



Physiological performance, yield and quality of crops as influenced by boron

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ABSTRACT

The objective of this investigation was to assess the direct and residual effect of graded levels of boron (B) on growth, yield and quality parameters of crops in cauliflower-cowpea-okra cropping sequence. For this experimentation, cauliflower was grown as a test crop to assess the direct effect of B fertilization while cowpea and okra were grown as succeeding test crop to assess the residual effect of B fertilization. The study revealed an incremental trend in plant physiological and quality parameters corresponding to the escalating B level. Leaf area index (LAI), total chlorophyll content and NR activities in plant leaves and quality parameters, viz. ascorbic acid, protein and starch in edible portion in all crops were found significantly highest with application of 2 kg B/ha. However, on contrary starch content of the crops exhibited an inverse relationship with the higher B application rate wherein depletion of 31.7% of starch content in crops was observed with application of 2 kg B/ha over the control.

Keywords: Boron, Cropping sequence, Quality, Yield

Boron (B) is an indispensable micronutrient which acts as a key role in crop production and crop quality. B is concerned with an extensive metabolic function in plants. The few propounded tasks of B in plant physiological and biochemical processes encompasses cell wall structure and membrane integrity, sugar transport, lignification, carbohydrate metabolism, phenol metabolism, protein metabolism, nucleic acid metabolism and indole acetic acid (IAA) metabolism (Verma *et al.* 20012). It acts a crucial function in nitrogen (N) metabolism as it augments nitrate levels and decreases nitrate reductase (NR) activity in restricted B environment (Nazir *et al.* 2017). The application of B significantly enhanced quality parameters such as total soluble solids content and curd compactness in cauliflower (Meena *et al.* 2018). B application enhances growth, yield, protein and ascorbic acid content of vegetables and bettered its quality by augmenting protein and ascorbic acid content of roots (Maurya and Bineeta 2016). Kastori *et al.* (1995) recorded a decline in the leaf area and chlorophyll contents

in B stress plants. A decreased nitrate reductase (NR) activity and increased build-up of nitrate were observed in B-deficit plants (Kumar *et al.* 2018). B insufficiency decreases chlorophyll and soluble protein (largely photosynthetic enzymes) concentrations of leaves affecting Hill reaction activity and photosynthetic rate (Jaiswal *et al.* 2015).

Borkakati and Takkar (2000) reported that 44 and 34 % of the alluvial and lateritic soils of Assam were deficient in B. Of late, commercial farming of vegetable cropping sequence particularly cauliflower-cowpea-okra is attaining popularity in Assam owing to its superior nutritive value, taste, brief duration, enhanced productivity and high marketability also. Amongst the vegetable crops, cauliflower, cowpea and okra require micronutrient B for plant growth, maturity and quality aspects. However, suitable requirement of B for vegetable cropping sequence has not been established and recommended. Moreover, appropriate recommendation of B for cauliflower based cropping system is not yet established particularly for the soils of Assam with a view to create boron application more rationale and proficient. Therefore, a field experiment was undertaken to formulate an experiment on effect of graded levels of B on crop physiological and quality parameters in cauliflower-cowpea-okra sequence.

MATERIALS AND METHODS

Field experiment was conducted from 2015–17 at the Experimental Farm of Department of Horticulture, Assam Agriculture University, Jorhat, Assam (26°47'N latitude,

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94°12'E longitudes and altitude of 86.6 m above MSL). The soil of the experimental block was sandy clay loam texture, pH 4.80, high organic carbon (0.85%), low available N (264 kg/ha), medium in available P (14.4 kg/ha) and available K (240 kg/ha). The field experiments were laid out for all the three crops in sequence in a RBD with four replications. Soil application of B at the rates of 0, 0.5, 1.0, 1.5 and 2.0 kg/ha were restricted to cauliflower only to assess the direct effect of B fertilization while B fertilization was exempted in cowpea and okra to assess the residual effect of B fertilization. While the recommended doses of fertilizers and FYM were applied to cauliflower, cowpea and okra at the time of sowing. The crop was raised with recommended package of practices (Table 1). The plant samples were collected at different stages during crop period from each of the individual plots and were subjected for further analysis of physiological and quality parameters.

Leaf area index (LAI) was measured with the help of a leaf area meter.

$$\text{Leaf area index (LAI)} = \text{Leaf area (cm}^2\text{)}/\text{Land area (cm}^2\text{)}$$

Leaf chlorophyll in fresh leaf was estimated by non-maceration method (Hiscox and Israelstam 1979). The in vivo assay of NR activity in leaf was carried out following the methods of Hageman and Flesher (1960). Protein in plant samples were estimated by as per the procedures of Lowry *et al.* (1951). Ascorbic acid in fresh leaf was estimated using 2, 6-Dichlorophenol-Indophenol Visual Titration method (AOAC 2001). Starch content was estimated using Anthrone method (Mcready *et al.* 1950). The total soluble solids (TSS) in the edible portion of the crops were estimated by a digital refract meter (AOAC 2000).

The experimental data acquired from different observations were analyzed statistically by using Fisher's method of analysis of variance in RBD as outlined by Panse and Sukhatme (1985). Significance or non significance of the variance due to various treatment effects was determined by calculating respective 'F' values.

RESULTS AND DISCUSSION

Crop physiological parameters: Results showed that direct application of B fertilization with 2 kg B/ha in

cauliflower exhibited the highest LAI of 6.53 at the maturity stages followed by 6.51 and 5.38 at the curd initiation and vegetative stages, respectively. While the residual impact of B fertilization showed an increasing LAI value of 1.97, 3.08 and 3.09 at the vegetative, curd initiation and maturity stages in cowpea. In respect of okra, LAI value 2.76, 3.87 and 3.88 were recorded at the vegetative, curd initiation and maturity stages in cowpea. Since, B application augmented the vegetative growth of plant up to the certain period and then work on the reproductive unit as evidenced in groundnut, which is the ramification of the increased LAI (Kabir *et al.* 2013). Highest LAI was found with the appliance of 2 kg/ha which has the ability to produce higher metabolites in the cropping sequence.

Direct response of B fertilization improved the total chlorophyll content with the fertilization of 2 kg B/ha as observed at the vegetative stage of crop growth. In cauliflower, the total chlorophyll content of 7.17 mg/g was recorded at the same stage and, its content declined to 7.04 mg/g at the curd initiation stage and 4.97 mg/g at the maturity stage. In cowpea and okra also, a prominent residual effect of B fertilization was observed. In cowpea, the highest total chlorophyll content of 6.95 mg/g was recorded at vegetative stage and then decreased to 6.35 and 4.65 mg/g at the flowering and at maturity stage. Similarly, same trend was replicated in okra with the highest total chlorophyll content of 9.42 mg/g, 7.66 mg/g and 6.03 mg/g at the vegetative, fruiting and maturity stage, respectively with the application of 2 kg B/ha. Possible reason for augmenting chlorophyll content in the plant leaves due to B application might be due to role of B in maintaining the normal configuration of chloroplast (Seth and Aery 2013).

Application of 2 kg B/ha resulted in increasing the highest nitrate reductase (NR) activities in all stages of crop growth. In cauliflower, significantly the highest NR activity of 5.52 $\mu\text{mole NO}_2$ g/fw/h (fw= fresh weight) was recorded in treatment T₅ at the vegetative stage. In cowpea and okra leaves at the vegetative stage, NR activities of 7.32 $\mu\text{mole NO}_2$ g/fw/h and 2.59 $\mu\text{mole NO}_2$ g/fw/h were recorded. The maximum NR activity of 8.82 $\mu\text{mole NO}_2$ g/fw/h was recorded at the flowering stage in cowpea followed by 5.69 $\mu\text{mole NO}_2$ g/fw/h in okra at the same stage. This

Table 1 Details of field experiment for cauliflower-cowpea-okra cropping sequence

Particular	Test crops		
	Cauliflower	Cowpea	Okra
Module of crop test	To assess direct effect of B fertilization	Residual effect of B fertilization	
Variety	Girija	KSP-170	Green gold
Plot size	4 × 3 sq m	4 × 3 sq m	4 × 3 sq m
Spacing	55 cm × 40 cm	40 cm × 20 cm	45 cm × 30 cm
B levels	0, 0.5, 1.0, 1.5 and 2.0 kg/ha	B application exempted	
Fertiliser dose	80:60:60 kg/ha N:P ₂ O ₅ :K ₂ O	15:35:10 kg/ha N:P ₂ O ₅ :K ₂ O	50:50:50 kg/ha N:P ₂ O ₅ :K ₂ O
Farmyard manure (FYM)	10 t/ha	9 t/ha	10 t/ha

incremental trend of NR activities in plant leaves for all the crops with added level of B may be attributed to the fact that the adequate and quick supply of B through phloem tissues to the floral meristems can influence the uptake and metabolism of N (Matas *et al.* 2009).

Quality parameters: In cauliflower, pooled data revealed that application of 2 kg B/ha recorded significantly the highest ascorbic acid content in all stages of crop growth. In cauliflower leaves, the highest ascorbic acid content of 53.7 mg 100/g was recorded at the vegetative stage while, its content augmented to 55.4 mg 100/g at the curd initiation stage and further, its content declined to 40.8 mg 100/g at the maturity stage. Similarly, a prominent residual effect of B fertilization was recorded in cowpea and okra leaves with the ascorbic acid content of 32.1 mg 100/g and 26.5 mg 100/g at the vegetative stage (Table 2).

Significantly, the highest ascorbic acid content of 24.5 mg 100/g was registered under treatment T₅ in curd of cauliflower. Residual effect of B application amplified the maximum ascorbic acid content to 56.3 mg 100/g in pod of

cowpea while, in fruit of okra, its content declined to the lowest by 17.4 mg 100/g. Probable reason of the role of B in augmenting the ascorbic acid in leaves and edible portion of crops might be attributed to the soil application of B in crops which resulted in improved physiological activities and catalytic action. Further, B influences the activity of biosynthesis of amino acid and protein and remobilization of amino acids from protein which affects the partitioning of nitrogenous compounds. In the presence of B, protein and ascorbic acid synthesis reaction is more so ultimately the level of protein and ascorbic acid is increased (Allen and David 2006). Since B acts as a vital role in the translocating carbohydrates from leaves to other plant parts, larger concentrations of ascorbic acid could have been translocated to the curd (Randhawa and Bhail 1974).

Data showed that addition of 2 kg B/ha recorded the highest protein content of 3.36, 5.80 and 4.42% in the curd of cauliflower, pod of cowpea and fruit of okra, respectively. It might be due to the fact that B helps in metabolic process, sugar translocation, protein synthesis and plant defense

Table 2 Effect of boron application on leaf area index (LAI), total chlorophyll content, in-vivo nitrate reductase activity and ascorbic acid

Boron levels (kg/ha)	Leaf Area Index (LAI)			Total chlorophyll content (mg/100 g)			In-vivo nitrate reductase activity (μmole NO ₂ /gfw/h)			Ascorbic acid (mg/100 g)		
	Cauliflower	Cowpea	Okra	Cauliflower	Cowpea	Okra	Cauliflower	Cowpea	Okra	Cauliflower	Cowpea	Okra
<i>Vegetative stage</i>												
B ₀	5.16	1.74	2.52	5.20	4.98	7.40	3.10	4.62	1.65	37.16	22.59	17.19
B _{0.5}	5.21	1.81	2.58	6.09	5.65	8.05	4.46	5.25	1.92	44.75	25.54	19.94
B _{1.0}	5.27	1.86	2.63	6.59	6.22	8.57	5.35	6.15	2.19	48.43	28.21	22.36
B _{1.5}	5.31	1.92	2.69	6.92	6.61	9.01	5.40	6.60	2.32	51.78	30.30	24.53
B _{2.0}	5.38	1.97	2.76	7.17	6.95	9.42	5.52	7.32	2.59	53.58	32.09	26.49
CD _(P=0.05)	0.03	0.02	0.03	0.15	0.16	0.14	0.08	0.08	0.09	1.95	1.04	1.45
<i>Curd initiation stage</i>												
B ₀	6.24	2.85	3.63	5.05	4.52	5.65	4.40	5.51	3.60	45.74	23.39	19.59
B _{0.5}	6.33	2.91	3.69	5.90	5.18	6.35	6.47	6.75	5.02	48.76	26.21	22.49
B _{1.0}	6.36	2.95	3.74	6.42	5.67	6.91	7.36	7.65	5.29	50.91	28.56	24.76
B _{1.5}	6.42	3.01	3.79	6.77	6.04	7.31	7.41	8.10	5.42	53.01	31.10	26.92
B _{2.0}	6.51	3.08	3.87	7.04	6.35	7.66	7.53	8.82	5.69	54.94	34.39	28.93
CD _(P=0.05)	0.02	0.02	0.03	0.16	0.18	0.16	0.08	0.08	0.08	1.88	1.58	1.41
<i>Maturity stage</i>												
B ₀	6.28	2.85	3.64	3.66	3.16	4.49	2.39	3.68	1.40	30.94	19.99	14.59
B _{0.5}	6.36	2.91	3.69	4.23	3.81	5.05	2.49	3.85	1.62	34.01	22.81	17.36
B _{1.0}	6.42	2.96	3.75	4.57	4.27	5.39	3.00	4.75	1.89	36.11	25.16	19.76
B _{1.5}	6.48	3.01	3.79	4.78	4.63	5.72	3.48	5.20	2.02	38.27	25.09	21.70
B _{2.0}	6.53	3.09	3.88	4.97	4.65	6.03	3.90	5.92	2.29	40.31	27.04	23.74
CD _(P=0.05)	0.03	0.02	0.03	0.12	0.04	0.16	0.08	0.08	0.09	30.94	19.99	14.59

Table 3 Distribution of crop quality parameters and crop yield in the sequence

Boron levels (kg/ha)	Ascorbic acid (mg/100 g)			Protein (%)			Starch (mmol hexose/m ²)			Total soluble solids (⁰ Brix)			Crop yield (q/ha)		
	Cauli- flower	Cowpea	Okra	Cauli- flower	Cowpea	Okra	Cauli- flower	Cowpea	Okra	Cauli- flower	Cowpea	Okra	Cauli- flower	Cowpea	Okra
B ₀	21.7	50.0	12.7	2.32	4.21	3.37	2.21	2.17	2.24	6.80	5.40	6.61	190.9	56.9	170
B _{0.5}	22.2	51.3	13.9	2.79	4.80	3.84	2.14	2.10	2.17	7.21	5.80	6.90	200.3	61.8	180
B _{1.0}	22.9	52.5	15.2	2.96	5.22	4.01	2.07	2.03	2.21	7.40	6.00	7.11	212.6	65.9	188
B _{1.5}	23.8	53.4	16.2	3.21	5.51	4.26	1.81	1.71	1.74	7.61	6.31	7.32	223.4	68.6	199
B _{2.0}	24.6	56.3	17.4	3.36	5.80	4.42	1.51	1.47	1.54	7.90	6.52	7.50	232.5	71.5	206
CD _(p=0.05)	0.24	0.32	0.18	0.08	0.07	0.07	0.05	0.07	0.08	0.02	0.07	0.08	5.20	1.76	6.29

mechanism (Mandal and Das 2014). Jaiswal *et al.* (2015) also reported that increase in protein content might be due to the significant role of B in protein and nucleic acid metabolism.

Results showed that the starch content decreased with the application of B wherein the lowest was recorded with 2 kg B/ha in all the stages of crop growth in the cropping sequence. The lowest starch content of 1.51 mmol hexose/m² was recorded with 2 kg B/ha in curd of cauliflower. The residual effect of B fertilization decreased the starch content to the lowest by 1.47 mmol hexose/m² in pod of cowpea followed by 1.54 mmol hexose/m² in the fruit of okra with the 2 kg B/ha. This signified an inverse relationship between added levels of B with starch content in leaves. This decrease in starch content in edible portion of crops might be ascribed to the fact that application of a higher dose of B increased the starch phosphorylase enzyme activities which in turn decreased starch content and might be accountable for the higher assimilation of starch (Chatterjee *et al.* 2005).

Data showed that direct fertilization of 2 kg B/ha augmented the TSS content upto 7.9⁰ Brix in curd of cauliflower while residual effect of the same B dose improved the TSS content to 6.5⁰ and 7.5⁰ Brix in pod of cowpea and fruit of okra. This enhanced concentration of TSS in the edible portion of crops might be probably due to improved physiological activities and catalytic action on addition of B which further intensified the translocation of sugars and growth modifying substances in plants (Singh *et al.* 2002).

Crop yield: Boron application exerted a significant impact on yield of all crops (Table 3). In cauliflower, the maximum curd yield of 232 q/ha was noticed on direct B application with 2 kg ha⁻¹ with a significant yield augmentation up to 17.8% over the control (190 q/ha). While the residual impact of B fertilization with 2 kg B/ha in cowpea and okra escalated the highest pod yield to 71.5 q/ha and fruit yield of 206 q/ha. An increase in yield up to 20.4% over the control (56.9 q/ha) in cowpea and 17.5% over the control (170.0) in okra were observed. The improvement in cauliflower yield due to B fertilization might be due to the improved availability and translocation of nutrients to plants, thus producing sufficient carbohydrates and proteins beside with its function in increasing their translocation from the place of synthesis to the storage organs (Verma *et al.* 2012).

Based on the finding of present study it can be inferred that application of 2 kg B/ha was found significant and most effective in augmenting the crop physiological parameters like LAI, total chlorophyll content and NR activities in plant leaves and quality parameters, viz. ascorbic acid and protein in edible portion in all crops as compared to other boron levels except starch content.

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