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Standardization the application of essential micro-nutrient combinations for best exploitation of quality and yield traits in broccoli under sub-Himalayan region of west Bengal

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Abstract
Broccoli (*Brassica oleracea var italica*) which is an important vegetable crop, supposed to be the first of the Cole crops evolved from the wild species of cabbage or kale. It is gaining popularity throughout the sub-Himalayan region of West Bengal especially in Terai zone due to ever growing demand for its tender knob and processed products like soup, vegetable curry preparation and others makes it popular. But due to the deficiency of some micronutrients in the soil of terai region, broccoli not gives good return for this reason the experiment was done to give a recommendation and standardize dose of application to the farmers for better yield. An experiments was conducted at Horticultural Farm of Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar, West Bengal. The present experiment was carried out to standardize the application of micronutrients at crop foliage and ensure rapid uptake of nutrients. In this experiment three important micronutrients with dose *viz.*, molybdenum in the form of ammonium molybdate (0.3% and 0.5%), sulphur in from of ammonium sulphate (0.05%, 0.25% and 0.5%) and zinc in the forms of zinc sulphate (0.5%, 1.0% and 1.5%) along with their combinations were applied through foliar spray at 30 and 45 days after transplanting on locally popular cultivar "Green Magic" of broccoli. The present investigation treatment 0.03% M + 0.05% S + 1.5% Z for head size and diameter, 0.05% M + 0.05% S+ 1.5% Z for number of leaf and 0.05% M + 0.05% S+ 1.5% Z for net head weight and chlorophyll content of the head were found to be best. Whereas, combination treatment 0.03%Mo+ 0.5%S + 1.5% Zn for vitamin A and 0.03%Mo+ 0.5%S + 1% Zn for leaf chlorophyll content and ascorbic acid were found to be best.

Keywords: Broccoli, terai-zone, zinc, sulphur and molybdenum

Introduction
Broccoli (*Brassica oleracea var italica*) which is an important vegetable crop, supposed to be the first of the Cole crops evolved from the wild species of cabbage or kale (Rubatzky and Yamaguchi, 1997) [13]. It is gaining popularity throughout the sub-Himalayan region of West Bengal especially in Terai zone due to ever growing demand for its tender knob and processed products like soup, vegetable curry preparation and others makes it popular. It is a rich source of vitamin C, E, B_1, carotenoids, phenolic products (Lemoine *et al*., 2010; Goncalves *et al*., 2011; Parente *et al.,* 2013) [4, 11] and possesses anticancer properties due to presence of high amount of indole-3-carbinol (Solunke *et al.,* 2011) [17]. This high nutritional property that associated with health conciseness among the consumers is positively influencing on its demand in daily diet. The climatic condition of sub-Himalayan Terai region of West Bengal is highly suitable for broccoli cultivation which argued for the possibility of gaining more net profit by the farmers by cultivation of this high valued crop. But, lack of standardised package of practice coupled with high acidic soil condition in this Terai region are becoming major constrain (Pati and Mukhopadhyay, 2011) [12] in its cultivation as it greatly related with micronutrient deficiency viz., boron and molybdenum (Lal 1993) [7] and ultimately prohibiting full exploitation of the economical traits as well as resulted in yield loss and lower return than the expected. Naturally this situation is negatively influencing farmer's interest of cultivation in spite of being a high valued crop. Present experiment was designed to Study the manifestation of growth and yield attributes of Broccoli through application of boron, molybdenum, zinc as well as to optimise sole and combined doses of micronutrients for better exploitation of the economic traits.

Material and Methods
The field experiments were carried out at Horticultural Farm of Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar,

West Bengal, situated at 26 º 40' N latitude and 89 º 38' E longitudes with average altitude of 43 m above the mean sea level (MSL) under the range of sub-Himalayan region of West Bengal and soil pH 5.5-6.5 during autumn-winter season.

Considering the fact that application of micronutrients at crop foliage ensure rapid uptake of nutrients in completely available form and faster response by directly enter into the metabolic processes as because they are not either fixed or diluted in some large volumes of soil (Baloch *et al.,* 2008), in this experiment three important micronutrients with standardized dose *viz.,* molybdenum in the form of ammonium molybdate (0.3% and 0.5%), sulphur in from of ammonium sulphate (0.05%, 0.25% and 0.5%) and zinc in the forms of zinc sulphate (0.5%, 1.0% and 1.5%) along with their combinations (Saha *et al*. 2010; Lashkari *et al*, 2007 and Salih *et al.,* 2016) [15, 8, 16] were applied through foliar spray at 30 and 45 days after transplanting on locally popular cultivar "Green Magic" of broccoli. Therefore, there were total of nineteen treatment combinations which were laid out in randomized block design with 3 replications maintaining the spacing of 45 x 45 cm with plot sized of 5.4 m x 5.4 m. Recommended dose of major nutrients *i.e.,* N, P_2O_5, K_2O (120 kg, 60 kg and 60 kg/ha, respectively) were provided throughout the cropping period along with standard package were followed. Samples were collected for observation from ten randomly selected plants from each replication for each treatment. Data were recorded at 60 days after transplanting on seven morphological traits *viz.* plant height (cm), leaves per plant, head length (cm), head diameter (cm), leaf length, leaf width (cm) and head weight (g) and six bio-chemical traits viz. vitamin A (mg/ 100g), chlorophyll A (mg/100g) and chlorophyll B(mg/ 100g) in leaf and head, chlorophyll A in head (mg/100g), chlorophyll B in head (mg/ 100g) and ascorbic acid of head (mg/100g). Total chlorophyll content was estimated as per Sadasivam and Manickam (1996) [14] and ascorbic acid was estimated as per AOAC (1990). Collected data were analysed statistically by using SPSS 22.0. (Duncan's multiple range test**)**.

Result

There was significant response observed for all the characters under study irrespective of micro nutrient treatments as sole as well as combinations. Plant heights recorded at 75 days after planting revelled that there was significant variation in response to different treatment combinations. Tallest plant (61.32 cm) was recorded in combination of 0.05% Mo, 0.25% S and 1% Zn, which was at par with the combination treatment of 0.03% Mo, 0.05% S, and 1.5% Zn. Again, the combined treatment of 0.03% Mo, 0.05% S, and 1.5% Zn showed significant maximum positive effect on head length (29.36 cm) and head diameter (30.22cm) indicated that this combination treatment might be very effective to up regulate the bio-chemicals at desired amount to promote the better growth of economical plant parts of broccoli. Whereas, control treatment with no micronutrient exhibited plant population with lowest magnitude for all these traits which clearly indicated the importance of micronutrients on cell development and bio-synthetic pathways that promotes better conditioning for normal growth and development of plant (Marschner, H. 1995; Bambara and Ndakidemi, 2010; Mendel and Haensch, 2002 and Yang *et al.*,2000) [9, 3, 10, 18].

Data represented in table 1 clearly indicated the relationship between number of leaf, leaf length and leaf width. The significant maximum leaf numbers were recorded for combination treatment of 0.5% each of Mo + S + Zn, 0.05%Mo+ 0.25%S + 1.5% Zn and 0.05%Mo+ 0.5%S + 1% Zn *i.e.,* 22.84, 22.78 and 22.73, respectively. But, all these treatment combinations exhibited comparatively significantly very low leaf length and leaf width. However, the maximum leaf length and leaf width were recorded to be significantly highest at combined treatment of 0.05%Mo+ 0.05%S + 1.5% Zn *i.e.,* 41.58 cm, and 29.35 cm, respectively followed by 0.03%Mo+ 0.5%S + 1.5% Zn *i.e.,* 40.87 cm, and 25.59 cm, respectively. These treatment combinations exhibited comparatively significantly low number of leaves per plant that indicated there might be negative correlation between number of leaf and leaf size and suggested for further detailed study. In the present investigation, none of the morphological parameters found to have significant predominant influence on the main head weight except in the combine treatment 0.05%Mo+ 0.05%S + 1.5% Zn where leaf size showed positive effect and showed maximum head weight (1150.54 g). However, treatment combination 0.05%Mo+ 0.5%S + 1.5% Zn was significantly at par (1149.91 g).

Along with the morphological parameter bio-chemical parameter were also influenced by different combinations of micro-nutrients. Combined effect of different micronutrient showed significant effect in case of vitamin-A content in head of broccoli (Table 2). Maximum amount of vitamin-A (1.78 mg/100g) were observed in the combination of 0.03%Mo+ 0.5%S + 1.5% Zn followed by 0.03%Mo + 0.5% S + 0.5% Zn *i.e.,* 1.43 mg/100g and 0.05%Mo+ 0.5%S + 1% Zn *i.e.,* 1.4 mg/100g, while lowest amount of vitamin-A were observed at control application. Greater extent of significant differentiate response were observed for Chlorophyll-A and Chlorophyll-B in leaf throughout the treatment. Chlorophyll-A (414.04 mg/g) and Chlorophyll-B (146.5 mg/g) in leaf were recorded highest in combination of 0.03%Mo+ 0.5%S + 1% Zn and 0.03% Mo+ 0.25%S + 0.5% Z respectively. Significantly highest Chlorophyll-A and Chlorophyll-B in head were recorded at 0.03%Mo+ 0.5%S + 1.5% Zn i.e., 90.7 and 30.85 mg/100g respectively. However, data did not show any relationship between leaf and head for different components of chlorophyll that might be the gene responsible for chlorophyll production response differently as per vegetative plant parts. Considering the overall performance significantly highest amount of ascorbic acid (116.70mg/100g) showed by the treatment of 0.03%Mo+ 0.5%S + 1% Zn, while lowest amount of ascorbic acid (34.58 mg/g) was found in control application.

Table 1: Effect of combination treatments on different quantitative characters of broccoli

	Treatment Combination	Plant Height (cm)	Head Length (cm)	Head Diamt (cm)	Leaf No	Leaf Length cm)	Leaf Width (cm)	Main Head Weight (g)
1	M_0+S_0+Z_0 (CONTROL)	34.57 ^{i}	14.24 ^{j}	17.25 ^{h}	14.11 ^{j}	29.16 ^{l}	16.61 ^{m}	490.25 ^{j}
2	$M_{0.03}$+$S_{0.05}$+$Z_{0.5}$	42.68 ^{f}	16.71 ^{i}	18.66 ^{g}	16.44^{g}	31.77 ^{i}	17.66 ^{l}	691.35 ^{f}
3	$M_{0.03}$+$S_{0.05}$+$Z_{1.0}$	58.44 ^{b}	20.35 ^{e}	23.22 ^{c}	17.22 ^{f}	34.26 ^{e}	23.32 ^{d}	907.04 ^{c}
4	$M_{0.03}$+$S_{0.05}$+$Z_{1.5}$	61.24 ^{a}	29.36 ^{a}	30.22 ^{a}	14.21 ^{j}	34.66 ^{e}	24.56 ^{c}	1005.35 ^{b}
5	$M_{0.03}$+$S_{0.25}$+$Z_{0.5}$	38.24 ^{h}	18.25 ^{fg}	21.66 ^{e}	21.33 ^{c}	31.77 ^{i}	20.33 ^{g}	655.57 ^{g}

6	$M_{0.03}+S_{0.25}+Z_{1.0}$	48.12 ^{e}	17.47 ^{h}	13.91 ^{k}	14.54 ^{i}	30.57 ^{j}	18.67 ^{jk}	480.25 ^{j}
7	$M_{0.03}+S_{0.25}+Z_{1.5}$	43.33 ^{f}	18.12 ^{g}	19.22 ^{f}	13.74 ^{k}	29.77 ^{k}	17.56 ^{l}	585.37 ^{h}
8	$M_{0.03}+S_{0.5}+Z_{0.5}$	41.5 ^{g}	17.36 ^{h}	17.5 ^{h}	19.32 ^{d}	30.66 ^{j}	18.44 ^{k}	552.56 ^{i}
9	$M_{0.03}+S_{0.5}+Z_{1.0}$	54.21 ^{d}	16.52 ^{i}	15.55 ^{j}	21.64 ^{b}	28.61 ^{l}	19.75 ^{h}	416.16 ^{l}
10	$M_{0.03}+S_{0.5}+Z_{1.5}$	59.17 ^{b}	20.36 ^{e}	22.5 ^{d}	15.64 ^{h}	40.87 ^{b}	25.59 ^{b}	1011.02 ^{b}
11	$M_{0.05}+S_{0.05}+Z_{0.5}$	47.51 ^{e}	18.54 ^{f}	22.62 ^{d}	22.84 ^{a}	35.65 ^{d}	22.75 ^{e}	906.87 ^{c}
12	$M_{0.05}+S_{0.05}+Z_{1.0}$	55.54 ^{c}	17.51 ^{h}	18.5 ^{g}	19.33 ^{d}	32.23 ^{hi}	20.99 ^{f}	590.91 ^{h}
13	$M_{0.05}+S_{0.05}+Z_{1.5}$	58.24 ^{b}	22.95 ^{c}	25.62 ^{b}	20.77 ^{d}	41.58 ^{a}	29.35 ^{a}	1150.54 ^{a}
14	$M_{0.05}+S_{0.25}+Z_{0.5}$	32.12 ^{j}	17.74 ^{h}	15.88 ^{j}	18.54 ^{e}	32.59 ^{h}	17.68 ^{l}	551.97 ^{i}
15	$M_{0.05}+S_{0.25}+Z_{1.0}$	38.29 ^{h}	21.63 ^{d}	22.5 ^{d}	18.31 ^{e}	33.88 ^{fg}	17.78 ^{l}	778.25 ^{e}
16	$M_{0.05}+S_{0.25}+Z_{1.5}$	61.32 ^{a}	26.36 ^{b}	23.12 ^{c}	22.78 ^{a}	33.46 ^{g}	18.82 ^{i}	1016.34 ^{b}
17	$M_{0.05}+S_{0.5}+Z_{0.5}$	34.74 ^{i}	14.54 ^{j}	16.55 ^{i}	16.25 ^{g}	28.75 ^{l}	13.39 ^{n}	454.25 ^{k}
18	$M_{0.05}+S_{0.5}+Z_{1.0}$	38.54 ^{h}	17.58 ^{h}	19.22 ^{f}	22.73 ^{a}	33.74 ^{fg}	18.77 ^{jk}	807.68 ^{d}
19	$M_{0.05}+S_{0.5}+Z_{1.5}$	58.59 ^{b}	18.57 ^{f}	22.5 ^{d}	19.33 ^{d}	36.56 ^{c}	22.57 ^{e}	1149.91 ^{a}

Means followed by the same letters are not significant at 0.05 percent level according to Duncan's test.

Table 2: Effect of combination treatments on different qualitative characters of broccoli

	Treatment Combination	Vit A	Chll Le A	Chl Le B	Chl He A	Chl He B	Ascorbic Acid
1	$M_0+S_0+Z_0$ (CONTROL)	0.79 ^{k}	270.83 ^{k}	96.34 ^{e}	35.00 ^{k}	7.44 ^{l}	34.58 ^{n}
2	$M_{0.03}+S_{0.05}+Z_{0.5}$	0.89 ^{jk}	291.99 ^{h}	97.98 ^{e}	49.11 ^{g}	16.04 ^{g}	38.94 ^{m}
3	$M_{0.03}+S_{0.05}+Z_{1.0}$	0.99 $^{h-j}$	370.13 ^{d}	133.11 ^{c}	27.40 ^{m}	5.15 ^{n}	65.81 ^{e}
4	$M_{0.03}+S_{0.05}+Z_{1.5}$	1.01 $^{g-i}$	275.23 ^{j}	89.63 ^{f}	31.04 ^{l}	8.53 ^{k}	68.70 ^{d}
5	$M_{0.03}+S_{0.25}+Z_{0.5}$	1.08 $^{f-i}$	397.80 ^{b}	146.52 ^{a}	31.97 ^{l}	9.28 ^{k}	66.25 ^{e}
6	$M_{0.03}+S_{0.25}+Z_{1.0}$	0.96 ^{ij}	340.73 ^{f}	94.55 ^{e}	49.53 ^{g}	17.70 ^{f}	77.81 ^{c}
7	$M_{0.03}+S_{0.25}+Z_{1.5}$	1.07 $^{f-i}$	317.32 ^{g}	87.92 ^{f}	28.07 ^{m}	6.36 ^{m}	80.22 ^{b}
8	$M_{0.03}+S_{0.5}+Z_{0.5}$	1.43 ^{b}	383.63 ^{c}	89.27 ^{f}	43.25 ^{h}	12.75 ^{i}	62.95 ^{g}
9	$M_{0.03}+S_{0.5}+Z_{1.0}$	1.15 $^{d-g}$	414.04 ^{a}	140.17 ^{b}	58.01 ^{e}	19.30 ^{e}	116.70 ^{a}
10	$M_{0.03}+S_{0.5}+Z_{1.5}$	1.78 ^{a}	246.41 ^{l}	81.01 ^{gh}	59.76 ^{d}	21.56 ^{d}	39.90 ^{m}
11	$M_{0.05}+S_{0.05}+Z_{0.5}$	1.22 $^{c-f}$	236.80 ^{m}	78.74 ^{i}	41.69 ^{i}	24.59 ^{c}	62.90 ^{g}
12	$M_{0.05}+S_{0.05}+Z_{1.0}$	1.3 $^{b-d}$	272.81 ^{k}	84.35 ^{fg}	39.28 ^{j}	10.76 ^{j}	64.38 ^{f}
13	$M_{0.05}+S_{0.05}+Z_{1.5}$	1.21 $^{c-f}$	364.14 ^{de}	88.90 ^{f}	71.80 ^{c}	25.48 ^{bc}	53.31 ^{k}
14	$M_{0.05}+S_{0.25}+Z_{0.5}$	0.98 $^{h-j}$	395.70 ^{b}	87.29 ^{f}	81.04 ^{b}	25.70 ^{b}	63.89 ^{fg}
15	$M_{0.05}+S_{0.25}+Z_{1.0}$	1.13 $^{e-h}$	282.29 ^{ij}	73.17 ^{j}	53.05 ^{f}	18.58 ^{ef}	51.43 ^{l}
16	$M_{0.05}+S_{0.25}+Z_{1.5}$	1.19 $^{c-f}$	359.40 ^{e}	98.57 ^{e}	80.23 ^{b}	12.86 ^{i}	58.10 ^{i}
17	$M_{0.05}+S_{0.5}+Z_{0.5}$	1.28 $^{b-c}$	343.62 ^{f}	106.73 ^{d}	48.28 ^{g}	14.53 ^{h}	57.95 ^{i}
18	$M_{0.05}+S_{0.5}+Z_{1.0}$	1.4 ^{b}	289.42 ^{h}	110.36 ^{de}	40.86 ^{i}	12.55 ^{i}	55.75 ^{j}
19	$M_{0.05}+S_{0.5}+Z_{1.5}$	1.32 ^{bc}	296.24 ^{h}	96.05 ^{e}	90.72 ^{a}	30.85 ^{a}	51.42 ^{l}

Means followed by the same letters are not significant at 0.05 percent level according to Duncan's test.

Discussion

Data obtained from the field clearly indicated that there was significant effect of the micro-nutrients treatments on the yield, growth and biochemical parameters of the broccoli which justified the application of micronutrients at optimum level along with the macronutrients to promote better growth and yield in the Terai agro-climatic region to fetch higher net return by the farmers. These phenomena might be due to beneficial effects of applying foliar plant nutrients particularly zinc, boron, iron and manganese and its sources play a key role in improving the productivity and quality of crop due their involvement in various enzymes and other physiologically active molecule. Lahijie (2012) [6] and Khosa *et al*. (2011) [5] were reported that micronutrients play vital roles in the growth and development of plants, due to their stimulatory and catalytic effects on metabolic processes and ultimately on flower yield and quality. However, in the present investigation treatment 0.03% M + 0.05% S + 1.5% Z for head size and diameter, 0.05% M + 0.05% S+ 1.5% Z for number of leaf and 0.05% M + 0.05% S+ 1.5% Z for net head weight and chlorophyll content of the head were found to be best. Whereas, combination treatment 0.03%Mo+ 0.5%S + 1.5% Zn for vitamin A and 0.03%Mo+ 0.5%S + 1% Zn for leaf chlorophyll content and ascorbic acid were found to be best.

After thorough evaluation the combination treatments of 0.05% M + 0.05% S+ 1.5% Z, 0.03%Mo+ 0.5%S + 1% Zn and 0.03%Mo+ 0.5%S + 1.5% Zn can be recommended to the farmers of Terai agro-climatic region for enhancing their net return by best exploitation of quality and yield traits of broccoli.

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