Original Research Article………..
International Journal of Agricultural Invention
(online available at www.agriinventionjournal.com)

International Journal of Agricultural Invention **9(1): 165-172: June, 2024**
ISSN: 2456 – 1797 (P)

An overview: Role of micronutrients in Horticultural crops

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ARTICLE INFO
Original Research Article
Received on April 12, 2024
Revised on April 23, 2024
Accepted on May 13, 2024
Published on May 21, 2024

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PUBLICATION INFO
International Journal of Agricultural Invention (IJAI)
RNI: UPENG/2016/70091
ISSN: 2456-1797 (P)
Vol.: 9, **Issue:** 1, **Pages:** 165-172
Journal Homepage URL
http://agriinventionjournal.com/
DOI: 10.46492/IJAI/2024.9.1.22

ABSTRACT

Micronutrients are practically as crucial as macronutrients as they play a crucial role in metabolism and proper functioning of the tissues, to improve plant growth, yield and quality. Micronutrients basically needed in very minute amount by the plants and they can be obtained from the soil, chemical fertilizers, and other sources but deficiency of these micronutrients can cause severe malfunctioning of the plants. Fruit crops cannot be produced successfully unless the plants are properly nourished. The regulation of plant growth in fruit crops is largely dependent on the integrated supply of micronutrients and macronutrients in appropriate amounts and balances. All cellular and metabolic processes depend on micronutrients. The micronutrient requirements of different plants vary. We highlight the key roles that mineral micronutrients play in fruit production in this review.

KEYWORDS

Micronutrients, Quality, Mobility, Liebig's Law, Challenges

HOW TO CITE THIS ARTICLE

Singh, J., Nigam, R., Tiwari, A., Rathi, M. S., Kumar, A. (2024) An overview: Role of micronutrients in Horticultural crops, *International Journal of Agricultural Invention,* 9(1): 165-172. DOI: 10.46492/IJAI/2024.9.1.22

The micronutrients that are also known as the trace elements are necessary for the regular, healthy growth and reproduction of both plants and animals. The following trace elements are necessary for plant growth: zinc (Zn), manganese (Mn), copper (Cu), iron (Fe), boron (B) is not thought to be necessary for all higher plants, despite the fact that it is known to be necessary for the bacterial fixation of atmospheric nitrogen (N) in leguminous plants. However, it has been demonstrated to benefit crops in other plant families, like the *graminae* (e.g., *Oryzae sativa*, *Triticum* sp. etc.) (Asher and C. J., 1991) and is considered as a "beneficial" element. Silicon (Si), sodium (Na), selenium (Se), vanadium (Va), and aluminum (Al) are additional advantageous elements that have not yet been demonstrated to be "essential" (Barker *et al*., 2007). The following trace elements are known to be necessary for animal health: cobalt (Cu), chromium (Cr), fluorine (F), iodine (I), Fe, Mn, Mo, Se, and zinc (Zn). Nonetheless, it is also believed that seven more components are necessary for humans (Graham *et al*., 1996).

A trace element, also known as a micronutrient, must meet three requirements in order to be considered essential for plants or animals:

- The organism cannot grow and reproduce normally without the element
- Its action must be specific and cannot be replaced by any other element
- It must be direct

Nevertheless, Epstein (1965) claimed that even if an element does not meet all of the requirements outlined by (Arnon and Stout), it can still be considered essential if it is a part of a molecule that is known to be an essential metabolite (Arnon and Stout, 1939). However, (Epstein, 1965) advocated that an element can also be regarded as essential if it is a component of a molecule known to be an essential metabolite, even if it cannot be demonstrated that it fulfils all of the criteria proposed by (Arnon and Stout).

Micronutrients function as ion channel and transport protein regulators or catalysts (Kermeur *et al*., 2023; Weber *et al*., 2023). For instance, iron (Fe) is a micronutrient that acts as a signaling molecule, influencing physiological processes such as the uptake and transport of other nutrients (Gao *et al*., 2019; Herlihy *et al*., 2020).

Due to their wide range of uses and nutritional value, horticultural crops which include fruits, vegetables, nuts, herbs, and ornamental plants play a crucial part in the world economy. Historically, characteristics like size, shape, and color have played a major role in determining the quality of these crops (Ariesen-Verschuur *et al.*, 2022). Growing numbers of health-conscious consumers are always on the lookout for foods that are more than just nourishment. As highlighted by (Çakmakçı & Çakmakçı, 2023), they seek additional functional health benefits, driving the demand for crops rich in mineral nutrients (P, Ca, Mg, Fe, and Zn) and bioactive compounds (vitamin C, sugars, carotenoids, and antioxidants).

Micro Nutrients

Definition and its Classification

Micronutrients are necessary components for plants to have healthy growth, development, and reproduction, but they must be present in little amounts. Despite their modest size, these amounts are essential for a number of physiological and metabolic activities. "Micronutrient" refers to the amount of these components in plant nutrition, not their importance. Iron (Fe), zinc (Zn), manganese (Mn), copper (Cu), molybdenum (Mo), boron (B), and chloride (Cl) are a few basic elements that are categorized as micronutrients (Aftab, 2020). Sometimes disregarded, nickel (Ni) and cobalt (Co) are important for symbiotic relationships and stress tolerance in leguminous plants (Parwez *et al.*, 2021), and cobalt is important for growth and nitrogen fixation in higher plants in the Fabaceae or Leguminosae family (X-Hu *et al.*, 2021).

Scenario of Micronutrients in Indian Soils

Deficiencies of zinc (Zn) and boron (B) in many of the states, and of iron (Fe), manganese (Mn) and molybdenum (Mo) in some states, have started limiting the productivity and quality of many horticultural crops (Shukla *et al.*, 2018). In India, moderate zinc deficiencies affect 40-55% of soils, whereas moderate Boron deficiencies affect 25-30% of soils. Less than 15% of soils are deficient in other micronutrients (Takkar and Kaur, 1984). When paired with two or three of the other forty controllable yield-limiting factors/ stresses, these deficiencies/limitations do reduce yield significantly on their own. However, when combined, they have a compounding effect that operate additively and dramatically reduce production. With the exception of B shortages in mango and cauliflower in the Konkan and Chota Nagpur regions, respectively, almost all micronutrient toxicities or deficiencies in India are classified as mild to moderate. The inadequacies in phosphate and nitrogen found in 80-90% of Indian soils are evident in the size, color, growth habit, yield, and flowering of the leaves. Soil production in traditional horticulture was mostly dependent on the soil's inherent fertility. Due to the large amounts of organic manures that farmers were spreading the low yield levels, micronutrient shortages were comparatively rare.

Nowadays, the majority of horticultural crops' nutrient needs are satisfied by chemical fertilizers. Severe nutritional imbalances and shortages were caused by the widespread disregard of micronutrients throughout the transition from the traditional to the modern system.

Major Role in Plant Growth and Development

Micronutrients are essential for preserving plants' overall wellness and vigor. They participate in a number of physiological and biochemical processes, each of which adds in a different way to the efficiency and well-being of plants. A shortage or imbalance can result in poor crop quality, lower production, and physiological problems (Aftab, Tariq, 2020). Li *et al.* (2021) stated that Fe is more than just a basic element; it is the foundation of many enzymatic functions. The efficient functioning of processes including photosynthesis, respiration, and nitrogen metabolism depends on Fe's presence. Zinc is another key component that plays a vital role in various biological processes, including glucose metabolism and DNA synthesis (Balandr´an-Valladares *et al*., 2021). Transforming sunlight into energy, photosynthesis is more than just a process; it's a vital one that keeps plants alive. Chlorophyll, which is essential to this process, depends on magnesium (Mg) for both synthesis and its function (Tang and Luan, 2020). A shortfall of any of the micronutrient can leads to inefficient conversion of energy thus can leads to stunted growth of the plants (Li *et al*., 2021; V´ elez-Bermúdez and Schmidt, 2023).

Liebig's Law of Minimum

Perhaps the most well-known limiting factor theory is the "law of the minimum," which was put forth by (Justus von Liebig, l862). He went on to say: "A deficiency or absence of one necessary constituent, all others being present, renders the soil barren for crops for which that nutrient is needed. Sometimes experts refer to it as the "barrel concept." When a barrel has staves with varying heights, the barrel's capacity is determined by the lowest stave. The ability for yield is thus determined by the growth factor that is least abundant, whether it is climatic, edaphic, biological, or genetic.

Mobility of Micronutrients in Soil and Plants

Finding a specific nutrient shortage in plants is made easier by understanding how mobile micronutrients are in plants. When a plant lacks a mobile micronutrient, the deficit manifests itself on the lower leaves because the immobile nutrients cannot go to the growing points, causing the deficient symptoms to develop in the younger plant parts. The availability of nutrients to plants and the mode of delivery are significantly impacted by the mobility of micronutrients in the soil. The highly soluble mobile micronutrients do not adsorb on clay complex. While the ions of the immobile micronutrients are very reactive and settle in the soil, the less mobile micronutrients are soluble as well but are adsorbed on clay complex, which limits their mobility (B. R. Choudhary *et al*., 2013). The mobility of the micronutrients is showed in given table 1.

Table 1. Mobility of Micronutrients

Mobility	In Plants	In Soil
Mobile	Zn (Moderate)	$B0^{3-}$, CI^{-}, Mn^{2+}
Less Mobile	Mo, Mn, Cu, Fe, Cl	Cu^{2+}
Immobile	Boron	Zn^{2+}

Role of Micronutrients in Horticultural Crops

Boron

Compared to other micronutrient deficiencies, Boron deficiency is more prevalent (Gupta, 1983). Boron insufficiency is the cause of brown heart in turnips, radishes, and storage roots of rutabaga, as well as hollow stems in cauliflower and broccoli (Shelp and Shattuck, 1987a; Shelp *et al*, 1987, 1992a). Even in cases when leaves show no symptoms, poor fruit and seed formation in nut crops suggests that B insufficiency is physiological in origin (Nyomora *et al.,* 1997). If the concentration of Boron is lower in the plants, it affects the seed set as well as fruit set and formation in the plant because it plays major role in the development of cell wall, its elongation and stability of the membrane.

Zinc

According to (Cakmak, 2008), zinc increases the viability of seeds, the vigor of seedlings, and their tolerance to both biotic and abiotic stressors.

Because zinc is quite immobile in the soil, mango, banana, guava, litchi, apple, grape, and pomegranate are among the frequent fruits and vegetables that lack it. In visual terms, little-leaf and rosette symptoms are the most prevalent signs of zinc insufficiency.

Iron

Iron deficiency is easy to diagnose but difficult to treat. Since iron deficiency (iron-chlorosis) is a significant nutritional problem in horticultural crops, determining the prognosis of Fe deficiency is a difficult challenge. According to (Pestana *et al*., 2003), Bicarbonate concentrations in soils or irrigation water bicarbonate are the most common causes of iron chlorosis (Tagliarani and Rombola, 2001). According to a study on the accumulation of heavy metals like zinc and copper in rural Bangalore's grape plantations, the level of these metals rose by 60-120% in just ten years. When these heavy metals are present in excess, iron chlorosis takes place. Therefore, the risks associated with widespread iron chlorosis can be decreased only by combining a balanced diet with enough humified organic manures. Foliar correction of micronutrients, particularly zinc, is therefore advised.

Manganese

There are additional instances in the biosynthesis route of phenols and lignin where manganese is associated.

Soluble phenols are often linked to resistance to disease (Bell, 1981) and are reduced in cases of Mn shortage (Brown *et al.,* 1984). Mn deficiency significantly inhibits photosynthesis. (Graham and Rovira, 1984) reported that a decrease in the exudation of organic compounds from the roots could result in a weaker population of rhizome flowers that are less able to compete with viable root diseases in the rhizosphere.

Copper

Lower plant forms require copper in trace amounts (Bortels, 1927); at larger concentrations, copper is especially poisonous (Keast *et al.,* 1985). Tropical fruit crops seem to have very little copper shortage overall. Copper is necessary for photosynthesis, the activity of several enzymes, seed development, and the synthesis of lignin, which provides stems and shoots with their physical strength. Copper aids in the synthesis of chlorophyll by activating several plant enzymes (Ram and Bose, 2000). Multiple buds sprouting at the tips of twigs, dieback of twigs, death of growing points, and occasionally rosetting are indications of copper deficiency. Banana leaves might have dull, brownish foliage, or they can be chlorotic, darker than usual. The ideal range of micronutrients in the vegetable crops is as shown in table 2.

Table 2. Ideal range of micronutrients (ppm) in several vegetable crops

S. N.	Vegetable Crops	Zn	Fe	B	Cu	Mn
i.	Beans	20-200	50-300	20-75	7-30	50-300
ii.	Beet root	20-200	50-200	-	5-15	50-250
iii.	Brinjal	20-250	50-300	25-75	8-60	40-250
iv.	Cabbage	20-200	30-200	25-75	5-15	25-200
v.	Carrot	25-250	50-300	30-100	5-15	60-200
vi.	Cauliflower	20-250	30-200	30-100	4-15	25-250
vii.	Onion	25-100	60-300	22-60	15-35	50-250
viii.	Peas	25-100	50-300	-	7-25	30-400
ix.	Radish	19-150	50-200	25-125	5-25	50-250
x.	Tomato	20-50	40-200	25-60	5-20	40-250
xi.	Turnip	20-250	40-300	40-100	6-25	40-250

Source: (Anjaneyulu *et al.,* 1999)

Identification of Micronutrient Deficiencies in Horticultural Crops

- Every plant in a limited area is impacted if there is a nutritional issue, and every section of a plant with the same age is affected.

- There might be a deficiency of micronutrients such as calcium or sulphur if the symptoms are on younger leaves. Furthermore, Sulphur shortage is the cause of symptoms that resemble N but emerge on younger leaves. Deficiencies in calcium, boron, or copper may be the cause of symptoms on the terminal or developing tips of younger leaves. Short internodes and interveinal chlorosis are signs of a zinc, iron, or manganese shortage.

- Examine to determine if the symptoms are on the younger leaves or older leaves. If the symptoms are found on the older leaves, a deficiency in N, P, K, or Mg may be the cause. Furthermore, a case of N or P insufficiency appears if the chlorosis is uniform. Symptoms on leaves Marginal area are indication of a Potassium deficiency. Symptoms of an inverted V-shaped vein are caused by a magnesium shortage.

- Chemical analysis of leaf samples can give the final proof of the specific nutrient deficiencies

Effect of Micronutrients on Quality of Horticultural Crops

Micronutrients play a crucial role in the growth and development of horticultural crops, ensuring their overall quality, yield, and nutritional value. A sufficient amount of evidence is available to demonstrate the beneficial effects of boron on cucurbit fruit form, size, and yield; fruit tearing; the color and look of vegetables such as carrots, radish, and cauliflower; and the purity of sugar beet juice. These essential nutrients are required in smaller quantities compared to macronutrients such as nitrogen, phosphorus, and potassium, but their absence or deficiency can have significant impacts on plant health and productivity.

Here's How Micronutrients Influence the Quality of Horticultural Crops

Nutritional Value

Micronutrients like iron, zinc, copper, manganese, boron, molybdenum, and chlorine are essential for various physiological processes in plants. They contribute to the synthesis of enzymes, chlorophyll, and other compounds crucial for photosynthesis, respiration, and overall metabolism. Consequently, crops that receive adequate micronutrient supply tend to have higher nutritional value, including increased levels of vitamins, minerals, and antioxidants. (Anees *et al*., 2011)

Plant Growth and Development

Micronutrients are involved in various growth and development processes of plants, including cell division, cell elongation, and differentiation. For example, zinc is critical for hormone synthesis and protein metabolism, while boron is essential for cell wall formation and pollen germination. Adequate micronutrient supply promotes proper plant growth, leading to higher yields and improved crop quality.

Disease Resistance

Micronutrient deficiencies can weaken plants' defense mechanisms against pests and diseases. For instance, zinc deficiency may increase susceptibility to fungal infections, while manganese deficiency can lead to reduced resistance against bacterial pathogens. By ensuring optimal levels of micronutrients, horticultural crops can better withstand biotic stresses, resulting in higher-quality produce with fewer blemishes or lesions (Gajewska and Skłodowska, 2007)

Color, Flavor and Texture

Certain micronutrients influence the color, flavor, and texture of horticultural crops. For example, boron contributes to the development of sugars and enhances fruit flavor, while manganese is involved in chlorophyll synthesis, which affects leaf color and overall appearance. Additionally, calcium is crucial for cell wall integrity, contributing to the firmness and texture of fruits and vegetables.

Micronutrients can significantly enhance sensory qualities, enhancing the fruits' appearance, flavor, and other qualitative characteristics. According to (Mumivand *et al*., 2021 and Shireen *et al*., 2018), there is a significant impact that microelements can have on the market appeal of horticultural produce, which can increase its commercial value. This effect is further supported by studies on copper conducted by (Kheder *et al.*, 2019 and L´ opez-Vargas *et al*., 2018) and zinc by (Garci´ a-L´ opez *et al.*, 2018 and Ma *et al.*, 2017).

Post-harvest Shelf Life

Adequate micronutrient uptake during plant growth can enhance the post-harvest shelf life of horticultural crops. For instance, calcium plays a vital role in maintaining cell membrane stability and reducing physiological disorders such as blossom end rot in tomatoes and peppers. Proper post-harvest handling combined with sufficient micronutrient levels can prolong the freshness and quality of harvested produce (Mandal *et al*., 2023). Micronutrients are known to alter the course of events. Khakpour *et al*. (2022) have demonstrated that Fe, a trace element essential for multiple enzymatic processes in plants, can significantly improve the postharvest quality of fruits and vegetables. Melons' poor storability in Brazil has been solved by pre-harvest Ca and B spraying from fruit set till harvesting. Enhanced Ca binding to the cell wall could improve the shelf life by increasing the amount of methoxylated pectin in the melon skin cells (Chitara and Praca, 2004).

Micronutrients and Future Challenges in Horticulture Production

It seems doubtful that the other vital micronutrients that have been added to the list will be as significant as the ones that have previously been found. To diagnose and treat micronutrient deficiencies and toxicities, it is imperative to use expertise in these areas. Further improvement is required in the experimental methods used to identify micronutrient problems. Mature leaves accumulate B and Mn in the margins and provide an inaccurate image, making it difficult to analyze leaves for manganese and boron deficiencies. Diagnoses are further complicated by the delayed sampling of defective leaves.

Other factors are blamed for the difficulties caused by fertilizers and chemicals, which have an indirect effect on micronutrient availability. Since clinical and subclinical shortages of certain micronutrients have been observed globally, the public interest will be well served if it receives high-quality horticulture produce (Cakmak, 2008).

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