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Effect of boron levels, mulching and moisture regimes on uptake of boron on cauliflower

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Abstract
Boron in soils plays an important role in determining its availability to growing plants. Information as regards to the B fraction in the soils of Jammu and Kashmir is very limited. Therefore, field experiment were conducted for two years (2015-16 and 2016-17) with cauliflower (*Brassica oleracea* var. botrytis L) as a test crop on sandy clay loam with treatment combination of four levels of boron as borax @ 0, 2.5, 5.0 and 7.5 kg ha^{-1}, mulching @ 6 t paddy straw mulch ha^{-1} and no mulch along with 20% (W_1) and 30% (W_2) plant available water moisture regimes constituting 16 treatment combinations replicated thrice in Factorial RBD. Borax @5.0 improved the B uptake by 77.2% and 21.3% over the 0 and 2.5 during 2015-16 and 76.5% and same values were 21.2% over the 0 and 2.5 during 2016-17 respectively. Irrespective of B levels, the uptake of B with 6 t paddy straw mulch ha^{-1} registering 5.83% and 5.66% enhancement during 2015-16 and 2016-17, respectively. Irrespective of B levels, the B uptake increased insignificantly with 20% reduction of PAW *i.e.*, W_1 (36.18 g ha^{-1}) over 30% reduction of PAW *i.e.*, W_2 (35.84 g ha^{-1}) registering 0.94% enhancement during 2015-16. Similarly, B uptake was recorded increased insignificantly with W_1 (36.26 g ha^{-1}) over W_2(35.95 g ha^{-1}) registering 0.86% enhancement during 2016-17.

Keywords: Cauliflower, boron levels, uptake, mulching and moisture regimes

Introduction
Present agriculture is entirely reliant on high yielding crop cultivars and chemicals in the form of pesticides and fertilizers. As a result, soils are screening a quick turn down in their capacity to provide the necessary micronutrients in required quantities. Experimental evidences have established the fact that prolonged use of chemical fertilizers and pesticides creates nutrient-imbalance in agricultural soils (Bohme *et al.* 2005) [2]. Accelerated exhaustion of the trace rudiments from the restricted soil reserves have controlled and inhibited sustainable increase in yield of several crops including vegetables. One of the major causes of such situation is the indiscriminate use of major nutrients and giving less importance on micronutrients which are very much necessary for quality vegetable production. Consequently, current years have witnessed an ever-sharpening investigation spotlight on micronutrients. The sufficient amount of micronutrients necessary for better plant growth which resulted in higher yield due to increased growth, better flowering and higher fruit set (Ram and Bose, 2000) [12]. On the other hand, several aspects like micronutrient fertilization of vegetables, especially cole crops have not acknowledged due consideration. Analysis of soil and plant samples indicated that 33% of soils in India are potentially deficient in Boron (B) (Singh, 2006) [6, 13, 14, 16]. Crops grown in about half of the country's soils suffer from one or more micronutrient disorders (Singh, 1991) [6, 13, 14, 16]. Boron deficiency and response to it have been recorded in 132 crops in more than 80 countries over last 60 years. It is estimated that over 15 Mha worldwide is annually fertilized with B. The fact that B is needed for successful fertilization and seed set it is of critical importance in vegetables crops in terms of giving good shape to the fruits and besides enhancing productivity (Ganeshamurthy *et al.* 2005) [6]. Among numbers of factors soil temperature and moisture are also most important to control availability of B. Boron occurs in the soils in extremely small quantities. Most of the available boron in humid region is held largely in the organic matter and is released by the microbial decomposition of organic matter for the use of the plant. Cauliflower is the essentially cool season vegetable grown in India and Jammu territory, a widespread area is under the farming of this crop. Being a crucifer, it has an elevated prerequisite for trace elements like B, the deficiency of which may provoke crippling reductions in terms of yield and quality. An enormous widen of territory, where vegetables are

grown are found to be deficient in these micronutrients. In order to make the accurate dose of boron for getting higher yield in small and scattered land holding under Jammu territory, the present investigation was undertaken.

Present agriculture is entirely reliant on high yielding crop cultivars and chemicals in the form of pesticides and fertilizers. As a result, soils are show a quick turn down in their capacity to provide the necessary micronutrients in required quantities. Experimental evidences have established the fact that imbalanced use of chemical fertilizers and pesticides creates nutrient-imbalance in agricultural soils (Bohme *et al.* 2005) [2]. Accelerated exhaustion of the essentials trace from the restricted soil reserves have controlled and inhibited sustainable increase in yield of several crops including vegetables (REF??). One of the major causes of such situation is the indiscriminate use of major nutrients and giving less importance on micronutrients which are very much necessary for quality vegetable production. Consequently, current years have witnessed an ever-sharpening investigation spotlight on micronutrients. The sufficient amount of micronutrients necessary for better plant growth which resulted in higher yield due to increased growth, better flowering and higher fruit set (Ram and Bose, 2000) [12]. On the other hand, several aspects like micronutrient fertilization of vegetables, especially cole crops have acknowledged due consideration only on major nutrients like N, P, K and very less on micronutrients. Analysis of soil and plant samples indicated that 33% of soils in India are potentially deficient in Boron (B) (Singh, 2006) [6, 13, 14, 16]. Crops grown in about half of the country's soils suffer from one or more micronutrient disorders (Singh, 1991) [6, 13, 14, 16]. Boron deficiency and response to it have been recorded in 132 crops in more than 80 countries over last 60 years (Shorrocks 1997) [15]. It is estimated that over 15 Mha worldwide is annually fertilized with B. The fact that B is needed for successful fertilization and seed set it is of critical importance in vegetables crops in terms of giving good shape to the fruits and besides enhancing productivity (Ganeshamurthy *et al.* 2005) [6]. Among numbers of factors soil temperature and moisture are also most important to control availability of B. Boron occurs in the soils in extremely small quantities (Shorrocks 1997) [15]. Most of the available boron in humid region is held largely in the organic matter and is released by the microbial decomposition of organic matter for the use of the plant. Cauliflower is the essentially cool season vegetable grown in India and Jammu territory, a widespread area is under the farming of this crop. Being a crucifer, it requires elevated amount of trace elements like B, the deficiency of which may cause crippling reductions in terms of yield and quality (Dhakal *et al.*, 2009) [5]. An enormous widen of territory, where vegetables are grown are found to be deficient in these micronutrients. In order to make the accurate dose of boron for getting higher yield in small and scattered land holding under Jammu territory, the present investigation was undertaken.

Materials and Methods

An experiment was laid out to assess the response of cauliflower *cv*. "Pusa Snowball-1 (PSB-1)" to graded levels of B along with mulching and moisture regimes. The experiment of this investigation were conducted in the experimental area of the Division of Soil Science and Agriculture Chemistry, (SKUAST), Jammu, Chatha in the light textured soil *i.e*. sandy clay loam with factorial Randomized Block Design (FRBD) constituting 16 different treatment combinations with 3 replications. Experiment was carried out for the two consecutive years of 2015-16 and 2016-17. The experiment layout comprises of 48 no. of plots having size 4 x 3 m^2 each. The treatment comprises of four levels of boron *viz.*, B_0, $B_{2.5}$, $B_{5.0}$, and $B_{7.5}$ applied through borax (0, 2.5, 5.0 and 7.5 kg ha^{-1}). Boron was applied through Borax (11% of B) in the soil application before seedling transplanting. Boron uptake by curd was calculated by multiplying the B concentration in curd with the corresponding yield of cauliflower (Solanki, *et al.*, 2018) [16].

Treatment details

Apart from different levels of boron, the other nutrients of N, P, and K were added in accordance with the recommended dose of fertilizers for cauliflower as per package of practices for vegetable crops, SKUAST, Jammu (120 kg N, 60 kg P_2O_5, and 60 kg K_2O ha^{-1}). The recommended dose of nitrogen was applied through urea (46% N), phosphorus through Diammonium phosphate (18% N, 20% P) and potassium through murate of potash (62% K_2O). Half dose of nitrogen, full dose of phosphorus and potassium and remaining amount of nitrogen was split into two equal parts and each part was top dressed at one and two months after transplanting. The samples were cleaned, dried and analyzed for investigations and the processed soil samples were used for determination of B fraction and different soil characteristics. The treatments with their symbols are described in Table 1 below:

Table 1: Treatment combination with notation used for the field experiment

Notation	Symbol	Treatment Détails
T_1	B_0 M_0 W_1	Control, No mulching & 20% of Plant avalable water (PAW)
T_2	B_0 M_0W_2	Control, No mulching & 30% of PAW
T_3	B_0 M_1W_1	Control, 6t paddy straw mulch ha^{-1} & 20% of PAW
T_4	B_0 M_1 W_2	control, 6t paddy straw mulch ha^{-1} & 30% of PAW
T_5	$B_{2.5}$ M_0 W_1	2.5 kg borax ha^{-1}, No mulching & 20% of PAW
T_6	$B_{2.5}$ M_0 W_2	2.5 kg borax ha^{-1}, No mulching & 30% of PAW
T_7	$B_{2.5}$ M_1 W_1	2.5 kg borax ha^{-1}, 6t paddy straw mulch ha^{-1} & 20% of PAW
T_8	$B_{2.5}$ M_1 W_2	2.5 kg borax ha^{-1}, 6t paddy straw mulch ha^{-1} & 30% of PAW
T_9	$B_{5.0}$ M_0 W_1	5.0kg borax ha^{-1}, No mulching & W_1 20% of PAW
T_{10}	$B_{5.0}$ M_0 W_2	5.0 kg borax ha^{-1}, No mulching & W_2 30% of PAW
T_{11}	$B_{5.0}$ M_1 W_1	5.0 kg borax ha^{-1}, 6t No mulching ha^{-1} & 20% of PAW
T_{12}	$B_{5.0}$ M_1 W_2	5.0 kg borax ha^{-1}, 6t paddy straw mulch ha^{-1} & 30% of PAW
T_{13}	$B_{7.5}$ M_0 W_1	7.5 kg borax ha^{-1}, No mulching & 20% of PAW
T_{14}	$B_{7.5}$ M_0 W_2	7.5 kg borax ha^{-1}, No mulching & 30% of PAW
T_{15}	$B_{7.5}$ M_1 W_1	7.5 kg borax ha^{-1}, 6t paddy straw mulch ha^{-1} & 20% of PAW
T_{16}	$B_{7.5}$ M_1 W_2	7.5 kg borax ha^{-1}, 6t paddy straw mulch ha^{-1} & 30% of PAW

Results and Discussion

Effect of boron levels and mulching on uptake of boron by cauliflower

Results revealed that the B uptake varied from 22.92, 33.49, 40.63, and 47.01 g ha^{-1} with the application of borax @ 0, 2.5, 5.0 and 7.5 kg ha^{-1} during 2015-16.While the uptake values were 23.05, 33.57, 40.70 and 47.10 g ha^{-1} during 2016-17, respectively (Table 2). The significant uptake of B was 40.62 and 40.70 g ha^{-1} witnessed with $B_{5.0}$ treatment during 2015-16 and 2016-17, respectively. Thus, the data highlighted the fact that the $B_{5.0}$ treatment improved the B uptake by 77.2% and 21.3% over the B_0 and $B_{2.5}$ during 2015-16 and 76.5% and 21.2% over the B_0 and $B_{2.5}$ during 2016-17, respectively. Irrespective of B levels, the uptake of B increased significantly with M_1 (37.03g ha^{-1}) over M_0 (34.99 g ha^{-1}) registering 5.83% enhancement during 2015-16. Similarly, B uptake was found to increase significantly with M_1 (37.10 g ha^{-1}) over M_0 (35.11g ha^{-1}) registering 5.66% enhancement during 2016-17. The interaction effect of B levels and mulching, however, was insignificant during both the years. Findings of Aitken *et al*. (1987) [1]; Sinha *et al*. (1991) [14]; and Hossain *et al*. (2011) [8] have also demonstrated that application of borax increased the B uptake by cauliflower.

Table 2: Effect of boron levels and mulching on uptake of boron (g ha^{-1}) by cauliflower

Boron levels	Mulching levels								
	2015-16			2016-17			Overall		
	M_0	M_1	Mean	M_0	M_1	Mean	M_0	M_1	Mean
B_0	21.96	23.88	22.92	22.15	23.95	23.05	22.05	23.91	23.98
$B_{2.5}$	32.80	34.18	33.49	32.86	34.28	33.57	32.83	34.23	33.53
$B_{5.0}$	38.97	42.27	40.62	39.05	42.36	40.70	39.01	42.31	40.66
$B_{7.5}$	46.24	47.78	47.01	46.38	47.82	47.10	46.31	47.80	47.05
Mean	34.99	37.03		35.11	37.10		35.05	37.06	
$CD_{(0.05)}$									
B	1.058			1.078					
M	0.748			0.762					
B x M	NS			NS					

B_0- control, $B_{2.5}$- @ 2.5 kg borax ha^{-1}, $B_{5.0}$- @ 5.0 kg borax ha^{-1}, $B_{7.5}$- @ 7.5 kg borax ha^{-1}, M_0- no mulch, M_1- @ 6 t paddy straw mulch ha^{-1}

Effect of boron levels and moisture regimes on uptake of boron by cauliflower

An Results revealed that the B uptake were 22.92, 33.49, 40.63 and 47.01 g ha^{-1} with the application of borax @ 0, 2.5, 5.0 and 7.5 kg borax ha^{-1} during 2015-16.Where, same values were 23.05, 33.57, 40.70 and 47.10 g ha^{-1} during 2016-17, respectively (Table 3). Mean value indicated that the significant uptake of B was 40.63 and 40.71 g ha^{-1} witnessed with $B_{5.0}$ treatment during 2015-16 and 2016-17, respectively. Thus, the data highlighted the fact that the $B_{5.0}$ treatment improved the B uptake by 77.2% and 21.3% over the B_0 and $B_{2.5}$ during 2015-16 and 76.6% and 21.2% during 2016-17 respectively. Irrespective of B levels, the B uptake increased insignificantly with W_1 (36.18 g ha^{-1}) over $W_2$35.84g ha^{-1}) during 2015-16 and 2016-17 years, respectively. The interaction effect of B levels and moisture, however, was insignificant during both the years. The findings were corroborated by Kotur and Kumar, (1989) [10]; Gupta, (1993) [7]; Chaudhary, (1998a; 1998b) [3, 4] and Khadka *et al*. (2005) [9] in cauliflower.

Table 3: Effect of boron levels and moisture regimes on uptake of boron (g ha^{-1}) by cauliflower

Boron levels	Moisture regimes								
	2015-16			2016-17			Overall		
	W_1	W_2	Mean	W_1	W_2	Mean	W_1	W_2	Mean
B_0	23.28	22.56	22.92	23.39	22.71	23.05	23.33	22.63	22.98
$B_{2.5}$	33.61	33.67	33.49	33.68	33.45	33.57	33.64	33.56	33.6
$B_{5.0}$	40.79	40.46	40.63	40.87	40.54	40.71	40.83	40.5	40.66
$B_{7.5}$	47.04	46.99	47.01	47.11	47.08	47.10	47.07	47.03	47.05
Mean	36.18	35.84		36.26	35.95		36.21	35.93	
$CD_{(0.05)}$									
B	1.058			1.078					
W	NS			NS					
B x W	NS			NS					

B_0- control, $B_{2.5}$ @ 2.5 kg borax ha^{-1}, $B_{5.0}$- @ 5.0 kg borax ha^{-1}, $B_{7.5}$- @ 7.5 kg borax ha^{-1}, W_1- 20% reduction of, plant available water W_2- 30% reduction of plant available water

Effect of mulching and moisture regimes on uptake of boron by cauliflower

Data in Table 4 revealed that significant mulching effect over the maintenance of different soil moisture regimes on B uptake were 34.99 g ha^{-1} and 37.03 g ha^{-1} with the effect of mulching (M_1), during 2015-16, while the same were 35.11 g ha^{-1} and 37.10 g ha^{-1} during 2016-17 respectively. Thus, the data highlighted the fact that the M_1 improved the B uptake by 5.83% and 5.66% during 2015-16 and 2016-17, respectively. Irrespective of mulching levels, the B uptake increased insignificantly with 20% reduction of PAW (W_1), over 30% reduction of PAW (W_2), value being 35.84 g ha^{-1}, registering 0.94% and 0.86% enhancement during 2015-16 and 2016-17 respectively. The interaction effect of mulching levels and moisture, however, were insignificant during both the years. The findings were corroborated by Kotur and Kumar, (1989) [10]; Gupta, (1993) [7]; Chaudhary, (1998a; 1998b) [3, 4] and Khadka *et al*. (2005) [9] in cauliflower.

Table 4: Effect of mulching and moisture regimes on uptake of boron (g ha^{-1}) by cauliflower

Mulching levels	Moisture regimes								
	2015-16			2016-17			Overall		
	W_1	W_2	Mean	W_1	W_2	Mean	W_1	W_2	Mean
M_0	35.14	34.85	34.99	35.24	34.98	35.11	35.19	34.91	35.05
M_1	37.22	36.84	37.03	37.29	36.91	37.10	37.25	36.87	37.06
Mean	36.18	35.84		36.27	35.95		36.22	35.89	
$CD_{(0.05)}$									
W	NS			NS					
M	0.748			0.762					
W x M	NS			NS					

M_0- No mulch, M_1- @ 6 t paddy straw mulch ha^{-1}, W_1- 20% reduction of plant available water, W_2- 30% reduction of plant available water

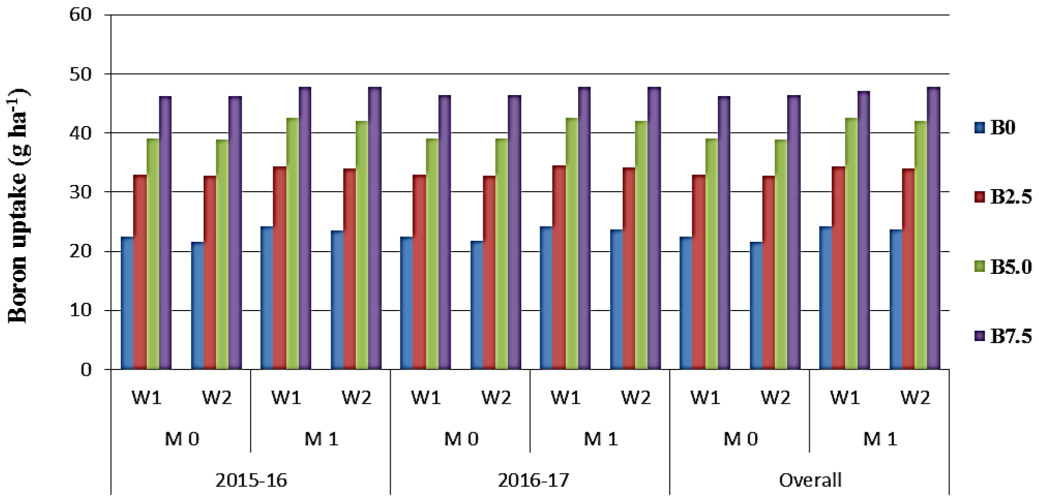
Effect of boron levels mulching and moisture regimes on uptake of boron by cauliflower

The combined effect of B levels, mulching and moisture regimes on B uptake was presented in Table 5 The treatment combinations of $B_{5.0}M_1W_1$ was statistically superior to rest of the treatments. Minimum uptake 24.17 g ha^{-1} was recorded in $B_0M_0W_2$ and maximum uptake 42.54 g ha^{-1} during 2015-16. Thus, the data showed the fact that B uptake improved significantly. The extent of uptake was augmented up to 23.9% and 76% over B_0, with $B_{2.5}$ and $B_{5.0}$ treatments during 2015-16, respectively. In the following year (2016-17), B uptake also improved significantly by 24.0 and 75.8% with both the treatments. During 2016-17, the treatment, M_1 registered highest uptake of B *i.e.*, 42.63 g ha^{-1} which was statistically superior to

Table 5: Effect of boron levels, mulching and moisture regimes on uptake of boron (g ha^{-1}) by cauliflower

Mulching boron levels moisture regimes	2015-16				2016-17				Overall			
	M_0			M_1	M_0		M_1		M_0		M_1	
	W_1	W_2	W_1	W_2	W_1	W_2	W_1	W_2	W_1	W_2	W_1	W_2
B_0	22.39	21.52	24.17	23.59	22.54	21.76	24.24	23.66	22.46	21.64	24.20	23.62
$B_{2.5}$	32.89	32.71	34.33	34.02	32.93	32.79	34.44	34.12	32.91	32.75	34.38	34.07
$B_{5.0}$	39.04	38.91	42.54	42.01	39.12	38.98	42.63	42.09	39.08	38.94	42.58	42.05
$B_{7.5}$	46.22	46.27	47.85	47.72	46.36	46.40	47.87	47.77	46.29	46.31	47.07	47.74
Mean	35.13	34.85	37.22	36.83	35.23	34.98	37.29	36.91	35.18	34.91	37.05	36.87
$CD_{(0.05)}$												
B x M x W	NS				NS							

B_0- control, $B_{2.5}$- @ 2.5 kg borax ha^{-1}, $B_{5.0}$- @ 5.0 kg borax ha^{-1}, $B_{7.5}$- @ 7.5 kg borax ha^{-1}, M_0- no mulch, M_1- @ 6 t paddy straw mulch ha^{-1}, W_1- 20% reduction of plant available water W_2- 30% reduction of plant available water



B_0- control, $B_{2.5}$- @ 2.5 kg borax ha^{-1}, $B_{5.0}$- @ 5.0 kg borax ha^{-1}, $B_{7.5}$- @ 7.5 kg borax ha^{-1}, M_0- no mulch, M_1- @ 6 t paddy straw mulch ha^{-1}, W_1- 20 % reduction of plant available water, W_2- 30 % reduction of plant available water.

Fig 1: Effect of boron levels, mulching and moisture regimes on uptake of boron by cauliflower

rest of treatments. Minimum uptake of B was 24.24 g ha^{-1} recorded in M_0 (no mulch). Similar trend was recorded in the pooled data of two years experiment. Maximum uptake 42.58 g ha^{-1} was found at the treatment combinations of $B_{5.0}M_1W_1$ was statistically superior to rest of the treatments. Minimum uptake 24.20 g ha^{-1} was recorded in $B_0M_0W_2$ registering 75.9% and 23.8% enhancement. The interaction effects of B levels, mulching and moisture, however, was insignificant during both the years of experimentation. These findings also are in conformity with the findings of Vaiyapuri *et al.* (2009) [17]; Sinha *et al.* (1991) [14] and Moreno and Moreno, (2008) [11].

Conclusion

The study revealed that higher magnitude of the B uptake in deficient and responsive soils could be attributed to low content of soil B limiting the uptake in control plots, and in contrast, the high level of borax induces the more amount of readily soluble boron in the available pool of soil matrix. Response of mulch, in terms of B uptake, may be attributed to the fact that straw mulch render some moderation in soil temperature (approx. by 1.8 ^{0}C) than that of no mulch and hence augment soil microbial activity which, in turn, facilitate B mineralization from organic matter or other sources. The uptake of B, enhances the ability of membranes to transport vital nutrients. Moreover, the fluctuation of soil temperature was less which favoured the mineralization process. Low to moderate water stress environment encourages root proliferation and thus, increases both water and nutrient uptake including B.

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