Response of Cauliflower (*Brassica oleracea v*ar. *Botrytis*) to the Application of Boron and Phosphorus in the Soils of Rupandehi District

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ABSTRACT

A field experiment was conducted at Paklihawa Campus of the Institute of Agriculture and Animal Science, Rupandehi, Nepal, during Oct 2004 to Feb 2005 to study the effects of boron and phosphorus on the soil nutrient status, nutrient uptake by plant and yield of cauliflower (*Brassica oleracea* var. *botrytis* L.) variety *Snowball-16*. Sixteen treatment combinations, including four levels of boron (0, 0.65, 1.3, 1.95 kg boron ha^{-1}) and four levels of phosphorus (0, 30, 60, 90kg P_2O_5 ha^{-1}) were included. The soil was loamy with very low in boron. Curd yield, harvest index, boron and phosphorus uptake by plant and available boron in soil were significantly increased by the application of boron and phosphorus in soils. Available phosphorus in soils after the crop harvest was significantly increased by phosphorus application. The highest curd yield, boron and phosphorus uptake by plant as well as available boron and phosphorus in soils after the crop harvest were obtained from the application of 1.3 kg boron with 60 kg P_2O_5 ha^{-1}. The boron uptake by plant was decreased by the application of more than 1.3kg boron ha^{-1} while the phosphorus uptake was increased with increased application of phosphorus upto 90 kg P_2O_5 ha^{-1}. There were quadratic responses of curd yield, harvest index and plant boron uptake to the applied boron; quadratic response of plant phosphorus uptake to the applied phosphorus, while responses of curd yield, and harvest index to the applied phosphorus were linear. Highly significant positive correlations between curd yield and leaf boron content (r = 0.68**) as well as curd yield and plant phosphorus content (r = 0.79**) were observed. In conclusion, the combined application of 1.3 kg boron and 60 kg P_2O_5 ha^{-1} was found to be the best for cauliflower production under Paklihawa soil conditions of Rupandehi district and can be recommended to the growers of this region.

Key words: Borax, *Brassica oleracea* var. *botrytis*, curd yield, phosphorus

INTRODUCTION

Cauliflower is an economically important winter vegetable of Nepal. It is nutritionally rich and has medicinal value. The agro-climatic conditions across the country favor the production of cauliflower even in summer season with export potentiality. From production aspect, it requires balanced dose of plant nutrients, particularly nitrogen, phosphorus, potassium, boron and molybdenum (Mengel and Kirkby 1987). The productivity of cauliflower is not satisfactory due to poor soil fertility and imbalanced fertilization. Micronutrients deficiency is more prevalent in Nepalese soils (Fujimoto

1998, Jaishy et al 2000). The deficiency of boron causes browning and bitterness of curd with hollow stem. Similarly, poor root growth, delayed crop maturity and curd quality deterioration are caused by phosphorus deficiency (Mitra 1990). Boron deficiency is commonly found in sandy loam soils due to more leaching of this element; therefore, its problem is more prevalent in Rupandehi district. Due to soil alkalinity, phosphorus fixation by soil constituents is another problem of the area.

Although several studies have been conducted on boron and phosphorus requirements of cauliflower in the various parts of the world, there is limited information under Nepalese soil conditions on this aspect. Moreover, no research work has been reported on the effects of boron and phosphorus in cauliflower production in the Rupandehi district. The present research, therefore was conducted to determine the effects of different doses of boron and phosphorus on the nutrient status, uptake and yield of cauliflower.

MATERIALS AND METHODS

TREATMENT DETAILS

The experiment was conducted at Horticulture farm of Institute of Agriculture and Animal Science, Paklihawa Campus, Rupandehi, Nepal. Field experiment was conducted during Oct 2004 to Feb 2005 in a randomized complete block design consisting of 16 treatment combinations with three replications. Individual plot size was 6.75 m^2 (3×2.25 m^2) having 25 plants. The test crop was cauliflower of variety *Snowball-16*. The treatment combinations were 0, 0.65, 1.3, 1.95 kg B ha^{-1} and 0, 30, 60, 90 kg P_2O_5 ha^{-1}. Boron was applied through Borax (11% B) and phosphorus through single super phosphate (16% P_2O_5). The recommended dose of nitrogen was applied through urea and potassium through muriate of potash. Half dose of nitrogen, full dose of phosphorus and potassium and 70% of boron were incorporated into the soil at the time of seedling transplanting. Remaining 30% boron was applied as a foliar spray of 0.4% boron solution at two months after seedling transplanting. Remaining amount of nitrogen was split into two equal parts and each part was top dressed at one and two months after transplanting.

Table 1. Treatment combinations used for the field experiment

Treatment no.	Treatment combinations		Symbol
	Boron (B), kg ha^{-1}	Phosphorus (P_2O_5), kg ha^{-1}	
T_1	0	0	B_0P_0
T_2	0	30	B_0P_{30}
T_3	0	60	B_0P_{60}
T_4	0	90	B_0P_{90}
T_5	0.65	0	$B_{0.65}P_0$
T_6	0.65	30	$B_{0.65}P_{30}$
T_7	0.65	60	$B_{0.65}P_{60}$
T_8	0.65	90	$B_{0.65}P_{90}$
T_9	1.30	0	$B_{1.3}P_0$
T_{10}	1.30	30	$B_{1.3}P_{30}$
T_{11}	1.30	60	$B_{1.3}P_{60}$
T_{12}	1.30	90	$B_{1.3}P_{90}$
T_{13}	1.95	0	$B_{1.95}P_0$
T_{14}	1.95	30	$B_{1.95}P_{30}$
T_{15}	1.95	60	$B_{1.95}P_{60}$
T_{16}	1.95	90	$B_{1.95}P_{90}$

SOIL SAMPLING AND LABORATORY ANALYSIS

Composite soil samples from each block were taken before transplanting of cauliflower seedlings. The samples were air-dried and sieved through 2 mm for analysis. Nitrogen, phosphorus, potassium and boron were analyzed by Kjeldahl distillation unit (Bremmer and Mulvaney 1982), Olsen's bicarbonate (Olsen et al 1954), Ammonium acetate (Pratt 1965) and Azomethine-H (Gaines and Mitchell 1979) methods, respectively. Organic matter content (Walkley and Black 1934), soil texture by hydrometer (Gee and Bauder 1986) and soil pH by digital pH meter were analyzed.

Table 2. Physico-chemical properties of the soil before the field experiment

Rep	OM, %	Total N, %	P_2O_5, kg ha^{-1}	K_2O, kg ha^{-1}	B (μg gm^{-1})	pH	Sand, %	Silt, %	Clay, %	Soil textural class
1	1.27	0.126	196.7	156.9	< 0.1	7.7	45	38	17	Loam
2	1.19	0.118	200.3	144.6	< 0.1	7.6	43	40	17	Loam
3	1.24	0.141	185.0	148.7	< 0.1	7.6	44	39	17	Loam

After the crop harvesting, the composite soil samples from each plot were sampled and were analyzed for boron and available phosphorus by using Azomethine-H (Gaines and Mitchell 1979) and Olsen's Bicarbonate (Olsen et al 1954), respectively. Plant samples from each plot were analyzed for total boron and phosphorus using Azomethine-H (Gaines and Mitchell 1979) and vanadomolybdophosphoric yellow (Moore 1991), respectively.

DATA OBSERVATION AND STATISTICAL ANALYSIS

Fresh weight of total biomass and curd weight were taken from central nine plants from each plot. The analysis of variance followed by DMRT (Duncan's Multiple Range Test) was used to analyze the data and to separate the means. Correlation analysis was used to show the relationship between yield and yield parameters. The data analysis procedures were followed as described by Gomez and Gomez (1984) using MSTATC, Minitab and MS-Excel.

RESULTS AND DISCUSSION

Curd yield

The boron and phosphorus and their interaction effects in relation to curd yield were highly significant (Table 3). The individual effect of boron on curd yield was the highest (19.44 mg ha^{-1}) at $B_{1.3}$ level, which was significantly greater than $B_{1.9}$ and B_0 levels but similar to $B_{0.65}$. Like this P_{90} level had the highest (17.07 mg ha^{-1}) curd yield which was significantly higher than P_{30} and P_0 levels but at par with P_{60}. The curd yield was highly correlated with plant phosphorus uptake (r = 0.79**) and leaf boron (r = 0.68**) uptake. The curd yield was increased upto $B_{1.3}$ levels of boron application into soil while it was decreased at $B_{1.95}$ level. Similarly, the curd yield was increased from P_0 to P_{90} levels of phosphorus application. The maximum curd yield (26.47 mg ha^{-1}) was found from $B_{1.3}P_{60}$, which was similar to $B_{1.3}P_{90}$, $B_{1.95}P_{30}$ and $B_{1.95}P_{90}$ levels of boron and phosphorus application.

Table 3. Curd yield response of cauliflower to applied boron and phosphorus

Treatments	Curd yield, mg ha^{-1}				
	P_0	P_{30}	P_{60}	P_{90}	Mean
B_0	9.65f	9.44f	14.99e	17.07de	12.79c
$B_{0.65}$	16.69de	15.73e	20.58c	22.46bc	18.86b
$B_{1.3}$	19.44cd	22.58bc	26.47a	26.24a	22.29a
$B_{1.95}$	14.53e	25.65ab	20.88c	24.73ab	22.85a
Mean	15.08D	18.35C	20.73B	22.63A	19.19
SEM (0.05)	B*P 1.094	B 0.54	P 0.54		
LSD (0.05)	3.159	1.58	1.58		
CV, %	9.87				

Means followed by the same letter(s) in column and row are not significantly different at 5% level.

Curd yield responded linearly to boron and phosphorus applications (Figure 1a, 1b). Similar findings were also reported by Baral et al (1986) that application of 60 kg P_2O_5 along with 1.5 kg boron ha^{-1} increased the total curd weight, curd size and marketable curd yield. Soil application of borax at the rate of 20 kg ha^{-1} increased curd yield (Mishra 1972, Thakur et al 1991). The results were in agreement with the finding of Pandey et al (1974) and Randhawa and Bhail (1976). The increase in yield might be due to synergistic interaction effects between applied boron and phosphorus in the soil.

Harvest index
The phosphorus application to soil had no significant effect on harvest index of cauliflower but applied boron and their interaction effects were found to be significant (Table 4). The maximum harvest index (49.14%) was obtained from $B_{1.95}P_{30}$ which was similar to all treatments except control, B_0P_{30}, and B_0P_{60}. The harvest index with applied boron had quadratic relationship (Figure 1c) while with applied phosphorus had linear (Figure 1d). The mean harvest index was increased from B_0 to $B_{1.95}$ and $B_{1.95}$ (39.9%) was significantly higher than B_0 while it was similar to $B_{0.65}$ and $B_{1.3}$ levels.

Table 4. Harvest index of cauliflower as affected by boron and phosphorus application

Treatments	Harvest index, %				
	P_0	P_{30}	P_{60}	P_{90}	Mean
B_0	28.14cd	22.85d	31.93bcd	46.08ab	32.25b
$B_{0.65}$	39.56abc	37.81abcd	42.30abc	34.54abcd	38.55ab
$B_{1.3}$	41.55abc	39.39abc	36.26abcd	40.16abc	39.34ab
$B_{1.95}$	33.76abcd	49.14a	40.05abc	36.67abcd	39.90a
Mean	35.75ns	37.30ns	37.64ns	39.36ns	37.51
SEM (0.05)	B*P 4.719	B 2.36	P 2.36		
LSD (0.05)	3.63	6.81	6.81		
CV, %	21.79				

Means followed by the same letter(s) in column and row are not significantly different at 5% level.

Boron uptake

The applied boron and phosphorus as well as their interaction effects were highly significant on boron uptake by plant (Table 5 and 6). The individual effect of applied boron on boron uptake by leaf and curd were the highest (19.5 µg gm^{-1} and 17.75 µg gm^{-1}) at $B_{1.3}$ level and it was significantly higher than $B_{1.95}$, $B_{0.65}$ and B_0 levels. Like this, the individual effect of applied phosphorus on boron uptake by leaf was the highest (4.33 µg gm^{-1}) at P_{30} level and it was significantly higher than P_{90}, P_{60} and P_0 levels. The $B_{1.3}$ had the highest mean boron uptake by leaf (20.22 µg gm^{-1}) and curd (17.6 µg gm^{-1}) which were significantly higher than $B_{1.95}$, $B_{0.65}$ and B_0 levels. Similarly, among the different levels of phosphorus, P_{60} had the highest mean boron uptake by leaf (14.29 µg gm^{-1}) and curd (17.12 µg gm^{-1}) which were significantly higher than other levels of phosphorus including control. The highest boron uptake by plant leaf and curd were recorded at $B_{1.3}P_{60}$. The boron uptake by plant leaf and curd was increased with increasing levels of boron upto $B_{1.3}$ and phosphorus upto P_{60} levels, and then it was decreased. The curd boron content was correlated (r = 0.5*) and leaf B content was highly correlated (r = 0.66**) with phosphorus content of plant. The curd boron was also highly correlated (r = 0.63**) with leaf boron. The boron uptake by cauliflower leaf and curd with applied boron had quadratic relationship (Figure 1e, 1f).

Table 5. Boron uptake by cauliflower leaf as affected by boron and phosphorus fertilization

Treatments	Boron uptake by leaf, µg gm^{-1}				
	P_0	P_{30}	P_{60}	P_{90}	Mean
B_0	1.98m	4.33l	0.65p	1.66n	2.157d
$B_{0.65}$	11.15h	8.66i	8.00j	1.02o	7.208c
$B_{1.3}$	19.50d	17.67e	26.82a	22.00b	20.22a
$B_{1.95}$	5.00k	11.74g	21.70c	15.19f	14.69b
Mean	9.40D	10.60B	14.29A	9.96C	11.06
SEM (0.05)	B*P 0.044	B 0.022	P 0.022		
LSD (0.05)	0.129	0.064	0.064		
CV, %	6.7				

Means followed by the same letter(s) in column and row are not significantly different at 5% level.

Table 6. Effects of boron and phosphorus on boron uptake by cauliflower curd

Treatments	Boron uptake by curd, µg gm^{-1}				
	P_0	P_{30}	P_{60}	P_{90}	Mean
B_0	5.33l	6.71k	11.07i	4.03m	6.78d
$B_{0.65}$	11.41h	10.93i	14.41f	9.37j	11.53c
$B_{1.3}$	17.75d	13.72g	23.51a	17.26e	17.60a
$B_{1.95}$	11.03i	13.74g	19.47c	21.68b	16.94b
Mean	11.3C	11.28C	17.12A	13.55B	13.21
SEM (0.05)	B*P 0.079	B 0.039	P 0.039		
LSD (0.05)	0.229	0.114	0.114		
CV, %	10.3				

Means followed by the same letter(s) in column and row are not significantly different at 5% level.

The result confirmed the earlier work of Gupta (1993) that optimum level of soil phosphorus increased the boron uptake by cauliflower. Similar findings were also reported by Stoyanov (1971) that optimum level of phosphorus supply increased the boron uptake by plant. Kotur and Kumar (1989) also showed a positive response of added phosphorus on boron uptake by cauliflower.

Phosphorus uptake

The individual as well as interaction effects of applied boron and phosphorus on phosphorus uptake by cauliflower was significant (Table 7). The individual effect of applied boron on phosphorus uptake by plant was the highest (30.05 kg ha^{-1}) at $B_{1.3}$ level and it was greater than $B_{1.95}$, $B_{0.65}$ and B_0 levels. The effect of applied phosphorus on phosphorus uptake by plant was the highest (29.73 kg

ha^{-1}) at P_{90} level and it was significantly higher than P_{30} but similar to P_{60} level. The mean phosphorus uptake by cauliflower was increased with increasing levels of boron from B_0 to $B_{1.95}$ and it also increased with increasing level of phosphorus upto P_{60} level. The maximum phosphorus uptake was recorded at $B_{1.95}P_{90}$. The phosphorus uptake from $B_{1.3}P_{30}$, $B_{1.3}P_{60}$, $B_{1.3}P_{90}$, $B_{1.95}P_{30}$ and $B_{1.95}P_{60}$ were similar to $B_{1.95}P_{90}$. Highly significant correlation (r = 0.66**) was found between plant phosphorus uptake and leaf boron content. The phosphorus uptake by plant with applied phosphorus had quadratic relationship (Figure 1g).

The present results support the findings of several workers (Robertson and Loughman 1974, Loughman 1977) who reported that boron played an important role in phosphate transport across cell membranes. Malewar and Indulkar (1993) revealed that boron containing phosphorus fertilizer showed significant increase in phosphorus uptake as compared to non-boron phosphorus sources. Similar finding was also reported by Randhawa et al (1979) that boron deficiency caused thickening of roots and retarded root elongation, resulting smaller absorbing root surface and reduced phosphorus uptake.

Table 7. Phosphorus uptake by cauliflower as influenced by boron and phosphorus application

Treatments	Phosphorus uptake by cauliflower, kg ha^{-1}				
	P_0	P_{30}	P_{60}	P_{90}	Mean
B_0	25.85bcd	20.83de	25.66bcd	29.73bc	25.52b
$B_{0.65}$	25.26bcd	19.51de	32.68b	26.12bcd	25.89b
$B_{1.3}$	30.05bc	41.55a	41.64a	40.01a	38.31a
$B_{1.95}$	24.51cd	44.02a	43.34a	45.75a	39.41a
Mean	26.41B	31.48B	35.83A	35.40A	32.27
SEM (0.05)	B*P 2.33	B 1.16	P 1.16		
LSD (0.05)	6.73	3.36	3.36		
CV, %	12.75				

Means followed by the same letter(s) in column and row are not significantly different at 5% level.

Soil boron

The applied boron, phosphorus and their interactions had significant effects on boron status of soil (Table 8). The individual effect of applied boron on soil boron content was the highest (1.32 μg gm^{-1}) at $B_{1.3}$ and it was significantly higher than $B_{1.95}$, $B_{0.65}$ and B_0. The highest boron content of soil was obtained from $B_{1.3}P_{60}$ which was significantly higher than other treatments. The mean soil boron status was increased with increasing levels of applied boron up to 1.3 kg boron ha^{-1} and it was also increased with increasing levels of phosphorus up to P_{90}. The $B_{1.3}$ level had the highest mean soil boron content (1.31 μg gm^{-1}) which was significantly higher than $B_{1.95}$, $B_{0.65}$ and B_0 levels. The soil application with 90 kg P_2O_5 ha^{-1} had the highest mean soil boron content (1.1 μg gm^{-1}) which was significantly greater than other levels of boron, including control.

Table 8.   Estimates of soil boron after the crop harvest from boron and phosphorus applied plots

Treatments	Soil boron content, $\mu g\ gm^{-1}$				
	P_0	P_{30}	P_{60}	P_{90}	Mean
B_0	0.10i	0.10i	0.10i	0.10i	0.1d
$B_{0.65}$	0.60g	0.54g	0.93e	1.40b	0.86b
$B_{1.3}$	1.32c	0.72f	1.76a	1.45b	1.31a
$B_{1.95}$	1.20d	0.33h	0.10i	1.46b	0.75c
Mean	0.80B	0.422D	0.722C	1.103A	0.76
SEM (0.05)	B*P 0.025	B 0.012	P 0.012		
LSD (0.05)	0.074	0.037	0.037		
CV, %	5.32				

Means followed by the same letter(s) in column and row are not significantly different at 5% level.

Soil phosphorus
The applied phosphorus had significant effect on phosphorus content of soil but the applied boron and their interaction effects were found to be insignificant. The mean available soil phosphorus was the highest (292.7 kg ha^{-1}) at P_{90} level which was similar to P_{60} but significantly higher than P_{30} and P_0 levels. The phosphorus content of soil was the highest at $B_{0.65}P_{90}$ and it was similar to treatments consisting of P_{90} and P_{60} levels. But they were significantly different from P_0 and P_{30} levels. The mean available soil phosphorus was increased from P_0 to P_{90} (Table 9) and the P_{60} was similar to P_{90}. It seems that the application of 60kg P_2O_5 ha^{-1} is judicious for the higher level of soil phosphorus in the soils of Paklihawa. The higher doses of applied phosphorus above P_{60} level might have reacted with other soil mineral elements and made them unavailable form in soils.
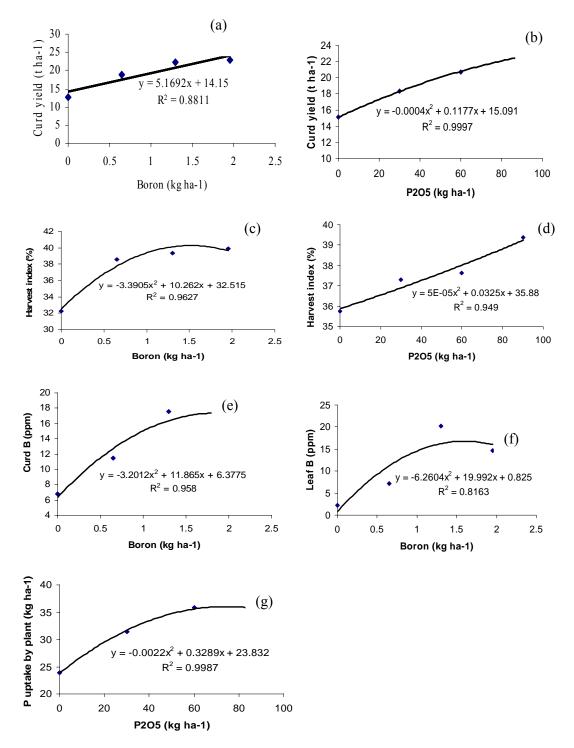
Figure 1. Response of cauliflower characteristics to different levels of boron and phosphorus applied.

Table 9. **Estimates of phosphorus content of soil after the crop harvest from boron and phosphorus applied plots**

Treatments	Available soil phosphorus (kg ha^{-1})				
	P_0	P_{30}	P_{60}	P_{90}	Mean
B_0	224.9bc	252.0abc	253.4abc	291.9abc	255.5ns
$B_{0.65}$	247.2bc	243.8bc	301.3ab	344.2a	284.1ns
$B_{1.3}$	200.7c	245.2bc	276.8abc	278.2abc	250.2ns
$B_{1.95}$	240.9bc	244.7bc	277.2abc	256.7abc	254.9ns
Mean	228.4C	246.4BC	277.2AB	292.7A	261.19
SEM (0.05)	B*P 28.31	B 14.16	P 14.16		
LSD (0.05)	81.77	40.88	40.88		
CV, %	18.77				

Means followed by the same letter(s) in column and row are not significantly different at 5% level.

CONCLUSION

The study showed that yield of cauliflower was the highest at 1.3 kg boron with 60kg P_2O_5 ha^{-1}. The research showed a significant correlation between boron and phosphorus uptake by plants. Similarly, significant correlation between plant boron uptake and soil phosphorus content and vice versa were also observed. Synergistic interaction could be obtained by applying boron and phosphorus within soil and plant system. It can be recommended that 1.3 kg boron with 60 kg P_2O_5 ha^{-1} is optimum for cauliflower production at Paklihawa location in Rupandehi district, Nepal but further research is needed to quantify these effects at different locations of the district.

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