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Effects of Boron Fertilization on Calcium:Boron Ratio and Boron Mobility in Cauliflower

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ABSTRACT

Greenhouse studies were conducted on two different alfisols, Bajaura (Loam) and Junga (Sandy loam), that are deficient in boron (B) for cauliflower (*Brassica oleracea* L. var. *botrytis*). The calcium:boron (Ca:B) ratio in cauliflower leaves with applied B (1 to 3 mg kg^{-1} soil) varied from 1276 to 521 in the Bajaura soil with high exchangeable-Ca; no deficiency or toxicity symptoms were evident. In the Junga soil with low exchangeable-Ca, however, the Ca:B ratio varied from 505 to 223 with toxicity symptoms visible when 2 and 3 mg kg^{-1} B has been applied. This corresponds to a Ca:B ratio of 256 and 223. Farm yard manure application showed an ameliorating effect on Ca:B ratio with a tendency to decrease a high Ca:B ratio in the absence of B application and increase a lower Ca:B ratio when incorporated with higher levels of B. The B mobility from leaves to curd decreased with increasing levels of B application and thus provided a circumstantial evidence for B retranslocation under conditions of low B supply i.e. conditional mobility.

Keywords: Ca:B ratio, boron mobility, cauliflower, boron, farm yard manure

In context of emerging widespread deficiencies of micronutrients in soil-plant systems (Sahrawat *et al.*, 2010; Chander *et al.*, 2012, 2013; Wani *et al.*, 2013), micronutrient management is gaining importance. Boron (B) deficiency in crops is more widespread than a deficiency of any other micronutrient. Boron-deficiency decreases or inhibits the growth of vegetative and reproductive plant parts and stunted root and shoot tips are commonly observed in severely B-deficient plants. Several physiological impairments as a result of B-deficiency were reported by Parr and Loughman (1983), such as sugar transport, cell wall synthesis, lignification, cell wall structure, carbohydrate metabolism, RNA metabolism, respiration, indole acetic acid (IAA) metabolism, phenol metabolism and membrane integrity. So for, the well described roles of B are its involvement in (a) cell wall intactness and synthesis, possibly by formation of B-pectin complexes and (b) plasma membrane integrity (Cakmak *et al.*, 1995; Hu *et al.*, 1996).In addition to B status in plant tissues, the calcium:boron (Ca:B) ratio is also an important parameter determining B-deficiency or toxicity. The occurrence of B-deficiency disorders even when B is in ample supply in the soil, suggests that B-deficiency in plants is physiological in nature and related to B mobility within the plant (Shelp *et al.*, 1995). Boron is unique among the essential plant nutrients in that it has restricted mobility in many plant species and is freely mobile in others (Brown and Shelp, 1997). Among different species, *Brassica sp.* has high B requirement. Cauliflower is one of the most important crops of this genera grown in the North Western Himalayan regions and other parts of the country. Studies have indicated emerging deficiencies (16 to 19%) of boron in Himachal Pradesh (Chander *et al.*, 2005) and cauliflower crop in the region often shows the deficiency symptoms of boron, consisting of browning of the curd, marginal mottling of the leaves and hollow condition of the stem. These disorders reduce curd yield considerably while simultaneously reduce the market value of the curd also. In this context the present studies were planned for optimizing yield by understanding nutrient dynamics in two soils present in different sub agro-climatic zones of the region.

MATERIALS AND METHODS

Details of experimental soils

Two soils, one in mid-hills sub-humid (Bajaura; 31^{o}51'0''N, 77^{o}9'0''E) and other in high-hills wet-temperate (Junga; 30^{o}59'46''N, 77^{o}12'56''E) conditions of Himachal Pradesh were chosen because of their low B content (0.30 mg kg^{-1} in both soils), for bulk surface (0 to 0.15 m) soil sample collection to conduct greenhouse studies at the Department of Soil Science, HP Agricultural University, Palampur. The Bajaura soil had higher exchangeable-Ca (1999 mg kg^{-1}) in comparison to the Junga soil (933 mg kg^{-1}). The available-N, P, K contents were 329, 6.7, 123 kg ha^{-1} in Bajaura soil and 329, 2.3 and 73 kg ha^{-1} in Junga soil, respectively. Bajaura soil was loamy in texture and neutral in reaction (pH 7.1), while Junga soil was sandy loam in texture and slightly acidic (pH 6.2). Soils of both locations had high organic-C to the extent of 11.3 mg kg^{-1} in the Bajaura soil and 12.9 mg kg^{-1} in the Junga soil.

Details of greenhouse studies

The experiments were conducted in plastic pots filled with 10 kg of 2 mm sieved air dried soil. The experimental design for each soil was a completely randomized design with 12 treatment combinations of four levels of B (0, 1, 2 and 3 mg kg^{-1} soil) and three levels of farm yard manure (FYM) (0, 10 and 20 g kg^{-1} soil) with three replications of each treatment. The FYM was incorporated on wet weight basis (55% moisture), and contained 21.5 mg kg^{-1} B and 1.27% Ca contents. The nitrogen (N), phosphorus (P) and potassium (K) contents of the manure were 0.80, 0.09 and 0.40%, respectively. Uniform applications of N, P and K were made at the rate of 62.5, 25.0 and 15.0 mg kg^{-1}, respectively. Whole quantity of B, P and K were applied as basal while N was applied in three splits viz. 50 per cent at the time of transplanting and remaining in two equal splits at one month intervals after transplanting of the crop. The sources of B, N, P and K application were borax, urea, single super phosphate and muriate of potash, respectively. One cauliflower (cv. Palam Uphaar) seedling was raised in each pot up to maturity.

Plant Ca and B analysis

At harvest, the plants were separated into leaves, curd and root parts and dried in an oven at 65$\pm$5 ^{o}C to a constant weight. For B estimation, the powdered plant parts were dry ashed at 550 ^{o}C for 6 hours and the ash was digested in 6 M HCl. Boron was then determined using carmine method (Hatcher and Wilcox, 1950). Calcium was extracted with 1 N ammonium acetate and determined with the help of atomic absorption spectrophotometer. The B mobility from leaves to curd was determined by dividing the B-content in curd with B-content in leaves and the B mobility from roots to leaves by dividing the B-content in leaves with that in roots (Shelp and Shattuck, 1987).

Statistical analysis

The data generated from the study was analysed statistically by standard procedure by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Plant Ca, B contents and Ca:B ratio

The B and Ca contents in different cauliflower parts (Table 1) increased with B as well as FYM application. Enhanced B availability in soil and thus increased plant B content with applied B is on expected lines (Chander *et al.*, 2010). Moreover, B functions in plants at the membrane level (Shelp *et al.*, 1995) and helps in maintaining membrane integrity (Cakmak *et al.*, 1995) and hence enhanced ability of membranes to transport nutrients like Ca. Thus Ca content increased with increasing B. An increase in plant B and Ca with FYM may be due to the beneficial effect it exerts on nutrient availability in soil. The B content in parts of cauliflower grown on Junga soil was more as compared to that grown on Bajaura soil. This may be due to higher availability of B in Junga soil due to its coarse texture (Keren *et al.*, 1985). Besides this, higher exchangeable-Ca in Bajaura soil might have depressed B content in cauliflower grown on this soil (Kumar and Babel, 2011). Among parts of cauliflower, the highest content of B and Ca were found in leaves followed by roots and least in curd. The differential behavior of nutrient distribution among different parts of cauliflower in the present study may be explained in terms of their retranslocation. In the literature, B and Ca are generally regarded as not being retranslocated.

Leaf Ca:B ratio, an important parameter to estimate the B status of plants, decreased with B application in both the experimental soils (Table 2). A decrease in Ca:B ratio with the application of B is obvious due to enhanced availability of B in soil and subsequent uptake by the plant. The lower Ca:B ratios in cauliflower grown in Junga soil in comparison to Bajaura soil may be due to low exchangeable-Ca and higher available-B due to lighter texture in Junga soil. According to Kotur and Kumar (1989) , the Ca:B ratio in leaf tissue above 900 is associated with B deficiency and below 280 with its toxicity, and B critical levels of 11 and 37 mg kg^{-1} in leaf tissue were reported for its deficiency and toxicity, respectively. In this context, the Ca:B ratio in leaves of cauliflower grown in Bajaura soil was >900, but we did not observe any deficiency symptoms in cauliflower. This might be because of sufficient B content in leaves which was above the reported 11 mg kg^{-1}. With the application of B from 1 to 3 mg kg^{-1} in Bajaura soil and in absence or at 1 mg kg^{-1} B application in Junga soil, the Ca:B ratio in leaves remained within permissible limits. At higher levels of B application (2 and 3 mg kg^{-1}) in Junga soil, the Ca:B ratio was much below the critical value which we observed to be associated with the appearance of B toxicity symptoms such as poor plant vigour, stunted growth, and leaf necrosis at the tip and margins. In line with Ca:B ratios, curd yield (Chander and Verma, 2009) also increased significantly and beneficially with B application up to 1 mg kg^{-1} in Junga soil and up to 2 mg kg^{-1} in Bajaura soil. The application of FYM showed an ameliorating effect on Ca:B ratio, which had a tendency to decrease it in the absence of B application and increase at higher levels of B.

Boron mobility

The pooled data for B mobility worked out by distribution of B within different parts of the cauliflower plant showed a decrease in B mobility from leaves to curd and an increase from roots to leaves with increasing levels of B application from 1 to 3 mg kg^{-1} (Table 3). There is little doubt that the distribution of B in plants is related primarily to its translocation in the xylem to sites of greater water loss i.e. primary translocation (Shelp *et al.*, 1995). Probably due to this reason, B mobility from roots to leaves increased with external B supply. However, there is considerable controversy regarding the role that the phloem plays in providing B to sites that do not lose water readily i.e. secondary translocation (Shelp *et al.*, 1995) or retranslocation from leaves to curd. In the present study, the B mobility from leaves to curd decreased with increasing levels of B. This provided a circumstantial evidence for B retranslocation under conditions of low B supply i.e. conditional mobility. Earlier studies while comparing the relative element composition of younger tissues to old leaves indicated that the former, particularly the head, were supplied with nutrients principally by the phloem and that B was relatively phloem-immobile (Shelp and Shattuck, 1987; Liu *et al.*, 1993), but B deficiency triggers some physiological changes leading to increased mobility to counter the situation.

SUMMARY AND CONCLUSIONS

From the Ca:B ratios under present investigation, wherein it varied well within critical limits with applied B in Bajaura soil, it can be inferred that B can be applied well up to 2 mg kg^{-1} in a loamy alfisol with high exchangeable-Ca to realize economic yield. But in a sandy loam alfisol like in Junga with low exchangeable-Ca, B at lower level (1 mg kg^{-1}) economically increased yield with optimum Ca:B ratio, while higher levels produced toxicity symptoms with unfavourable Ca:B ratios indicating the need to still test lower levels of B in such soils. The inclusion of farm yard manure exerted ameliorating effect on extreme Ca:B ratios and performed role in balancing the plant nutrition. The study also indicated a circumstantial evidence of B retranslocation in cauliflower.

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Table 1 - Effect of boron and FYM application on nutrient content in different parts of cauliflower

	Bajaura soil						Junga soil					
	B (mg kg^{-1})			Ca (%)			B (mg kg^{-1})			Ca (%)		
	Leaves	Curd	Roots	Leaves	Curd	Roots	Leaves	Curd	Roots	Leaves	Curd	Roots
Boron levels												
B_0	17.3	3.44	5.06	2.11	0.17	0.49	27.6	4.89	6.39	1.35	0.13	0.22
B_1	30.2	5.05	6.50	2.28	0.19	0.57	51.0	6.79	8.44	1.74	0.16	0.24
B_2	40.5	5.55	7.94	2.48	0.21	0.61	79.7	8.56	10.5	2.05	0.18	0.27
B_3	54.2	6.89	9.50	2.80	0.23	0.68	101.3	9.78	13.4	2.22	0.20	0.32
CD (5%)	2.65	0.62	0.77	0.13	0.01	0.03	3.44	0.84	0.82	0.11	0.01	0.02
FYM levels												
F_0	35.2	4.58	6.88	2.31	0.18	0.55	58.9	6.67	8.67	1.32	0.13	0.20
F_{10}	35.3	5.58	7.42	2.43	0.20	0.57	67.8	7.88	10.1	2.09	0.19	0.28
F_{20}	36.1	5.54	7.46	2.51	0.21	0.64	68.0	7.92	10.3	2.12	0.19	0.31
CD (5%)	NS	0.54	NS	0.11	0.01	0.02	2.98	0.73	0.71	0.10	0.01	0.02

(Source: Chander *et al.*, 2010)

Table 2 - Effect of B and FYM application on Ca:B ratio in cauliflower leaves

Treatment	Bajaura soil				Junga soil			
	F_o	**F_{10}**	**F_{20}**	**Mean**	**F_o**	**F_{10}**	**F_{20}**	**Mean**
B_0	1565	1143	1119	1276	564	479	471	505
B_1	739	785	753	759	363	338	333	345
B_2	592	618	632	614	194	282	292	256
B_3	477	531	556	521	153	257	258	223
Mean	843	769	765		319	339	339	
CD (5%)	B=108; F=NS; BXF=187				B=41; F=NS; BXF=71			

Table 3 - Effect of B and FYM application on B mobility in different parts of cauliflower

Treatment	B mobility from leaves to curd				B mobility from roots to leaves			
	F_o	**F_{10}**	**F_{20}**	**Mean**	**F_o**	**F_{10}**	**F_{20}**	**Mean**
B_0	0.211	0.221	0.183	0.205	3.40	4.08	4.07	3.85
B_1	0.159	0.154	0.149	0.154	4.98	5.49	5.55	5.34
B_2	0.116	0.127	0.124	0.122	6.58	6.24	6.33	6.38
B_3	0.099	0.120	0.120	0.113	7.06	6.50	6.45	6.67
Mean	0.146	0.156	0.144		5.51	5.58	5.60	
CD (5%)	B=0.025; F=NS; BXF=NS				B=0.063; F=NS; BXF=NS			