The Application of Micronutrients in Vegetable Crops: Enhancing Growth, Yield and Nutritional Quality

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Vegetable crops play a crucial role in human nutrition, providing essential vitamins, minerals, and dietary fibre. To ensure their optimal growth, development, and nutritional value, it is imperative to understand the importance of micronutrients. While macronutrients such as nitrogen, phosphorus, and potassium are vital for plant growth, micronutrients, including iron, zinc, manganese, copper, boron, molybdenum, and chlorine, are equally essential for their overall health and productivity. This essay aims to explore the application of micronutrients in vegetable crops, highlighting their significance in enhancing growth, yield, and nutritional quality.

In India, adoption of intensive and modern cropping practices with high-yielding crop cultivars and unbalanced fertilizer application resulted in emergence of widespread micronu- trient deficiency in soils and crops of India leading to re- duced crop yield and low micronutrient concentration in agricultural produce. According to results from the analy sis of more than 2.0 lakh soil samples collected from 508 districts of the country, on average 36.5, 12.8, 7.1, 4.2 and 23.2% soils are deficient in Zn, Fe, Mn, Cu and B respec- tively. More than 50% samples are found deficient in Zn and B in 110 and 63 districts of the country, respectively. Over the years, Zn deficiency has declined in soils of the country because of regular and more use of Zn fertilizer whereas deficiency of Fe and Mn increased slightly. In ad- dition, multi-micro and secondary nutrient deficiencies like S+Zn, Zn+B, S+B, Zn+Fe, S+Fe, Zn+Mn, Zn+Cu and Fe+B, S+Zn+B, S+Zn+Fe and Zn+Fe+B have emerged in different parts of the country. Responses of different crops to micronutrient application have been recorded in different micronutrient deficient soils. Inclusion of micronutrients in balanced fertilization schedule increased internal use effi- ciency of NPK. Therefore, micronutrient management de- pending upon crops, soil types, severity of deficiency, source, method, time, rates and frequency of application needs to be undertaken for sustainable agricultural production and maintenance of human health.

Importance of Micronutrients:

Micronutrients are required in smaller quantities but are equally vital for plant health. They play essential roles in various physiological and biochemical processes, including photosynthesis, enzyme activation, hormone synthesis, and cell division. Deficiencies of micronutrients can result in visible symptoms such as leaf chlorosis, stunted growth, poor fruit set, and reduced yield. Hence, the application of micronutrients is crucial for maintaining balanced plant nutrition and maximizing crop productivity.

Role of different micronutrients

- Iron (Fe) is an essential micronutrient required for normal growth and plant function. Iron act as catalyst in synthesis of chlorophyll molecule and helps in the absorption of other elements. It is a structural component of porphyrin molecules like cytochrome, hemes, hematin, ferrichrome and leg hemoglobin. These substances are involved in oxidation- reduction reactions in respiration and photosynthesis. It also involves in DNA synthesis, protein synthesis, reduction of nitrates and sulphates. Further many metabolic pathways are activated by iron and it is a prosthetic group constituent of many enzymes. Vegetable crops like tomato, onion, carrot and spinach contain high percentage of Iron.

- Zinc (Zn) is another important micronutrient that plays a critical role in plant growth and development. It is necessary for the synthesis of proteins and enzymes, and also plays a key role in the development of plant tissues. Zinc deficiencies can result in poor growth, small leaves, and poor crop yields. To address zinc deficiencies, farmers can apply zinc sulphate or zinc chelates to the soil or spray zinc foliar applications directly onto the leaves. In states like Gujarat, Bihar and Madhya Pradesh zinc deficiency is found almost stagnant during four decades despite much efforts have gone to popularize zinc application in various crops. Zinc deficiency is increasing in soils, so zinc content in seed and in blood plasma of animal and humans is decreasing. In Haryana and Punjab, zinc concentration in grains of wheat is improving from 23 to 72 mg kg-1.
- Manganese (Mn) serves as an activator for enzymes in growth processes. It assists iron in chlorophyll formation. It is part of the system where water is split and oxygen gas is liberated. The other protein in which manganese is an integral constituent is the manganese containing superoxide dismutase. This enzyme is widespread in aerobic organisms. The function of this enzyme is to provide protection from free oxygen radicals formed when O_2 receives a single electron. Superoxide dismutase convert this highly toxic free radical into hydrogen peroxide (H_2O_2) which is subsequently broken down to water.
- Copper (Cu) is a secondary micronutrient that is important for carbohydrate and nitrogen. It is required for lignin synthesis which is needed for cell wall strength and prevention of wilting. It is present in plants in complexed form. Like other potentially toxic heavy metals, copper in excess is bound to phytochelatins (Greek meaning "plant claws") and sulfur containing peptides. Copper in solution is present as cuprous (Cu^{+}) and cupric (Cu^{++}). Cuprous copper is readily oxidized to cupric and so cuprous copper is only found in complexed forms. Cuprous complexes are usually colorless, whereas the cupric complexes are often blue or brown. Copper is an activator of several enzyme systems in plants and functions in electron transport and energy capture by oxidative proteins and enzymes. It may play a role in vitamin A production
- Boron (B) is another important secondary micronutrient that is necessary for the growth and development of vegetable crops. It plays a role in the development of cell walls, and is also involved in the transport of sugars and the metabolism of carbohydrates. It is necessary for sugar translocation and helps in pollen grain germination. It is present in soil solutions with a pH less than 8 mainly as an un-disassociated boric acid ($B(OH)_3$), the principle form taken up by roots, and disassociates to $B(OH)_4^-$ only at higher pH values.
- Molybdenum (Mo) is a secondary micronutrient that is necessary for the metabolism of nitrogen in plants. It plays a key role in the conversion of nitrate to ammonia, which is necessary for the synthesis of amino acids and proteins. It is related to the valency changes it undergoes as a metal component of enzymes. Only a few

enzymes have been found to contain molybdenum in plants. In higher plants two molybdenum containing enzymes, nitrogenase and nitrate reductase, are of vital importance in crop production. All biological systems fixing N2 require nitrogenase. Each nitrogenase molecule contains two molybdenum atoms, which are associated with iron. Therefore, the root nodule requirement is relatively high.

- Nickel (Ni) is important for activation of urease, an enzyme essential for nitrogen metabolism and also control senescence. It is required for iron uptake and it can substitute for zinc and iron as a cofactor for some enzymes. It is considered as an essential element for higher plants nutrition; on the other hand, Ni at relatively higher concentrations may be toxic to most of plant species.
- Chlorine (Cl) is most commonly used as sanitizer, due to its low cost for maintaining the fruit quality like appearance, soluble solids content, acidity, pH, texture and flavor, shelf life and also control microbial growth. It is essential for photosynthesis (chlorotic tissues), helps in stomatal regulation and raises cell osmotic potential, necessary for shoot apex and root growth.
- Cobalt (Co) has a role in nodulation and hence it is imperative that adequate cobalt supply is made to lignin vegetables like French bean, garden pea, pea and other vegetable beans, and take advantage of their capacity for symbiotic N2 fixation. Economy in N also assures better soil-health due to reduced NO3 pollution and better organic matter status even in marginal soils.

Table – 1 Crop-Specific Micronutrient Requirements (in ppm)

Vegetable	Fe	Mn	Zn	Cu	B
Beans	50-300	50-300	20-200	7-30	20-75
Beet root	50-200	50-250	20-200	5-15	-
Brinjal	50-300	40-250	20-250	8-60	25-75
Cabbage	30-200	25-200	20-200	5-15	25-75
Carrot	50-300	60-200	25-250	5-15	30-100
Cauliflower	30-200	25-250	20-250	4-15	30-100
Onion	60-300	50-250	25-100	15-35	22-60
Peas	50-300	30-400	25-100	7-25	-
Radish	50-200	50-250	19-150	5-25	25-125
Tomato	40-200	40-250	20-50	5-20	25-60
Turnip	40-300	40-250	20-250	6-25	40-100

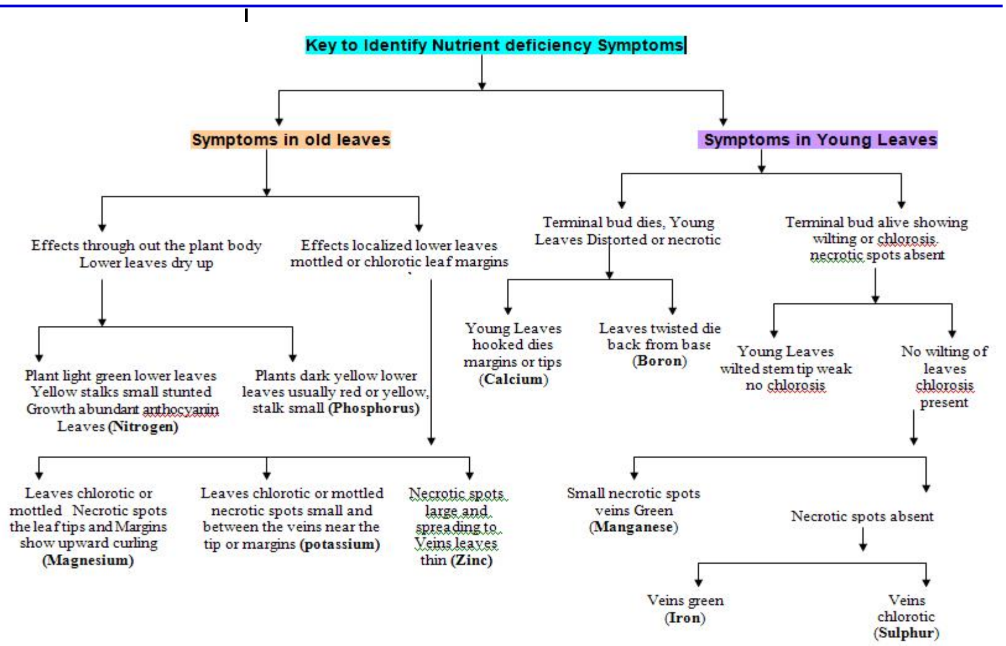
Source: Anjaneyulu, K. and Raja, M.E. (1999). Micronutrient disorders in vegetable crops and their correction. *Indian Horticulture (Jan.-March)*. pp 15-16.

General description of mineral toxicity symptoms on plants

- **B:** High B may induce some interveinal necrosis, and severe cases turn leaf margins straw color (dead) with distinct boundaries between dead and green tissue. Roots appear relatively normal.
- **Cl:** High Cl results in burning leaf tips or margins, reduced lead size, sometimes yellowing, resembles K deficiency, and root tips die.
- **Cu:** High Cu may induce Fe deficiency (chlorosis). Light colored leaves with red streaks along margins. Plants become stunted with reduced branching and roots are often short or

barbed (like wire). Laterals may be dense and compact.

- **Fe:** Excess Fe is a common problem for plants grown in flooded acidic soil. May induce P, K and Zn deficiencies. Bronze or blackish-straw-coloured leaves extending from margins to midrib. Roots may be dark red and slimy.
- **Mn:** Excess Mn may cause leaves to be dark green with extensive reddish-purple specks before turning bronze yellow, especially interveinal tissue. Uneven distribution of chlorophyll. Margins and leaf tips turn brown and die. Sometimes Fe deficiency appears, and main roots become stunted with increased number and density of laterals.
- **Mo:** Excess Mo induces symptoms similar to P deficiency (red bands along leaf margins), and roots often have no abnormal symptoms.
- **Zn:** Excess Zn may enhance Fe deficiency. Leaves become light colored with uniform necrotic lesions in interveinal tissue, sometimes damping off near tips. Roots may be dense or compact and may resemble bared wire.
- **Ni:** High Ni results in white interveinal banding alternating with green semichlorotic areas with irregular oblique streaking,dark green veins and brown patches. Yellowing of leaves may resemble Fe or Mn deficiency.
- **Co:** Pale green leaves with pale longitudinal stripes.



Source: https://agritech.tnau.ac.in/agriculture/mpt_key.jpg

General description of mineral toxicity symptoms on plants

- **Fe:** Leaves turn yellow, midriff remains green and middle part remains yellow, in severe conditions leaves become white, young leaves show stunted growth and in rare case edges of leaf and leaf tip are burnt.
- **Zn:** Deficiency of zinc causes the plant to appear weak, the leaves turn yellow, rust spots appear on the leaves and short internodes, the plant is stunted, the seeds are not filled, the leaves fall and the new leaves are small and bunched.
- **Cu:** Intervein turns yellow, leaves turn brownish green. Leaf loses its colour. The leaves are wilted. The top of the leaf dries up.
- **Mg:** New leaves become pale. The middle old leaves turn yellow and die. On top of it, white coloured spots are formed. Even the smallest veins remain green.
- **Mo:** The anterior surface of the leaf assumes a whip-like shape. The leaves are yellowish green and appear pale. Sometimes a gummy sap oozes

from under the affected branch. The leaves become twisted. The edge of the leaf breaks.

- **Bo:** The leaves around the growing bud turn blue, the leaf blade, bud and tip are especially affected and burn, growth is stunted and seeds do not set.

Type of application methods

Vegetable crops respond very well to the application of micronutrients. Generally, micronutrients are applied in following ways:

i. **Soil application:** Micronutrient containing materials can well be applied to soil mixed with other fertilizers at the time of land preparation or transplanting of vegetables. Care should be taken to avoid excess application of micronutrients to avoid toxicity. Doses of micronutrients depend on soil type, crop, etc. On the basis of soil and plant analysis report, the foliar recommendation has been given for different micronutrients is as follows: Rate of application varies with the type of soil. As a higher rate of manganese is required for both organic and sandy soils which are alkaline in reaction; high rate of zinc is applied when soil is neutral to alkaline in reaction.

ii. **Seedling root dip:** This method of application is not widely practiced in India. Generally, 0.2-0.3 per cent solution of zinc sulfate is used for root dipping of vegetable seedlings.

iii. **Seed treatment:** Seeds of vegetables can be treated with the chemical compounds containing Cu, Fe, Zn, B, Mn, etc. prior to sowing. Seed treatment of pumpkin and squashes with borax @ 0.5% increases number of female flowers and ultimately yield.

iv. **Foliar spray:** Foliar application of micronutrients is widely used. Most of the micronutrients, after foliar spray, enters the plant body though leaves within few hours to one day. They mostly enter the leaf via stomata. Since the stomata are mostly present on the undersurface of the leaf, the foliar spray should be applied to both under and upper surfaces of the leaf as evenly as possible for rapid and complete absorption of the nutrient solution. 2-4 foliar sprays at an interval of 7-10 days are sufficient to correct the deficiency symptoms.

Table 4: Recommended concentration of micronutrients for foliar application

Micronutrient	Concentration
B	0.5-0.6% borax
Cu	0.1-0.2% copper sulphate + 0.5% lime*
Fe	0.4% ferrous sulphate + 0.2% lime*
Mn	0.4-0.6% manganese sulphate + 0.2-0.3% lime*
Mo	0.05% sodium or ammonium molybdate
Zn	0.4-0.6% zinc sulphate + 0.1-0.3% lime*

*Lime is added to neutralize the solution, otherwise leaves may get scorched. Minimum 450 litres of water must be used per hectare.

Source: Choudhary, B.A., Sharma, B.D. and Sharma, S.K. (2013). Micronutrients in vegetable crops. CIAH/Tech./Pub. No. 44, pp. 25. Central Institute for Arid Horticulture, Bikaner, Rajasthan, India.

Application methods for vegetables

- Brinjal: Supplementation of copper (40 kg/ha) in unploughed soil increased the yield of brinjal as well as increased ascorbic acid content, in addition to significant increase in total soluble solids, crude protein and acidity quality. Ascorbic acid, acidity and protein content of the fruits can be improved along with brinjal production by spraying boron, and the time of first fruiting can be advanced by a week or so. Supplementation of zinc (25 kg/ha zinc sulphate) and copper (12.5 kg/ha copper sulphate) increases yield and ascorbic acid content. Combined supplementation of these elements maximizes yield and quality. Zinc and copper are necessary for high yield and quality of brinjal.

- Cauliflower: Along with the major nutrients, the production can be increased by the use of micronutrients such as zinc, boron and molybdenum. Soil application of zinc (4.2 kg/ha) significantly increased leaf area, boll size, leaf to boll ratio and cold weight. Such results are recorded in many parts of the country. Some micronutrients interact beneficially with the major nutrients. Also, some negatives are also seen. According to a study, these elements can be better utilized by cauliflower if boron is supplemented along with phosphorus. Boron deficiency does not cause cavities in bolls. Generally giving 15 kg borax per hectare can increase leaf number, boll size, boll weight and yield. Another important micronutrient for cauliflower is molybdenum, which was found to increase leaf width, boll diameter, boll weight and leaf molybdenum content at 0.24. Research has shown that adding sat, boron and molybdenum to the soil or by spraying can increase the production of cauliflower.
- Chilli: Plant height and leaf area can be increased by spraying boron. From the quality point of view, boron supplementation increases the content of ascorbic acid, casein and chlorophyll a, chlorophyll b and total chlorophyll. If potassium and zinc are supplemented simultaneously, the production is increased.
- Coriander: Many coriander seeds are added to vegetables and dishes as for flavour and aroma. Spraying of ferrous sulphate solution (0.5%) in deficient soils at 45 days after sowing has been found to be very beneficial for this crop.
- Garlic: Zinc is important in this crop with special medicinal properties. Its supplementation increases bud number and weight. The results also suggest that supplementation with selenium appears to increase the selenium content of garlic plants. Therefore, this sowing garlic on soil contaminated with selenium leads to its special uptake, hence it is worth considering from the health point of view.
- Onion: It provides protection against intense summer heat (loo). Onion is used throughout the year in salads, spices and cooking with other vegetables. Gujarat ranks first in the productivity of this crop. Spraying copper solution in onion maximizes productivity. Combined supplementation of copper, zinc, boron and iron has been found to be particularly useful for this crop. It also maximizes total soluble solids, total sugars and onion production and ascorbic acid.
- Okra: Spraying of copper (0.25%) in okra has been found useful. Besides, the yield can be increased by spraying the composite mixture.
- Potato: Potato is an important vegetable crop. Micronutrients like iron, zinc and boron and sulphur are especially useful for this. The maximum amount of iron is required in potato leaves at 40-70 days. So it is advisable to sprinkle iron after 40-50 days. Adding these nutrients to potato crops with manure can be of particular benefit.
- Sweet potatoes: Research suggests that boron supplementation has can be useful in increasing yield for sweet potato crops.
- Tomato: Calcium, zinc and boron are important micronutrients for tomato. Its supplementation can lead to increase in production along with better quality. High levels of ascorbic acid and

acidity can be achieved with zinc and boron supplementation.

Conclusion

In conclusion, the application of micronutrients in vegetable crops is essential for maximizing their productivity and nutritional value. Micronutrients such as iron, zinc, manganese, copper, boron, and molybdenum play critical roles in various plant processes, including photosynthesis, enzyme synthesis, and nutrient uptake. Deficiencies in these micronutrients can lead to stunted growth, poor crop yields, and nutrient deficiencies in the harvested vegetables. However, by applying micronutrient fertilizers to the soil or using foliar sprays, farmers can effectively address these deficiencies and promote healthy growth and development in vegetable crops. By recognizing the importance of micronutrients and implementing proper application strategies, farmers can enhance the quality and quantity of vegetable production, contributing to improved food security and nutrition for the growing population.

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Table 2: Micronutrient absorption by vegetables (g/ha)

Type of Crop	Area cultivated	N	P	K	S	Fe	Mn	B	Zn	Cu	Mo
Vegetable	884	21.72	25.68	229.2	14.93	3926	238	501	151	102	21

Source: Fertilizer News (2001), 46(5) pg: 41-56

Table 3: Source and rate of micronutrients for soil application

Micronutrient	Source	Quantity required (kg/ha) (every 3 years)	Volume of solution + Lime solution Percentage (for spraying)
B	Borax- 11% Boron Boric acid- 17% Boron	15 10	0.2
Cu	Copper sulfate- 25% Cu	20	0.4+0.25
Fe	Ferrous sulfate- 20% Fe	50	0.5+0.25
Mn	Manganese sulfate- 24% Mn	40	0.5+0.25
Mo	Sodium molybdate- 38% Mo Ammonium molybdate- 54% Mo	1.5 1	0.05
Zn	Zinc sulfate- 21% Zn	25	0.5+0.25

Source: Shakbhaji Pako Magazine (March 2013) AAU

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