Introduction

In India, on an average 33 percent soils are deficient in boron (Singh, 1999). On B deficient soils, the production of food grain, vegetables and fruits is drastically low. Green vegetables are a good source of minerals, vitamins and fibre in human diet. The demand of green vegetables is soaring every year. Okra, also named Lady's finger (*Abelmoschus esculetus* (L.) *Moench*) is a very popular green vegetable in several countries. The production of okra is lower in the areas of low B fertility. Several workers have reported the response of okra to B application (Suryanarayana and Rao, 1981; Chattopadhyay et al., 2003; Abdul-Rafique and Abdul-Muhsi, 2004). As the amount of B to be uniformly applied in the field is very small, boronated superphosphate can be used for the uniform application of B. It is also important to standardize the method of its application to achieve the highest production and use efficiency of applied nutrients. The present report examines the effect of different levels of B supplementation to diammonium phosphate (DAP) and the time of application on yields, B and P uptake by okra (*Abelmoschus esculetus* (L.) *Moench*).

Materials and Methods

A field experiment was conducted during Kharif 07-08 on Okra (cv. Parbhani Kranti) at Jeolikote (Distt. Nainital, Uttarakhand). The experimental soil had a sandy loam texture, 6.5 pH and 0.217 dS m^{-1} electrical conductance in 1: 2 soil water suspension, 13.5 g organic C and 0.58 mg hot water soluble B kg^{-1} soil. The treatments were: 0 B (Control), 0.10% B (100% Basal), 0.20% B (100% Basal), 0.30% B (100% Basal), 0.45% B (100% Basal), 0.60% B (100% Basal), 0.75% B (100% Basal), 0.30% B (100% Top dressing at 30 d after emergence (DAE)), 0.30% B (100% Top dressing at 45 DAE), 0.30% B (50% Basal + 50% Top dressing at 30 DAE), 0.30% B (50% Basal + 25% Top dressing each at 30 and 45 DAE) and foliar spray of 0.15% B alone at 30 and 45 DAE. These treatment were imposed in a randomized block design with three replicates. The gross plot size was 3 × 1.5 m. Boron supplementation of diammonium phosphate (DAP) was done through Granubor II (15 % B). All plots received application of 80 kg N and 60 kg ha^{-1} P_2O_5 through DAP and urea and 60 kg ha^{-1} K_2O as muriate of potash. Seeds of okra (cv. Parbhani Kranti) were sown with a row to row spacing of 60 cm and a plant to plant spacing of 40 cm. Half of the N dose was top dressed in two splits at 25 and 50 d after emergence. The number of flowers per plant was recorded on five randomly selected plants per plot. Green fruits were harvested from each plot in nine pickings and weighed. A portion of the harvest was washed thoroughly first in tap water, then in 0.1 M HCl and finally in distilled water. The fruits were cut into small pieces, air dried and finally oven dried at 60˚C to record the dry matter yield. At the end of last picking, the plants were harvested close to soil surface and washed thoroughly and dried as indicated above. One g finely ground plant sample was soaked in 2 ml 15% magnesium nitrate solution, ashed in a muffle furnace at 550˚C. The ash was dissolved in 2 ml of 6 N HCl, diluted and filtered. The filtrate was analyzed for B by the Azomethine-H method and for P by the yellow molybdovanadate method (Tandon, 2003). Total B and P uptake by crop was computed. Apparent use efficiencies of applied B and P were calculated taking the uptake values of the control into account.

Results and Discussion

Application of B either by basal application to soil or by foliar spray increased the number of flowers per five plants, yield of fruits and total dry biomass yield significantly over control (Tab. 1). The highest number of flowers/5 plant was recorded in the treatment where 0.30 % B was added with application of half quantity as basal application and rest half was top dressed in two equal splits at 30 and 45 DAE. The highest yield (8511 kg fresh wt. ha^{-1}) was recorded with application of 0.60% B as 100 per cent basal however, a comparable yield was obtained with application of 0.75% B as 100 percent basal or 0.30% B as 50 percent basal and rest in two equal top dressings at 30 and 45 DAE. A similar trend was noted for noted for total biomass (dry matter) yield. Kumar and Sen (2004) reported that application of 20 kg borax ha^{-1} to okra (cv. Prabhani Kranti) increased the number of nodes on the main axis, number of fruits per plant, fruit yield per plant, yield per hectare and net return per hectare significantly over the control.

The effect of different treatments on the concentration of B and P in plant tissue was statistically not significant possibly because of a dilution effect in both cases (Tab. 2). However, the concentration of B in okra plant increased from 27.7 µg g^{-1} plant tissue (control) to 33.8 µg g plant tissue (0.10% B (100% Basal) or 0.15% B (Foliar spray at 30 and 45 DAE). Even at the highest basal application rate of B under 0.75% B (100% Basal), B concentration in plants remained at 31.4 µg g^{-1} plant tissue and did not reach the toxicity limit (72 µg g^{-1} plant tissue) reported by Al Badrawy and Bussler (1977).

Application of B either by basal application to soil or by foliar spray increased the total uptake of B and P by the crop significantly over control. The highest total B uptake (225.8 g B ha^{-1}) was recorded in the treatment receiving 0.60% B as 100 percent basal application to soil. The highest total P uptake (18.84 kg P ha^{-1}) was recorded in the treatment receiving 0.75% B as 100 percent basal. Teare (1974) reported that B-deficient roots of bean contained about half the level of P g^{-1} dry weight as the control, the major reduction was in the inorganic P fraction. Storage forms of P and hexose-P were also reduced. Robertson and Loughman (1974) also noted that B deficiency reduced P absorption by whole plants and root segments of *Vicia faba*. The effect of different treatments on the content of hot water soluble B was statistically not significant.

The highest apparent recovery of applied B (70.5 %) was recorded at application of 0.15% B as two foliar sprays at 30 and 45 DAE. The highest apparent recovery of foliar applied B could be ascribed to complete avoidance of soil fixation or leaching losses of B. In general, the apparent recovery value of B applied as 100 percent basal decreased with increasing B doses. The apparent recovery of applied B at application of 0.60% B as 100 percent basal resulting in the highest yield was only 19.8 percent while the value for application of 0.30% B as 50 percent basal and rest in two equal top dressings at 30 and 45 DAE which gave a comparable yield was more than 1.8 fold higher (35.9%).

The highest apparent recovery of applied P (71.9%) was recorded under application of 0.75% B as 100% basal. In general, the apparent recovery value of P increased with the increasing B doses. The apparent recovery of applied P at application of 0.60% B as 100 percent basal, which gave the highest yield was only 64.8 percent while the value for application of 0.30% B as 50 percent basal and rest in two equal top dressings at 30 and 45 DAE which gave a comparable yield was 54.2 percent. It appeared from the data that the use efficiency of applied P was synergistically influenced by B fertilization. Subrahmanyam et al. (1993) reported that the total lipid content including that of phospholipids in B deficient okra had fallen to 78 and 87% of control (optimum supply of B) values for roots and leaves, respectively.

Thus, on B deficient acidic soils application of 0.30% B as 50 per cent basal through B supplemented DAP (60 kg P_2O_5 ha^{-1}) and rest in two equal top dressings at 30 and 45 DAE can be recommended for getting optimum yields of okra.

References

Abdul Rafique AKM, Abdul Muhsi AA. Effect of micronutrient supplement in growth and development of okra (Abelmoschus esculentus, (L.) Moench). Bangladesh Journal of Botany, 2004; 33: 129-131.

Al Badrawy R, Bussler W. Symptoms of boron deficiency and boron excess in Hibiscus esculentus. Zeitschrift-fur-Pflanzenernahrung-und-Bodenkunde, 1977; 140: 505-513.

Chattopadhyay SB, Mukhopadhya TP, Thapa U. Response of foliar feeding of boron and molybdenum on growth and yield of okra in Terai Zone of West Bengal Environment & Ecology, 2003; 21: 702-705.

Kumar M, Sen NL. Effect of zinc, boron and gibberellic acid on yield of okra [Abelmoschus esculentus (L.) Moench]. Indian Journal of Horticulture, 2005; 62: 308-309.

Robertson GA, Loughman BC. Reversible effects of boron on the absorption and incorporation of phosphate in Vicia faba L. New Phytologist, 1974; 73: 291-298.

Singh MV. Current status of responses of micronutrients to crops in different agro ecological region- An experience of AICRP micro and secondary nutrient and pollutant elements in soils and plants. Fertilizer News, 1999; 44(4): 63-82.

Subrahmanyam D, Sah R, Rathore,VS. Influence of boron deficiency on growth, protein and lipid contents in tomato and okra seedlings. Acta Physiologiae Plantarum, 1993; 15: 1, 25-30.

Suryanarayana V, Rao KVS. Effect of growth regulators and nutrient sprays on the yield of okra. Vegetable Science, 1981; 8: 12-14.

Tandon HLS. Methods of analysis of soils, plants, waters and fertilizers. Fertilizer Development and Consultation Organization, New Delhi, India, 1993;144.

Teare ID. Boron nutrition and acid-soluble phosphorus compounds in bean roots. HortScience, 1974; 9: 236-238.

Table 1: Effect of different B treatments on number of flowers, yield and total biomass yield of okra (Kharif, 2007). DAE = days after emergence

Treatments	Flowers/ 5plants	Yield (kg fresh fruit wt.ha^{-1})	Total Biomass yield (kg dry wt. ha^{-1})
0.00% B	7	3111	2572
0.10% B (100% Basal)	12	5326	4381
0.20% B (100% Basal)	15	6500	5308
0.30% B (100% Basal)	17	7874	6476
0.45% B (100% Basal)	18	8122	6633
0.60% B (100% Basal)	17	8511	7000
0.75% B (100% Basal)	16	8337	6952
0.30% B (100% Top dressing at 30 DAE)	17	6333	5138
0.30% B (100% Top dressing at 45 DAE)	17	6578	5331
0.30% B (50% Basal + 50% Top dressing at 30 DAE)	19	7841	6362
0.30% B (50% Basal + 25% Top dressing at 30 DAE + 25% Top dressing at 45 DAE)	20	8315	6790
0.15% B (Foliar spray at 30 and 45 DAE)	16	7593	6154
SEM	1	121	110
C.D. (p = 0.05)	3	356	321

Table 2: Effect of different B treatments on the concentration of B and P in plant tissue and their total uptake by okra crop. DAE = days after emergence

Treatments	B conc. ($mg\ kg^{-1}$)	P conc. ($g\ kg^{-1}$)	Total B uptake ($g\ ha^{-1}$)	Total P uptake ($kg\ ha^{-1}$)
0.00% B	27.73	1.84	71.3	4.7
0.10% B (100% Basal)	33.80	2.59	148.8	11.4
0.20% B (100% Basal)	30.50	2.27	161.7	12.0
0.30% B (100% Basal)	33.12	2.57	214.6	16.6
0.45% B (100% Basal)	32.01	2.77	212.3	18.4
0.60% B (100% Basal)	32.24	2.42	225.8	17.0
0.75% B (100% Basal)	31.36	2.72	218.2	18.8
0.30% B (100% Top dressing at 30 DAE)	29.93	2.05	154.1	10.5
0.30% B (100% Top dressing at 45 DAE)	29.29	2.16	156.1	11.5
0.30% B (50% Basal + 50% Top dressing at 30 DAE)	31.13	2.31	197.5	14.9
0.30% B (50% Basal + 25% Top dressing at 30 DAE + 25% Top dressing at 45 DAE)	31.11	2.09	211.2	14.2
0.15% B (Foliar spray at 30 d and at 45 d after emergence)	33.79	2.24	208.7	13.7
SEM	1.96	0.30	11.7	1.7
C.D. (p = 0.05)	NS	NS	34.4	5.0