Assessment Concerning the Role of Foliar Administration of Micronutrients on Growth, Yield, and Quality Characteristics of Vegetable Crops

Abstract

Vegetables are one of the main elements in terms of ensuring a person's food security and nutritional well-being. Integrated application of macronutrients coupled with adequate incorporation of micronutrients is one of the key factors for quality vegetable production. For ensuring maximum vegetable production with superior quality foliar nutrition is the better alternative in the era of climate change. Foliar application is the easiest and most effective ways to administer micronutrients as compared to other methods. Trace element such as iron (Fe), zinc (Zn), manganese (Mn), molybdenum (Mo), boron (B), chlorine (Cl), copper (Cu), and nickel (Ni) are essential for vegetable crops. The primary goal of this review article is to investigate the merits of micronutrients and the production potential of various vegetable crops through foliar nutrition. Additionally, this study aims to clarify the role of micronutrients in quality vegetable production.Several studies suggested that exogenous application of micronutrients has a tremendous effect on overall growth and quality in a variety of crops. Many researches have demonstrated that *via*applications of Boron @250ppm significantly influenced fresh weight of fruit, number of fruits per plant,number of seeds per plant, germination %, vigour index and root and shoot lengths of seedlingsin sweet pepper. Various researchers also concluded that application of Zn @1000 ppm + B @200 ppm + Mo @50 ppm provides significant impact on head diameter, volume of head, chlorophyll a, chlorophyll b and chlorophyll total in cabbage.

Keywords: Micronutrients, foliar spray, vegetable crops, growth, yield, quality,

1. Introduction

Vegetables are usually considered as a protective food because these are a potential source of vitamins, minerals, and dietary fibres. India is the leading producer of vegetables after China, reported by (FAO) of the United Nations. India produced 204.61 million metric tonnes of vegetables across an area of 11.28 million hectares in the years 2021–2022 (Anonymous, 2022). India mostly exports to its neighbours, especially the UAE, Bangladesh, Pakistan, Saudi Arabia, Sri Lanka, and Nepal. But the irony is India still has only 1% share of the global market. As a result, there is a large scope for improvement in the area of vegetables production and productivity in order to satisfy the demands of the expanding population and provide nutritional security.

This can be accomplished by combining existing technology with integrated nutrient management techniques (INM) (Paramesh *et al.*, 2023). INM is a technology that can provide effective and affordable solutions for supplying macro- and micronutrients to plants. (Wang *et al.*, 2019). Current era the vegetable cultivation is quite intensive and highly responsive to fertilisers and superior varieties or hybrids, which generated the issue of nutrient imbalance in soils due to excess nutrient mining. To fulfil the needs of future food security food production must increase substantially while agriculture's environmental impact must drop significantly. (Foley *et al*., 2011). According to the criteria of essentiality of nutrients by Arnon and Stout, (1939) there are a total of 17 essential nutrients that plants need for the effective completion of their lives.

Micronutrients are important factor for improving the quality and productivity of a variety of crops in the horticulture industry (Tripathi *et al.*, 2015). It aids in the catalytic process of nutrient absorption and balances other nutrients (Singh and Kalloo, 2000). Micronutrients are found in soil at lower levels than macronutrients, plants grown in micronutrient-deficient soils exhibit decreased productivity and yield (Havlin *et al.*, 2005). However, their deficiency may result in a variety of physiological disorders or diseases in plants, which may subsequently lead to a reduction in both the amount and quality of vegetable products (Sharma *et al.,* 2016).

India suffers from a widespread zinc deficiency. The magnitude of boron deficit is next to zinc in India. Sometimes, a nutrient's availability inhibits the activity of another nutrient, causing an antagonistic effect. When the roots are incapable of providing enough nutrition, foliar spray of micronutrients is the best alternative (Kinaci*et al*., 2007). Foliar feeding is an effective approach to supply nutrients during a period of rapid plant growth, when it can strengthen the plant's mineral condition and increase crop output (Kolota*et al*., 2001). In current scenario foliar spraying became very popular, due to their effectiveness towards absorption (Bozorgi *et al*., 2011). Within a few hours to a day of foliar spraying, the majority of micronutrients enter the plant body through the leaves. To address micronutrient deficiencies of Fe, Cu, Mn, Zn, and B especially in dry and semi-arid areas, foliar spray is highly recommended (Kaya *et al*., 2005).

The purpose of this research is to emphasise the importance of micronutrients in sustainable vegetable production by using an appropriate application strategy, to address the issues of micronutrient deficiency, and to develop strategies for their optimal management for long-term olericulture. As a result, an effort has been undertaken in the current review to summarise the research relating to the overall significance of foliar micronutrition in vegetable crops.

2. Micronutrient's Significance

Micronutrient deficiencies have a significant impact on plant growth, metabolism, and the reproductive stage. Contrarily, plants are affected by even a minor deficit or excess.

Plants can absorb micronutrients in both ionic and non-ionic forms. The mobility of micronutrients in plant plays a significant role in determining the deficiency of particular nutrient. The availability of nutrients to plants and the technique of administration both are significantly influenced by the mobility of micronutrients in the soil.An important aspect of regulating nutrient supply in plants is soil pH. All macro and micronutrients are most readily available in soils within a pH range of 6.5 to 7.0. (Choudhary *et al*., 2013).

Table 1. Types of micronutrients acquired by plants

Element	**Ionic forms**	**Non-Ionic forms**
Boron (B)	H_2BO^{3-}, HBO_3^{2-}, $B_4O_7^{2-}$	
Manganese (Mn)	Mn^{2+}	$MnSO_4$ with EDTA
Iron (Fe)	$Fe^{2+,}$ Fe^{3+}	$FeSO_4$ with EDTA
Copper (Cu)	Cu^{2+}	$CuSO_4$ with EDTA
Molybdenum (Mo)	MoO_4^{2-}	
Chlorine (Cl)	Cl^-	
Zinc (Zn)	Zn^{2+} , $Zn(OH)_2$	$ZnSO_4$ with EDTA

EDTA: ethylenediaminetetracetic acid

Source: Singh *et al.*,2016. An introduction of plant nutrients and foliar fertilization: A review. Precision farming: A new approach.

Table 2. Mobility of nutrients in soil and plant

Mobility	**Soil**	**Plant**
Mobile	BO_3^{2-}, Mn^{2+}, Cl^- ,Mn^{2+}	N, P, K
Moderately mobile	-	Zn
Less mobile	$Cu^{2+,}$ NH_4^+, K^+, Ca^+, Mg^{2+}	S, Fe, Mn, Cu, Mo, Cl
Immobile	Zn^{2+}, HPO_4^{2-}, HPO_4^-	Ca, B

Boron (B), is essential for growth, development, and a range of physiological activities, including fruiting, cell division, water interactions, hormonal movement, sugar translocation, cell wall formation, lignification, phenol, carbohydrates, IAA, and RNA metabolism, pollen germination, pollen tube growthconferring drought tolerance (Ahmad *et al*., 2009; Malek *et al*., 2011).It is utilized by plants as boric acid (H_3BO_3). Moreover, plants need boron to efficiently fix nitrogen (Hakala *et al*. 2006). The main functions of boron in plants are to facilitate the metabolism and solubility of calcium.Iron (Fe) is an important element of chlorophyll biosynthesis. Furthermore, it is a part of numerous enzymes which is involved in the transfer of energy such as reduction and fixation of nitrogen and synthesis of lignin *etc*. Leghemoglobin and cytochromes both contain iron, which is essential for their structural integrity. During respiration and photosynthesis, it engages in a number of oxidation-reduction activities. (Borlotti *et al*., 2012).Zinc (Zn) is absorbed by plants as Zn^{2+}. Zn is primarily utilized by plants as a metal enzyme activator. Zinc is also involved in an array of enzymatic processes including the production of IAA which boosts flower production, fruit set, and seed maturity. Zn is a critical element of several enzymes, including proteinase, peptidase, aldolase, dehydrogenase, and phosphohydrolase (Mousavi, 2011).Copper (Cu)is an essential micronutrients for regulating a variety of biochemical reaction in plants due to its stability as a cofactor for many proteins and enzymes. It facilitates the utilisation of iron during chlorophyll synthesis (Harris and Lavanya, 2016). Copper isessential for the transmission of electrons during photosynthesisand respiration.

Maganese (Mn) is taken by plants as Mn^{2+}, but it quickly oxidises to Mn^{3+} and Mn^{4+} forms. It is a part of the water-splitting enzyme involved in O_2 evolution and electron transfer in the photosystem-II of photosynthesis. (Pankaj *et al*., 2018). Due to its involvement with super oxide dismutase (SOD), it detoxifies cells from the effects of oxidative stress. Chlorine (Cl), is inexpensive and maintains fruit qualities like appearance, soluble solids content, acidity, pH, texture, and flavour, as well as controls bacteria development in plants (Rahman *et al*., 2012).Plants take up chlorine as chloride (Cl^-) through both their roots and leaves. Additionally, it controls the water potential of plants by adjusting the osmotic pressure, which includes stomata opening, cell elongation, turgor pressure, and osmotic pressure.Plants absorb molybdenum (Mo) as molybdate ions. It accelerates the metabolic process and encourages photosynthesis (Chattopadhyay and Mukhopadhyay, 2003). Both the fixation of ambient nitrogen and the uptake of nitrates depend on Mo. Nickel (Ni) in the form of Ni^{2+} is absorbed by plants.Urease, an enzyme required for the metabolism of nitrogen and the regulation of senescence, is activated by nickel (Ni). Similarly, it substitutes Zn and Fe as a cofactor for several enzymes. An excess of one of the six metal ions—Ni^{2+}, Mg^{2+}, Fe^{2+}, Mn^{2+}, Cu^{2+}, and Zn^{2+}can generate a scarcity of the other with the lowest availability because they appear to be competing in their absorption, (Wood *et al*., 2004).

2.1 Deficiency symptoms of Micronutrients in vegetable crops

The adoption of intensive cropping system leads to imbalanced use of chemical fertilisers, expansion of vegetable agriculture on marginal areas and micronutrient deficiency in soil. To get high quality produce, micronutrient deficiencies must be detected before visual symptoms which are expressed by the plants at the stage of hidden hunger. In the event of a deficiency, a mobile nutrient in the plant travels to the growing tips. As a result, deficienciesbecome visible on the lower leaves. A deficiency in an immobile nutrient usually appear on the younger plant parts because it doesn't migrate to the growing sites,Therefore, careful application of micronutrients is crucial in vegetable production to produce a yield of exceptional quality.

Boron deficiency is extremely problematic in calcareous soils, sandy leached soils, acidic soils and reclaimed yellow or lateritic soils.A lack of boron results in the breakdown of the growing tip, which ultimately kills the shoot tip, rosette appearanceof plant due to shortening of terminal growth, terminal leaves that are light green become thick, curled, and brittle, restricted root growth, and flowers abortion. Brown heart or heart rot in sugarbeet and turnips, browning of curds and hollow stem in cauliflower, knob splitting in knol-khol, akashin in radish, cracked stem in celery, and fruit cracking in tomatoes are some of the indications of boron deficiency.In the case of zinc deficiency plants shows short terminal leaves, weak bud formation and leaves have dead regions. Short internodes and a reduction in leaf size are the most evident Zn deficiency symptoms. The main manifestations of zinc deficiency are mottling and rosseting in vegetables and fern leaf in potatoes. Tomato, potato, bean, and onion crops are particularly vulnerable to a Zn deficit (Sainju*et al*., 2003). In India iron deficiency is very common in alkaline and calcareous soil. An excess of iron could cause Fe-toxicity under anaerobic conditions (Singh *et al*., 2003).Fe deficiency is primarily exhibited by yellow leaves due to low quantities of chlorophyll. Green vein colour and yellow interveinal regions on immature leaves are signs of iron deficiency.

Copper deficiency is most frequent in sandy soil, calcareous soil, and soil with high organic matter contents. Its symptoms include slow growth, deformed young leaves, necrosis of the apical meristem, curled tips, dieback of stems and twigs, ragged leaf edges, and a chance of plant top withering (Das, 2018).Copper availability is reduced by 100 times with every unit increase in soil pH (between pH 7 and pH 8). (Singh *et al*., 2016). A distinctive sign of Mn deficiency is interveinal chlorosis. The size of the leaves decreases. The main disorders caused by a manganese deficiency are speckled yellow in beetroot, interveinal yellow mottling in cabbage, yellow striping in the onion, chlorosis and necrosis of the bean leaves, and marsh spot in the pea.Mo deficiency is very common in alluvial soils. Mottling, burning, withering, and frequent cupping of elder and middle leaves are visual signs of Mo deficiency. Growth impairment, shoot distortion, older leaves with interveinal yellowing and necrotic edges are the symptoms of Mo shortage. The most prevalent disorder caused by a deficiency of molybdenum in cauliflower is whiptail.

Deficiency of nickel can results as delayed nodulation and less efficient nitrogen fixation in leguminous vegetable crops. It is crucial for cowpea throughout the reproductive period. In vegetable crops like potatoes and beans, the susceptibility to chlorine deficit is higher (Singh, 2016).

2.2 Foliar Application of micronutrients (Foliar Nutrition)

Foliar application is the technique of exogenous application of micronutrient solutions to the foliage of the plants at appropriate concentrations. Foliar treatments of micronutrients including molybdenum, zinc, copper, iron, manganese, and boron are preferable because they provide rapid availability of nutrients, improve instant uptake of applied nutrients, eradicate the issue of soil fixation, supplement when an immediate response is required, and last but not least, provide nutrients that may not be easily available for root uptake.Foliar treatment is thus a potentially effective strategy to maximise the profitability of vegetable crops in a limited amount of time. When micronutrients are sprayed on leaves, several of those nutrients are quickly absorbed by the leaves.In current scenario foliar spraying became very popular,due to their effectiveness towards absorption (Bozorgi *et al*., 2011). Within a few hours to a day of foliar spraying, the majority of micronutrients enter the plant body through the leaves. To address micronutrient deficiencies of Fe, Cu, Mn, Zn, and B especially in dry and semi-arid areas, foliar spray is highly recommended (Kaya *et al*., 2005). Foliar application of micronutrients is a common practise to reduce environmental pollution because it enhance nutrient uptake by reducing the amount of fertiliser given to the soil (Abou-El-nour, 2002).

Table 3: Meteorological condition favouring foliar applications

Time of Day	Late evening; after 6:00 p.m. Early morning; before 9:00 a.m.
Temperature	Low temperature 18-19^{0}C (Ideal 21^{0}C)
Humidity	Greater than 70 % relative humidity
Wind speed	less than 5 mph
Rainfall	Within 24 to 48 hours after a foliar application may reduce the application effectiveness, as not all nutrient materials are immediately absorbed into the plant tissue

Source: Patil and Chetan, 2016. Foliar fertilization of nutrients.

Table. 4. Commonly used micronutrient fertilizers for foliar spray

Micronutrient	Fertilizers
Boron	Solubor (20% B), Boric acid (17% B), Borax (11% B),
Iron	Ferrous sulphate (19% Fe), Ferrous ammonium sulphate (14% Fe), Chelated Fe (12% Fe)
Zinc	Zinc oxide (55-70% Zn), Zinc sulphate (33% Zn), Chelated Zn (12% Zn)
Copper	Cuprous oxide (89% Cu), Cupric oxide (75% Cu),Copper sulphate (25% Cu), Chelated Cu (13% Cu)
Molybdenum	Ammonium molybdate (54% Mo), Sodium molybdate (39% Mo)
Manganese	Manganese oxide (41-68% Mn), Manganese sulphate (30% Mn), Manganese chloride (17% Mn), Chelated Mn (12% Mn)
Chlorine	Ammonium chloride (66% Cl), Potassium chloride (47% Cl)

Source: Patel *etal.*, 2022. Role of Micronutrients Foliar Nutrition inVegetable Production: AReview. *Journal of Experimental Agriculture International*

Table.5. Effect of foliar applicationof micronutrients on vegetable crops

Crop	Foliar nutrition	Stage	Improved characters	References
Cabbage	Zn @1000 ppm + B @200 ppm + Mo @50 ppm	At 15 DAS and 20 & 35 DAT	Maximum head diameter (12.96 cm) and volume of head (842.42 cm^3), chlorophyll a (0.276 mg/g), chlorophyll b (0.295 mg/g) and chlorophyll total (0.637 mg/g) at 45 DAT	Patel *etal.* (2021)

Sweet Pepper	• Boron @250ppm • Boron @350ppm	at the pre-flowering and flowering stage	• Maximum number of fruits per plant (4.50), fresh weight of fruit (80.25g), seeds per fruit (161), number of seeds per plant (727.25), % germination (78.25%), root length (2.75cm) of seedling, shoot length (2.94cm) of seedling, vigor index (1.833) • Fruit length (7.70cm) with an average fresh weight (75.25g) average number of seeds per fruit (55.66) and weight of 500 seeds (2.549 g)	Maria *et al.*, (2021)
Onion	Micronutrient Mixture i.e. iron-@ 2.5%, boron @0.5%, zinc @3%, copper @1% and manganese- @1%	at 30 and 45 DAP	Plant height (63.72 cm), number of leaves/plant (12.71), polar diameter (58.62 mm), equatorial diameter (46.88 mm), average weight (61.72 g) of bulb, yield ha-1 (266.80 q), highest % of A grade bulb(29.82), and B: C ratio (4.61)	Biswas *et al.* (2020)
Chilli	$FeSO_4$ @0.2 % + $CaNO_3$ @0.2% + Boron @0.1 %	60, 90 and 120 DAT	Plant height (70.02.cm), no. of primary branches per plant (8.51),plant spread (36.13 cm), number of fruits per plant (47.80), dry fruit yield per ha (52.61 q ha-1), average fruit weight (6.64 g), fruit length (10.52 cm),fruit width (1.36 cm) and seed yield (9.61 q ha-1. oleoresin content (6.34%), vitamin c content (67.60 mg /100 g)	Malik *etal.* (2020)
	ZnSO4 @ 0.4%	1 st spray at flower bud initiation stage and second spray after 25 days	Plant height (101.8 cm), No. of branches (12.33), Fruit Length (7.28cm), Fruit diameter (2 cm), No. of fruits per plant (131), Fruit yield per plant (378.67g)	Angami *et al.*, (2017)
	• H_3BO_3 @0.25 % • H_3BO_3 @0.1 % • H_3BO_3 @0.50 %,	at 30 and 60 DAT	• Fruit yield per plant (395.33 g) and maximum yield per hectare (109.8 q/ha) • Average fruit length (11.12 cm) and fruit diameter (1.175 cm) • Average number of seeds per fruit (55.66) and weight of 500 seeds (2.549 g)	Dongre *et al.*, (2000)
Cauliflower	Boric acid @0.2 % + Ammonium molybdate @0.1 % + $ZnSO_4$ @ 0.5 % + $MnSO_4$ @0.5%	30, 45, 60 DAT	The highest plant height (76.78 cm), number of leaves per plant (25.60), days to first curd initiation (44.06), days to 50 % curd maturity (56.66), curd diameter (41.22cm), Curd depth (9.54cm), gross curd weight (1.84 kg), net curd weight (0.65 kg) and curd yield (34.98 t/ha)	Punam *et al.* (2020)

	$FeSO_4$ @0.5 % + Borax @0.2 % + $ZnSO_4$ @0.5 %	At 45 and 60 DAT	Maximum length of leaf (32.26 cm) and total biomass production (2849.20 g), yield per plot (34.80 kg), curd size per plant (235.68 cm^2), number of days required for curd initiation (67.89) and curd maturity (81.19), total biomass production, curd size, curd yield, ascorbic acid content (65.96 mg/100g), net Income and B:C ratio (2.65)	Moklikar*et al.* (2018)
Broccoli	Borax @0.2 % + $ZnSO_4$ @0.5 %	20, 35 and 50 DAT	Recorded significantly maximum plant height (46.27 cm), leaves plant-1 (24.62), stem girth (16.85 cm), plant spread (62.20 cm), leaf area (557.50 cm2), weight and diameter of central head (313.67g,17.37cm), secondary head (88.83g, 5.33cm), total head weight (402.50g) with total head yield (136.80 qha-1)	Tudu *etal.* (2020)
	• $ZnSO_4$ @0.60 % • $CuSO_4$ @ 0.40% • Boric acid @ 0.40% • Ammonium molybdate @ 0.40%	At 25th day of planting and 45th and 65th DAT	• Plant spread (63.86 cm), stalk length (17.92 cm), root length (6.40 cm) and ascorbic acid content (86.29 mg/100g). • Minimum number of days to 50% maturity (72.36). • Maximum curd yield (135.05 q/ha), TSS% (7.52) and carbohydrate % (39.83) • Maximum reducing sugar content (0.81%)	Singh *etal.* (2018)
Tomato	B @100 ppm+ Zn @100+ Mo @50 ppm+ Cu @100 ppm,+Fe @100 ppm+ Mn @100 ppm	at an interval of 10 days starting from 30 DAT	Number of flowers $cluster^{-1}$ (5.33), number of fruits $cluster^{-1}$ (4.06) and percentage of fruit set (76.26%), fruit diameter (6.21), fruit length (6.28 cm), fruit weight (67.62g) and number of fruits $plant^{-1}$ (24.66), yield $plant^{-1}$ (1.43kg) and yield qha^{-1} (288.77)	Ahirwar*et al.*, (2019)
	$FeSO_4$ @0.2 % + $CaNO_3$ @0.2 % + Boron @0.1 % + $ZnSO_4$ @0.2 %	15 and 21 DAT	Plant height (135.75cm), Plant girth (3.20 cm), Days to first flowering (24.29), Days to first fruiting (35.33), Days to maturity (63.33 days), No. of fruits per plant (72.07), Fruit length (5.66 cm), Fruit diameter (4.77 cm), Fruit weight (80.06g), Yield per plant (4.77 kg) and Yield per ha (562.57 q).	Dixit *et al.* (2018)
	B @1.25g/l + Zn @1.25 g/l	foliar sprays two times	Plant height (2.93m) number of leaves (39.33)	Shnain*et al.*, (2017)
	Boric acid @100 ppm, $ZnSO_4$ @100 ppm, Ammonium molybdate @50 ppm, $CuSO_4$@100 ppm,	an interval of 10 days starting from 40 DAT	Highest plant height (95.7 cm), number of fruits per plant (46.4), fruit weight (61.9 g), fruit yield per plot (63.5 kg), yield/ha (564.1 q) and benefit cost ratio (3.04)	Sathiyamurthy *et al.*, (2017)

	$FeSO_4$@100 ppm, $MnSO_4$@100 ppm			
	Boron @100 ppm + Zn @100 ppm + Cu @100 ppm + Fe @100 ppm + Mn @100 ppm	thrice times foliar spray were made at 10 days interval starting from 40 DAT	Plant height (131.73 cm), number of branches plant-1 (5.81), fresh weight of plants (25.65 t ha-1), dry matter yield of plants (7670.03 kg ha-1), maximum days to last picking (166.68), number of fruits plant-1 (34.26), fruit length (5.52 cm), fruit diameter (4.64 cm), fruit volume (67.53 cm3), single fruit weight (49.20 g), fruit weight plant-1 (1.68 kg), number of locules fruit-1 (3.03), pericarp thickness (6.23 mm), fruit yield ha-1 (46.78 t) and marketable fruit yield ha-1 (45.62 t). This treatment had maximum net return (1, 66,757 Rs./ ha) and B:C Ratio (2.72 : 1)	Saravaiyaetal., 2014
	Nitrogen @5.5 g/100 ml+ boron @5 g/100 ml + zinc @5 g/ml	15 and 21 DAT	Plant height (80.4 cm), number of leaves per plant (57), leaf length (10.42 cm), maximum per cent fruit set (57%), number of fruits per plant (33.67), fruit weight (92.7g), fruit length (7.48cm), fruit diameter (5.08cm), number of large sized fruits (15.67) with least number of small fruits (6.33), yield per plant (1.14kg) and yield per hectare (1275kg ha^{-1})	Ali *et al.*, (2013)
Potato	• Borax @0.1% + $ZnSO_4$@0.2% + $MnSO_4$ @0.2% • Borax @ 0.1% + $ZnSO_4$@0.2% • $ZnSO_4$ @0.2%+ $MnSO_4$ @0.2%	-	• Highest tuber weight (127.00g) • The highest Dry matter content (22.67%) • Highest starch content (21.42%)	Miyu *etal.*, 2019
Sponge gourd	• Boron @ 0.75 g/L • Boron @0.25g/l • ZnSo4 0.25g/L • Boron and Iron @0.75g foliar	30,45 and 60 days of sowing	• Fruit diameter (14.45mm), fruit length (26.3cm), Fruit yield (1.75 kg per plant) and individual fruit weight (170.09g.), no. of fruits, (15.00), highest percentage of fruit set (75.33) • TSS content (7.6^0Brix) • Titratable acidity (4.30 g/L) • Maximum deduction in pH (5.1)	Ashraf *et al.* (2019)
Moringa	$FeSO_4$ @1% + Citric Acid 0.1% ; $ZnSO_4$ @0.5% ;	Vegetative, Flowering, and Pod setting	Maximum plant height (1.43m, 2.39m, 5.36m), trunk girth (2.20m, 18.01m, 32.00 m), number of pods per tree (120 pods), pod length (80.25cm), pod girth (7.9cm), ascorbic acid content (61.34 mg/100g, 65.39	Sandeep etal., 2019

	$MnSO_4$ @0.5% ; Boric Acid 0.2% ; ($FeSO_4$ @1% + 0.1% Citric Acid) + $ZnSO_4$ @0.5% ;$ZnSO_4$ @0.5% + $MnSO_4$ @0.5%	stage	mg/100g, 68.91mg/100g and in pod 43.06 mg/100g) and carotenoid (29.50 mg/100g, 30.13mg/100g, 35.10mg/100g and in pod 5.11 mg/100g) content were recorded in T8 (Mixture of all micronutrients) number of panicles per tree (20.71, 64.20,120.00), number of flowers per panicle (16.97, 29.33, 54.67) and number of pods per panicle (2.29).	
Brinjal	Borax @0.2% + $FeSO_4$ @0.5% + $ZnSO_4$ @0.5%	-	Plant height (82.67 cm),no. of leaves (173.27), no of branches (12.60), leaf area (2431.12 cm2), leaf area index (0.540), and days to 1st flower initiation (37.33), days to first fruit set (42.33), days to 1st picking (58.33), number of clusters/plant (3.6), no. of flowers per cluster (5.2), number of fruits/ cluster (3.3)	Uikey*et al.*, (2018)
	Boron @0.25% +APSA-80	at 30, 45 and 60DAT.	Maximum plant height (62.93 cm), number of branches (6.36) and leaves (55.67) per plant, Earliest flowering and fruiting (72 and 94 days), number of fruits per plant (8.63) and total yield (356.55 q/ha), seed viability 30DAH (93.02%), highest (8.50 g/fruit), benefit : cost ratio of (4.07 and 4.63)	Gogoi *et al.*, (2012)
	Borax @0.5%	at 35, 50 and 65 DAT	Number of flowers per plant, number of productive flowers per plant, number of fruits per plant, individual fruit weight and yield (32.15 t/ha)	Karuppaiah, (2005)
Bitter gourd	Boric acid @100 ppm (0.571g/l) and mixture of micronutrients *viz.*, (Boric acid @100 ppm + $ZnSO^4$ @100 ppm + Ammonium molybdate @50 ppm + $CuSO_4$ @100 ppm + $FeSO_4$ @100 ppm + $MnSO_4$ @100 ppm	at 30, 40 and 50 DAS	maximum length of vines (5.58 m), fruit length (25.01 cm), fruit girth (10.75 cm), fruit weight/vine (2.197 kg), yield (197.01 q/ha) and vitamin C (64.65 mg/100gm). Highest B: C ratio (2.69).	Bharati et al. (2018)
	$ZnSO_4$ @0.5 % + $FeSO_4$ @0.5%	at 30, 45 and 60 DAS	Highest fruit yield (16.33 t/ha)	Vala and Savaliya. (2014)
	$ZnSO_4$+ $FeSO_4$+ $MgSO_4$ each @0.5%	at 35 and 45 DAS	Maximum vine length (547.54 cm), number of nodes (155.69), total leaf area per plant (3749.70 cm^2), leaf area index (1.253), Total chlorophyll content at 90 DAS (2.20 mg g-1), Soluble protein at 90 DAS (8.71mg g-1), No. of female flowers plant-1 (34.61), Sex ratio (1:10.77), Fruit set percentage (77.75 %)	Karthick *et al.*, (2018)

Water spinach	Borax @1.5 g/litre + $ZnSO_4$ @1.5 g/litre twice at 15 days interval	twice at 15 days interval at vegetative stage	Maximum vine length (49.19 cm), no. of nodes/plant (23.89) and average internode length (2.18 cm), days to 50% flowering (131.00), days to fruit harvest (249.20) and chlorophyll content (46.16 SPAD-502)	Sarkar *et al.* (2017)
Okra	$MgSO_4$ @0.5 % + $MnSO_4$ @0.5 % + FeSO4 @0.5 % + ZnSO4 @0.5 %	at 30, 45 and 60 DAS	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)	Dubalgunde*et al.* (2017)
Eggplant	• ZnSO 4@0.5 % • Borax @0.5 %	micronutrients were sprayed at an interval of 10 days, starting from flowering	• Plant height (64.48cm) cm, no. of fruits plant^{-1} (26.13) • Fruit length (24.04 cm), fruit diameter (5.10 cm) and average fruit weight (75.77 g)	Pandav *et al.* (2016)
Coriander	$FeSO_4$@0.5 %	30 and 45 DAS	Net assimilation rate (0.085 mg g^{-1}day^{-1}in rabi and 0.063 mg g^{-1}day^{-1}in kharif), crop growth rate (7.52 mg m^{-2} day^{-1}in rabi and 7.78 mg m^{-2} day^{-1}in kharif, umbels per plant (33.7 in rabi and 13.8 in kharif) and highest seed yield per hectare (623.3 kg in rabi and 599.9 kg in kharif)	Diana and Nehru (2015)
Cowpea	Fe @ 2 ppm	*sprayed every 15 days*	Nutrient uptake (Fe- 154.00 mg.kg-1, B- 47.00 mg.kg-, Zn- 42.00 mg.kg-1) and protein percentage of seed (28.9)	Salih (2014)

*DAS- days after sowing
*DAT- days after transplanting

3. Factors affecting the effectiveness of foliar feeding

Growth stages are one of the most important aspects that affect the efficacy of foliar nutrition with respect to its optimum effectiveness. Various endogenous (related to leaf anatomical structure, crop type, and leaf coverage), exogenous (nutrient concentrations, soil type, and pH of solution), and environmental factors (day time, humidity, temperature, rainfall, wind speed, etc.)influence the feasibility of foliar feeding. Hot and humid climates conditions are more conducive to the highest level of tissue permeability. Early mornings and late nights are the times when these conditions are most frequently observed (Zahed *et al.*, 2021).Within 24 to 48 hours of application, rain may decrease the effectiveness of foliar treatment. Micronutrientsmust be water soluble for foliar treatment. The concentration of the spray solution shouldn't injure the leaf tissue or leave any residue on the plant's surface. In order to prevent the leaves from getting scorched, which could have catastrophic consequences, the pH of the spray solution must be controlled. The spray solution is most frequently neutralized with lime.

4. Benefits of FoliarNutrition in vegetable crops

Foliar spray of micronutrients facilitates in the rapid restoration of nutritional deficiencies.It can be used in conjunction with other sprayings, such as insecticides, pesticides.It is advantageous when the soil is deficient in nutrient content,It is applicable even under adverse conditions, such as root rot disease, drought condition etc. It is also beneficial when the top soil is insufficiently moist for plant roots to absorb nutrients.Foliar application requires only a small doses of micronutrients for enhancing factors for yield and yield quality characteristics.

5. Limitations of FoliarNutrition in vegetable crops

A high concentration of the sprays will result in a scorching or burning effect. To increase efficiency, an adhesive agent is required. Maximum leaf area is required for efficient spraying. The effectiveness of foliar spraying is based on environmental factors such as temperature, humidity, wind speed, *etc.* Costs associated with multiple applications may be prohibitive.Excess application may cause foliar burn.

6. Conclusion

Foliar application of micronutrients has a dynamic role in in elevating crop yields and productivity. Under intensive cropping systems, foliar micronutrient supplementation has a huge potential to increase productivity while also improving crop quality under drought condition and ensure disease resistance. This assessment of the review of literature leads us to the conclusion that micronutrient foliar feeding is effective in enhancing the growth, production, and quality characteristics of vegetable crops.

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