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Foliar Micro-nutrition of Vegetable Crops - A Critical Review

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Foliar Micro-nutrition is the application of micronutrients to plants by spraying directly onto their leaves. Although it is not economical to spray macronutrients and micronutrients through foliar spraying, researchers prefer soil application for macronutrients and foliar applications of micronutrients. Several researches have demonstrated that the method which is used to deliver the required micronutrient in appropriate concentration to improve nutrient status along with increased yield and quality potential are adapted by combining applications of $FeSO_4$ at a dose of 0.2%, Calcium nitrate at 0.2%, Boron at 0.1% and $ZnSO_4$ at 0.2% has revealed a 51% increase as compared to control in potato. Application of $ZnSO_4$ (0.4%) and $ZnSO_4$ (0.6%) provides significant impact on growth and yield characteristic of Chilli; Zinc Sulfate (0.5%) and Borax (0.5%) also shows better result on the number of fruits per plant, fruit length, fruit diameter and yield per plant in Eggplant. Applying $ZnSO_4$ (0.5%) shows better results on plant height, weight of head and yield of head in cabbage cultivations. Combined application of Boron (100 ppm) + Molybdenum (50 ppm) along with 60 kg/fed of Nitrogen. The results showed increased 38.02% on curd yield of cauliflower

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over control. A study reveals that application of (0.5%) Zn+ (0.1%) B along with 75 kg/ha of potassium in combination showed 31.73% increases yield of watermelon. Application of boron at 0.25% and zinc 0.5% showed a 31.17% increase in the total onion yield. The combined application of $MgSO_4$ (0.5%), $MnSO_4$ (0.5%), $FeSO_4$ (0.5%) and $ZnSO_4$ (0.5%) has increased yield of okra 31.8% over control. In general this critical review lays an emphasis from the review point of that micronutrients have been found to show satisfactory results than control conditions and has an immense potential in vegetable production to increase yield attributes.

Keywords: Foliar micro-nutrition; micronutrient; vegetable crops; yield attributes; spray; concentration.

1. INTRODUCTION

It is well known that plants need various inorganic nutrients in addition to carbon dioxide (CO_2) and water for their growth and production. Inherent in soil, most of these nutrients are reduced and can be used for various purposes. This requires the use of fertilizer in nutrients which is the most widespread method for soil fertilization. However, the bioavailability of plants in terms of nutrients has many restrictions. Nutrients like phosphorus (P), potassium (K) and most micronutrients are comparatively scarce, since they are mostly fixed on the exchange sites on soil in insoluble form. In addition soluble nutrients i.e., nitrogen (N) gets easily leached down the soil [1]. It is very well known that plant leaves can absorb nutrients in a natural process in the similar manner by which plants obtain additional nutrients form rainwater. This technique is used for spraying dilute solutions of particular nutrients on the foliage of the plants. It is now compulsory to fertilize croplands to produce a satisfactory production with intensive land use and farming progress [2]. Nonetheless, inorganic fertilizers are now exorbitant due to high input costs as these inorganic macronutrients are used for the soil feeding process and are needed in large quantities in comparison with foliar applications. All vegetables react to small amounts of both micro and macro- nutrients in a proactive manner [3]. In particular, the current global scenario highlights strongly the need for sustainable farming practices for sufficient food production. Clearly, the expense of inorganic fertilizers has so dramatically escalated that they are mostly beyond the control of both small and marginal farmers. This makes it normally impossible for farmers to make substantial or suitable use of synthetic macro nutrients [4]. Small proportions of these fertilizers may be used as a foliar application as a substitute. Photosynthesis and chlorophyll production in green plants are the vital areas of micronutrients. The foliar application of nutrients for vegetable crops will also be checked, as will some process details including factors influencing the application of foliar nutrients on the nutritional content of vegetables by mineral fertilizers.

2. ROLE OF FOLIAR NUTRITION

Foliar nutrition will enhance the efficiency of the use of nutrients which plants need to increase ungently for maximum growth and yield [5]. It can also make faster use of the substance and can remedy detected shortcomings in less time than can be achieved with soil applications. Foliar nutrition is the most efficient method for placing fertilizers under problems of soil fixation which normally needs reduced amounts of nutrients compared to soil application. Application of micronutrients in limited quantities and macronutrients, e.g., N, P or K, without phytotoxicity is the most effective usage of foliar nutritional methods [6]. Foliar spray with micronutrients is one way to improve production and reduce environmental risks among other methods of application of plant nutrients. Moreover, it is easy and needs little infrastructure [7].

The potential benefits of foliar nutrition could be concluded as follow [8]:

1. Nutrient availability during the maximum demand cycles if urgent response is required.
2. Provide plants with certain nutrients (zinc and iron) which may not be readily available for root uptake.
3. Providing a source of nutrient during stress when soil applications are not practical.
4. The management of nutrient depletion in high-potential loss environments.
5. Allowing flexibility in supplying nutrients related to improving the quality of the harvest.
6. Providing plants with a nutrient boost while applying other foliar chemicals reducing applications.

3. PROPER TIMING OF FOLIAR NUTRITION

In relation to the optimal effectiveness of the foliar treatment the timing of the foliar spray, particularly with regard to the growth stage, can be considered crucial and carefully taken. The effectiveness of foliar nutrition is influenced by various endogenous (related to leaf anatomical structure) as well as exogenous (nutrient concentration, soil type and pH) and environmental factors. Including day time, humidity, temperature and wind speed affect the physical as well as biological aspects of foliar application (Table 1). Plant tissue permeability is critical in nutrient absorption in the plant: warm, moist and calm conditions favor the maximum permeability of tissue, and conditions most frequently seen in late-night hours and often in early morning hours. Rainfall may reduce application effectiveness within 24 to 48 hours of application of foliar since the plant tissue does not absorb every nutrient material immediately.

Table 1. Meteorological conditions favoring foliar application of nutrients (Adapted from MWL [9])

Time of Day	Late evening; after 6 p.m. or early morning; before 9 a.m.
Temperature	65-85 F; 70 ideal (21C)
Humidity	> 70% relative humidity
Temperature/ Humidity Index	140-160
Wind Speed	< 5 mph

4. MICRONUTRIENTS

As compared to the macronutrients, concentrations of eight micronutrients viz., iron (Fe), zinc (Zn), manganese (Mn), copper (Cu), boron (B), chloride (Cl), molybdenum (Mo), and nickel (Ni) are very small. Four additional elements such sodium (Na), cobalt (Co), vanadium (V) and silicon (Si) has been established as beneficial micronutrients in some plants [10].

5. FUNCTIONS

Within micronutrients, boron has a vital role to play in growth, development and in several other physiological processes such as N metabolism, protein formation, cell division and cell wall formation [11]. Seemingly Fe is the structural component of porphyrin molecules; cytochromes, hemes, hematin, ferrichrome, and leghemoglobin. These substances are involved in oxidation-reduction processes in respiration and photosynthesis. Zn is also an essential element in a number of enzymes i.e., dehydrogenase, aldolase, isomerases, proteinase, peptidase and phosphohydrolase [12]. Both photosynthesis (reduction of CO_2 to carbohydrates) and respiration (oxidation of carbohydrates to CO_2) involve the transfer of electrons that requires Cu. Also lignin formation in cell walls, carbohydrate and lipid metabolism in plant tissues are highly regulated by the functioning of Cu. Most of oxygen (O_2) in the atmosphere originates from Mn facilitated electron transfer in photosynthesis. Cl is important in the functioning of Mn in photosynthetic production of carbohydrates from CO_2 and evolution of O_2. Mo an essential component of nitrate (NO_3) reductase, an enzyme concentrated in chloroplasts, which catalyzes the conversion of NO_3 to nitrite (NO_2). All vegetables respond constructively to the application of small quantities of micronutrients [13].

Case study: no. 1 Studies on foliar application of some macro and micronutrients improves tomato growth, flowering and yield [14].

In this study an experiment was laid to consider the possible effect of some macro and micro nutrients with different concentration levels as foliar application on the vegetative growth, flowering and yield of tomato cultivar (cv) “Roma”. The nutrients were dissolved in tap water with respective concentration and were applied with knap sack sprayer as foliar feeding to each block 15 days after transplanting and 2nd dose was applied 21 days after transplanting with different treatments. The result shows that, maximum fruit length (7.48 cm), maximum fruit diameter (5.08 cm), minimum number of small fruits per plant (6.33), highest number of medium fruits per plant (11.66) and in case of large size fruits as maximum number of large sized fruits per plant (15.67) were perceived in T5 (nitrogen (5.5 g/100 mL + Boron 5 g/100 mL + Zinc 5 g/100 mL) respectively which is significantly effective over T1 (control) [Table 2].

Table 2. Effect of foliar application of some macro and micro nutrients on tomato fruit size and fruit number

Treatments	Fruit length (cm)	Fruit diameter (cm)	Small fruits per plant	Medium fruits per plant	Large fruits per plant
T1= control	4.55^{d}	3.48^{d}	12.00^{a}	7.33^{d}	6.33^{d}
T2= nitrogen 5.5 g/100 mL	6.27^{c}	4.37^{c}	8.00^{bc}	8.66^{c}	10.00^{c}
T3= Boron 5 g/mL	6.92^{b}	4.69^{b}	9.00^{b}	10.67^{b}	12.00^{b}
T4= Zinc 5 g/mL	6.42^{b}	4.54^{b}	7.66^{bc}	9.00^{c}	11.06^{b}
T5= nitrogen 5.5 g/100 mL + Boron 5 g/100mL + Zinc 5 g/mL	**7.48^{a}**	**5.08^{a}**	**6.33^{d}**	**11.66^{a}**	**15.67^{a}**

Table 3. Effect of foliar application of some macro and micro nutrients on plant yield

Treatments	Total fruits per plant	Yield per plant (kg)	Yield per plot (kg)	Yield per hectare (kg)
T1= Control	25.66^{d}	0.56^{d}	12.75^{d}	637.50^{e}
T2= Nitrogen 5.5 g/100 mL	26.66^{d}	0.73^{c}	16.65^{c}	832.50^{d}
T3= Boron 5 g/mL	31.67^{b}	0.93^{b}	21.50^{b}	1075^{b}
T4= Zinc 5 g/mL	28.33^{c}	0.89^{b}	19.75^{b}	987.50^{c}
T5= nitrogen 5.5 g/100 mL + Boron 5 g/100 mL + Zinc 5 g/mL	**33.67^{a}**	**1.14^{a}**	**25.5^{a}**	**1275^{a}**

Any two means not sharing same letter differ significantly ($p \le 0.05$), in columns, figures sharing similar letters are not different statistically ($p \le 0.05$).

Similarly in Table 3, it is observed that total number of fruits including small, medium and large (33.67), highest yield/ plant (1.14 kg), Maximum yield/plot (25.5 kg) and maximum yield/hectare (1275 kg) were found to be higher in T5 (nitrogen (5.5 g/100 mL + Boron 5 g/100 mL + Zinc 5 g/100 mL) respectively.

Any two means not sharing same letter differ significantly ($p \le 0.05$), in columns, figures sharing similar letters are not different statistically ($p \le 0.05$).

Case 2. Study on effect of some macro and micronutrients on growth and yield of tomato (*Solanum lycopersicum* L.) cv. Arka Rakshak [15].

In this study and experiment was conducted to evaluate the effect of some macro and micro nutrients with different concentration levels as foliar on the vegetative growth, flowering and yield of tomato cv Arka Rakshak. The T5 revealed most significant ($p \le 0.05$) influence on all parameters under study as compared to T8 (control). The maximum plant height (135.75 cm), earliest flowering (24.29 days), earliest fruiting (35.33 days) and minimum days to maturity (63.33 days) recorded in T5-Mixture of all spray respectively, which was significantly ($p \le 0.05$) superior in compare to other treatments (Table 4).

In Table 5, it was observed that the maximum number of fruits per plant (72.07), maximum fruit weight (80.06 g), maximum yield per plant (4.77 kg) and maximum yield per ha (562.57 q) were recorded in T5-mixture of all spray, which was significantly superior over other treatments.

Case 3. Studies on promising influence of Micronutrients on yield and quality of Chilli under Mid Hill conditions of Arunachal Pradesh [16].

In this study an experiment was laid out during spring season of 2015 and 2016 in the mid hill conditions of Arunachal Pradesh to evaluate the effect of foliar application of micronutrients on growth, yield and quality of chilli cv. Kashi Anmol. Experiment was laid out with twelve treatments. The first foliar application of the treatment was sprayed at flower bud initiation stage and second spray after (twenty-five) 25 days. The overall result indicated superiority of treatment 0.4% $ZnSO_4$ towards plant growth and yield (Table 6).

Table 4. Growth and earliness attributing traits of tomato affected by foliar spray of macro and micronutrients

Treatment	Plant height (cm)	Days to first flowering	Days to first fruiting	Days to maturity
T1- $FeSO_4$ @ 0.2% spray	99.75	26.50	38.50	69.25
T2-Calcium nitrate @ 0.2% spray	102.50	27.05	38.83	68.80
T3-Boron @ 0.1% spray	111.08	28.31	40.31	68.25
T4-$ZnSO_4$ @ 0.2% spray	105.25	28.07	40.31	69.30
T5-mixture of all spray	135.75	24.29	35.33	63.33
T6-T2+T4 spray	123.24	27.54	39.57	67.75
T7-T2+T3 spray	127.5	26.75	38.79	65.28
T8- control water spray	93.75	33.02	44.81	76.96
CD ($p \leq 0.05$)	7.15	4.40	4.69	5.9

Table 5. Yield and yield attributing traits of tomato affected by foliar spray macro and micronutrients

Treatment	No of fruits per plant	Fruit weight (g)	Yield per plant (kg)	Yield/ha (q)
T1- $FeSO_4$ @ 0.2% spray	59.50	72.01	3.27	373.78
T2-Calcium nitrate @ 0.2% spray	65.31	66.67	3.45	389.25
T3-Boron @ 0.1% spray	59.28	72.89	3.32	383.05
T4-$ZnSO_4$ @ 0.2% spray	61.56	73.56	3.52	412.93
T5-mixture of all spray	**72.07**	**80.06**	**4.77**	**562.57**
T6-T2+T4 spray	64.00	74.55	3.78	452.73
T7-T2+T3 spray	60.25	71.07	3.55	399.36
T8- control water spray	50.53	60.22	2.04	275.61
CD ($p \leq 0.05$)	**7.60**	**9.66**	**0.64**	**90.33**

Table 6. Effect of foliar micronutrients application on Growth and yield characteristics of chilli cv. Kashi Anmol

Treatments	Plant height (cm)	No. of Branches	Fruit length (cm)	Fruit diameter (cm)	No. of fruits per plant	Fruit yield per plant (g)
T1 ($CuSO_4$ 0.2%)	90.17	12.67	6.59	1.96	119.22	320.33
T2 ($CuSO_4$ 0.4%)	91.03	9.67	6.59	1.93	96.56	186.33
T3 ($CuSO_4$ 0.6%)	62.7	9.67	6.83	1.83	83.89	155.67
T4 ($MnSO_4$ 0.2%)	87.57	12.33	7.09	2	115.78	342
T5 ($MnSO_4$ 0.4%)	86.23	10.67	6.38	1.96	110.33	225.5
T6 ($MnSO_4$ 0.6%)	93.53	12.67	5.78	1.99	93.67	150.33
T7 ($ZnSO_4$ 0.2%)	91.8	10.67	6.09	1.95	129.56	258.5
T8 ($ZnSO_4$ 0.4%)	101.8	12.33	7.28	2	131	378.67
T9 ($ZnSO_4$ 0.6%)	**97.8**	12.67	**6.53**	**1.88**	**109.67**	**234.67**
T10 (Boric acid 0.2%)	101.17	12.33	6.81	1.82	120.22	253.83
T11 (Boric acid 0.4%)	96.87	12.33	7.13	1.98	112.67	338.5
T12 (Boric acid 0.6%)	93.6	**14.33**	6.44	1.87	111.78	218.67
T13(water)	73.73	9.67	5.77	1.78	72.78	106.75
CD ($p \leq 0.05$)	**12.95**	**NS**	**0.8**	**0.11**	**32.3**	**27.95**

Case 4. Studies on effect of foliar application of micronutrients on potato (*Solanum tuberosum* L.) [17].

In this study an experiment was conducted to consider the effect of foliar application of micronutrients on potato (*Solanum tuberosum* L.) cv. "Kufri Joyti" for growth, yield and quality attributes of potato. The experiment was developed with eight treatments. Weight of tuber was significantly increased due to different micronutrient spray as compared to control. The highest tuber weight was observed in T8 (127.00 g) followed by T6 (124.00 g) and T4 (124.00 g) respectively. The effect of micronutrients sprays significantly ($p\leq0.05$) influenced dry matter and starch in potato tuber. The highest Dry matter content was observed in T5 (22.67%) followed by T6 (22.23%) which was at part with T8 (22.23%) followed by T3 (22.03%) respectively. The highest starch content was observed in T7 (21.42%) which was at pat with T8 (21.42%) [Table 7].

Case 5. Studies on effect of foliar application of Micronutrients on growth and yield parameters in Eggplant cv. HLB 12 [18].

In this study an investigation carried out during autumn-winter season of 2014 and 2015. The experimental treatments viz. T1 (control-water spray), T2 (zinc sulfate 0.3%), T3 (zinc sulfate 0.4%), T4 (zinc sulfate 0.5%), T5 (iron sulfate 0.3%), T6 (iron sulfate 0.4%), T7 (iron sulfate 0.5%), T8 (borax 0.3%), T9 (borax 0.4%) and T10 (borax 0.5%). The data presented in Table 8 suggest that maximum fruit per plant (26.13) was found in treatment T4 (zinc sulfate 0.5%) as compared to other treatments. The longest fruit (24.04 cm), the maximum fruit diameter (5.10 cm) and the heaviest fruits (75.77 g) were harvested from treatment 10 (borax 0.5%) compared to other treatments respectively.

Case 6. Studies on effect of foliar application of micronutrients on growth and yield of cabbage (*Brassica oleracea* L var. Capitata) cv GOLDEN ACRE [19].

In this study an experiment was conducted with a view to workout effects of micronutrients and growth regulators alone or in combination of both on growth and yield of cabbage. The treatments comprised of three levels of micronutrients. The result revealed that, the treatment M1 (zinc sulphate 0.5%) recorded the maximum plant height (24.36 cm) on pooled basis. The highest head weight (888.00 g) and maximum yield of head (25.97 t/ha) were obtained during 1st year respectively (Table 9).

Table 7. Effect of foliar application of micronutrients on potato yield and quality attributes

Treatments	Average weight of tuber (g)	Dry matter %	Total Starch %
T1= Control) FYM (25 ton/ha) + RDF 15=0:120:100 kg NPK/ha	118.00	20.55	18.42
T2= control + 0.1% Borax	97.00	21.43	18.72
T3= control + 0.2% Zinc Sulphate	123.00	22.03	19.92
T4=control + 0.2% Manganese Sulphate	124.00	21.93	20.42
T5=control + 0.1% Borax + 0.2% Zinc Sulphate	121.00	**22.67**	19.52
T6=control + 0.1% Borax + 0.2% Manganese Sulphate	124.00	22.23	20.42
T7=control + 0.2% Zinc Sulphate + 0.2% Manganese Sulphate	103.00	21.8	**21.42**
T8=control + 0.1% Borax + 0.2% Zinc Sulphate + 0.2% Manganese Sulphate	**127.00**	22.23	21.42
CD ($p\leq0.05$)	**5.73**	**1.12**	**0.018**

Table 8. Effect of micronutrients on number of fruits per plant, fruit length (cm), fruit diameter and average fruit weight (g) of eggplant cv HLB 12

Treat Symb.	Treatments	No. of fruits per plant	Fruits length (cm)	Fruit diameter (cm)	Average fruit weight (g)
T1	Control (water spray	18.80	15.70	3.94	56.06
T2	Zinc sulfate (0.3%)	22.70	19.41	4.50	65.61
T3	Zinc sulfate (0.4%)	25.56	20.71	4.65	70.57
T4	Zinc sulfate (0.5%)	**26.13**	21.12	4.73	71.71
T5	Ferrous sulfate (0.3%)	20.54	17.18	4.17	61.79
T6	Ferrous sulfate (0.4%)	22.59	18.76	4.35	63.57
T7	Ferrous sulfate (0.5%	23.23	19.14	4.45	64.51
T8	Borax (0.3%)	22.27	20.12	4.49	69.52
T9	Borax (0.4%)	25.46	23.17	4.89	73.60
T10	Borax (0.5%	25.42	**24.04**	**5.10**	**75.77**
CD ($p\leq0.05$)		**2.14**	**1.50**	**0.39**	**3.12**

Table 9. Effect of micronutrients on growth and yield of cabbage cv. GOLDEN ACRE

Treatments	Plant Height (cm)			Weight of head (g)			Yield of head (t/ha)		
	1st year	2nd year	Pooled	1st year	2nd year	pooled	1st year	2nd year	pooled
M0 (Control)	23.44	23.02	23.23	802.0	686.82	744.40	22.53	21.78	22.15
M1 ($ZnSO_4$ 0.5%)	23.86	24.86	**24.36**	**888.0**	753.33	820.67	**25.97**	22.75	24.36
M2 (Fe $SO_4$0.5%)	23.54	23.55	23.55	852.0	710.33	781.17	25.84	22.29	24.06
C.D. (P=0.05)	**NS**	**1.11**	**0.75**	**51.13**	**40.04**	**31.77**	**2.99**	**NS**	**1.32**

Case 7. Studies cauliflower growth and quality response to nitrogen fertilization and micronutrients foliar application in newly reclaimed areas [20].

In this study two field experiments during 2017/18 and 2018/19 season were conducted to evaluate the effect of soil application of nitrogen levels and foliar application of micronutrients, they observed that, effects of either B or Mo foliar application on yield of cauliflower curds compared with untreated plants, nevertheless the combined application of B and Mo together was more effective than application of B and Mo when the separately applied. Moreover, inorganic nitrogen at 60 kg/fed was more effective in the presence of B and Mo at 100 and 50 ppm, respectively, than the other combinations and achieved the highest curd yield, the maximum yield (22.74 tone/fed) and (22.93 tone/fed) in season of 2017/2018 and 2019/2019 respectively (Table 10).

Values are the means of three replicates. Values followed by the same letters within a column for each genus are not significantly different at the 1% level of probability according to Duncan's multiple range tests. N1= 30 kg nitrogen/fed., N2= 45 kg nitrogen/fed., N3= 60 kg nitrogen/fed., B 0 + Mo 0= control, B 100= 100 ppm of boron, Mo 50= 50 ppm of molybdenum and B 100 + Mo 50= 100 ppm of boron combined with 50 ppm of molybdenum.

Similarly from Table 11, it was observed that with the nitrogen levels of 60kg/ha and combined boron and molybdenum (B 100 + Mo 50), the curd fresh weight was increased compared with control and maximum fresh weight (1980.17 g) and (2099.1 g) in season of 2017/2018 and 2018/2019, respectively.

Values are the means of three replicates. Values followed by the same letters within a column for each genus are not significantly different at the 1% level of probability according to Duncan's multiple range test. N1= 30 kg nitrogen/fed., N2= 45 kg nitrogen/fed., N3= 60 kg nitrogen/fed., B 0 + Mo 0= control, B 100= 100 ppm of boron, Mo 50= 50 ppm of molybdenum and B 100 + Mo 50= 100 ppm of boron combined with 50 ppm of molybdenum.

Table 10. Main effects of nitrogen levels, micronutrients treatments and their interactions on cauliflower Curds yield (tone/fed)

Treatments	2017/2018 season			2018/2019 season		
	N1(30 kg/fed	N2(45 kg)	N3(60 kg)	N1(30 kg)	N2(45 kg)	N3(60 kg)
B 0 + Mo 0	13.14^{f}	13.14^{f}	13.43^{f}	13.16^{f}	13.84^{f}	14.21^{ef}
B 100	14.01^{ef}	14.63^{ef}	15.94^{de}	14.28^{ef}	15.05^{ef}	16.45^{de}
Mo 50	16.41^{de}	18.92^{bc}	21.04^{ab}	16.61^{de}	19.17^{bc}	21.53^{ab}
B 100 + Mo 50	17.75^{cd}	20.23^{bc}	**22.74^{a}**	18.48^{cd}	20.32^{bc}	**22.93^{a}**

Table 11. Main effects of nitrogen levels, micronutrients treatments and their interactions on cauliflower Curd fresh weight (g)

Treatments	2017/2018 season			2018/2019 season		
	N1(30 kg/fed)	N2(45 kg)	N3(60 kg)	N1(30 kg/fed	N2(45 kg)	N3(60 kg)
B 0 + Mo 0	1128.92^{h}	1289.40^{gh}	1367.57^{fg}	1246.92^{h}	1293.02^{gh}	1368.33^{gh}
B 100	1402.91^{fg}	1488.78^{ef}	1508.14^{ef}	1425.39^{fg}	1541.51^{f}	1587.01^{ef}
Mo 50	1576.69^{de}	1683.81^{cd}	1859.86^{ab}	1711.19^{de}	1804.15^{cd}	1974.12^{ab}
B 100 + Mo 50	1625.08^{de}	1799.74^{bc}	1980.17^{a}	1758.81^{d}	1929.03^{bc}	2099.11^{a}

Case 8. Studies on impact of foliar spray of micronutrients on growth, yield and quality of broccoli (*Brassica oleracea* var. italic) cv. Pusa KTS-1 [21].

In this study a field experiment was conducted during the winter season of 2015-2016 and 2016-2017 years. The five micronutrient levels were applied as foliar feeding to broccoli variety (cv.Pusa KTS-1). The data revealed in Table 12 indicate that, highest stalk length was observed in (T14) zinc sulphate 0.4%. Longest root length was noted in foliar spray of (T15) zinc sulphate @ 0.60% (16.40 cm) over control (T0) (11.61 cm). Application of (T5) boric acid @ 0.40% recorded maximum pooled value of total yield (135.05 q/ha). The maximum pooled value of ascorbic acid content was recorded with treatment (T15) zinc sulphate @ 0.60% (86.29 mg). The pooled analysis of TSS revealed that (T5) boric acid @ 0.40% produced maximum TSS (7.52) over the other treatments.

Case 9. Studies effect of foliar ZnO and FeO nanoparticles application on growth and nutritional quality of Red Radish and assessment of their accumulation on Human health [22].

In this study tow open field experiments were organized in order to assess the effects of green synthesized nanoparticles of Zn and Fe oxides on plant growth traits photosynthetic capacity and nutritional quality of red radish (cv. Champion). Treatments included: chicken manure, foliar application of ZnO+FeO at the rate of 60, and 55 ppm, respectively, chicken manure plus ZnO+FeO. The statistical analysis in Table 13 showed that the highest values of plant height (26.01 cm), leaf area (77.49 cm^2), fresh weight of root (63.33 g), Dry weight of root (14.98 g), root diameter (23.07mm), leaf chlorophyll (40.76 SPAD) and Total yield (18.48 t/ha) were obtained from treatment T3 respectively.

Values followed by the same letter are not statistically different according to Tukey test ($P < 0.05\%$).

Case 10. Studies effect of soil application of potassium and foliar spray of zinc and boron on yield, yield contributing character and quality of watermelon [*Citrullus lanatus (thunb.)*] in lateritic soils of Konkan [23].

The above study worked on effect of soil application of potassium and foliar spray of Zinc and Boron on yield and quality of watermelon, the treatments included levels of potassium i.e. K0, K1, K2 and K3 @ 0, 25, 50 and 75 kg/ha, respectively and foliar application of micronutrients i.e. M0, M1, M2, M3 @ 0, 0.5% Zn, 0.1% B and 0.5% Zn + 0.1% B at flowering respectively. Result showed that, the application of 75 kg K_2O/ha through soil along with 0.5% Zn and 0.1%B through foliar application found effective to increased yield and yield attributing characters as well quality of watermelon in terms

Table 12. Effect of foliar spray of micronutrients on growth, yield and quality attributes of broccoli (*Brassica oleracea* var. italica) cv. Pusa KTS-1 at harvest stage under Varanasi region

Treatments	Stalk length (cm)	Root length (cm)	Yield (q/ha)	Vitamin C (mg/100 g)	TSS (%)
Control (T0)	15.93	11.61	124.50	80.97	6.59
Ammonium Molybdate @ 0.20% (T1)	17.49	13.62	128.93	82.03	6.79
Ammonium Molybdate @ 0.40% (T2	17.37	13.78	131.66	84.28	7.28
Ammonium Molybdate @0.60% (T3)	16.43	13.89	125.55	83.18	7.04
Boric Acid @ 0.20% (T4)	16.93	13.91	131.38	81.67	6.68
Boric Acid@ 0.40% (T5)	16.45	14.93	**135.05**	84.34	**7.52**
Boric Acid @ 0.60% (T6)	15.51	12.92	128.93	83.48	7.20
T7 (Copper sulphate @ 0.20%)	15.53	12.85	124.88	81.70	6.42
T8 (Copper sulphate @ 0.40%)	15.39	13.44	127.42	82.58	6.99
T9 (Copper sulphate @ 0.60%)	15.48	13.95	124.38	81.05	6.61
T10 (Ferrous sulphate @ 0.20%)	15.15	12.94	125.96	81.02	6.54
T11 (Ferrous sulphate @ 0.40%)	15.99	14.08	124.99	81.99	7.01
T12 (Ferrous sulphate @ 0.60%)	16.47	14.90	127.89	82.26	7.23
T13 (Zinc sulphate @ 0.20%)	17.93	14.99	128.47	83.49	6.77
T14 (Zinc sulphate @ 0.40%)	**18.73**	15.87	128.88	84.01	7.04
T15 (Zinc sulphate @ 0.60%)	17.92	**16.40**	134.98	**86.29**	7.15
CD (P=0.05)	**1.75**	**1.65**	**1.78**	**0.39**	**0.09**

Table 13. Effect of treatments on plant growth parameters, chlorophyll of leaves, and total yield of red radish

Growth parameters	Chicken manure (T1)	FeO + ZnO GNPs (T2)	Chicken manure + FeO +ZnO (T3)
Plant heights (cm)	24.35[b]	23.50[b]	26.01[a]
Leaf area (cm^2)	73.61[b]	72.86[b]	77.49[a]
Fresh weight of root (g)	59.71[b]	61.53[ab]	63.33[a]
Dry weight of root (g)	11.88[c]	12.68[bc]	14.98[a]
Rood diameter (mm)	20.31[b]	18.01[c]	23.07[a]
Leaf chlorophyll (SPAD)	35.35[c]	37.84[b]	40.76[a]
Total yield (t/ha)	16.06[b]	16.87[ab]	18.48[a]

Table 14. Effect of soil application of potassium and foliar spray of zinc and boron on yield and yield contributing characters of watermelon

Treatments	Average wt. of fruits/plot (kg)				Yield (tone/ha)			
	M0	M1	M2	M3	M0	M1	M2	M3
K0 (0 kg/ha)	3.50	3.50	3.84	3.55	28.2	28.4	29.8	29.9
K1 (25 kg/ha)	3.83	4.14	3.67	3.81	33.4	34.2	35.3	33.2
K2 (50 kg/ha)	4.00	4.23	3.98	3.87	38.3	36.0	37.4	36.5
K3 (75 kg/ha)	4.22	**5.30**	4.03	4.17	41.1	42.1	42.8	**43.8**
C.D(P=0.05)	**0.21**		**0.21**		**0.9**		**0.9**	

of TSS and Sugar %. It was observed that the treatment combination K3M3 (75 kg K_2O ha^{-1} and 0.5% Zn + 0.1% B) showed highest yield (43.8 t ha^{-1}) respectively which was found significantly superior over the rest of the combinations (Table 14).

Case 11. Studies the effect of foliar application of micronutrients on growth and yield of onion (*Allium cepa* L.) cv. Agri found dark red [24].

In this study an experiment was conducted to determine the effect of foliar application of micronutrients on growth and yield of onion (*Allium cepa* L.) cv. Agri found drark red. The treatments consist of foliar sprays of 4 micronutrients. Significantly the maximum fresh weight of bulb per plant (130.67 g), Maximum Dry weight of bulb per plant (27.44 g) and the maximum bulb yield of (394.86 q/ha) were recorded in the treatment T3 (B 0.25%) [Table 15].

Case 12. Studies effect of foliar application of micronutrients on Physio-Chemical feasibility of Okra (*Abelmoschus esculentus* L.) [25].

This study worked out an experiment during 2014-2015, to study the effect of foliar application of micronutrient on physiochemical feasibility of okra. Statistical analysis of data revealed that, the maximum weight of fruit (910.11 g), maximum length of fruit (7.30 cm), maximum diameter of fruit (1.98 cm) and maximum yield (20.72 mt/ha) were observed with application of treatment M5 i.e. combination of Mg, Mn, Fe, Zn at 0.5% each as compared to control (Table 16).

Case 13. Studies effect of foliar spray and soil application of micronutrients on yield and quality of coriander in lateritic soils of Konkan region [26].

In this study an experiment was laid out to evaluate the foliar spray and soil application of micronutrients on yield and quality of coriander. The result of the research revealed that, the highest yield (11.18 t/ha), Highest chlorophyll content (2.54 mg/g) and ascorbic acid content (524.79 mg/100 g) were obtained with the application of 0.5 per cent $ZnSO_4$ through foliar spray along with 100 per cent RDF (T5) respectively (Table 17).

Table 15. Effect of foliar spray of micronutrients on growth attributing and yield parameters of Onion

Treatments	Fresh weight of bulb/plant (g)	Dry Weight of bulbs (g)	Bulb yield (q/ha)
T1=Zn 0.5%	128.45	26.97	297.42
T2=Mn 1.0%	110.10	23.71	271.78
T3=B 0.25%	**130.67**	**27.44**	**394.86**
T4=Cu 1.0%	95.28	20.00	205.12
T5=Zn 0.5 + Mn 1.0%	123.48	25.93	297.42
T6=Zn 0.5 + B 0.25%	120.19	25.23	292.3
T7=Zn 0.5 + Cu 1.0%	98.54	20.65	210.25
T8=Zn 0.5 + Mn 1.0 + B 0.25 +Cu 1.0%	126.12	26.48	333.32
T9=Control (Water spray)	109.00	22.89	271.78
C.D. at 5% level	**19.35**	**3.54**	**NS**

Table 16. Effect of micronutrients weight of fruit, length of fruit (cm), diameter of fruit (cm) and yield (mt/ha) of okra

Treatments	Weight of fruits (g)	Length of Fruit (cm)	Diameter of fruit (cm)	Yield (mt/ha)
M1 $MgSO_4$ (0.5%)	9.07	5.77	1.79	16.90
M2 $MnSO_4$ (0.5%)	9.10	5.72	1.82	17.18
M3 $FeSO_4$ (0.5%)	9.31	5.81	1.88	17.79
M4 $ZnSO_4$ (0.5%)	9.90	7.11	1.91	19.13
M5 M1 to M4 (0.5%)	**10.11**	**7.30**	**1.98**	**20.72**
Control	8.98	7.01	1.69	14.13
CD at 5%	**1.190**	**0.901**	**0.589**	**-**

Table 17. Effect of foliar spray and soil application of micronutrients on yield and quality characteristics of coriander

Treatments	Yield (t/ha)	Chlorophyll content (mg/g)	Ascorbic acid (mg/100 g)
T1-Absolute control	5.32	1.48	187.43
T2-100% RDF (60:60:30 N: P_2O_5: K_2O kg ha^{-1})	9.68	1.76	308.21
T3-100% RDF + $ZnSO_4$ @ 0.25% Foliar spray	10.17	2.38	420.67
T4-100% RDF + $ZnSO_4$ @ 15 kg ha^{-1} through soil	10.04	2.33	404.01
T5-100% RDF + $ZnSO_4$ @ 0.5% Foliar spray	**11.18**	**2.54**	**524.79**
T6-100% RDF + $ZnSO_4$ @ 20 kg ha^{-1} through soil	10.56	2.48	495.64
T7-100% RDF + $CuSO_4$ @ 0.25% Foliar spray	9.91	2.28	395.68
T8-100% RDF + $CuSO_4$ @ 15 kg ha^{-1} through soil	9.80	2.23	374.85
T9-100% RDF + $CuSO_4$ @ 0.5% Foliar spray	10.14	2.35	458.15
T10-100% RDF + $CuSO_4$ @ 20 kg ha^{-1} through soil	9.98	2.30	404.01
CD at 5%	**0.75**	**0.067**	**5.553**

6. CONCLUSION

Foliar application of micronutrients has a dynamic role to play in vegetable production in order to increase all attribute characters to better meet the requirements of food supply in general as an additional supplementation for nutrients. It can be concluded from this review of literature point of view that, foliar micro nutrition in vegetables has been found beneficial for improving overall growth, yield and quality. In all cases of these experiments, foliar application of micronutrients has found to show satisfactory results when compared to the controlled condition. Among different concentrations of micronutrients, it is found that combined application of $FeSO_4$ @ 0.2%, calcium nitrate @ 0.2%, Boron @ 0.1% and $ZnSO_4$ @ 0.2% provided better result over control in many vegetables. Application of zinc (300 ppm) has showed better result on vegetative growth and yield characteristics over control in potato.

Combined application of Boron 100 ppm + molybdenum 50 ppm along with 60 kg/fed of nitrogen showed better result in Cole crops. Combined application of $MgSO_4$ (0.5%), $MnSO_4$ (0.5%), $FeSO_4$ (0.5%), $ZnSo_4$ (0.5%) and Borax (0.5%) has given better result in most of the vegetables.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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