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Role of micronutrients in vegetable production: A review

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Abstract
The nutrient elements which are required comparatively in small quantities are called as micro or minor nutrients or trace elements. Micronutrients are essentially as important as macronutrients to have better growth, yield and quality in plants. Proper plant nutrition is essential for successful production of vegetable crops. Integrated supply of micronutrients with macronutrients in adequate amount and suitable proportions is one of the most important factors that control the plant growth in vegetable crops. Micronutrients which are essential for all higher plants are boron (B), chlorine (Cl), copper (Cu), iron (Fe), zinc (Zn), manganese (Mn), molybdenum (Mo) and nickel (Ni). Micronutrients like Cl, Cu, Fe and Mn are involved in various photosynthetic processes and Zn, Cu, Fe and Mn are associated with various enzymatic activities, Mo is specific for nitrate reductase only. Boron is associated with the carbohydrate metabolism and reproductive phase of the plants along with photosynthesis or enzymatic activities. Judicious use of micronutrients is essential for vegetable cultivation to get maximum yield of high quality produce. Plants differ in their need for micronutrients. In this review, we focus on the major functions of mineral micronutrients in vegetable production.

Keywords: Vegetable crops, micronutrients, functions, enzymatic activities

Introduction
Vegetables are non woody herbaceous plant or part of the plant that are consumed by humans or other animals as food. It is the science of vegetable growing, dealing with the culture of non-woody (herbaceous) plants for food. It is the production of plants for use of their edible parts such as root, fruits, flower bud, bulbs, tubers etc.
India stands second in fruit and vegetable production in the world rankings (Singh, 2012) [18]. The importance of micronutrients in agriculture is truly well recognized and their uses have significantly contributed to the increased productivity of several crops (Tirpathi *et al*., 2015) [20]. Vegetables play an important role in the human diet. The vegetables are rich sources of protein, minerals, Phosphorus, Iron, Iodine, Vitamins like Vitamin A, Vitamin B, Vitamin C, and Vitamin K. They occupied an important part in the daily diet of the Indian population. Vegetables are highly beneficial food for the maintenance of health and prevention of diseases. They contain valuable food ingredients which can be successfully utilized to build up and repair the body. Vegetables have great export potential and a source of foreign exchange (Dastagiri, 2015) [3]. The sufficient amount of micronutrients necessary for better plant growth which resulted in higher yield due to increased growth, better flowering and higher fruit set (Ram and Bose, 2000) [14].
Micronutrients improve the chemical composition and general condition of vegetable crops and are known to acts as catalyst in promoting various organic reactions in plants (Karthick *et al*., 2018).
Micronutrients such as iron, zinc, manganese, copper and boron are the important elements with specific and essential physiological functions in plants; required in small quantities for normal growth and development of plants. Zinc is an essential component of a number of enzymes, *i.e*., dehydrogenase, aldolase, isomerases, proteinase, peptidase and phosphohydrolase (Mousavi, 2011) [9, 10]. The demand for increasing vegetable production will require a thorough knowledge on the relationship between micronutrients and crop growth. Foliar micronutrient is one tool to maintain or enhance plant nutritional status during the growing season. Often quick effects are seen and deficiencies can be corrected before yield or

quality losses occur. Foliar fertilization also allows for multiple application timings post planting. In addition, there is reduced concern for nutrient loss, tie up, or fixation when compared to soil applications. Growers should carefully follow recommendation for micronutrients to avoid unnecessary costs and possible toxic effects or deleterious interaction in other nutrients (Mauraya *et al*., 2018) [7]. Nowadays, micronutrients are gradually gaining momentum among the vegetable crops because of their beneficial nutritional support and at the same time ensure better harvest and returns. The demand for increasing vegetable production will require a thorough knowledge of micronutrients in vegetable crops. But the available information regarding the impact of micronutrients on vegetable crops is scanty. Therefore, in current review an attempt has been made to summarize the literature pertaining to overall significance of micronutrients in vegetable plants. Singh *et al.* (2017) [19] indicated that foliar application of zinc (30 ppm) significantly increased the number of tubers/plant, average weight, length, diameter of tuber, tuber yield/plot and tuber yield/hectare as compared to control in potato.

Importance of Iron

Iron is the third most limiting nutrient for plant growth and metabolism, primarily due to the low solubility of the oxidized ferric form in aerobic environments (Zuo and Zhang, 2011; Samaranayke *et al*., 2012) [21, 17]. Vegetable crops need iron to produce chlorophyll and to activate several enzymes including those involved in the oxidation/reduction processes of photosynthesis and respiration. (Borlotti *et al*., 2012) [1]. Vegetable crops like tomato, onion, carrot and spinach contain high percentage of Iron. Iron deficiency is common with interveinal chlorosis of young leaves and veins remain green except in severe cases. If the chlorosis is severe and persistent, yellowing increases to the point of bleaching and burns can develop within this chlorotic area. Because iron does not move easily within the plant, older leaves can remain green while flushes of new growth are chlorotic.

Importance of Boron

Boron is the key element in vegetable production. Boron plays an essential role in the growth and development of new cells in the meristematic region of plants. Boron is necessary for cell wall formation, development of fruit and seed. It helps in pollen formation, pollination and flowering of plants (Malek and Rahim, 2011) [5]. The primary role of boron in plants is to improve solubility and metabolism of Ca and its mobility and also helps in the absorption of nitrogen (Pandav *et al*., 2016) [12]. Boron does not easily move around the plant and therefore, the deficiency appears first in young tissues, growing points, root tips and developing fruits. Its deficiency may cause sterility, poor fruit set, small fruit size and ultimately lower yield. Deficiency of boron also leads cracking and distorted growth in fruits (Harris, 2016) [4]. The vegetable crops like, Brassica crops, sugar beet, potatoes etc. are highly sensitive to boron deficiency. The sources of Boron are borax (Sodium tetraborate, 10.5% boron, Boric acid (17.0% boron) and Disodium octaborate tetrahydrate (20% boron).

Importance of Zinc

Zinc is an essential micronutrient and it act as a component and activator of many plant enzymes. Zinc is essential in the formation of carbohydrate and auxins, which help with growth regulation and stem elongation. (Pankaj *et al*., 2018) [13]. It is essential for regular growth, development and reproduction of plant. Furthermore, application of zinc was found to increase the green pigments of necrotic leaf of plants. Zinc is also a constituent of ribosomes and is essential for their structural integrity (Trivedi *et al*., 2013). Premature shedding of male flowers and impaired pollen tube development can lead to poor fruit set. Growth is ceased at the growing point. Its deficiency causes interveinal chlorosis of older leaves then leaves turn grey-white and fall prematurely or die. Stunted growth, distortion in shape and clustering of leaves on short branches known as rosette. The crops like tomato, potato, beans and onion are highly sensitive to Zn deficiency.

Importance of Copper

Copper is involved with carbohydrate and nitrogen metabolism. Copper plays pivotal role in regulating multiple biochemical reactions in plants (Tripathi *et al*., 2015) [20]. Copper is essential for photosynthesis, for the functioning of several enzymes, in seed development and for the production of lignin which gives physical strength to shoots and stems. Copper activates several enzymes in plant, helps in chlorophyll synthesis (Ram and Bose, 2000) [14]. The deficiency symptoms include restriction of terminal growth, die back of twigs, death of growing points and sometimes rosetting, and multiple buds form at the end of twigs.

Importance of Molybdenum

Molybdenum is an essential trace element for plant metabolism and its functions in enzyme nitrate reductase which is responsible for reduction of nitrate to nitrite during N assimilation in plants. It helps in protein synthesis and sulphur metabolism. Low and adequate levels of molybdenum has a positive effect on carotenoid formation. Molybdenum deficiency can be common in nitrogen-fixing legumes.

Importance of Manganese

Manganese plays an important role in oxidation and reduction process in plants, such as the electron transport in photosynthesis. Manganese also has played a role in chlorophyll production.

Manganese has important role on activates several enzymes which involve to oxidation reactions, carboxylation, carbohydrates metabolism, phosphorus reactions and citric acid cycle. Of the most important these enzymes, protein manganese in Photosystem II and superoxide dismutase can be pointed. There is more than 90% of superoxide dismutase in chloroplasts which about 4 to 5 percent of it is in mitochondria (Millaleo *et al*., 2010; Mukhopadhyay and Sharma, 1991; Jackson *et al*., 1978; Uehara *et al*., 1974) [8, 11]. Manganese (Mn^{2+}) In terms of biochemical functions is similar to magnesium (Mg^{2+}), both ions connects ATP with complexes enzymes (phosphotransferase and phosphokinase). Dehydrogenase and Decarboxylase in the Krebs cycle (TCA) are also activated by Mn^{2+} (Marschner, 1995; Burnell, 1988) [6].

Manganese deficiency causes a light green mottle between the main veins and interveinal chlorotic areas become pale green or dull yellowish colour (Mousavi *et al*., 2011) [9, 10].

Importance of Chlorine

Chlorine 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 (Rahman *et al*., 2012). It is

essential for photosynthesis (chlorotic tissues), helps in stomatal regulation and raises cell osmotic potential, necessary for shoot apex and root. Vegetable crops like potato and beans are more sensitive to chlorine deficiency (Singh, 2016).

Importance of Nickel

Nickel is component of some plant enzymes involved in N metabolism and biological N fixation. In 1945, W.A. Roach and C. Barcley obtained the first evidence that Ni significantly increased yields of potato (Roach and Barcley 1946) [16]. The deficiency of nickel causes leaf tip necrosis in nitrogen fixing plants. The deficiency of nickel also delayed nodulation and reduced efficiency of nitrogen fixation in leguminous vegetable crops. Nickel was needed in cowpea at reproductive phase (Das, 2018) [2].

Conclusions

Micronutrients play a central part in metabolism and in the maintenance of tissue function and indispensable for growth and development of crops in general and vegetables in particular. The nutritional value of crops is becoming a major issue. Therefore, the application of micronutrients to sustain soil health and crop productivity besides maintaining the quality of vegetables is of profound importance. Foliar application of micronutrients shows better efficacy than soil application as the uptake and assimilation of micronutrients by later method takes more time.

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