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Influence of Boron and Organic Manure Nutrition on Productivity, Nutrient Uptake and Soil Properties in Autumn Cauliflower under Western Himalayas Conditions

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ABSTRACT: *The present investigation was carried out in the farmers' field adjoining to Hill Agricultural Research and Extension Centre, Bajaura, Kullu (India) with the broader aim of assessing productivity and nutrient status in cauliflower. A total of 13 treatments comprising two levels of FYM (20 and 30 t ha*$^{-1}$*); two boron fertilizer sources (borax-10.6% B and granubor II-14.8% B); three rates of boron (0.5, 1.0 and 1.5 kg ha*$^{-1}$*) and farmers' practice* i.e. *cauliflower cultivation practice of the farmers' of local area) were replicated three times in a factorial randomized block design. The study revealed that FYM @ 30 t ha*$^{-1}$ *led to significant increase of 5.7% in curd yield over 20 t ha*$^{-1}$*. Whereas, average magnitude of increase in N, P and K uptake following FYM application @30 t ha*$^{-1}$ *was to the tune of 23, 55 and 21%, respectively in comparison with 20 t FYM ha*$^{-1}$*. Similarly a significant build up of organic matter (12.0%), N (2.5%), P (36.4%) and K (5.3%) after harvest was recorded under higher level of applied FYM i.e. 30 t ha*$^{-1}$*. Among two sources of boron granubor-II was found superior. Significant respective increases of 3.7, 3.7, 5.6 and 14.8% in curd yield, N, P and K uptake were registered under granubor-II as compared to borax. As regard different boron levels, B application @ 1.5 kg ha*$^{-1}$ *enhanced cauliflower yield by 8.0 and 5.0%, respectively over 0.5 and 1.0 kg ha*$^{-1}$ *B. Similarly, B application at highest level exerted a significant effect on N (8.2%), P (14.2%), and K (7.8%) uptake over 0.5 and 1.0 kg ha*$^{-1}$ *B application. After harvest of cauliflower, boron @ 1.5 kg ha*$^{-1}$*, significantly improved soil organic carbon and available P status in soil by 2.9 and 4.2%, respectively over 0.5 kg ha*$^{-1}$ *B application.*

Keyword: *Autumn cauliflower, Boron, Organic manure, Western Himalayas*

INTRODUCTION

The mid hill zone of Western Himalayan has huge potential for growing various vegetable crops including off-season cauliflower i.e. autumn cauliflower. It fetches high premiums in local and super vegetable markets. Despite favourble conditions prevailing for growing automn cauliflower under above conditions, per unit average productivity of this is lesser (110 to 118 q ha^{-1}) than the desired levels of 130 q ha^{-1} (Anonymous 2007). Low and imbalanced use of chemical fertilizers is one of the major reasons for low productivity of cauliflower.

The farmers indiscriminately use N fertilizer while the application of P and K fertilizers is very limited. Thus, an imbalanced fertilizer use has led to multinutrient deficiencies particularly of boron, resulting in yield stagnation and deteriorated soil health. Several physiological impairments as a result of B-deficiency were reported by Parr and Loughman (1983). Modern agriculture over the years has resulted in greater depletion of boron (B) in soil, so its deficiencies have emerged as a serious obstacle in sustaining higher production of food as well as horticultural crops in all parts of the country (Singh *et al*. 2009).). Studies revealed that cauliflower grown under mid hills of Western Himalayan are deficient in B (21-65% areas have B level below 0.50 mg kg-1 soil) (Raina *et al.* 2006) and require appropriate B application for correcting its deficiency (Chander 2004; Singh 2003).

Besides, above factors, intensive cropping system having less use of organic manure not only deteriorating the soil physical, chemical and biological properties, but also aggravating the deficiency of many nutrient including B in the soil. Also, due to decrease in soil organic matter, there is continuous

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decline in soil friendly organisms, which play an important role in sustaining soil fertility. However, the soil quality may be rejuvenate by the continuous application of organic manures such as FYM, crop residues, etc. along with recommended doses of inorganic fertilizers.

The use of organic manures influences the transformation of essential plant nutrient elements in soil and thus, their availability to crops. Soil organic matter adsorbs more B than mineral soil constituents on weight basis (Gu and Lowe 1990). Moreover, added organic matter may coat the B fixing mineral surfaces by soluble organic compounds which may increase B-efficiency in soil. Also, it is well established fact that much of the B in soil is associated with organic matter in tightly bound compounds that are formed within growing plants themselves, which is released in available form by microbial action when added to the soil (Berger 1962; Berger and Pratt 1963). Integrated effect of FYM and B is more than their individual influence on different crops (Singh 2000) and the continuous application of FYM maintained the level of available-B content in soil (Rattan *et al.* 1999).

Adequate boron nutrition has been found to be critical not only for higher yields but also for better quality of the crop (Blevins and Lukarzewski 1998). Study was therefore undertaken to optimize the rate of B fertilization and evaluate efficiency of various boron sources with FYM on cauliflower in the Western Himalayas.

MATERIALS AND METHODS

Study Site

Field experiment on cauliflower (*Brassica oleracea* var. *botrytis*) was conducted in the farmers' field adjoining to the experimental farm of CSK HPKV Hill Agricultural Research and Extension Centre, Bajaura in Kullu, India (*$32^0 2'$ N latitude and 72°E longitude, 1090 m above mean sea level*) having sub humid climate. The study area falls under mid hill and is characterized by severe winters in the month of December to February and mild summers from June to August. Annual temperature ranges from 0.7 to 34^0C. Monsoon in general sets in by the end of June. The average annual rainfall is uneven and most of this is received during mid June to mid September.

Experimental Details

The field experiment was replicated thrice in a Factorial randomized block design comprising 13 treatments *viz.* two levels of FYM (20 and 30 t ha-1); two boron fertilizer sources (borax-10.6% B and granubor II-14.8% B); three rates of boron (0.5, 1.0 and 1.5 kg ha^{-1}) and one absolute control (farmers' practice *i.e.* cauliflower cultivation practice of the farmers' of local area). All the plots received uniform doses of recommended NPK fertilizer (125:75:65). Nitrogen (N), P and potassium (K) were supplied through urea (46% N), single super phosphate (16% P_2O_5) and muriate of potash (60% K_2O), respectively, whereas, Farm yard manure (FYM) and B fertilizers (borax and Granubor-II) were applied as per the treatments. Existing farmers practices was '10 t ha^{-1} FYM' + '125 kg ha^{-1} 12:32:16 as basal dose (10 kg $bigha^{-1}$)' + '375 kg ha^{-1} (30 kg $bigha^{-1}$)' urea as top dressing in two splits). The cauliflower was grown as per the package of practices. Irrigation was done as and when required.

The experimental soil had initial pH 7.0, organic carbon 4.2 g kg^{-1} and the available status of N, P, K and B was 206 kg ha^{-1}, 19.0 kg ha^{-1}, 190 kg ha^{-1} and 0.62 mg kg^{-1}, respectively. The soil reaction was determined by 1:2.5::Soil : water suspension method (Jackson 1967)', 'Organic carbon by rapid titration method (Walkley and Black 1934)', 'available-N following Alkaline permanganate method (Subbiah and Asija 1956)', 'available–P by 0.5 M $NaHCO_3$ at pH=8.5 (Olsen *et al.* 1954)' and 'available K by Neutral ammonium acetate method (Merwin and Peach 1951)'. The 'hot water soluble or available B' was extracted by boiling of soil for 30 minutes on hot water bath and its further determination using Carmine method (Hatcher and Wilcox 1950).

Soil Analysis

Representative soil samples (0-15 cm depth) were collected from each plot before transplanting. The samples were also collected at different stages of cauliflower growth (25, 45 DAT and harvest). The soil samples were dried in shade, ground in pestle mortar, passed through 2mm sieve and subjected to laboratory analysis. The N, P, K and B in plots receiving different treatments were estimated using standard methods as given above.

Plant Analysis

Plant samples (leaves and curd) collected at different pickings from all the field plots, were air dried and then, dried in an oven at 60 °C for 72 hours. The dried samples were now ground in a Willey Mill fitted with stainless steel parts, and passed through 1 mm sieve and stored in paper bags for analysis. The N, P and K concentrations in above samples were estimated by Micro–Kjeldahl, Vanado–molybdo–phosphoric acid yellow colour and Wet digestion methods, respectively as outlined by Piper (1950), whereas, B in plant samples by estimated by following Carmine method (Hatcher & Wilcox 1950) i.e. digestion by dry ashing at 550°C for 2 hrs followed by digestion with 6.0 N HCl and further determination using standard procedure.

Marketable Curd Yield (q ha^{-1})

Curd yield (without non-wrapper leaves and stalk) per plot was recorded by weighing marketable curds at different harvests and adding to express it in quintals per hectares.

Statistical Analysis

The data generated from the current study was subjected to the determination of analysis of variance through the requisite statistical computation following the procedures outlined by Gomez and Gomez (1984) to predict the cause and effect relationship among various parameters. The correlations were computed by using formula of Robinson *et al*. (1951). The correlation coefficients were further partioned into direct and indirect effects (Dewey and Lu 1959). To test the significance of these correlations coefficients, 'r' values obtained were compared against correlation coefficient values in Fisher and Yates tables (1957) at n-2 d.f. at 5 % level of significance.

RESULTS AND DISCUSSION

Marketable Yield

Effect of FYM

The FYM applied at different rates exhibited a significant effect on the marketable yield of cauliflower (Table 1). The highest curd yield (140.7 q ha^{-1}) was registered under FYM applied @ 30 t ha^{-1} than obtained with 20 t ha^{-1} FYM (133.1 q ha^{-1}). There was 5.7% higher curd yield with FYM applied @ 30 t ha^{-1} over 20 t ha^{-1} FYM (Table 1).

The increased marketable yield emanating from the application of FYM was mainly due to additional nutrients supplied by FYM and improved soil properties. A highly significant response of cauliflower to FYM can also be interpreted in terms of its effect on improvement in soil nutrients reserves, and soil physical conditions. Similar results on beneficial effect of FYM on yield and quality of different crops, have also been reported by Kanwar *et al.* (2002) and Chander (2004).

Effect of Boron Sources

Among two boron fertilizer sources, the granubor-II source significantly increased curd yield in comparison to borax (Table 1). The increase in curd yield was 3.7% higher with granubor-II over borax. Granubor-II was found superior over borax in increasing marketable yield, probably due to more boron content in granubor-II (Table 1). The increased yield under Granubor-II may also be attributable to its higher solubility in comparison with borax. However, in a study involving cauliflower, Singh (2006) reported that borax and granubor-II were equally effective and there were no difference in yield and quality.

Effect of Boron Levels

Different boron levels exercised a marked and significant effect on curd yield (Table 1). The highest curd yield (142.7 q ha^{-1}) was recorded with an application of boron applied @ 1.5 kg ha^{-1}, resulting 8.0 and 5.0 % increase, respectively over 0.5 and 1.0 kg ha^{-1} B (Table 1). The enhanced yield of cauliflower as a result of B application is attributable to the increased availability of nutrients to plants (Singh and Thakur 1991), thereby manufacturing more carbohydrates and proteins (Takkar and Randhawa 1978; Verma 1983) alongwith its role in enhancing their translocation from the site of synthesis to the storage organs (Sharma 2002). Further, B plays a key role in many metabolic processes such as cell wall differentiation, cell development, N-metabolism, fertilization, fat metabolism, harmone metabolism, active salt absorption and photosynthesis (Nason and McElory 1963) which in turn contributed to higher fresh and dry matter yield of cauliflower. Saha *et al.* (2006) have also reported a similar promotive effect of B application on cauliflower yield and growth parameters.

Control Vs others

The data revealed that the treatments significantly increased the marketable yield of cauliflower over farmers' practice (Table 1).

The interactions among different treatments were non-significant (Table 1).

Nutrient Uptake

Effect of FYM

Application of FYM significantly influenced the N, P and K uptake at harvest stage. The increase in leaf N uptake was 25% due to 30 t ha^{-1} FYM over @ 20 t ha^{-1}

Table 1
Effect of FYM, Boron and its Sources on Marketable Yield (q ha^{-1}) and Nutrient Uptake (Kg ha^{-1}) in Cauliflower

Treatments	*Yield(q ha^{-1})*	*N*			*P*			*K*		
		Leaves	*Curd*	*Total*	*Leaves*	*Curd*	*Total*	*Leaves*	*Curd*	*Total*
FYM (t ha^{-1})										
20	133.1	9.9	15.2	25.1	1.8	3.6	5.4	8.5	13.1	21.6
30	140.7	12.4	18.1	30.5	2.7	5.8	8.5	10.3	15.6	25.9
CD (5%)	2.01	0.11	0.21	0.26	0.08	0.12	0.16	0.13	0.19	0.25
Boron sources										
Borax	134.4	10.9	16.2	27.1	2.1	4.4	6.5	9.2	14.0	23.2
Granubor-II	139.4	11.3	17.1	28.4	2.4	5.0	7.4	9.5	14.8	24.3
CD (5%)	2.01	0.11	0.21	0.26	0.08	0.12	0.16	0.13	0.19	0.25
Boron levels (kg ha^{-1})										
0.5	132.1	10.8	15.8	26.6	2.1	4.3	6.4	9.1	13.7	22.7
1.0	135.9	11.1	16.4	27.6	2.3	4.6	6.9	9.3	14.3	23.6
1.5	142.7	11.8	17.5	29.3	2.5	5.1	7.6	9.7	15.2	24.9
CD (5%)	2.46	0.14	0.25	0.32	0.1	0.15	0.19	0.15	0.24	0.31
Control Vs others										
Control	97.7	4.5	5.9	10.4	0.8	0.9	1.8	3.2	4.1	7.3
Others	136.9	11.2	16.6	27.8	2.3	4.7	7.0	9.4	14.4	23.8
CD (5%)	*3.62*	*0.20*	*0.34*	*0.46*	*0.15*	*0.21*	*0.32*	*0.21*	*0.33*	*0.41*

FYM (Table 1). Likewise, the magnitude of increase in N uptake in curd was 19% with FYM applied @ 30 t ha^{-1}, over 20 t ha^{-1} FYM. Further, the leaf and curd P uptake at harvest, significantly improved due to FYM @ 30 t ha^{-1}, which increased the leaf and curd P uptake by 50 and 61%, respectively as compared to 20 t ha^{-1} FYM (Table 1). The increase in leaf and curd K uptake at 30 t ha^{-1} FYM was 21.2 and 19%, respectively over 20 t ha^{-1} FYM (Table 1). The higher uptake of N, P and K is attributable to beneficial effect of FYM on nutrient availability in soil and improvement in soil properties. FYM itself contains reasonable amounts of various nutrient including N, P, K, etc., which are released into the soil upon decomposition and then these nutrients are absorbed by the plants. Chander (2004) have also reported similar results.

Effect of Boron Sources

The leaf N, P and K uptake increased by 3.7, 5.6 and 14.8 %, respectively with granubor-II, over borax (Table 1). Such an increase in curd N, P and K uptake at harvest was 6.2, 13.6 and 4.6 %, respectively with granubor-II, over borax. The increased concentration of nutrients with granubor-II at different stages may be because of its higher solubility and boron content resulting better absorption by plants (Byers *et al.* 2001). Moreover, B stated to play an important role in enhancing ability of membranes to transport vital nutrients including N, P and K (Loughman, 1983).

Effect of Boron Levels

The increase in leaf N uptake of cauliflower at 1.5 kg ha^{-1} B was 9.3 and 6.3%, respectively over 0.5 and 1.0 kg ha^{-1} B (Table 1). Whereas, increase in curd N uptake with 1.5 kg ha^{-1} B was 10.8 and 6.7%, respectively over 0.5 and 1.0 kg ha^{-1} B (Table 1). The increase in leaf P uptake at 1.5 kg ha^{-1} of applied boron was 19 and 8.7 %, respectively over 0.5 and 1.0 kg ha^{-1} B (Table 1). However, increase in curd P uptake with boron @ 1.5 kg ha^{-1} was 18.6 and 10.8%, respectively over 0.5 and 1.0 kg ha^{-1} B. Further, increase in leaf K uptake with 1.5 kg ha^{-1} B was 6.6 and 4.3%, respectively over 0.5 and 1.0 kg ha^{-1} of B applied (Table 1). Whereas, increase in curd K uptake at 1.5 kg ha^{-1} B was 12.6 and 7.9 %, respectively over 0.5 and 1.0 kg ha^{-1} B application (Table 1).

Boron is stated to play an important role in phosphate transport across membranes (Loughman 1983). Use efficiency of N might have increased in the presence of boron (Waring 1953). Moreover, the application of B was found to enhance P availability in soil. Further, K-uptake by plants does not occur in the absence of B (Schon *et al.* 1991). Boron is credited with maintaining membrane integrity (Cakmak *et al.* 1995) and hence enhanced ability of membranes to transport vital nutrients. These results are in confirmity with the findings Singh *et al.* (1994) and Kotur (1998).

Control Vs others

Further, all treatments significantly increased the uptake of nutrients (N, P and K) over farmers' practice at the harvest of cauliflower (Table 1).

Interaction Effect

The combined application of FYM and boron sources greatly influenced P uptake in leaves at harvest (Table 2a). A significant increase in leaf P uptake at the harvest was observed for individual and combined application of FYM and boron sources. The highest leaf P uptake was observed with combined application of 30 t ha^{-1} FYM and granubor-II boron fertilizer.

The interaction between FYM and boron sources was also significant in case of curd P uptake at harvest (Table 2b). There was a significant individual as well as collective influence of FYM and boron sources and the highest curd P uptake was recorded with application of 30 t ha^{-1} FYM and granubor-II.

The individual as well as the combined effect of boron levels and its sources was also significant for cauliflower curd K uptake (Table 2c) at harvest.

Further, the interaction between FYM, boron levels and its sources significantly influenced curd K uptake (Table 2d). The highest curd K uptake was observed with combined application of granubor-II applied @ 1.5 kg ha^{-1} and 30 t ha^{-1} FYM.

Table 2a
Interaction Effect of FYM and Boron Sources on Leaf P uptake (kg ha^{-1}) at Harvest

FYM (t ha^{-1})	*Boron sources*	
	Borax	*Granubor-II*
20	1.7	1.9
30	2.5	2.9

CD (5%) 0.12

Table 2b
Interaction Effect of FYM and Boron Sources on Total P (Leaves + Curd) Uptake (kg ha^{-1})

FYM (t ha^{-1})	*Boron sources*	
	Borax	*Granubor-II*
20	5.1	5.7
30	8.0	9.0

CD (5%) 0.23

Table 2c
Interaction Effect of Boron Levels and its Sources on Curd K uptake (kg ha^{-1}) at harvest

Boron sources	*Boron levels (kg ha^{-1})*		
	0.5	*1.0*	*1.5*
Borax	13.4	14.0	14.6
Granubor-II	14.0	14.6	15.8

CD (5%) 0.34

Table 2d
Interaction Effect of FYM, Boron and its Sources on Curd K Uptake (kg ha^{-1}) at Harvest

FYM (t ha^{-1})	*Borax (kg ha^{-1})*			*Granubor-II (kg ha^{-1})*		
	0.5	*1.0*	*1.5*	*0.5*	*1.0*	*1.5*
20	12.0	12.7	13.4	12.7	13.5	14.1
30	14.7	15.1	15.7	15.2	15.7	17.4

CD (5%) 0.48

As discussed earlier, the increased nutrient concentration and uptake in leaf and curd due to individual and collective effect of FYM and boron may be probably due to the beneficial synergistic effect of FYM and boron on nutrient availability in soil, improvement in soil physical properties (Singh and Sharma 1990) and improved efficiency of P and K uptake due to FYM application (Waring 1953; Schon *et al.* 1991). An enhancement in P and K uptake with increasing levels of B was also observed by Kotur (1997).

Soil Properties

Soil pH

The effect of FYM, boron and its sources on soil pH was registered non-significant at all the stages of sampling (Table 3).

Table 3
Effect of FYM, Boron and its Sources on Soil pH and Organic Carbon at Different Growth Stages

Treatments	*pH*			*OC (g 100g^{-1})*		
	25 DAT	*45 DAT*	*AH*	*25 DAT*	*45 DAT*	*AH*
FYM (t ha^{-1})						
20	6.9	7.0	7.0	0.51	0.63	0.67
30	6.9	7.0	7.0	0.59	0.69	0.75
CD (5%)	NS	NS	NS	0.01	0.01	0.01
Boron sources						
Borax	7.0	6.9	6.9	0.56	0.65	0.72
Granubor-II	7.0	6.9	6.9	0.56	0.65	0.72
CD (5%)	NS	NS	NS	NS	NS	NS
Boron levels (kgha^{-1})						
0.5	7.0	7.0	6.9	0.55	0.65	0.70
1.0	6.9	7.0	6.9	0.55	0.66	0.71
1.5	6.9	7.0	6.9	0.56	0.67	0.72
CD (5%)	NS	NS	NS	NS	0.01	0.01
Control Vs others						
Control	6.9	7.0	6.9	0.46	0.48	0.51
Others	6.9	7.0	6.9	0.55	0.66	0.71
CD (5%)	*NS*	*NS*	*NS*	*0.02*	*0.02*	*0.02*

DAT- Days after transplanting; AH - After harvest; OC – Organic carbon

Organic Carbon

Effect of FYM

At 25 DAT, application of FYM @ 30 t ha^{-1} increased the soil organic carbon by 15.6% as compared to 20 t ha^{-1} FYM (Table 3). Likewise, the soil organic carbon showed a consistent and significant increase of 9.5% at 45 DAT with FYM @ 30 t ha^{-1}, over 20 t ha^{-1} FYM (Table 3). As regards the soil organic carbon after harvest, a significant improvement was registered with a corresponding increase of 12.0% due to 30 t ha^{-1} FYM over 20 t ha^{-1} FYM (Table 3). The improved status of soil organic carbon is understandable due to the fact that FYM addition directly adds organic carbon to the soil after its decomposition. Kumar (2004) and Chander (2004) have also reported the significant effect of FYM on the build-up of soil organic carbon.

Effect of Boron Sources

The effect of different boron sources on soil organic carbon at all the sampling times was found non-significant (Table 3).

Effect of Boron Levels

The increased levels of boron from 0.5 to 1.5 kg ha^{-1} did not influence soil organic carbon at 25 DAT (Table 3). However, its content significantly improved by 3.1% at 45 DAT due to boron @ 1.5 kg ha^{-1} over 0.5 kg ha^{-1} of boron applied (Table 3). However, boron applied @ 1.5 kg ha^{-1} was statistically at par with @ 1.0 kg ha^{-1} B, which was statistically at par with 0.5 kg ha^{-1} B. Further, boron @ 1.5 kg ha^{-1}, significantly improved soil organic carbon after harvest by 2.9 % over 0.5 kg ha^{-1} B (Table 3). However, boron applied @ 1.5 kg ha^{-1} was statistically at par with 1.0 kg ha^{-1} B, which remained at par with boron @ 0.5 kg ha^{-1} (Table 3). The increased organic matter status following boron fertilization is probably due to enhanced root biomass i.e. more high order lateral, etc. Lehto and Malkonen (1994) have also reported increase in organic matter concentration in upper layer of soil following B application.

Control Vs others

There was a significant effect of different treatments on the soil organic carbon over farmers' practice at all the sampling times (Table 3).

The interactions among different treatments were however, observed to be non- significant.

Available Nutrient Status

Effect of FYM

At 25 DAT, increase in soil available N with 30 t ha^{-1} FYM was 7.8% over 20 t ha^{-1} FYM. The soil N status at 45 DAT (Table 4) showed a significant increase with FYM applied @ 30 t ha^{-1}, which increased soil N

Table 4
Effect of FYM, Boron and its Sources on Soil Available Nutrients Status (Kg ha^{-1}) at different Growth Stages

Treatments	*N*			*P*			*K*		
	25 DAT	*45 DAT*	*AH*	*25 DAT*	*45 DAT*	*AH*	*25 DAT*	*45 DAT*	*AH*
FYM (t ha^{-1})									
20	217	265	239	21.5	24.3	23.6	206	224	208
30	234	273	245	26.9	34.1	32.2	218	233	219
CD (5%)	0.91	1.14	1.49	0.56	0.82	0.76	1.50	1.43	0.50
Boron sources									
Borax	225	268	242	23.6	28.6	27.4	211	228	214
Granubor-II	226	269	243	24.8	29.6	28.5	212	229	214
CD (5%)	0.91	NS	NS	0.56	0.82	0.76	NS	NS	NS
Boron levels (kg ha^{-1})									
0.5	224	268	241	23.7	28.5	27.2	211	228	212
1.0	225	268	242	24.3	29.1	27.9	212	229	212
1.5	227	269	243	24.7	29.9	28.6	213	230	213
CD (5%)	1.11	NS	NS	0.69	1.01	0.94	NS	NS	NS
Control Vs others									
Control	195	234	219	19.1	20.9	20.2	194	201	186
Others	226	268	242	24.2	19.2	27.9	212	229	213
CD (5%)	*1.63*	*2.05*	*2.68*	*1.02*	*1.49*	*1.37*	*2.71*	*2.58*	*1.29*

DAT- Days after transplanting; AH- After harvest content by 3.0% over 20 t ha^{-1} FYM. Similarly, the soil N status after crop harvest improved by 2.5% with 30 t ha^{-1} FYM over 20 t ha^{-1} FYM (Table 4). The build up of available-N following FYM application could be expected due to increased population of microbes which, in turn, increased mineralization of organic-N compounds and thus increased available-N content in soil. Sahu and Nayak (1971) and Singh *et al.* (1980) also noted build-up of available-N following FYM application.

The increase in soil available P at 25 DAT under 30 t ha^{-1} FYM was 25% over 20 t ha^{-1} FYM. Likewise, the build of soil P at 45 DAT (Table 4) also increased significantly by 40% due to FYM @ 30 t ha^{-1}, over 20 t ha^{-1} FYM. Further, soil P after harvest showed a consistent and significant increase of 36.4 % with 30 t ha^{-1} FYM, over 20 t ha^{-1} FYM (Table 4). The improvement of available-P with FYM incorporation may be explained on the basis of solubilization of phosphate by the action of organic acids produced during the decomposition of FYM (Singh and Subbiah 1969), formation of protective coating on sesquioxides which reduce P-fixation (Singh and Lal 1976) and complex formation of humic and fulvic acid, thereby replacing phosphate ions by sesquioxides (Bhardwaj and Patil 1982). The build-up in available-P with the application of FYM were earlier also reported by Sahu and Nayak (1971) and Singh *et al.* (1980).

Soil available K at 25 DAT was registered significantly higher by 5.8% under FYM application @ 30 t ha^{-1} in comparison with 20 t ha^{-1} FYM (Table 4) Likewise, a significant increase in soil K at 45 DAT was observed due to FYM applied @ 30 t ha^{-1} with a corresponding increase of 4.0% over FYM applied @ 20 t ha^{-1} (Table 4). As regards the build-up of soil K after harvest, a significant increase was registered due to FYM application @ 30 t ha^{-1} and the increase was 5.3 % over FYM applied @ 20 t ha^{-1} (Table 4). The improved build-up of K can be explained due to the solvent action of organic acids produced during the decomposition of FYM (Brady 1999; Tisdale *et al.* 1995).

The over-all increase in soil status due to FYM may be attributed to additional nutrients supplied by it. The beneficial effect of FYM on nutrient status of soils may also be due to the fact that FYM itself contains reasonable amounts of N, P, K and B which might have resulted into their build up in the soil upon decomposition. The incorporation of FYM also improves all physical and microbiological properties of soils which, in turn, might have resulted into the build-up of these nutrients in soil.

Effect of Boron Sources

The application of granubor-II, significantly increased the soil available N at 25 DAT by 0.4% over borax (Table 4). However, application of different boron sources had non-significant effect on the availability of soil N at 45 DAT and after cauliflower harvest.

Soil available P at 25 DAT, significantly increased with granubor-II by 5% over borax. Likewise, at 45 DAT the soil P showed a positive and significant increase of 3.5% due to granubor-II as compared to borax (Table 4). Further, at harvest a significant increase (4.0%) in the build-up of above parameter was recorded with granubor-II over borax.

The different boron sources did not exhibit any significant effect on soil available K at all the sampling times (Table 4).

Above results are in conformity with the findings of Parmar *et al.* (2007), who observed significant effect of N, P, K and borax fertilizers on build up of nutrients in soil after potato harvest.

Effect of Boron Levels

The boron applied @ 1.5 kg ha^{-1}, significantly increased soil available N at 25 DAT by 1.3 and 0.9% over 0.5 and 1.0 kg ha^{-1} B, respectively. However, boron @ 1.0 kg ha^{-1} was statistically at par with 0.5 kg ha^{-1} of applied B (Table 4). The boron levels (0.5 to 1.5 kg ha^{-1}) however, did not exhibit any significant effect on soil available N at 45 DAT and after harvest.

The application of boron @ 1.5 kg ha^{-1} significantly increased soil available P at 25 DAT by 4.2% over 0.5 kg ha^{-1} B. The boron applied @ 1.5 kg ha^{-1} was statistically at par with 1.0 kg ha^{-1} B, which was at par with 0.5 kg ha^{-1} B (Table 4). Similarly, boron application @ 1.5 kg ha^{-1} significantly increased the soil P content at 45 DAT by 4.9% over 0.5 kg ha^{-1} B. The boron applied @ 1.5 kg ha^{-1} remained at par with 1.0 kg ha^{-1} B, which was at par with 0.5 kg ha^{-1} B (Table 4). A significant increase (5.1%) in soil P was observed at harvest with 1.5 kg ha^{-1} B over boron applied @ 0.5 kg ha^{-1} (Table 4). The values of soil available P obtained with 1.5 kg ha^{-1} B were statistically at par with 1.0 kg ha^{-1} B, which was at par with the application of 0.5 kg ha^{-1} B.

The different boron levels (0.5 to 1.5 kg ha^{-1}) had non-significant effect on soil available K at all the sampling times (Table 4).

Overall, decrease in available-P at harvest may be due to increased yield and P-uptake by cauliflower as result of boron application. Similarly, the application of B did not affect the available-N and K content significantly at 45 DAT and after harvest. However, the contents of N and K decreased significantly after harvest with increased levels of B application. A decrease in available N and K content at harvest might be due to their enhanced uptake as a result of higher yield with B application.

Varghese and Duraisami (2005) registered an increased availability of all nutrients following boron application. Application of boron resulted in an increased content of available-P in soil and the increase was maintained upto 45 DAT followed by decrease at harvest. An increase in the content of available-P as a result of B application might be attributed to the probable borate-phosphate anion exchange mechanism. A similar increase in available-P with B application has also been reported earlier by Saha and Haldar (1998) and Chander (2004).

Control Vs others

Like other parameters, all the treatments significantly increased the soil available N, P and K status over farmers' practice during all the sampling times (Table 4).

The interactions among different treatments were observed non- significant.

Overall, a highly significant response of cauliflower to FYM can be interpreted in terms of its effect on improvement in soil nutrients reserves and soil physical conditions. Also, the FYM contains considerable amount of macro and micronutrients essential for growth and development (Kanwar *et al.* 2002).

Likewise, the different boron sources exhibited a significant effect on different plant and soil parameters as compared to farmers' practice. However, granubor-II source was found superior in improving soil and plant characters probably due to its granular form and because of its higher boron content (15%) and high solubility.

Similarly, the probable reason for increased cauliflower, yield and nutrient uptake as a result of B application may be attributed to the increased availability of nutrients to plants (Chander 2004).

Inter-relationships among Different Parameter at 25 and 45 DAT

A high positive correlation between organic carbon (OC) and available B was observed at 25 and 45 DAT (Table 5a). Path analysis further revealed that there was a direct contribution of OC towards available B at 25 and 45 DAT (Table 5b). The direct contribution of pH in affecting available B was however found poor at 25 DAT. Whereas, the direct contribution of pH towards available B was found to be negative at 45 DAT. Soil pH indirectly influenced available boron through organic carbon (OC). This suggests that the organic matter is one of the major source of available-B. Nutall *et al.* (2003) also found similar results.

Table 5a
Correlations among different soil characters

	25 DAT		*45 DAT*	
	pH	*Available B*	*pH*	*Available B*
OC	0.33	0.65*	0.36	0.79*
pH		0.29		0.09

* Significant at 5% level of significance

Table 5b
Direct or Indirect Effects of Dependent Variables on Available B

	25 DAT		*45 DAT*	
	OC	*pH*	*OC*	*pH*
OC	<u>0.618</u>	0.029	<u>0.871</u>	-0.078
pH	0.203	<u>0.090</u>	0.313	<u>-0.217</u>

Underlined values denote direct effect

Inter-relationships among Different Parameter after Harvest

The data on inter- relationships among different characters in Table 6a indicated very high positive correlations between OC and available B; OC and yield; OC and B uptake; available B and yield; available B and B uptake and B uptake and yield. Though, the information on available B and B uptake in plant is not given in this paper (For data, see Kumar *et al.* 2011). The relationships between OC and pH; pH and available B; pH and yield and pH and boron uptake were also positive but either moderate or weak.

Path analysis revealed that B uptake directly influenced yield to a maximum extent. The direct contribution of OC and available B towards yield were also positive but negligible (Table 6b). The direct contribution of pH in influencing yield was negative. Soil OC, pH and available B affected yield indirectly mainly through B uptake. The present results are in accordance with the findings of Goldberg *et al.* (2002) and Nutall *et al.* (2003). Sakal *et al.* (1987) have also reported that the available-B was positively and significantly correlated with yield, % B concentration in plant and B uptake by plants, which confirms the present findings.

Table 6a
Correlations among Different Characters Studied at Harvest

	pH	*Available B*	*Yield*	*B uptake*
OC	0.38	0.80*	0.89*	0.95*
pH		0.14	0.31	0.42
Available B			0.83*	0.86*
Yield				0.93*

* Significant at 5% level of significance

Table 6b
Direct or Indirect Effects of Dependent Variables on Cauliflower Yield at Harvest

	OC	*pH*	*Available B*	*B uptake*
OC	<u>0.016</u>	-0.032	0.045	0.857
pH	0.006	<u>-0.084</u>	0.008	0.379
Available B	0.013	-0.011	<u>0.057</u>	0.772
B uptake	0.015	-0.035	0.048	<u>0.898</u>

Underlined values denote direct effect

CONCLUSION

The FYM @ 30 t ha^{-1} led to significant respective increases of 5.7, 23.0, 55.0 and 21% in curd yield, N, P and K uptake over 20 t ha^{-1}. Similarly, a significant build up of organic matter (12.0%), N (2.5%), P (36.4%) and K (5.3%) after harvest was recorded under higher level of applied FYM i.e. 30 t ha^{-1}. Among two sources of boron, granubor-II enhanced curd yield, N, P and K uptake by 3.7, 3.7, 5.6 and 14.8%, respectively as compared to borax, whereas, effect of both sources on soil properties was registered almost similar. B application @ 1.5 kg ha^{-1} enhanced cauliflower yield by 8.0 and 5.0 % increase, respectively over 0.5 and 1.0 kg ha^{-1} B. Similarly, B @ 1.5 kg ha^{-1} exerted a significant effect on N (8.2%), P (14.2%), and K (7.8%) uptake over 0.5 and 1.0 kg ha^{-1} B application. Similarly, B application @ 1.5 kg ha^{-1}, significantly improved soil organic carbon and available P status in soil by 2.9 and 4.2%, respectively over 0.5 kg ha^{-1} B application. Thus, it is inferred from above study that application of B and FYM alongwith recommended doses of N, P and K has huge potential for enhancing autumn cauliflower productivity and sustaining soil health.

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