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Effect of Boron Levels on Growth and Yield of Cabbage in Calcareous Soils of Bangladesh

M. N. Alam

Dept. of Crop Science and Technology, University of Rajshahi, Rajshahi-6205, Bangladesh.

Abstract: A pot experiment was conducted to investigate the effect of B levels on growth, yield and yield components of cabbage during October 2004 to January 2005 in calcareous soils of Bangladesh. The genotype of cabbage was "KS Cross F_1 hybrid", which is suitable for pot experiment. The soil was medium fertile with low content of available B, P^H was 8.4 and silty clay loam in texture. There were eight levels of B (0, 1, 2, 3, 4, 5, 6, 7 kg B/ha) as boric acid in the treatments. The equal amounts of 50cm´50cm spacing/plant was considered, so the actual treatments i.e. B_0 (control), B_1 (0.15g), B_2 (0.30g), B_3 (0.45g), B_4 (0.60g), B_5 (0.75g), B_6 (0.90g) and B_7 (1.05g) boric acid per pot. The experiment was laid out in Randomized Complete Block Design (RCBD) with 3 replications. The RCBD design was selected because of pot arrangement. The doses of (50cm ´ 50cm equal amount) N: P: K: S: Mg: Zn = 120: 50: 75: 20: 10: 3 as urea (6.52g), TSP(5.95g), MP(3.75g), gypsum (2.78g), magnesium oxide(0.417g), zinc oxide (0.097g), respectively and vermicompost at 10t/ha equivalent amount (0.25kg/pot) also added in all pots. Urea was used 50% as basal and 50% at 35 days after transplanting (DAT) and also boric acid treatments used at pot soil preparation and at 30 DAT. Thirty six days old seedlings were transplanted on 03 October 2004 and harvested at 118 DAT. The irrigation was done very carefully by measuring cylinder and a special protection also taken against rainfall. Data were recorded at 15, 30, 45, 60, 75, 90, 118 DAT (at harvest) i.e. plant spread, number of loose leaves/plant, largest leaf length and breadth but other parameters also recorded after harvest of the crop. Growth, yield and other yield contributing characters of cabbage significantly affected by boron levels. The head weight and other growth and yield contributing parameters of cabbage increased up to 4.0 kg B/ha (B_4) and decreased gradually with the increases of B level (>4.0 kg B/ha). The highest head weight (811.33g) was obtained with B_4 followed by B_3 (748.67g) but both are statistically similar. The lowest head weight (384.33g) was found in B_0 but B_7 (406.0g) is statistically similar with B_0. The head weight of cabbage was strongly correlated with head diameter (r = 0.967**) and leaf breadth (r = 0.965**). The maximum cabbage head yield increase of 116.82% by B_4 and 94.97% by B_3 treatment. The results suggested that 3-4kg B/ha (0.45-0.60g boric acid/pot) is suitable in cabbage or any upland vegetable crop production for better growth and yield in calcareous soils, but above 4.0kg B/ha it may be harmful for crop growth and yield. The results also indicated that cabbage can be grown successfully in pot-soil for commercial production in green house with proper fertilization specially boron.

Keywords: Boron levels, cabbage growth, cabbage yield, pot-cultivated cabbage, calcareous soils

INTRODUCTION

High Ganges River Floodplain soils (AEZ-11) is one of the most important calcareous soils of Bangladesh. The soils have large content of $CaCO_3$, as well as high concentration of available Ca^{++} present in that soil. The P^H is generally ranges from 7.0-8.5 but in most of the upland soils ranges between 8.0-8.5.

Boron is an essential micronutrient required for normal plant growth and development. It is a very sensitive element and plants differ widely in their requirements but the ranges of deficiency and toxicity are narrow. The B concentration in soils varied widely with soil types and environment. The B requirements are common on upland crops in humid regions and also in calcareous soil.Boron deficiencies are widespread in humid regions by leaching losses[32]. It is wide spread and often incipient that B deficiency seems to exist in Bangladesh soils[19]. Zinc and boron normally becomes less available to plants with increasing soil P^H. When Ca availability is high, there is a greater requirement of B for plant growth and yield[31].

Many researchers observed that B application increased growth and yield of upland crops like-wheat, pulses, oil seeds, potato, carrot, radish and papaya.

Corresponding Author: Md. Nurul Alam, Dept. of Crop Science and Technology, University of Rajshahi, Rajshahi, Bangladesh. E-mail: nalam_ru@yahoo.com, Phone: +88-01199174547

Boron @ 3.0 kg/ha produced the highest grain yield of wheat, which was statistically similar to that produced by 2.0 kg B/ ha[7]. Pregno and Arour[18] also reported that the highest potato tuber yield was found when 2 kg B/ ha was applied to the soil followed by 4 kg B / ha. The highest yield of carrot was obtained when B was applied with a basal NPK[14]. Maurya and Singh[12] found that borax 10 kg/ha gave the highest radish yield increase viz. 41% over the control and the best protein and ascorbic acid content. Khanam *et al*.[11] observed that the application of Mg and B is necessary for improving yield potentialities of chickpea and lentil at BAU farm soil of Bangladesh. Szmid[27] reported that soil B content above 1.5-2.0 mg/L or below 0.5 mg/ L resulted the decrease in carrot root yield. However, in cole crops like cauliflower, broccoli and cabbage, boron requirement is very high. Application of different levels of B influenced the growth and yield in different crops also reported by Quaggio and Ranos[20] in potato, Efkar *et al*.[5] in potato, Porter *et al*.[17] in potato, Ali *et al*.[3] in papaya and Sohel *et al*.[26] in broccoli.

The requirements of B in vegetables generally more than other corps. Rasp mentioned that the effect of added trace elements in 12 years of crop rotation in which potatoes and cereals were grown in alternate years. It was found that only B tended to increase potato yield.

Alam[1] intensively observed in calcareous soils of Bangladesh and showed that B at 2kg/ha with NPKS increased cabbage head yield by 119% (on average) than NPKS alone. In fact information regarding B fertilizer requirements for vegetable should be meager in calcareous soils of Bangladesh. Therefore, an attempt was made to study the effect of B levels on growth, yield and yield components of cabbage in calcareous soil of Bangladesh.

MATERIALS AND METHODS

A pot experiment was conducted to investigate the effect of B levels on growth and yield of cabbage (*Brassica oleracea* var. *capitata* L.) in "Calcareous Dark Grey Floodplain Soil" which was originated from "High Ganges Floodplain" deposits[6] in Bangladesh. The test genotype of cabbage was KS Cross F_1 hybrid, which is suitable for pot experiment. The experimental initial soil was determined- soil texture by hydrometer method and other parameters by ASI method[9]. The experimental soil (0-15 cm) collected from the rice field in front of the Botanical garden at Rajshahi University. The well mixed initial pot soil sample having p^H=8.4, OM=1.36%, total N = 0.102%, Ca = 9.20 me/100g, Mg = 5.66 me/100g, K = 0.12 me/100g, P = 12.8mg/kg, S = 16.0 mg/kg, Fe = 6.6 mg/kg, Cu = 1.63 mg/kg, Mn = 2.25 mg/kg, Zn = 0.36 mg/kg, B = 0.17 mg/kg and also soil texture "Silty clay loam". There were eight levels of B (0, 1, 2, 3, 4, 5, 6, 7 kg B/ha) as boric acid in the treatments. The equal amounts of 50cm´50cm spacing/plant was considered, so the actual amount i.e. B_0 (control), B_1 (0.15g), B_2 (0.30g), B_3 (0.45g), B_4 (0.60g), B_5 (0.75g), B_6 (0.90g) and B_7 (1.05g) boric acid per pot. The earthen pots (size 30cm ´ 40cm having 8kg of soil) were arranged according to RCBD design with 3 replications. The RCBD design was selected because of pot arrangement. The doses of (50cm ´ 50cm equal amount) N: P: K: S: Mg: Zn = 120: 50: 75: 20: 10: 3 as urea (6.52g), TSP(5.95g), MP(3.75g), gypsum (2.78g), magnesium oxide(0.417g), zinc oxide(0.097g) per plot, respectively and vermicompost at 10t/ha equivalent amount (0.25kg/pot) also added in all pots. Urea was used 50% as basal and 50% at 35 days after transplanting (DAT) and also boric acid treatments used at pot soil preparation and at 30 DAT. Thirty six days old seedlings were transplanted on 03 October 2004 and harvested at 118 DAT. Irrigation was done very carefully by measuring cylinder and a special protection also taken against rainfall. Data were recorded at 15, 30, 45, 60, 75, 90, 118 DAT (at harvest) i.e. plant spread, number of loose leaves/plant, largest leaf length and breadth but other parameter also recorded after harvest of the crop. After collection of data, it was tabulate in proper form and subjected to statistical analysis with the help of computer package MSTAT-C and also tested DMRT. The correlation matrix also analyzed by SPSS program.

RESULTS AND DISCUSSIONS

Plant Spread: The plant spread of cabbage was significantly affected by the application of increasing rates of boron at different growth period (Table 2). The boron fertilizer was applied to the pot soil before transplanting of seedling and at 30 DAT. At 15 DAT, the highest plant spread (14.3 cm) was found in B_7 (50%=3.5 kg B/ha) followed by B_6, B_5, B_4, B_3, B_2 and B_1. But treatment B_6 with B_5, B_2 with B_1 did not differ significantly. At 30 DAT, the highest plant spread (22.43 cm) was obtained with B_7, but B_7 and B_6 are statistically similar. At 45 DAT, the highest plant spread was observed from B_4 to B_7 but the treatments B_2 and B_3 are also statistically similar. At 60 DAT, the highest plant spread (29.53 cm) was found by the application of B_4 gradually decreases up to B_7. These were no significance difference among treatments B_3 to B_7. At 75 DAT, the plant spread were maximum limit than other growth period. In this period, the treatment B_4 produced the highest plant spread (39.63 cm) but treatment B_1 to B_6 are similar. At 90 DAT, the highest

Table 1: Effect of different levels of boron on plant spread of cabbage at different days after transplanting.

Treatments	Plant spread (cm) at						
	15 DAT	30 DAT	45 DAT	60 DAT	75 DAT	90 DAT	118 DAT
B_0	7.03 f	11.03 f	16.86 d	21.40 d	30.86 c	32.13 d	28.43 e
B_1	9.06 e	12.56 f	19.73 c	25.83 c	36.06 ab	35.66 c	32.40 bc
B_2	9.56 de	14.43 e	23.13 b	28.00 b	38.06 a	38.46 b	34.10 abc
B_3	10.34 d	16.60 d	24.06 b	28.80 ab	39.20 a	39.46 ab	35.36 a
B_4	11.26 c	19.63 c	27.06 a	29.53 a	39.63 a	40.90 a	36.06 a
B_5	13.66 b	20.40 bc	28.36 a	29.26 ab	38.13 a	40.13 ab	34.53 ab
B_6	14.30 b	21.66 ab	27.33 a	28.66 ab	35.56 ab	35.76 c	31.46 cd
B_7	15.30 a	22.43 a	26.76 a	28.23 ab	32.40 bc	34.83 c	29.23 de
LSD	0.7913	1.670	1.541	1.254	4.10	2.14	2.527
CV (%)	2.88	3.96	5.64	4.88	4.67	2.37	3.18

In a column, figures having same letter(s) do not differ significantly by DMRT at the 1% level. DAT = Days after transplanting, LSD = Least significant difference, CV = Coefficient of variance. At 15 and 30 DAT the rate of B was 50%.

Table 2: Effect of different levels of boron on the number of loose leaves of cabbage at different days after transplanting

Treatments	Number of loose leaves Plant^{-1} at						
	15 DAT	30 DAT	45 DAT	60 DAT	75 DAT	90 DAT	118 DAT
B_0	5.33 d	6.66 c	9.66 b	11.66 e	15.00 e	14.33 d	13.00 d
B_1	5.33 d	8.00 b	11.00 ab	14.00 d	17.33 d	17.00 bc	14.66 bcd
B_2	6.00 cd	8.00 b	11.33 ab	15.33 bc	18.33 c	17.00 bc	15.66 a-d
B_3	6.33 c	8.33 b	12.00 a	15.33 bc	19.33 b	17.66 abc	17.00 ab
B_4	6.33 c	9.00 ab	12.66 a	16.00 ab	19.66 ab	19.33 a	18.00 a
B_5	6.66 bc	9.66 a	13.00 a	16.66 a	20.33 a	18.33 ab	16.66 abc
B_6	7.33 ab	10.00 a	13.06 a	15.66 bc	19.66 ab	17.33 abc	15.66 a-d
B_7	7.66 a	10.00 a	11.66 a	15.00 c	18.33 c	16.00 cd	13.66 cd
LSD	0.7725	1.244	1.789	0.8513	0.8996	1.875	2.813
CV (%)	4.99	5.88	6.24	2.36	2.00	4.51	7.45

In a column, figures having same letter(s) do not differ significantly by DMRT at the 1% level. DAT = Days after transplanting, LSD = Least significant difference, CV = Coefficient of variance. At 15 and 30 DAT the rate of B was 50%.

plant spread (38.46 cm) was also recorded in B_4 treatment. The plant spread gradually increased up to B_4 and than gradually decreased up to B_7. The lowest plant spread was found in control treatment at different growth period of cabbage.

At harvest, the plant spread responded significantly due to the application of different levels of boron. The highest plant spread (36.06 cm) at harvest was found by the application of B_4 treatment. But there is no significant difference among B_2, B_3, B_4 & B_5 treatment. The control treatment (B_0) and B_7 produced the lowest and statistically similar plant spread.

Porter *et al.*[17] showed that plants were stunted and yields reduced at application of grater than 4.5kg B/ha. Pregno and Arour[18] mentioned that the highest tuber yield was found when 2 kg B/ha was applied and followed by 4 kg B/ha. The plant growth was not increased by low rates of B but was reduced over 4 kg B/ha.

The results are in partial agreement with the findings of Maurya and Singh[12], Quaggio and Ranos[20], Efkar *et al.*[5], Alam *et al.*[2], Hossain *et al.*[8], Ali *et al.*[3], Talukder *et al.*[29], Hafiz Akter *et al.*[7], Kadir[10] and Noor *et al.*[15].

The results indicated that B at 4 kg/ha is suitable at proper growth of canopy for highest use of sunlight and control of soil environment. Application of 1kg B/ha produced the vigorous plant growth of pea than control, where NPK as basal[24].

Number of Loose Leaves per Plant: Application of different levels of B significantly influenced the number of loose leaves/plant at growth period of cabbage (Table 2). The number of loose leaves/plant was increase with time and maximum at 75 DAT. At 15 DAT, the highest rates (50%=3.5 kg B/ha) of B produced the maximum number of leaves per plant.

The maximum number of loose leaves at 90 DAT and at harvest was found at 4 kg B/ha (B_4). But at 60 and 75 DAT, the treatment B_5 produced the maximum number of loose leaves per plant. Similarly, at 30 and 45 DAT the maximum number of leaves per plant was produced by B_6.

The above results indicated that the maximum number of loose leaves per plant was found when 4 kg B/ha was applied and followed by 3 or 2 kg B/ha.

Largest Leaf Length: The leaf length responded significantly due to the application of different doses of B fertilizer at growth period of cabbage (Table 3). The leaf length increased gradually with increase of growth period up to 75 days and then decreased. At 15 DAT, the leaf length of cabbage was significantly influenced by B levels. The highest leaf length was recorded in B_6 (50%=3.0 kg B/ha) followed by B_7 (50%=3.5 kg B/ha) treatments but B_6 and B_7 are statistically similar. At 30 DAT, the highest leaf length (11.73 cm) was fond in B_5 and followed by B_4 but B_5 and B_4 are statistically similar.

At 45 DAT, the highest leaf length was obtained with B_4 followed by B_5, but B_4 and B_5 are statistically similar. At 60 DAT, the highest leaf length was also found in B_4 followed by B_3 but B_3 and B_4 are statistically similar. At 75 DAT, the highest leaf length was obtained by B_3 but B_3, B_2, B_4 and B_5 are not significantly difference.

At 90 DAT, the highest leaf length was found B_4 but B_3, B_4 and B_5 are statistically similar. At the time of harvest, the highest leaf length was found in B_4 and followed by B_3 and B_4 but B_3, B_4 and B_5 are not statistically difference. In all growth stages, the control (B_0) treatment produced shortest leaf length of cabbage. The growth of leaf length increased up to 90 DAT and then decreased gradually.

Kadir[10] reported that application of NPKSMgB was produced the highest leaf size of broccoli. The results are in partial agreement with the findings of Maurya and Singh[12], Quaggio and Ranos[20], Efkar *et al*.[5], Alam *et al*.[2], Hossain *et al*.[8], Ali *et al*.[3] and Hafiz Akter *et al*.[7].

Alam[1] found that addition of B (2 kg/ha) with NPKS significantly increased the leaf length of cabbage before head formation.

Largest Leaf Breadth: The leaf breadth of cabbage was significantly influenced by different doses of boron at growth period. The leaf breadth gradually increased up to 90 days and then decreased (Table 4). At 15 DAT. The highest leaf breadth (8.03cm) was recorded in B_7 followed by B_6, but B_6 and B_7 are not significantly difference. The B_4 is similar with B_5 and B_0 with B_1. At 30 DAT, the highest leaf breadth (10.30 cm) was found in B_7 and followed by B_6 and B_5, but B_6 and B_5 are statistically similar. At 45 DAT, the highest leaf breadth (12.57 cm) was recorded in B_4, the second highest and similar leaf breadth observed in B_3 and B_5. At 60 DAT, the highest leaf breadth (12.67 cm) was obtained with B_4 and followed by B_5, B_3 and B_6 but they are statistically similar. At 75 DAT, the highest leaf breadth (16.73 cm) was found in B_4 but treatment B_2, B_3 and B_4 are statistically similar. At 90 DAT, the highest leaf breadth (19.03 cm) was found in B_4 but the treatments B_2, B_3 and B_4 are statistically similar. The control treatment produced the smallest breadth of leaf at different growth period of cabbage.

At the time of harvest, the leaf breadth ranged from 14.73 to 17.66cm. The highest leaf breadth (17.66 cm) was obtained with B_4, the second highest and statistically similar leaf breadth were found in B_3, B_5 and B_6. The treatment B_0 is similar with B_7, and B_1 with B_6.

The results indicated that the maximum breadth of leaf was obtained when 4 kg B/ha (equivalent amount) was added to the soil and maximum at 90 DAT (19.03cm). Kadir[10] reported that application of NPKSMgB was produced the highest leaf size of broccoli.

The results agreed partially with the findings of Maurya and Singh[12], Alam *et al*.[2], Hossain *et al*.[8] and Ali *et al*.[3]. Alam[1] found that B at 2 kg/ha with NPKS or NPASMgZn increased the leaf breadth of cabbage, cauliflower and broccoli in calcareous soils of Bangladesh.

Plant Height: The plant height was measured at harvest of the crop. The plant height responded significantly due to the addition of boron fertilizer (0, 1, 2, 3, 4, 5, 6 and 7 kg B/ha) in the pot soil. The plant height ranged from 18.33 to 26.60 cm (Table 5). The highest plant height (26.60 cm) was obtained with 4 kg B/ha (B_4) followed by B_3 and B_5, but these three treatments are statistically similar. The plant height increased up to 4 kg B/ha and decreased gradually with increase of boron levels. The lowest plant height (18.33 cm) was also found in control (B_0). The results are in partial agreement with the findings of Porter *et al*.[19], Pregno and Arour[18], Azad[4], Talukder *et al*.[29], Kadir[10], Noor *et al*.[15] and Sarker *et al*.[22].

Head Diameter: The head diameter of cabbage significantly affected due to the addition of increasing rates of boron fertilizer (Table 5). The head diameter ranged from 10.87 to 18.23cm. Application of 1, 2, 3 and 4 kg B/ha increased head diameter by 13.90 (B_1), 15.77 (B_2), 17.77 (B_3) and 18.23 cm (B_4), respectively.

Table 3: Effect of different levels of boron on largest leaf length of cabbage at different days after transplanting.

Treatments	Largest leaf length (cm) at						
	15 DAT	30 DAT	45 DAT	60 DAT	75 DAT	90 DAT	118 DAT
B_0	5.63 f	7.83 d	9.63 e	14.16 c	15.83 c	16.33 c	16.06 cd
B_1	6.50 e	8.53 c	11.13 d	14.66 c	16.70 bc	17.16 bc	16.83 c
B_2	7.70 d	8.70 c	13.16 c	15.76 b	18.83 a	18.43 b	17.76 bc
B_3	8.53 c	9.83 b	13.70 bc	17.06 a	19.33 a	19.36 ab	18.73 ab
B_4	9.40 b	11.40 a	14.53 a	17.33 a	18.73 a	19.96 a	19.03 a
B_5	9.60 b	11.73 a	14.13 ab	16.76 ab	18.36 a	19.23 ab	18.43 b
B_6	9.96 ab	10.53 b	13.60 bc	14.63 c	17.16 b	17.03 bc	16.63 c
B_7	10.43 a	10.03 b	13.46 bc	14.23 c	16.03 bc	15.86 d	15.16 d
LSD	0.7002	0.6832	0.7002	1.034	1.132	2.390	1.246
CV (%)	3.39	2.87	2.22	2.73	2.64	2.29	3.81

In a column, figures having same letter(s) do not differ significantly by DMRT at the 1% level. DAT = Days after transplanting, LSD = Least significant difference, CV = Coefficient of variance. At 15 and 30 DAT the rate of B was 50%.

Table 4: Effect of different levels of boron on largest leaf breadth of cabbage at different days after transplanting

Treatments	Largest leaf breadth (cm) at						
	15 DAT	30 DAT	45 DAT	60 DAT	75 DAT	90 DAT	118 DAT
B_0	5.17 e	6.83 g	8.30 e	8.87 d	13.60 e	15.13 e	14.73 d
B_1	5.43 e	7.07 f	8.87 e	10.97 c	14.60 cd	16.36 cd	15.96 c
B_2	5.93 d	7.33 e	10.47 d	11.73 b	16.03 ab	17.83 bc	16.53 bc
B_3	6.60 c	6.47 d	12.20 b	12.00 ab	16.73 a	18.23 b	16.96 b
B_4	7.03 b	6.67 c	12.97 a	12.67 a	16.10 ab	19.03 a	17.66 a
B_5	7.37 b	9.87 bc	12.23 b	12.53 a	15.63 b	16.86 c	16.33 bc
B_6	7.80 a	10.03 b	11.60 bc	11.97 ab	14.73 c	16.06 d	15.13 cd
B_7	8.03 a	10.30 a	10.93 cd	11.67 bc	13.93 de	15.43 de	14.63 d
LSD	0.3919	0.2170	0.7086	0.7169	0.6918	0.9634	0.7064
CV (%)	2.43	1.05	2.67	2.55	1.87	4.88	2.78

In a column, figures having same letter(s) do not differ significantly by DMRT at the 1% level. DAT = Days after transplanting, LSD = Least significant difference, CV = Coefficient of variance. At 15 and 30 DAT the rate of B was 50%.

Table 5: Effect of different levels of boron on yield and yield components of cabbage at harvest.

Treatments	Plant height (cm)	Head diameter (cm)	Head thickness (cm)	Wt. of root(g)	Wt. of stem (g)	Wt. of loose leaves (g)	Wt. of Head (g)	% yield increase over control
B_0	18.33 e	10.87 e	9.23 cd	16.23 d	22.33 b	152.67 d	384.33 d	-
B_1	21.07 d	13.90 c	10.30 ab	17.83 cd	25.67 ab	194.0 cd	464.33 c	20.81
B_2	23.57 bc	15.77 b	10.70 a	19.83 abc	27.00 ab	248.0 abc	654.66 b	70.33
B_3	25.53 ab	17.77 a	10.80 a	20.83 a	28.00 a	251.67 abc	748.67 a	94.97
B_4	26.60 a	18.23 a	10.43 ab	20.30 ab	28.33 a	278.0 a	811.33 a	116.82
B_5	24.73 abc	14.23 c	9.70 bc	20.70 a	26.00 ab	218.33 abc	605.33 b	97.50
B_6	22.77 cd	12.13 d	8.93 cd	19.53 abc	24.00 b	212.33 bc	446.0 cd	16.04
B_7	20.97 d	10.33 e	8.40 d	18.13 bc	24.00 b	271.33 ab	406.0 cd	5.63
LSD	2.390	0.8171	0.8628	2.047	3.334	58.03	65.89	
CV (%)	4.29	2.37	3.62	4.39	5.31	10.46	4.60	

In a column, figures having same letter(s) do not differ significantly by DMRT at the 1% level. DAT = Days after transplanting, LSD = Least significant difference, CV = Coefficient of variance.

The maximum head diameter (18.23 cm) was found in B_4 but B_3 is similar with B_4. Application of above 4 kg B/ha decreased the head diameter of cabbage. The lowest head diameter was also found in control (B_0) and T_7.

Wang-Xiude *et al.*[33] reported that the formation containing 88% powdered poultry manure, 4% urea, 4% KCl and boron sulphate was the best for vegetative growth on 4 vegetables namely cucumber, cabbage, tomato and cauliflower. The results are in partial agreement with the findings of Yamada and Kamata[34], Singh[24], Sarker *et al.*[23] and Sarker *et al.*[22]. Alam[1] reported that B treated plot increased the cabbage head diameter than non-treated plot.

Head Thickness: The head thickness was influenced significantly by the application of different doses of boron fertilizer (Table 5). The head thickness ranged from 9.23 to 10.80 cm. The highest thickness of cabbage head (10.43 cm) was recorded in B_3 but B_3, B_4 and B_5 are statistically similar. The lowest thickness (8.40cm) of head was also found in control (B_0). The treatment B_1 and B_4 are statistically similar. The head thickness increased gradually up to 3 kg B/ha and above this level, it was decreased gradually. The head thickness of cabbage increased significantly by adding B fertilizer in the treatments of both the years[1].

Weight of Root: The root weight of cabbage significantly influenced due to application of different levels of boron. The root weight ranged from 16.23 to 20.83 cm. The highest weight (20.83 cm) of root was found in B_3, but treatments B_2, B_3, B_4, B_5 and B_5 are statistically similar. The lowest weight of root was also observed in control (B_0).

Weight of Stem: The stem weight was influenced significantly due to application of different levels of boron. The stem weight ranged from 22.23 to 28.33g. The maximum stem weight (28.33 g) was found in B_4 but B_2, B_3, B_4 and B_5 are statistically similar. The minimum stem weight was also found in control (B_0), B_6 and B_7.

Weight of Loose Leaves: The weight of loose leaves per plant significantly influenced due to the application of different levels of boron. The weight of loose leaves ranged from 152.67 to 278.0g (Table 5). The highest weight of loose leaves (278.0 g) was found in B_4 but B_2, B_3, B_4 and B_5 are similar. The lowest weight of loose leaves was also recorded in control treatment (B_0). Porter *et al.*[17] showed that potato plant growth was stunted at application of greater than 4.5 kgB/ha.

The findings partially agreed to the reports of Wang-Xiude *et al.*[33], Talukder *et al.*[29], Ali *et al.*[3], Noor *et al.*[15] and Alam[1].

Head Weight: The head weight was influenced significantly due to the effects of boron levels (Table 5). The head weight ranged from 384.33 to 811.33g. The highest head weight (811.33 g) was obtained by the application of B_4 followed by B_3 (748.67g) but they are statistically similar. The second highest (654.66g) head weight was obtained with B_2 followed by B_5 (605.33g) but their are no significant variation amount than. The lowest head weight (384.33g) was observed in control (B_0). Application of above 4 kg B/ha gradually decreased the head weight of cabbage.

The requirements of B fertilizer in vegetables are generally more than other corps. Rasp mentioned that the effect of added trace elements in 12 years of crop rotation in which potatoes and cereals were grown in alternate years. It was found that only B tended to increase potato yield.

Porter *et al.*[17] reported that the band application of B in a complete fertilizer was the most efficient technique and the tuber yield was not affected by application of less than 2.2 kg B/ha. They also showed that plants were stunted and yields reduced at application of grater than 4.5 kg B/ ha. Pregno and Arour[18] mentioned that the highest tuber yield was found when 2 kg B/ha was applied and followed by 4 kg B/ha. Sing *et al.*[24] showed that application of 1 kg B/ha with NPK produced the maximum growth and yield of pea than NPK.

Application of different levels of B influenced the growth and yield of upland crops reported by Maurya and Singh[12] in carrot, Panigrahi *et al.*[16] in cauliflower, Thakur *et al.*[30] in cauliflower, Mishra[13] in cauliflower, Pregno and Arour[18] in potato, Efkar *et al.*[3] in potato, Porter *et al.*[17] in potato, Talukder *et al.*[28] in cauliflower, Talukder *et al.*[29] in papaya, Ali *et al.*[3] in papaya, Hafiz Akter *et al.*[7] in wheat, Noor *et al.*[15] in cauliflower and Sohel *et al.*[26] in broccoli. Alam[1] intensively observed in calcareous soils of Bangladesh and showed that B at 2kg/ha with NPKS increased cabbage head yield by 119% (on average) than NPKS alone. In fact information regarding B fertilizer requirements for vegetable should be meager in calcareous soils of Bangladesh.

The relative or percent head yield increase over control by B_1 (20.81%), B_2 (70.33%), B_3 (94.97%), B_4 (116.82%), B_5 (57.50%), B_6 (16.04%) and B_7 (5.63%). The results suggested that 3-4 kg/ha of boron is suitable for cabbage or any upland vegetable crops for better growth and yield in calcareous soils of Bangladesh, but above 4 kg B/ha level it may be harmful for crop growth and yield.

Correlation Matrix: The correlation matrix showed that the head weight of cabbage was significantly correlated with all plant characters (Table 6). The head weight of cabbage showed strong positive relationship with head diameter (r = 0.967**) followed by largest

Table 6: Correlation matrix among different parameters of cabbage as influenced by different levels of boron.

Parameters	1	2	3	4	5	6	7	8	9	10	11
1. Plant spread	1.000										
2. Plant height	0.939**	1.000									
3. L. leaf length	0.957**	0.882**	1.000								
4. L. leaf breadth	0.965**	0.875**	0.948**	1.000							
5. Loose leaves/plant	0.950**	0.980**	0.925**	0.898**	1.000						
6. Head diameter	0.948**	0.860**	0.933**	0.983**	0.879**	1.000					
7. Head thickness	0.804**	0.582NS	0.802*	0.861**	0.620NS	0.893**	1.000				
8. Wt. of loose leaves	0.530NS	0.702NS	0.357NS	0.510NS	0.571NS	0.504NS	0.202NS	1.000			
9. Wt. of stem	0.955**	0.896**	0.872**	0.960**	0.873**	0.961**	0.830*	0.668NS	1.000		
10. Wt. of root	0.876**	0.953**	0.805*	0.744*	0.913**	0.741*	0.492NS	0.646NS	0.802*	1.000	
11. Head weight	0.937**	0.916**	0.932**	0.965**	0.908**	0.967**	0.784NS	0.623NS	0.948**	0.805*	1.0

NS = Not significant, * = 5% level of significance, ** = 1% level of significance

leaf breadth (r = 0.965**), stem weight (r = 0.948**) and leaf length (r = 0.932**).The head diameter was strongly correlated with leaf breadth (r= 0.983**). Similarly, plant spread was strong positive relationship with leaf length (r = 0.957**) and leaf breadth (r = 0.965**), plant height with number of loose leaves/plant (r = 0.980**).

Conclusion: The head weight and other yield contributing parameters were increased up to 4.0 kg B/ha (B_4), and plant growth and head weight was decreased gradually with increased of B levels (>4.0 kg B/ha). The highest head weight was obtained with B_4 followed by B_3, but both are statistically similar. The head weight of cabbage was strongly correlated with head diameter and followed by largest leaf breadth. The results suggested that 3-4 kg/ha of boron is suitable for cabbage or any upland vegetable crops for better growth and yield in calcareous soils of Bangladesh, but above 4 kg B/ha it may be harmful for crop growth and yield.

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