Journal of Pharmacognosy and Phytochemistry
Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
JPP 2018; 7(4): 3189-3192
Received: 04-05-2018
Accepted: 08-06-2018

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Assessment of effect of foliar spray of micronutrients on quantitative and qualitative attributes of broccoli (*Brassica oleracea* var. *italica*) cv. Pusa KTS-1

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Abstract
Broccoli, being a Cole crop, is a heavy feeder of plant nutrients. So, effective and appropriate concentration of micronutrients *i.e*., ammonium molybdate and boric acid, in maximization of broccoli yield (*Brassica oleracea* var. *italica*) cv. Pusa KTS-1 was studied under Varanasi field condition. In this investigation, effect of five micronutrients namely, ammonium molybdate {$(NH_4)_2MoO_4$)}, boric acid (H_3BO_3), copper sulphate ($CuSo_4$), ferrous sulphate ($FeSo_4$) and zinc sulphate (ZnSo4) on broccoli growth and yield were assessed. The result clearly indicated that the treatment (T_{15}) zinc sulphate @ 0.60% exhibited highest plant height (63.29 cm), leaf length (43.63 cm), leaf width (22.60 cm), fresh plant weight (1908.83 g) and phenol content (8.86%). However, foliar application of (T_5) boric acid @ 0.40% resulted in increased fresh curd weight (411.87 g), non-reducing sugar (1.80 %) and it also induced earliness (61.44 days). Thus, these micronutrients are one of the most important aspects for attaining higher yield and quality of broccoli.

Keywords: broccoli, micronutrients, qualitative, quantitative and yield

Introduction
Broccoli, being a Cole crop, is a heavy feeder of plant nutrients. Broccoli belongs to family Brassicaceae (2n=18), is a dicotyledonous biennial herbaceous for seed production and considered as annual when harvested for fresh consumption (Yamayuchi, 1983) [18]. It is a cool-weather crop and survives well when average daily temperature lies between 18 and 23 °C (Baloch, 1994) [2].
Mineral fertilizer including micronutrients improves growth and yield of broccoli due to their involvement in the meristematic activity and growth. Salwa *et al*. (2011) [11] stated that microelements are crucial substances for crop's growth; however, they are used in lower amounts compared to macronutrients, such as N, P and K. They play a major role in cell division and development of meristematic tissues, photosynthesis, respiration and acceleration of plant maturity (Zeidan *et al*., 2010) [20].
Plants differ widely in their requirements, but the ranges of deficiency and toxicity is trace. Boron and molybdenum deficiencies are very common in Cole crops. This deficiency of these elements causes many anatomical, physiological, and biological changes in broccoli plants. Hollow stem disorder is a major problem for broccoli production and is commonly associated with boron deficiency (Shelp *et al*., 1992) [13]. The deficiency of boron, zinc and molybdenum has threatened the ever-increasing areas of broccoli production. The affected heads become irregular in shape, smaller in size, and bitter in taste, which adversely affects the market demand of the crop. The deficient plant shows the symptoms of hollow stems, browning of heads and sword like leaves (whiptail). Many researchers observed that boron application increased growth and yield of the crops.
The requirement of micronutrients are supplied either through foliar spraying or soil application. But, from an ecological perspective, foliar fertilization is more acceptable, because the small amounts of nutrients is used for rapid use by plants (Stampar *et al*., 1999) [16] and it also paved for new approaches like nano foliar application. And also, foliar applications have several benefits including the quality of harvested crops during pre and post-harvest production of biofortified food crops and plant nutrition as well as its protection. Keeping this view in perspectives, experiment was conducted to know the aftermath of foliar spray of microelement fertilizers on quality and quantity of broccoli (cv. Pusa KTS-1.).

Materials and Methods

The experiment was conducted during the *rabi* season of 2015-2016 and 2016-2017 at the Vegetable Research Farm, Department of Horticulture, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, Uttar Pradesh. The impact of foliar spray of micronutrient fertilizers *viz*., ammonium molybdate $\{(NH_4)_2MoO_4)\}$, boric acid (H_3BO_3), copper sulphate ($CuSO_4$), ferrous sulphate ($FeSO_4$) and zinc sulphate ($ZnSO_4$) on yield and quality of broccoli (cv. Pusa KTS-1.) was studied by conducting an experiment in randomize block design with 3 replications. Each micronutrient consisted of three different concentrations (C) 0.20%, 0.40% and 0.60% and applied as foliar feeding to broccoli crop along with control. A spacing of 50×40 cm was maintained in the plot size of 3×2m. First spraying was done on 25th day of planting and subsequently 2nd and 3rd at 45th day and 65th days after transplanting, using hand sprayer. Observations on plant height (cm), leaf length (cm) and leaf width (cm) were recorded by randomly selecting five plants from each plot, while days to 50% curd initiation, fresh plant weight and fresh curd weight recorded based on plot. Other quality parameters such as phenol and non-reducing sugar % were estimated using respective standard method. The pooled values of recorded data over both the experimental years, on various quantity and quality attributes are presented in table 1. Analysis of variance (ANOVA) estimated to know the significant differences among the treatments.

Result and Discussion

A critical examination of data Table 1, revealed that the effect of foliar spray of micronutrients on plant height of broccoli was found significant at all the growth stages. The pooled analysis revealed that the highest plant height was exhibited by treatment (T_{15}) zinc sulphate @ 0.60% (21.49 cm) followed by (T_{14}) zinc sulphate @ 0.40% (20.47 cm) and (T_2) ammonium molybdate @ 0.40% (20.35 cm) at 30 DAT. While, at 60 DAT, it was maximum with treatment (T_{15}) zinc sulphate @ 0.60% (36.48 cm) followed by (T_2) ammonium molybdate @ 0.40% (36.43 cm) and (T_{14}) zinc sulphate @ 0.40% (34.92). The plant height was again highest with (T_{15}) zinc sulphate @ 0.60% (63.29 cm) followed by (T_2) ammonium molybdate @ 0.40% (62.72) and (T_{14}) zinc sulphate @ 0.40% (61.04 cm) at harvest stage. Minimum value of plant height was observed in control at all the stages of growth (14.39, 30.96, 54.97 cm, respectively). Agarwal and Ahmed, 2007 stated that Molybdenum gave maximum plant height. This may be due to enhanced photosynthesis in presence of zinc, boron and molybdenum; these results are in accordance with Rawat and Mathpal (1984) [10]. In this regard, Mallick and Muthukrishnan (1979) [6] explained that, the presence of zinc activates the synthesis of tryptophan which is the precursor of IAA and responsible for stimulation of plant growth. In contrast, Rajawat, 2011 [9] reported the negative effect of boron on plant vegetative growth. Thapa *et al*. (2016) [17] also emphasized the effect of Boron and molybdenum on normal plant growth and development. Although plants differ widely in their requirements, but the ranges of deficiency and toxicity are narrow. In contrast, Yılmaz *et al.* (2013) [19] reported that zinc application had no effect on plant height in broccoli.

The highest leaf length exhibited by treatment (T_3) ammonium molybdate @ 0.60% (9.05 cm) at 30 DAT, followed by (T_2) ammonium molybdate @ 0.40% (9.03 cm) and (T_4) boric acid @ 0.20% (9.02 cm) while, at 60 DAT it was maximum with treatment (T_{15}) zinc sulphate @ 0.60% (28.60 cm). However, at harvesting stage, the highest leaf length was again found in (T_{15}) zinc sulphate @ 0.60% (43.63 cm) followed by T_2 ammonium molybdate @ 0.40% (42.42 cm) and (T_{14}) zinc sulphate @ 0.40% (41.48 cm). Similarly, highest leaf width was exhibited by treatment (T_{15}) zinc sulphate @ 0.60% (7.55 cm) at 30 DAT followed by (T_{13}) zinc sulphate@ 0.20% (7.06 cm) and (T_9) copper sulphate @ 0.60% (7.05 cm) while, at 60 DAT it was maximum with treatment (T_{15}) zinc sulphate @ 0.60% @ 0.60% (15.42 cm) followed by (T_2) ammonium molybdate @ 0.40% (13.60 cm), even at harvest stage the maximum value of leaf width was recorded in (T_{15}) zinc sulphate @ 0.40% (22.60 cm) followed by (T_3) ammonium molybdate @ 0.60% (20.58) and (T_5) boric acid @ 0.40% (20.57cm). This increased leaf length and width may be due to involvement of zinc, boron and molybdenum in cell division and meristematic growth of the tissue. Similar findings were reported by Pawar and Tambe (2016) [8]. Zn, Mo and Boron are known to play a vital role in improving 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 of broccoli.

Foliar application of (T_{15}) zinc sulphate @ 0.60% recorded maximum fresh plant weight (1908.83 g) followed by (T_5) boric acid @ 0.40% **(**1707.90 g) and (T_{14}) zinc sulphate @ 0.40% (1660.26 g**)**. Minimum value of fresh plant weight was observed in control (1138.39 g). At 5% level of significance foliar application of (T_{15}) zinc sulphate at 0.60% concentration had positive effect on fresh plant weight of broccoli compare to other treatments. Similar finding was reported by Partha *et al*. (2010) [7].

Minimum days for curd initiation was observed in (T_5) boric acid @ 0.40% (61.44 days) followed by (T_4) boric acid @ 0.20% (62.83 days) and (T_6) boric acid @ 0.60% (63.35 days). While maximum number of days required for 50% curd initiation was observed in (T_0) control (77.82 days). At 5% level of significance application of boric acid @ 0.40% (T_5) was superior among all the treatments except (T_4) boric acid @ 0.20% and (T_6) boric acid @ 0.60%. Kumar (2009) [5] find the similar result and concluded that through foliar spray of 0.2% boric acid in broccoli; vegetative growth, curd initiation, curd production, yield and quality characters can be enhanced. The pooled analysis revealed that treatment (T_5) boric acid @ 0.40% (411.87 g) followed by (T_4) boric acid @ 0.20% (390.23 g), (T_{15}) zinc sulphate @ 0.60% (385.642 g) and (T_2) ammonium molybdate @ 0.40% (369.66) were significantly superior in increasing fresh curd weight of broccoli over (T_0) control, which recorded minimum value (251.92 g). This result was in conformity with finding of Singh *et al*. (2017) in cauliflower.

Maximum pooled value of yield noted in (T_5) boric acid @ 0.40% (135.05 q/ha) followed by (T_{15}) zinc sulphate @ 0.60% (134.98 q/ha), (T_2) ammonium molybdate @ 0.20% (131.66 q/ha) and (T_4) boric acid @ 0.20% (131.38 q/ha). At 5% level of significance (T_5) boric acid @ 0.60% recorded significantly superior total yield with respect to all studied treatments except (T_{15}) zinc sulphate @ 0.60% application which was at par. This indicate that zinc and boron are a vital nutrient for attaining an adequate yield of broccoli florets, especially in the soils with low micronutrient content. Similar finding was in conformity with findings of Chaudhari *et al*. (2017) [4] in cauliflower, Blevins *et al*. (1998) [3] and Yilmaz *et al.* (2013) [19] in broccoli.

Application of (T_5) boric acid @ 0.40% recorded the maximum pooled value of non-reducing sugar content (1.80

%) followed by (T_2) ammonium molybdate @ 0.40% (1.79 %), (T_{15}) zinc sulphate @ 0.60% (1.78 %) and (T_6) boric acid @ 0.60% (1.77 %) which were significantly superior to the other treatments. The lowest non-reducing sugar content was recorded in (T_0) control (1.58 %). This finding is in agreement with Sharma (2012) [12].

Pooled analysis revealed maximum phenol content in treatment (T_{15}) zinc sulphate @ 0.60% and (T_5) boric acid @ 0.40% (8.66 %) followed by (T_2) ammonium molybdate @ 0.40% (8.62 %). In contrast, Kumar (2009) [5] and Slosar *et al.* (2017) [15] had reported that the spray of 0.2% Copper Sulphate and zinc-fertilisation registered minimum phenol content in broccoli, respectively. The lowest phenols content was recorded in (T_0) control (7.39 %). At 5% level of significance pooled analysis revealed that the treatments (T_5) boric acid @ 0.40%, (T_2) ammonium molybdate @ 0.40% and (T_{15}) zinc sulphate @ 0.60% were statistically at par.

Table 1: Effect of foliar spray of micronutrients on qualitative and quantitative attributes of broccoli (*Brassica oleracea* var. *italic*. L.) cv. Pusa KTS-1 under Varanasi region.

Treatments	Plant height (cm)			Leaf length (cm)			leaf width (cm)			Fresh plant weight (g)	Days to 50 % curd initiation	Fresh weight of curd (g)	Yield (q/ha)	Non reducing sugar (%)	Phenols (%)
	30 DAT	60 DAT	Harvest stage	30 DAT	60 DAT	Harvest stage	30 DAT	60 DAT	Harvest stage						
Control (T_0)	14.39	30.96	54.97	7.99	20.95	33.56	6.14	9.99	14.18	1138.39	77.81	251.92	124.50	1.58	7.39
Ammonium Molybdate @ 0.20 % (T_1)	16.88	33.88	58.84	8.94	23.38	37.87	7.00	12.45	17.54	1345.43	68.89	346.34	128.93	1.66	8.40
Ammonium Molybdate @ 0.40% (T_2)	20.35	36.43	62.72	9.03	26.47	42.42	6.47	13.60	19.35	1601.33	67.31	369.66	131.66	1.79	8.62
Ammonium Molybdate @0.60% (T_3)	19.44	33.85	61.40	9.05	24.40	40.12	6.87	13.54	20.58	1482.54	67.80	366.28	125.55	1.71	8.40
Boric Acid @ 0.20 % (T_4)	17.36	33.00	57.97	9.02	23.52	38.40	7.03	12.41	18.59	1248.78	62.83	390.23	131.38	1.75	8.44
Boric Acid@ 0.40 % (T_5)	18.44	34.58	60.73	8.97	25.40	41.62	6.93	13.52	20.57	1707.90	61.44	411.87	135.05	1.80	8.66
Boric Acid @ 0.60 % (T_6)	17.40	34.00	57.82	8.44	24.35	39.95	6.52	12.46	18.53	1485.75	63.35	366.85	128.93	1.77	7.55
T_7 (Copper sulphate @ 0.20%)	18.35	33.11	55.84	8.51	23.94	37.71	6.95	11.54	16.49	1195.60	65.03	301.38	124.88	1.64	8.02
T_8 (Copper sulphate @ 0.40%)	18.96	33.48	56.70	7.91	25.57	37.98	6.61	12.43	16.50	1378.48	68.14	317.36	127.42	1.65	8.04
T_9 (Copper sulphate @ 0.60%)	18.95	33.40	57.02	7.87	24.47	37.58	7.05	12.40	16.03	1337.55	68.01	292.35	124.38	1.65	8.03
T_{10} (Ferrous sulphate @ 0.20%)	18.53	33.50	57.01	8.01	23.51	37.53	6.49	12.44	17.05	1372.47	68.55	333.42	125.96	1.65	7.65
T_{11} (Ferrous sulphate @ 0.40%)	18.42	33.97	57.05	7.50	24.58	37.49	6.45	12.59	17.50	1433.58	66.94	348.37	124.99	1.68	8.29
T_{12} (Ferrous sulphate @ 0.60%)	18.41	33.98	59.94	7.96	23.38	38.53	6.49	12.56	17.13	1365.20	66.84	344.78	127.89	1.67	8.45
T_{13} (Zinc sulphate @ 0.20%)	19.45	34.50	59.49	7.45	25.55	40.55	7.06	13.37	19.44	1503.42	67.93	349.02	128.47	1.66	8.47
T_{14} (Zinc sulphate @ 0.40%)	20.47	34.92	61.04	8.00	25.62	41.48	6.91	13.41	19.39	1660.26	65.90	366.84	128.88	1.72	8.58
T_{15} (Zinc sulphate @ 0.60%)	21.49	36.48	63.29	8.98	29.61	43.63	7.55	15.42	22.60	1908.83	64.94	385.64	134.98	1.78	8.86
SEm±	0.80	0.86	1.49	0.84	0.83	0.73	0.71	0.80	0.90	0.83	1.01	0.85	0.89	0.02	0.27
CD (P=0.05)	1.60	1.73	2.98	1.68	1.67	1.46	1.43	1.59	1.80	1.66	2.02		1.78	0.05	0.54

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