in the treatment $V_3B_{1.5}$ which was significantly different from the other treatments at Madaripur and Gazipur. The highest number of seeds per pod was counted in the treatment $V_3B_{1.5}$ which showed significant variation between the treatments but not at Gazipur. Ceyhan

and Onder (2007) reported significant variation in varietal response to different B rates. The highest 100-seed weight was observed in $V_2B_{1.5}$ which was significantly different from other treatments, however, statistically similar for V_2B_2 and V_2B_1 (Table 3). Among the three varieties of chickpea, BARI Chola-8 under Kabuli type and the seed size was inherently bigger than other two varieties. Every variety at 1.5 kg B ha^{-1} gave better contribution compared to 1 kg B ha^{-1} or 2 kg B ha^{-1}.

Table 4. Effects of varieties and B rates on the number of nodules per plant, nitrogen (N) and protein contents of chickpea (pooled data of two years)

Treatment	No. of nodules $plant^{-1}$		N content (%)		Protein content (%)	
	Madaripur	Gazipur	Madaripur	Gazipur	Madaripur	Gazipur
v_1B_0	22.5de	23.4d	3.25c	3.12b	17.2c	16.5b
v_1B_1	24.3cde	27.8c	3.67abc	3.45ab	19.5abc	18.3ab
$v_1B_{1.5}$	25.6abc	29.4bc	3.85abc	3.50ab	20.4abc	18.6ab
v_1B_2	25.0bcd	28.1c	3.69abc	3.46ab	19.6abc	18.3ab
v_2B_0	22.3e	24.3d	3.26c	3.06b	17.3c	16.2b
v_2B_1	23.0de	27.6c	3.45abc	3.25ab	18.3abc	17.2ab
$v_2B_{1.5}$	27.4ab	30.2b	3.99ab	3.78ab	21.1ab	20.0ab
v_2B_2	24.9b-e	28.7bc	3.76abc	3.55ab	19.9abc	18.8ab
v_3B_0	23.4cde	25.1d	3.33bc	3.18ab	17.7bc	16.9ab
v_3B_1	25.9abc	29.3bc	3.67abc	3.56ab	19.5abc	18.9ab
$v_3B_{1.5}$	27.8a	32.4a	4.05a	3.98a	21.5a	21.1a
v_3B_2	26.1abc	30.5ab	3.66abc	3.65ab	19.4abc	19.3ab
CV (%)	6.79	4.33	10.8	13.9	10.7	14.0
$LSD_{0.05}$	2.9	2.1	0.68	0.83	3.56	4.41

Values within the same column with a common letter do not differ significantly ($P<0.05$)

Presence of favorable soil environment and B nutrient along with other macro and micro nutrients might have promoted the nodule formation of chickpea varieties. Chickpea varieties and B rates demonstrated significantly a good number of active nodules per plant (Table 4). The number of nodules per plant ranged from 22.3 to 27.8 across the treatments. The maximum number of nodules per plant was counted from the treatment $V_3B_{1.5}$ which was significantly different from other treatments. The minimum number of nodules per plant was counted in V_2B_0 (Table 4). Alam *et al.* (2017) reported that the interaction between variety and boron level created significant variation in respect of number of nodules $plant^{-1}$. In contrast with our result, Alam *et al.* (2017) found the maximum number of nodules $plant^{-1}$ (30.8) in BARI Chola-8 with 3 kg B ha^{-1}. The variation

in the number of nodules per plant over the varieties might be due to variation in microbes and edhaphic condition of that area. The whole nodulation process is regulated by highly complex chemical communications between the plant and the bacteria. The protein content varied between 17.2 to 21.5% at Madaripur and 16.2 to 21.1% at Gazipur across the varieties and B rates. The highest protein content (21.5% at Madaripur and 21.1 at Gazipur) was measured from the treatment $V_3B_{1.5}$ which showed in most cases significantly similar with the other treatments. The lowest protein content in seed (17.2% at Madaripur and 16.2% at Gazipur) was measured from V_1B_0 treatment.

Effects of varieties

Chickpea yield in both locations was significantly different between the varieties (Table 5). The mean seed yield (mean of two years) ranged from 933 to 1198 kg ha^{-1} in Madaripur and 1237 to 1869 kg ha^{-1} in Gazipur across the varieties. The highest seed yield (1435 kg ha^{-1} in the 1st year and 961 kg ha^{-1} in the 2nd year at Madaripur and 1728 kg ha^{-1} in the 1st year and 2009 kg ha^{-1} in the 2nd year at Gazipur) was obtained from V_3 (BARI Chola-9) which was significantly higher than other varieties. The lowest mean seed yield of 933 kg ha^{-1} at Madaripur and 1237 kg ha^{-1} at Gazipur were recorded with the variety BARI Chola-8 (Table 5).The stover yield showed significant variation during two consecutive years in both the locations due to different chickpea varieties. The highest mean stover yield (2957 kg ha^{-1} in Madaripur and 3813 kg ha^{-1} in Gazipur) was recorded from BARI Chola-9 and the lowest stover yield of 2364 kg ha^{-1} at Madaripur and 3252 kg ha^{-1} at Gazipur was found in BARI Chola-8 (Table 5). This variation might be due to varietal characters; as a result BARI Chola-9 gave the highest yield. Boron doses exerted significant influence on the seed yield of chickpea. This result is supported by Alam et al. (2017) conducted in Rajshahi region of Bangladesh that BARI Chola-8 produced the highest seed yield. Plants must adapt their growth by sensing and responding to surrounding conditions like availability of nutrients in the soil for ensuring successful reproduction and yield.

Yield attributes showed significant variation due to chickpea varieties at the locations of Madaripur and Gazipur (Table 6). The highest plant height (39.3 cm at Madaripur and 49.4 cm at Gazipur) was recorded from V_3 (BARI Chola-9) which was significantly different from other varieties. The maximum number of pods per plant (29.9 at Madaripur and 47.5 at Gazipur) was found in V_3 which was significantly different to other, but statistically similar to BARI Chola-5 at Madaripur. The maximum number of seeds per pod (1.24 at Madaripur and 1.23 at Gazipur) was recorded from BARI Chola-9 followed by BARI Chola-5. The highest seed weight (24.9 g at Madaripur and 26.2 g at Gazipur) was obtained in BARI Chola-8 which was significantly different over other varieties (Table 6).

Table 5. Effects of chickpea varieties on yields

Chickpea variety	Seed yield (kg ha^{-1})						Stover yield (kg ha^{-1})					
	Madaripur			Gazipur			Madaripur			Gazipur		
	1st yr	2nd yr	mean	1st yr	2nd yr	mean	1st yr	2nd yr	mean	1st yr	2nd yr	mean
V_1	1456a	789b	1123	1341b	1602b	1472	3224a	1794b	2509	3410a	3590b	3500
V_2	1230b	635c	933	1188c	1286c	1237	3001b	1726b	2364	3237b	3267c	3252
V_3	1435a	961a	1198	1728a	2009a	1869	3102b	2811a	2957	3469a	4156a	3813
CV (%)	5.09	6.52	-	6.52	5.04	-	3.17	3.63	-	2.63	1.69	-
$LSD_{0.05}$	79.2	58.7	-	104	93.2	-	111	86.8	-	100	70.4	-

Values within the same column with a common letter do not differ significantly (P<0.05)

V_1=BARI Chola-5, V_3=BARI Chola-9, V_2=BARI Chola-8

Table 6. Effects of chickpea varieties on the yield attributes (pooled data of two years)

Chickpea variety	Plant height (cm)		No. of pods plant^{-1}		No. of seeds pod^{-1}		100 seed weight (g)	
	Madaripur	Gazipur	Madaripur	Gazipur	Madaripur	Gazipur	Madaripur	Gazipur
V_1	33.9c	46.7b	29.8a	41.5b	1.18ab	1.21a	13.2c	13.5c
V_2	36.3b	47.3b	23.1b	38.1c	1.11b	1.11b	24.9a	26.2a
V_3	39.3a	49.4a	29.9a	47.5a	1.24a	1.23a	20.9b	21.2b
CV (%)	4.98	1.83	1.27	3.72	6.54	6.46	2.26	2.96
$LSD_{0.05}$	2.1	0.99	0.40	1.78	0.09	0.09	0.50	0.68

Values within the same column with a common letter do not differ significantly (P<0.05)

V_1=BARI Chola-5, V_3=BARI Chola-9, V_2=BARI Chola-8

Chickpea varieties influenced significantly on the number of nodules per plant. The highest number of nodules per plant (25.8 at Madaripur and 29.3 at Gazipur) was counted in BARI Chola-9. This variation might be inherent characters of BARI Chola-9. Nitrogen and protein contents showed non-significant variation across chickpea varieties. BARI Chola-9 assimilated the highest protein content (19.9% at Madaripur and 19.0% at Gazipur) than the rest of the varieties (Table 7).

Table 7. Effects of chickpea varieties on the number of nodules plant^{-1}, N and protein content (pooled data of two years)

Chickpea variety	No. of Nodules plant^{-1}		N content (%)		Protein content (%)	
	Madaripur	Gazipur	Madaripur	Gazipur	Madaripur	Gazipur
V_1	24.3b	27.2b	3.62	3.38	19.2	17.9
V_2	24.4b	27.7b	3.61	3.41	19.2	18.1
V_3	25.8a	29.3a	3.68	3.59	19.5	19.0
CV (%)	2.90	3.41	8.84	10.2	8.80	10.3
$LSD_{0.05}$	0.8	1.1	ns	ns	ns	ns

Values within the same column with a common letter do not differ significantly ($P<0.05$)

V_1=BARI Chola-5, V_3=BARI Chola-9, V_2=BARI Chola-8

Table 8. Effects of different levels of boron on the yields of chickpea

Boron levels (kg ha^{-1})	Seed yield (kg ha^{-1})						Stover yield (kg ha^{-1})					
	Madaripur			Gazipur			Madaripur			Gazipur		
	1st yr	2nd yr	mean	1st yr	2nd yr	mean	1st yr	2nd yr	mean	1st yr	2nd yr	mean
0	1200c	758	979	1231c	1453c	1342	2856c	1989b	2423	2961b	3335c	3148
1	1328b	780	1054	1387b	1550bc	1469	2950c	2111ab	2531	3397a	3686b	3542
1.5	1555a	825	1190	1569a	1867a	1718	3382a	2184a	2783	3586a	3898a	3742
2	1414b	817	1116	1489ab	1659b	1574	3249b	2158a	2704	3542a	3767ab	3655
CV (%)	5.09	6.52	-	6.52	5.04	-	3.17	3.63	-	2.63	1.69	-
$LSD_{0.05}$	110	ns	-	122	143	-	110	138	-	196	198	-

Values within the same column with a common letter do not differ significantly ($P<0.05$)

Effects of boron application

Yields of chickpea varieties increased markedly due to application of boron. The mean seed yield at Madaripur ranged from 979 to 1190 kg ha^{-1} and at Gazipur ranged from 1342 to 1718 kg ha^{-1} due to application of different rates of B. The highest seed yield (1555 kg ha^{-1} in the 1st year & 825 kg ha^{-1} in the 2nd year at

Madaripur and 1569 kg ha^{-1} in the 1st year & 1867 kg ha^{-1} in the 2nd year at Gazipur) obtained in the plot receiving of 1.5 kg B ha^{-1} which was significantly different with the other plot receiving of 2.0 kg B ha^{-1} or 1.0 kg B ha^{-1} except the 2nd year at Madaripur that was showed non-significant (Table 8). Khanam et al. (2000) reported that the seed yield of chickpea was affected significantly due to different rates of boron application. The stover yield of chickpea varieties across the rates of boron showed in some exception almost similar trend of seed yield (Table 8).The seed yield (mean of two years) of chickpea in Gazipur was observed higher over the yield of Madaripur. Because chickpea plants in the 2nd year were infested by the disease *Fusarium* wilt in Madaripur. The weather of 2nd year and soil condition might be favoured for the disease *Fusarium* wilt.

Different boron fertilization showed significant effect on yield attributes of chickpea varieties except seeds per pod at Gazipur (Table 9). The highest plant height (38.2 cm at Madaripur and 49.9 cm at Gazipur) was noted from the rate of B 1.5 kg ha^{-1} followed by 2.0 kg ha^{-1} in both locations. The maximum number of pods per plant (30.1 at Madaripur and 44.8 at Gazipur) was counted from application of 1.5 kg B ha^{-1} followed by 2.0 kg B ha^{-1}. The maximum number of seeds per pod was recorded from application of 1.5 kg B ha^{-1} in both locations (Table 9). Similar results were also reported by Alam et al. (2017). The highest 100-seed weight (19.9 g at Madaripur and 20.8 g at Gazipur) was obtained from application of 1.5 kg B ha^{-1}. In most of the cases, the lowest yield attributes of chickpea varieties were found in B_0 treatment (Table 9).

Table 9. Effect of different rates of boron on the yield attributes of chickpea (pooled data of two years)

Boron levels (kg ha^{-1})	Plant height (cm)		No. of pods plant^{-1}		No. of seeds pod^{-1}		100 seed weight (g)	
	Madaripur	Gazipur	Madaripur	Gazipur	Madaripur	Gazipur	Madaripur	Gazipur
0	34.6c	45.4c	25.2d	38.1c	1.12b	1.14	19.4b	19.8b
1	35.7bc	47.9b	26.6c	42.9b	1.15ab	1.18	19.8a	20.4ab
1.5	38.2a	49.9a	30.1a	44.8a	1.24a	1.22	19.9a	20.8a
2	37.4ab	48.0b	28.5b	43.6ab	1.19ab	1.19	19.5b	20.2ab
CV (%)	4.98	1.83	1.27	3.72	6.54	6.46	2.26	2.96
$LSD_{0.05}$	2.09	1.83	1.20	1.26	0.08	ns	0.29	0.87

Values within the same column with a common letter do not differ significantly (P<0.05)

The number of nodules per plant increased with the increasing rates of boron application (Table 10). The highest number of nodules per plant (26.9 at Madaripur and 30.7 at Gazipur) was achieved by the application of 1.5 kg B ha^{-1}

which showed significant variation with other B application rates but statistically identical to application of 2 kg B ha^{-1} at Madaripur (Table 10).

Table 10. Effects of different levels of boron on the number of nodules $plant^{-1}$, N and protein content of chickpea (pooled data of two years)

Boron levels (kg ha^{-1})	No. of nodules $plant^{-1}$		N content (%)		Protein content (%)	
	Madaripur	Gazipur	Madaripur	Gazipur	Madaripur	Gazipur
0	22.7c	24.3c	2.28b	3.12b	17.4b	16.5b
1	24.4bc	28.2b	3.60ab	3.42ab	19.1ab	18.1ab
1.5	26.9a	30.7a	3.96a	3.74a	21.0a	19.9a
2	25.3ab	29.1b	3.70a	3.55ab	19.6a	18.8ab
CV (%)	2.90	3.41	8.84	10.2	8.80	10.3
$LSD_{0.05}$	1.7	1.2	0.39	0.48	2.06	2.55

Values within the same column with a common letter do not differ significantly ($P<0.05$)

The N and protein content accumulations were influenced significantly by the rates of B application. The N and protein contents varied from 2.28 to 3.96% N and 17.4 to 21.0% protein across the rates of B application. The highest N and protein contents were recorded in the treatment of 1.5 kg B ha^{-1} followed by 2 kg B ha^{-1} and 1 kg B ha^{-1} at both Madaripur and Gazipur whereas the minimum contents (N and protein) were observed in control (B_0) treatment (Table 10). Boron influences the absorption of N, P, K and positive role on protein synthesis (Raj, 1985).

Conclusion

All varieties of chickpea were found responsive to boron, but BARI Chola-9 response to boron comparatively was higher than that of other two varieties by the trial of two consecutive years. BARI Chola-9 and boron @ 1.5 kg ha^{-1} along with a blanket dose of $N_{20}P_{20}K_{25}S_{10}Zn_2$ kg ha^{-1} appeared as the best-suited combination on the basis of yield, quality (protein content) and yield components. All tested varieties like BARI Chola-5, BARI Chola-8 and BARI Chola-9 achieved higher yield in the plot receiving 1.5 kg B ha^{-1} than that of the plot receiving 1 kg B ha^{-1} or 2 kg B ha^{-1} at both Madaripur and Gazipur. Thus boron @ 1.5 kg ha^{-1} along with $N_{20}P_{20}K_{25}S_{10}Zn_2$ kg ha^{-1} can be recommended for chickpea cultivation in calcareous and terrace soils of Bangladesh.

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