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Response of different levels of boron levels mulching and moisture regimes on yield of cauliflower (*Brassica oleracea* var. Botrytis L.) CV PSB-1 under Jammu condition

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Abstract
A field experiment conducted for two successive seasons at University Research Farm Chatha, SKUAST, Jammu of J&K State during two successive years (*Rabi* seasons of 2015-16 and 2016-17) [12] to investigate the effect of different levels of boron levels, mulching and moisture regimes on yield of cauliflower (*Brassica oleracea* var. botrytis L.) [14]. The experiment was laid out in the light textured soil *i.e.* Sandy clay loam with Factorial Randomized Block Design (FRBD) constituting 16 different treatment combinations with 3 replications. 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}). The overall results (two years pooled data) clearly showed that the treatment combination of $B_{5.0}M_1W_1$ registered highest yield of 318.9 q ha^{-1} Whereas, the lowest curd yield 282.2 q ha^{-1} was registered by $B_0M_1W_1$ treatment thereby improving 13.00 % in cauliflower yield. Similarly, During *Rabi* 2015-16 [12] and *Rabi* 2016-17[12] thereby improving 12.79 % and 13.24 % in cauliflower yield respectively. The application of 5.0 kg borax ha^{-1} along with 30 t ha^{-1} FYM as well as 6 t paddy straw mulch ha^{-1} and 20 % reduction of plant available water is best suited to ameliorate the B deficiency and boosting the productivity of cauliflower production in light textured soils.

Keywords: boron, cauliflower, snowball and yield

1. Introduction
Cauliflower (*Brassica oleracea var. botrytis L.*) [14] Is an important cruciferous cool-weather half-hardy biennial grown as an annual vegetable crop of Jammu? Pusa Snowball -1, a late variety is most popular among the growers of Jammu regions, since it fetches a good premium both as a curd as well as a seed crop. The area under cauliflower crop during 2016-17 in the J&K state was only 325 hectares with total production of 85260 MT and productivity 26.20 MT ha^{-1} respectively. India ranks second in production of cauliflower & broccoli (36% of world production). During 2016-17, India produced 78, 87,000 MT of cauliflower from an area of 452.13 M ha and the average productivity is 19.6 tonnes per ha (Anonymous, 2017) [1]. Though primarily the crop is a cool season crop, it is grown not only during the winter months, but also during post monsoon and autumn season as an early produce for its higher return in Jammu condition especially due to expectation of good return during festival seasons. Jammu district of Jammu & Kashmir is traditionally a basmati paddy district; however, in some pockets of the district, the cultivation of vegetables including cauliflower is increasing day by day dueto relatively short time from planting to harvest and producers fetches good returns as cash crop.

From production aspect, it requires balanced dose of major plant nutrients, particularly nitrogen, phosphorus and potassium, boron and molybdenum (Mengele and Kirby, 1987) [9]. Availability of micronutrients such as iron, manganese, zinc, copper, and especially boron can influence cauliflower plant growth which can be reduced severely by high substrate and irrigation water pH (Bailey and Bilderback, 1997) [2]. It is sensitive to soil micronutrient B deficiency typical deficiency called "brown heart". Among numbers of factors soil temperature and moisture are 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. Because of over mining of the plant food elements by the crops most of the micronutrients become in short supply to the crops and some disorders appear resulting in low yields (Joshi, 1997) [5]. And boron is not an exception. Boron deficiency has been commonly reported in soils which are highly leached and/or developed from calcareous and alluvial deposits (Borkakati and Takkar, 2000) [4]. The availability of boron decreases due to intensive cultivation. In order to formulate the correct dose of boron for getting higher yield in small and scattered land holding under Jammu condition, the present investigation was undertaken.

Materials and methods

The experiments 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 *ie*. 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 *Rabi* 2015-16 [12] and *Rabi* 2016-17 [12]. The experiment layout comprises of 48 no. of plots having size 4 x 3 m^2 each.

Treatment details

The treatment comprises of 4 levels of boron (B_0, $B_{2.5}$, $B_{5.0}$, $B_{7.5}$) kg ha^{-1}applied through borax(11.37 % boron), 2 levels of soil mulching (no mulch, M_0 and @ 6 t straw mulch ha^{-1}, M_1) and 2 levels of moisture regimes (20 % Plant available water (PAW), W_1 and 30 % PAW, W_2) 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 (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. Remaining amount of nitrogen was split into two equal parts and each part was band placement at one and two months after transplanting. The treatments with their symbols are described in Table 1

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	5.0 kg 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 boron levels and mulching on curd yield: With the increase in boron levels the curd yield successively increased up to 5.0 kg of borax ha^{-1} in the order : B_0 (274.25 q ha^{-1}) > $B_{2.5}$ (297.09 q ha^{-1}) > $B_{5.0}$ (315.56 q ha^{-1}) (Table 2). However, with further increase of soil applied boron *i.e.* with 7.5 kg borax ha^{-1} (B_3) there was a significant yield reduction of 6.7 % and 4.9 % during 2015-16 and 2016-17, respectively. With a curd yield of 315.56 q ha^{-1}, $B_{5.0}$ (@ 5.0 kg borax ha^{-1}) treatment registered 15.06 % improvement over the curd yield (274.25 q ha^{-1}) with B_0 (control *i.e.* no borax application). On overall basis, the $B_{5.0}$ treatment (5.0 kg borax ha^{-1}) exhibited the highest mean yield of curd 314.90 q ha^{-1}, whereas the lowest mean yield 275.13 q ha^{-1} was registered by B_0 (control) treatment.

Table 2: Effect boron levels and mulching on curd yield (q ha^{-1}).

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	268.18	280.33	274.25	273.61	278.45	276.03	270.89	279.37	275.13
$B_{2.5}$	294.01	300.18	297.09	295.37	301.27	298.32	294.69	300.72	297.05
$B_{5.0}$	314.92	316.21	315.56	312.72	315.79	314.25	313.82	315.99	314.90
$B_{7.5}$	287.73	303.66	295.69	289.05	309.96	299.50	288.39	306.81	297.60
Mean	291.21	300.09		292.69	301.36		291.95	300.72	

Factor	2015-16 $CD_{(0.05)}$	2016-17 $CD_{(0.05)}$	Overall $CD_{(0.05)}$
B	2.343	2.349	5.133
M	1.657	1.661	3.630
B x M	3.314	3.322	7.259

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- @ 6t paddy straw mulch ha^{-1}.

The mean curd yield (300.09 q ha^{-1}) under mulched condition (M_1) was statistically superior over M_0 (291.21q ha^{-1}) during 2015-16. Similarly, during 2016-17, the curd yield was significantly higher under M_1 (301.36 q ha^{-1}) than that of M_0 (292.69 q ha^{-1}). On overall basis (Rabi 2015-16 and 2016-17) [12], the curd yield realized with M_1 (300.72 q ha^{-1}) was significantly superior over the M_0 (291.95 q ha^{-1}). Between the treatment combinations, significant difference due to the interaction of boron levels and mulching were pronounced. Similar findings also reported by Khadka *et al* (2005) [6], Bhattarai and Subedi (2009) [3] and Kumar *et al* (2010)[7]. Effect of boron levels and moisture regimes on curd yield : The highest mean curd yield 297.91 q ha^{-1} and 299.66 q ha^{-1} was observed with respect to moisture regimes(W_1) was statistically superior over(W_2) in two years (Rabi 2015-16 and Rabi 2016-17) [12] experiment (Table 3). 3).

Table 3: Effect of boron levels (B) and moisture regimes (W) on curd yield (q ha^{-1})

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	277.20	270.31	273.75	280.81	273.16	276.98	279.00	271.73	275.36
$B_{2.5}$	299.47	291.72	295.59	300.23	295.42	297.82	299.85	293.57	296.71
$B_{5.0}$	316.97	310.15	313.56	317.79	312.72	315.25	317.38	311.43	314.40
B_3	298.01	290.97	294.49	299.81	294.13	296.97	298.91	292.55	295.73
Mean	297.91	290.78		299.66	293.85		298.78	292.32	
Factor	2015-16 $CD_{(0.05)}$			2016-17 $CD_{(0.05)}$			Overall $CD_{(0.05)}$		
B	2.343			2.349			5.133		
W	1.657			1.661			NS		
B x W	NS			3.322			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

Out of four levels of B (B_0, $B_{2.5}$, $B_{5.0}$ and $B_{7.5}$), $B_{5.0}$ (5.0 kg borax ha^{-1}) levels exhibited the highest mean yield of curd 313.56 q ha^{-1}. Whereas the lowest mean yield 273.75 q ha^{-1} was registered by B_0(control) treatment during 2015-16. On mean basis, maximum curd yield was found at $B_{5.0}$ levels (315.25 q ha^{-1}) followed by $B_{2.5}$ (297.82 q ha^{-1}) $B_{7.5}$ (296.97 q ha^{-1}) and B_0 (276.98 q ha^{-1}) whereas, yield of $B_{2.5}$ (2.5 kg Borax ha^{-1}) and $B_{7.5}$ (7.5 kg borax ha^{-1}) were at par (*i.e.* 297.82 and 296.97 q ha^{-1}) of the mean data. The mean curd yield (299.66 q ha^{-1}) under moisture regimes condition (W_1) were statistically superior over W_2 (293.85 q ha^{-1}) of experiment. On overall basis (*Rabi* 2015-16 and 2016-17) [12], the curd yield Realized with W_1 (298.78 q ha^{-1}) was significantly superior over the W_2 (292.32 q ha^{-1}). A further reference to the data that moisture regimes showed the significant difference among themselves W_1 and W_2.The findings of present investigations are in line with findings of Prabhakar and Srinivas (1995a) [12], Sibale, (2015) [14] and Sengar & Sharma (2018) [13].*Effect of mulching and moisture regimes on curd yield:* It's noted from the Table 4 effect of mulching on cauliflower yield depicts that M_1 registered highest mean yield 300.09 q ha^{-1}, whereas minimum mean curd yield 291.21q ha^{-1} was recorded in M_0(control) of experiment. The highest mean curd yield 298.01 q ha^{-1} was observed with respect to moisture regimes W_1 was statistically superior over W_2 ofexperiment.

Table 4: Effect of mulching and moisture regimes on curd yield (q ha^{-1})

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	293.38	289.04	291.21	295.51	289.88	292.69	294.45	289.46	291.95
M_1	302.65	297.53	300.09	303.86	298.86	301.36	303.25	296.81	300.03
Mean	298.01	293.28		299.68	294.37		298.85	293.13	
Factor	2015-16 $CD_{(0.05)}$			2016-17 $CD_{(0.05)}$			Overall $CD_{(0.05)}$		
W	1.657			1.661			3.630		
M	1.657			1.661			NS		
W x M	N.S			N.S			7.259		

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

Among the mulching, maximum yield 301.36 q ha^{-1} was found at M_1 which was statistically significant whereas, the lowest yield 292.69 q ha^{-1} was recorded in M_0 of 2016-17 year of experiment. The mean curd yield (299.68 q ha^{-1}) under moisture regimes condition (W_1) was statistically superior over W_2 (294.37 q ha^{-1}). It is evident from the overall results that mulching (M) differ significant results over no mulching. Similarly, irrespective of boron levels, mulching and moisture regimes maintained a significant and consistent increase in yield on overall basis. Moisture (W) and mulching (M) are statistically significant in both years of experiment. However their interaction showed non- significant results. The findings of present investigations are in line with findings of Moniruzzaman *et al.*

(2007) [10] and Sengar & Sharma (2018) [13].*Effect of boron levels, mulching and moisture regimes on cauliflower yield:* Data presented in Table 5and fig.1 revealed the combined effect of boron levels, mulching and moisture regimes on cauliflower yield (q ha^{-1}). During *Rabi* 2015-16, the treatment combination of $B_{5.0}M_1W_1$ registered highest yield of 318.2 q ha^{-1}of cauliflower(*cv.* PSB-1) while that of $B_{5.0}M_0W_1$ registered 315.6 q ha^{-1} indicating an in-significant yield decline attributed to mulching. In comparison to $B_0M_1W_1$ which Yielded 282.1 q ha^{-1}, $B_{5.0}M_1W_1$ recorded 318.2 q ha^{-1} thereby improving 12.75 % in cauliflower yield. Similarly $B_{7.5}M_1W_1$ offered a yield value of 308.6 q ha^{-1} which is least (3.11 %) increase in cauliflower yield.

Table 5: Effect of boron levels mulching and moisture regimes on cauliflower yield (q ha^{-1})

Mulching Boron levels Moisture regime	Rabi 2015-16				Rabi 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	272.2	264.1	282.1	278.4	279.1	267.8	282.3	274.5	275.6	265.9	282.2	276.4
$B_{2.5}$	297.4	290.5	301.4	298.8	298.2	292.5	302.2	300.2	297.8	291.5	301.9	299.5
$B_{5.0}$	315.6	314.1	318.2	314.1	315.8	309.6	319.7	311.8	315.7	311.8	318.9	312.9
$B_{7.5}$	288.1	287.2	308.6	298.6	288.5	289.5	311.1	308.8	288.3	288.3	309.8	303.7
Factor	2015-16 $CD_{(0.05)}$				2016-17 $CD_{(0.05)}$				Overall $CD_{(0.05)}$			
B x M x W	4.686				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- @ 6t paddy straw mulch ha^{-1}, W_1- 20% reduction of Plant available water, W_2- 30% reduction of Plant available water.

During Rabi 2016-17, the treatment combination of $B_{5.0}M_1W_1$ registered highest yield of 319.7 q ha^{-1}of cauliflower (cv. PSB-1) while that of $B_{5.0}M_0W_1$ registered 315.8 q ha^{-1} indicating an in-significant yield decline attributed to mulching. In comparison to $B_0M_1W_1$ which yielded 282.3 q ha^{-1}, $B_{5.0}M_1W_1$ recorded 319.7 q ha^{-1} thereby improving 13.24 % in cauliflower yield. Similarly $B_{7.5}M_1W_1$ offered a yield value of 311.1 q ha^{-1} which is 2.76 % increase in cauliflower yield**.**

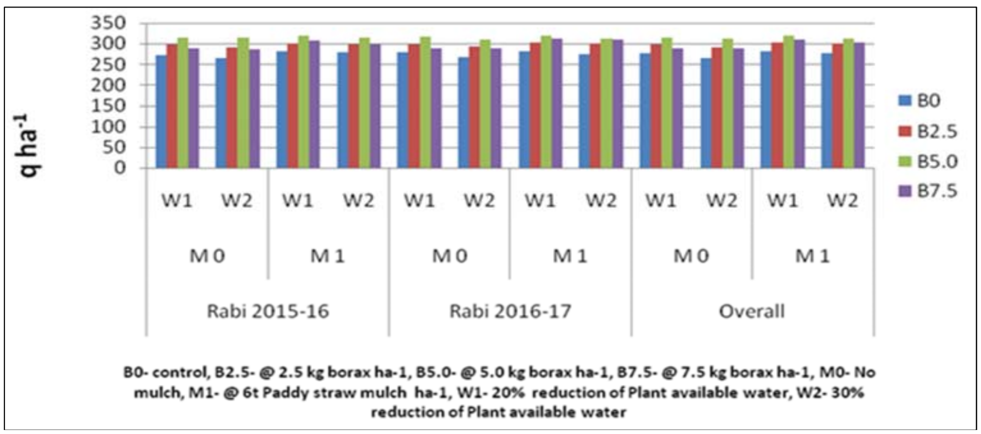

Fig 1: Effect of boron levels (B) mulching (M) and moisture regimes (W) on cauliflower yield.

Similar trend was observed in the overall data of experiment. Maximum yield was found at $B_{5.0}M_1W_1$ (318.9 q ha^{-1}) registered highest curd yield followed by $B_{2.5}M_1W_1$ (301.9 q ha^{-1}) while the minimum yield was offered by $B_0M_1W_1$ (282.2 q ha^{-1}) treatment combination. The cauliflower yield responded more by mulching, moisture regime and boron application. It may be due to its role in enhancing the translocation of carbohydrates from the site of its synthesis to the storage tissue in the curd as Boron is known to play beneficial role in the translocation of carbohydrates which helps in better seed or fruit set. These findings also are in conformity with the findings of Kumar and Choudhary (2002) [8], Singh (2003) [15] as well as Pizeetta *et al.* (2005) in Cauliflower.

Conclusion

The overall data clearly showed that the treatment combination of $B_{5.0}M_1W_1$ registered highest yield of 318.9 q ha^{-1} Whereas, the lowest curd yield 282.2 q ha^{-1} was registered by $B_0M_1W_1$ treatment thereby improving 13.00 % in cauliflower yield. Similarly, During *Rabi* 2015-16 [12] and *Rabi* 2016-17 thereby improving 12.75 % and13.24 % in cauliflower yield respectively. It can be recommended that application of 5.0 kg borax ha^{-1} along with 30 t ha^{-1} FYM as well as 6 t paddy straw mulch ha^{-1} and 20% reduction of plant available water is best suited to ameliorate the B deficiency and boosting the productivity of cauliflower production in light textured soils

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