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Use of boron and molybdenum to improve broccoli production

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ABSTRACT

Boron (B) and molybdenum (Mo) are important essential micronutrients required for normal plant growth and development and deficiencies are very common in Cole crops. To combat this and to produce quality broccoli cv. Pusa KTS 1 with more yield the present investigation was conducted during rabi season of 2015-16 at Horticulture Research Farm of Department of Applied Plant Science (Horticulture), Babasaheb Bhimrao Ambedkar University, Lucknow, Uttar Pradesh, India. There were ten treatments comprising recommended dose of fertilizers (RDF), Borax at two levels (1.5 and 2.5%), Ammonium molybdate at two levels (1.5 and 2.5%) and control without any fertilizer application and laid out at randomized block design with three replications. The observations and statistical analysis clearly revealed that the vegetative growth (plant height, stem circumference, plant spreading, number of leaves, length and width of leaves etc), curd weight, yield, and curd physico-chemical qualities were improved with application of boron and molybdenum in addition with RDF. However, combined application of boron and molybdenum were more effective than their sole application. Among the several applications, treatment T_7 [RDF + Borax (1.5%) + Ammonium molybdate (2.5%)] was found as the best combination for good growth, better yield and superior quality curd production of broccoli cv. Pusa KTS 1 under Lucknow condition.

Keywords **:** Boron, broccoli, micronutrient, molybdenum

Broccoli (*Brassica oleracea*L. var. *italica*Plank) is commonly known as cole crops (Sermenli, 2011) originated in Mediterranean region belongs to Crucifarae family. Thegenus *Brassica* containsSulphoraphane and glucocinolate as anti-cancer agent reported by Cancer Research Centre of USA (Damato*et al.*, 1994). With the recent advancement of horticulture,it is mostly cultivated in hilly states of India like Himachal Pradesh, Uttar Pradesh, Jammu and Kashmir, Nilgiri Hills and Northern plains of India. Broccoli is considered as a valuable vegetable due to presence of vitamins, antioxidants, glucosinolates and other anti-carcinogenic compounds (Parente*et al.*, 2013). 100 gram broccoli contains Carbohydrate 7g, Fat-0.4g, Sodium-33mg, Potassium-316mg, Dietary fiber-2.6g, Sugar-1.7g, Protein-2.8 g, Vitamin A-12 IU, Vitamin C-148 mg along with Calcium,Iron, Vitamin B_6, Magnesium, Phosphorus (Annon., 2015). Its florets also showed some amount of omega-3 fatty acidswhich help to control bad cholesterols. Thus, broccoli market value is becoming very high,specially in super markets, big hotels and restaurant etc.

Nutrient management is an importantpractice to get good crop. Broccoli being a cole crop is heavy feeder of plant nutrients. Apart from major nutrients boron (B) and molybdenum (Mo) are essential micronutrients required for its normal growth and development as deficiency of boron and molybdenum are very common in Cole crops. This deficiency causes many anatomical, physiological and biological disorders (Shelp and Liu, 1992). The affected curds have deformities in shape, size, bitter in taste and less productive which adversely affects the market value. It was seen that boron increased growth and yield of the crops as it helps in cell wall development, cell division, cell extension and pollen tube growth (Tandon, 1991). On the other hand molybdenum (Mo) helps in N_2 fixation because it is a part of metaprotein nitrogenase (Gupta and Vyas, 1994). Molybdenum is also an essential micronutrient in symbiotic nitrogen fixation. Thus, Mo deficiency can cause nitrogen deficiency in plants and it also helps to convert inorganic phosphorus into organic forms in the plant. Keeping these views, the present study was aimed to increase yield and quality of broccoli with optimized application of boron and molybdenum.

MATERIALS AND METHODS

Present experiment was carried out at Horticulture Research Farm of Department of Applied Plant Science (Horticulture), Babasaheb Bhimrao Ambedkar University, Lucknow, Uttar Pradesh, India during Rabi season of 2015-16. The seedlings of broccoli cv. Pusa KTS 1 were prepared in the nursery and planted in the main field at 45×35 cm spacing. Two doses of borax and ammonium molybdate (1.5 and 2.5% each) were studied with Recommended Dose of Fertilizers (RDF) having total ten treatments and three replications laid out under randomized block design. Soil of experimental field was silty loam having very high pH of 8.2 and comes under subtropical climatic zone with dry and hot summer. Recommended dose of fertilizers *i.e.*150 kg N,60 kg P_2O_5, 60 kg K_2O per hectare were applied in the form of Urea, Single Super Phosphate and Murate of Potash, respectively. Half of nitrogen was applied during the time

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Table 1: Effect of boron and molybdenum on change of vegetative growth of broccoli

Treatments	Plant height (cm)		Stem circumference (cm)		Plant spreading (cm)			
					30 DAT		60 DAT	
	30 DAT	60 DAT	30 DAT	60 DAT	East -West	North - South	East-West	North - South
T_0-Control	22.38	40.00	1.30	2.64	27.83	32.03	39.90	44.89
T_1-Recommended dose of fertilizer (RDF)	25.76	39.11	1.81	3.52	30.27	35.87	43.70	45.47
T_2- RDF + Borax (1.5%)	24.24	39.34	1.89	3.67	30.94	33.28	42.42	45.67
T_3- RDF + Borax (2.5%)	26.90	42.89	1.65	3.35	31.68	34.35	42.61	46.28
T_4-RDF + Ammonium molybdate (1.5%)	28.54	43.11	1.44	3.32	29.94	32.45	43.49	47.15
T_5-RDF + Ammonium molybdate (2.5%)	29.97	44.22	1.57	3.10	30.95	33.15	41.15	45.38
T_6-RDF + Borax (1.5%) + Ammonium molybdate (1.5%)	30.26	45.83	1.80	3.75	32.61	37.21	40.71	47.68
T_7-RDF + Borax (1.5%) + Ammonium molybdate (2.5%)	31.40	47.00	2.10	4.25	33.27	38.90	45.79	49.12
T_8-RDF + Borax (2.5%) + Ammonium molybdate (1.5%)	29.85	45.33	1.63	3.69	32.79	36.84	44.57	48.93
T_9-RDF + Borax (2.5%) + Ammonium molybdate (2.5%)	25.33	40.89	1.49	3.57	30.82	34.69	42.32	46.19
SEm (±)	**1.59**	**3.53**	**0.09**	**0.23**	**0.74**	**0.53**	**0.74**	**0.49**
LSD (0.05)	**4.78**	**10.51**	**0.29**	**0.69**	**2.23**	**1.60**	**2.24**	**1.49**

Table 1 Contd.

Treatments	No. of leaves		Length of leaves (cm)		Width of leaves (cm)	
	30 DAT	60 DAT	30 DAT	60 DAT	30 DAT	60 DAT
T_0-Control	7.04	12.67	22.71	35.36	11.74	21.96
T_1-Recommended dose of fertilizer (RDF)	7.24	13.89	25.62	36.81	13.11	24.04
T_2- RDF + Borax (1.5%)	7.59	14.11	24.28	38.17	12.80	25.19
T_3- RDF + Borax (2.5%)	7.42	13.66	23.50	36.55	12.62	25.79
T_4-RDF + Ammonium molybdate (1.5%)	7.58	13.89	24.17	37.96	13.51	26.10
T_5-RDF + Ammonium molybdate (2.5%)	7.84	13.44	24.73	37.62	13.22	26.17
T_6-RDF + Borax (1.5%) + Ammonium molybdate (1.5%)	7.66	13.33	26.44	37.54	13.19	25.96
T_7-RDF + Borax (1.5%) + Ammonium molybdate (2.5%)	8.39	15.11	28.21	40.14	14.10	26.73
T_8-RDF + Borax (2.5%) + Ammonium molybdate (1.5%)	7.00	14.33	25.10	38.03	13.43	26.14
T_9-RDF + Borax (2.5%) + Ammonium molybdate (2.5%)	7.77	13.55	24.93	37.59	13.11	24.66
SEm (±)	**0.41**	**0.54**	**1.07**	**1.08**	**0.44**	**0.52**
LSD (0.05)	**NS**	**1.62**	**3.18**	**3.20**	**1.31**	**1.56**

of transplanting and remaining 50 per cent of nitrogen was applied as top dressing after 30 days of transplanting. The effect was recorded in respect of vegetative growth (plant height, spreading, number and size of leaves), curd yield and curd quality (TSS, acidity, vitamin C and sugars etc) which were determined as per the standard procedures of AOAC (AOAC, 2000). The observed data were statistically analysed and treatment effects were compared at 5 % level of significance (Sahu and Das, 2014).

RESULTS AND DISCUSSION

Effect of boron and molybdenum on vegetative growth of broccoli

Experimental findings (Table 1) on use of boron and molybdenum showed that it has positive effect on

Table 2: Effect of boron and molybdenum on weight of broccoli curd with and without guard leaves

Treatments	Curd weight with guard leaves (g)	Curd weight without guard leaves (g)	Yield (kg plot^{-1})	Yield (q ha^{-1})
T_0-Control	248.33	207.00	1.86	131.91
T_1-Recommended dose of fertilizer (RDF)	335.00	279.67	2.51	178.01
T_2- RDF + Borax (1.5%)	334.67	291.67	2.62	185.82
T_3- RDF + Borax (2.5%)	310.67	252.00	2.26	160.28
T_4-RDF + Ammonium molybdate (1.5%)	326.33	270.67	2.43	172.34
T_5-RDF + Ammonium molybdate (2.5%)	282.67	231.00	2.07	146.81
T_6-RDF + Borax (1.5%) + Ammonium molybdate (1.5%)	375.33	309.33	2.78	197.16
T_7-RDF + Borax (1.5%) + Ammonium molybdate (2.5%)	406.33	329.67	2.96	209.93
T_8-RDF + Borax (2.5%) + Ammonium molybdate (1.5%)	364.00	306.33	2.75	195.04
T_9-RDF + Borax (2.5%) + Ammonium molybdate (2.5%)	359.67	292.33	2.63	186.52
SEm (±)	**22.33**	**21.48**	**0.19**	**13.71**
LSD (0.05)	**66.87**	**64.31**	**0.57**	**41.05**

Table 3: Effect of boron and molybdenum on curd initiation, maturity and physical characters of broccoli

Treatments	Days to curd initiation	Days to curd harvest after initiation	Number of frauds curd^{-1}	Curd length (cm)	Curd diameter (cm)	Curd moisture (%)
T_0-Control	62.70	20.03	7.99	11.58	14.29	74.03
T_1-Recommended dose of fertilizer (RDF)	63.46	18.89	9.65	12.47	15.28	75.15
T_2- RDF + Borax (1.5%)	64.07	16.49	10.84	13.02	14.48	76.69
T_3- RDF + Borax (2.5%)	64.01	19.05	8.13	12.30	15.05	76.80
T_4-RDF + Ammonium molybdate (1.5%)	62.65	17.83	8.50	12.29	15.21	77.69
T_5-RDF + Ammonium molybdate (2.5%)	65.28	17.91	8.84	12.07	14.86	74.44
T_6-RDF + Borax (1.5%) + Ammonium molybdate (1.5%)	61.48	17.15	11.05	13.13	15.67	80.12
T_7-RDF + Borax (1.5%) + Ammonium molybdate (2.5%)	60.29	15.58	12.25	14.06	17.15	82.55
T_8-RDF + Borax (2.5%) + Ammonium molybdate (1.5%)	62.04	16.22	9.89	13.34	16.15	79.11
T_9-RDF + Borax (2.5%) + Ammonium molybdate (2.5%)	63.46	16.83	9.96	12.25	15.38	77.17
SEm (±)	**0.83**	**0.88**	**0.77**	**0.39**	**0.51**	**1.46**
LSD (0.05)	**2.50**	**2.62**	**2.33**	**1.18**	**1.54**	**4.39**

increase of plant height significantly at all stages of crop growth over control. Among the various treatments the maximum plant height at 30 and 60 days after transplanting (DAT) was 31.40 cmand 47.00 cm, respectively observed in the treatment T_7 [RDF + Borax (1.5%) + Ammonium molybdate (2.5%)] and the lowest was in control. Similarly, the circumference at basal area of stem was measured better in the treated plants than the control and the maximum was under treatment T_7 [RDF + Borax (1.5%)+Ammonium molybdate (2.5%)].

Likewise, the number of leaves were also counted maximum underT_7 [RDF + Borax (1.5%) + Ammonium molybdate (2.5%)], however, it was statistically non-significant at 30 DAT. Similarly, length and width of leaves were also measured better under treated plants as compared to control plants. Among the treatments, application of RDF + Borax (1.5%) + Ammonium molybdate (2.5%) (T_7) was found as the best.Whereas, the minimum value was observed in the treatment T_0(control).In all cases of vegetative growth it was clearly

Table 4: Effect of boron and molybdenum on quality of broccoli curd

Treatments	Total sugars (%)	Reducing sugar (%)	Non-reducing sugar (%)	Vitamin C (mg 100^{-1} g)	T.S.S. (^{0}Brix)	Titratable acidity (%)
T_0-Control	3.04	2.59	0.35	81.37	7.37	0.32
T_1-Recommended dose of fertilizer (RDF)	3.26	2.79	0.51	83.41	8.03	0.36
T_2- RDF + Borax (1.5%)	3.42	2.73	0.69	86.47	8.10	0.41
T_3- RDF + Borax (2.5%)	3.33	2.79	0.53	85.25	7.73	0.36
T_4-RDF + Ammonium molybdate (1.5%)	2.90	2.48	0.40	87.34	8.20	0.39
T_5-RDF + Ammonium molybdate (2.5%)	3.23	2.73	0.53	85.98	8.20	0.38
T_6-RDF + Borax (1.5%) + Ammonium molybdate (1.5%)	3.01	2.32	0.68	87.61	8.97	0.34
T_7-RDF + Borax (1.5%) + Ammonium molybdate (2.5%)	3.71	3.12	0.92	91.70	9.10	0.42
T_8-RDF + Borax (2.5%) + Ammonium molybdate (1.5%)	3.53	2.82	0.70	87.41	7.57	0.36
T_9-RDF + Borax (2.5%) + Ammonium molybdate (2.5%)	3.16	2.80	0.69	85.32	8.20	0.36
SEm (±)	**0.27**	**0.14**	**0.08**	**1.23**	**0.43**	**0.06**
LSD (0.05)	**0.80**	**0.43**	**0.23**	**3.70**	**1.29**	**0.17**

observed that combined effect of boron and molybdenum was better as compared to their sole application along with RDF. But, interestingly, the increased amount of boron and ammonium molybdate more that 2.5% were not good and had a negative effect. These result corroborated with the findings of Singh and Singh (2015) while, experimented on effect of boron and molybdenum in broccoli. However, no literature had been found to explain this factor. The improvement in vegetative growth in term of plant height, stem circumference, number of leaves,plant spreading, length and width of leaves, might be due to effective influence of boron and molybdenum which enhanced photosynthetic activity, efficient assimilation of photosynthetic products and it resulted in rapid cell division and cell elongation in the growing portions of the plant ultimate caused a better vegetative growth. Nitrate reductase activity is reduced by Mo deficiency which is needed to convert inorganic phosphates to organic forms and also involved in several enzyme systems like nitrogeneous nitrate reductase, xanthine oxidase, aldehyde oxidase and sulfate oxidase. Nitrogen metabolism is adversely affected by Mo deficiency. Therefore, addition of Mo in the treatments caused better nitrogen metabolism and showed higher vegetative growth of broccoli in the present experiment.

Effect of boron and molybdenum on yield and yield attributing characters

The curd weight was measured in two ways with and without guard leaves as per market requirements. It was seen that the average curd weight (Table 2) was effectively improved due to the application of boron and molybdenum. Application of boron @ 1.5% with RDF caused a significant increase in curd weight (without leaves) above the RDF which proved that boron had positive effect on curd development. However, more amount of boron (2.5%) did not improved curd weight and both the doses of Ammonium molybdenum failed to increase curd weight (1.5% and 2.5%) when applied solely with RDF. But, the combine application of boron (1.5%) and Ammonium molybdenum (2.5%) [T_7- RDF + Borax (1.5%) + Ammonium molybdate (2.5%)] surprisingly increased the curd weight above all the treatments. Subsequently, as a result, highest yield (2.96 kg/plot or 209.93 q/ha, when planted at 45x35 cm spacing) was obtained from treatment T_7[RDF + Borax (1.5%)+Ammonium molybdate(2.5%)] followed by T_6.Singh *et al.* (2006), Mohanta*et al.* (2013), Pal *et al.* (2015) and Meena *et al.* (2015)also stated similar findings of higher yield with application of zinc, boron, molybdenum and other micronutrients in broccoli, carrot and tomato, respectively.

Effect of boron and molybdenum on quality of curds

Treatment T_7also caused early initiation (Table 3) as well as early harvesting of curds (60.29 days for curd initiation and 15.58 days from initiation to harvesting). Although, control plants showed early initiation of curdsbut, took more days to harvest from initiation. Less nutrient availability in control might delay the growth and development to attain the maturity of curd which ultimately delayed harvesting. All the treatments increased the number of frauds per curd that lead to increase in curd yield. Among them T_7 [RDF + Borax (1.5%) + Ammonium molybdate (2.5%)] recorded the

maximum length (14.06 cm). Due to that fact curd length and diameter were also improved. Higher moisture content in curds under T_7followed by treatment T_8might be either due to better root development but, root development study did not performed in the present study or due to Mo which influenced organic phosphate availability. These result corroborated with the findings of Firoz *et al.* (2008) and Singh *et al.* (2011) while working with broccoli curd and seed production study with application of boron and Mo.

Table - 4 showed that maximum T.S.S. (9.10 ^{0}Brix) was recorded in the T_7 [RDF + Borax (1.5%)+Ammonium molybdate(2.5%)] and minimum was observedin T_0. Maximum reducing sugar, total sugars and non-reducing sugar (2.82%, 3.71% and 0.92%, respectively) were also estimated under T_7[RDF + Borax (1.5%)+Ammonium molybdate(2.5%)] followed byT_8[RDF + Borax (2.5%) + Ammonium molybdate (1.5%)] and minimum was observed inT_0. Maximum vitamin C content was also recorded in T_7. Availability of Mo might helped to nitrogen metabolism and several enzymatic processes and more nitrogenous content might increase acidity content of broccoli as mentioned by Maji *et al*. (2015) in guava. These result also corroborated with the finding Saha *et al.* (2010) and Mohamed *et al.* (2011).Higher vegetative growth in the treated crops produced more photosynthetic metabolites that lead to the improvement of quality of broccoli curds.

The findings helped to conclude that the application of boron and molybdenum in a combined form is better with recommended dose of fertilizers. Application of RDF + Borax (1.5%) + Ammonium molybdate (2.5%) might be optimum dose for good growth, better yield and quality production of broccoli in Lucknow.

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