Review Article

Impact of Boron and Zinc on Vegetables: A Review

Abstract

Micronutrients are necessary for the development and continued existence of plant life, as well as the nourishment of crops. Boron and zinc are found to have beneficial effects on the growth, production, and quality of a wide variety of crops, such as tomatoes, chilies, brinjal, cauliflower, broccoli, okra, and carrots, amongst many others. The different studies show that boron in soil and foliar increases tomato vegetative growth and production. Boron 2 kg/ha in the soil and 150 ppm or 3.8 mg/L foliar spray improve yield. According to investigations, adding boron to chilli at 1-3 kg/ha increases yield. Boron, vermicompost, and magnesium are also claimed to increase yields in significant amount. The applying boron on brinjal produced a significantly higher yield, 26% yield increase over control. Applying borax in the soil and foliar concentration at 100 ppm increases cauliflower output and improves its vegetative characteristics. 100 ppm zinc foliar spray increases production by 150-200% in tomato. However, zinc treatment improves vegetative development and reproductive traits, directly increasing tomato output. Zinc applied at 0.5 to 0.75 % to chili increased overall yield significantly.it is also found that application of the zinc in bottle gourd, broccoli and okra found to be beneficial in increasing the overall production which will cause the benefit to the farmer. Concluding that the application of boron and zinc on vegetables found to be significantly beneficial in various ways as per discussed in the review.

Keywords- Micronutrients, Boron, zinc, growth and production.

1. Introduction

Vegetables refer to the edible and non-woody components of herbaceous plants. Fruits are of significant nutritional value and play a crucial role in promoting overall well-being and illness prevention. These substances provide significant nutritional components that can effectively contribute to the growth and restoration of the human body. Vegetables have a significant role in preserving the body's alkaline reserve. These entities are mostly esteemed for their substantial levels of carbohydrates, vitamins, and minerals. Various types of vegetables exist such as tomatoes, chilies, brinjal, cauliflower, broccoli, okra, and carrots and many others. The many plant parts that can be consumed include roots, stems, leaves, fruits, or seeds. Every category makes a unique contribution to the overall diet (Hanif *et al.,* 2006, Keatinge *et al.,* 2011) [1,2]. The varied climate in India facilitates the abundant availability of a wide range of vegetables. It has the second position globally in terms of fruits and vegetable output, behind China. According to the National Horticulture Database (3rd Advance Estimates) released by the National Horticulture Board, India recorded a vegetable production of 204.84 million metric tons in the fiscal year 2021-22. The total land area dedicated to vegetables are 11.35 million hectares. According to the Food and Agriculture Organization (FAO, 2021), India holds the distinction of being the foremost producer of ginger and okra within the vegetable category, while also securing the second position in the production of potatoes, onions, cauliflowers, brinjal, cabbages, and other related crops.

The adequate provision of nutrients to plants is crucial for the effective cultivation of vegetable crops. The integration of micronutrients and macronutrients in appropriate quantities and ratios is a critical determinant of plant growth and development. Micronutrients are often necessary in small amounts; yet, they play a crucial role in the development of plants. The prudent utilization of micronutrients is crucial in the context of vegetable growing in order to achieve optimal crop output and produce of superior quality. (Sidhu *et al.,* 2019)[3] Micronutrients are also essential for the growth of plants and play a vital role in maintaining balanced crop nutrition. The growth of plants can be restricted when any of the micronutrients in the soil are deficient, even if all other nutrients are present in sufficient quantities. The prevalence of micronutrient deficiencies is extensive in several regions due to soil characteristics, elevated pH levels, limited organic material, salt-induced stress, persistent drought conditions, excessive bicarbonate concentrations in irrigation water, and imprecise fertilizer application. (Fageria *et al.,*2002) [4] The fundamental micronutrients required for field or vegetable crop production include boron (B), copper (Cu), iron (Fe), manganese (Mn), molybdenum (Mo), and zinc (Zn). Nickel (Ni) and Cobalt (Co) are additional mineral nutrients that are deemed necessary for the growth of certain plants, albeit in low amounts (Fageria *et al.,*2002) [4]. Iron (Fe) is critical in cellular redox processes and several enzymes (Kermeur *et al.,* 2023) [5]. Manganese (Mn) and copper (Cu) play crucial roles in redox systems and serve as activators for a range of enzymes involved in photosynthesis, superoxide radical detoxification, and lignin formation (Khoshru *et al.,* 2023) [6]. Zinc (Zn) is known to have a significant impact on the structural and functional integrity of cell membranes, as well as the production of proteins and the detoxification of superoxide radicals. Nickel (Ni) serves as a metallic constituent of the enzyme urease, playing a crucial role in nitrogen (N) metabolism. Molybdenum (Mo) plays a crucial role in nitrogen metabolism, serving as a metallic constituent of nitrogenase, which is responsible for nitrogen fixation and nitrate reductase. Boron (B) plays a critical role in maintaining the stability and functionality of cell walls and membranes. On the other hand, chlorine (Cl) is required for the regular operation of photosystem II and the maintenance of cell osmotic balance (Cakmak *et al.,* 2023; Tripathi *et al.,* 2015)[7,8]. However in the context of India, the micronutrient that exhibits the highest deficiency in soil is zinc (Zn), with boron (B) which play eesential role in completing the life cycle and maintaining the yield potential. (Jatav *et al.,* 2020; Tavakoli *et al.,* 2014) [9,10], The productivity and quality of vegetables are greatly affected by these two nutritional deficiencies. Thus, preventing or correcting B and Zn deficiency in crops on inadequate soils will greatly improve vegetable output and quality. Selection of the right fertilizer source, application at the right rate, formulation, method, timing, and balancing of B and Zn micronutrients with other nutrients in soil can increase vegetable yield and quality. Boron and zinc in soil and foliar applications increase production and quality. so, in the paper, we discuss boron and zinc and their impact on vegetables (Chatterjee *et al.,* 2018) [11].

2. Boron-

Boron is a crucial element for plants, mainly absorbed by the roots in the form of boric acid. The stability of molecules containing cis-diol groups is crucial to their activity in plant metabolism (Brdar-Jokanović, M., 2020)[12]. It plays a role in the regulation of cellular processes such as maintaining the structural and membrane integrity of the cell wall and plasma membrane, development of roots and shoot meristem (Pereira *et al.,* 2021)[13], facilitating the movement of ions across the membrane, promoting cell division and elongation, supporting reproductive growth, facilitating the synthesis of biomolecules including carbohydrates and proteins, aiding in the metabolism of phenols and auxins, enabling nitrogen fixation, contributing to disease resistance, and assisting in managing abiotic stress shown in figure-1 (Kohli *et al.,* 2023; Sardrodi *et al.,* 2022 and Matthes *et al.,* 2020) [14,15,16]. Limited boron supply leads to suppressed leaf expansion, restricted root elongation, and impaired flower development. In contrast, excessive boron has been seen to diminish photosynthetic ability, hinder pollen germination, and inhibit pollen tube expansion (Day and Aasim 2020) [17]. The most significant effect of B deficiency is the inhibition of root elongation, and the presence of an excessive amount of B can stimulate the generation of reactive oxygen species (ROS). Both abscisic acid and salicylic acid are synthesized in reaction to B poisoning, and both can stimulate the antioxidant defense system to detoxify reactive oxygen species (ROS).

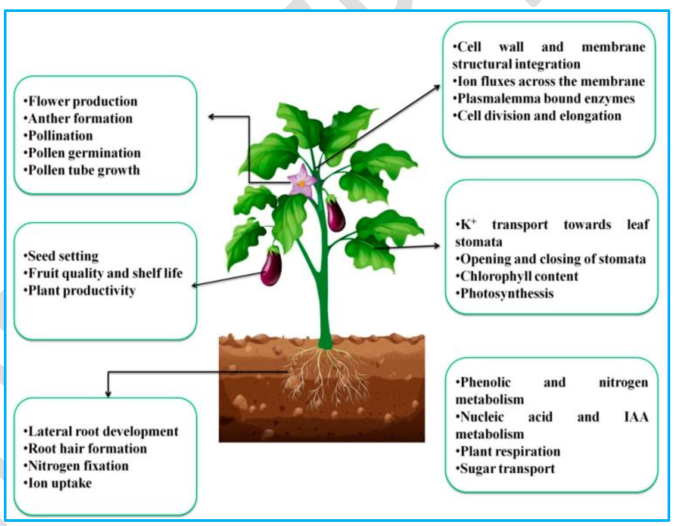

Figure-1 Different functions of Boron (Shireen *et al.,* 2018)[59].

A further response to boron toxicity is alterations in the expression levels and functionality of aquaporins in the roots, consequently diminishing water absorption and transportation of boron through the transpiration stream (Chen *et al.,* 2023) [18].

2.1 Impact on vegetables-

2.1.1 Tomato

Rahman *et al.* (2023) [19] reported that the utilization of a 150ppm concentration of H_3BO_3 on summer tomato plants resulted in the attainment of the most significant plant height, number of branches per plant, number of clusters per plant, number of flowers per cluster, weight of each fruit, number of fruits per plant, and overall yield. Mondal and Ghosh (2023) [20] revealed that plant height and branch number were not affected by applied treatments. However, the total chlorophyll content of leaves was improvised with boron soil application at 2 kg/ha at 30 days after transplanting and with boron foliar application of 0.25% at 60 days after transplanting. The treatment combination of boron in the soil at 2 kg/ha and zinc as foliar at 0.5% was superior for the total yield of tomato. Utilizing a root application containing 3.8 $mg \cdot L^{-1}$ H_3BO_3 demonstrated superior overall characteristics in terms of fruit quality and flavor. This superiority was observed in the quantities of lycopene, β-carotene, soluble protein, the sugar/acid ratio, and distinctive aromatic components present in the fruit. The strategic utilization of boron has been shown to significantly enhance the growth and maturation of tomato plants, while also influencing the attributes and taste of the resulting fruit (Xu *et al.,* 2021) [21]. The application of 2 kg of boron per hectare (ha^{-1}) was found to yield the highest number of flower clusters per plant, fruit set %, total yield, fruit weight loss, and total soluble solid content in the Rio Grand cultivar of tomato (Naz *et al.,* 2012) [22]. According to the findings of the various experiments the application of the boron in soil and foliar is found to be beneficial to increase the vegetative growth and overall yield of the tomato. It is reported that application of the boron 2 kg/ha in the soil and foliar application in concentration of 150 ppm or 3.8 mg/L will increase the overall yield.

2.1.2 Chili-

Shil *et al.* (2013) [23] show that the interaction effect between zinc and boron was significant in the yield of dry chili and the weight of ripe chili/plant. The highest yield was recorded during the application of zinc 3 kg/ha Boron 1 kg/ha that is 1138 kg/ha however in control 7.3 kg/ha is reported. Harris *et al.,* (2018) [24] reported that the maximum plant height, number of branches, number of leaves, number of flowers, total dry weight, number of fruits, and unripe fruit yield were observed with the foliar application of Boron (H_3BO_3) with Magnesium ($MgSO_4.7H_20$) at 100 ppm and the minimum was found in treatment without any foliar spray. Foliar application of Boron (H_3BO_3) + Magnesium ($MgSO_4.7H_20$) at 100 ppm increased yield by three-fold than treatment without any foliar spray. Nawrin *et al.,* (2020) [25] revealed that the highest plant height, leaf number per plant, leaf area, dry weight, fruit length, fruit number per plant, and fruit yield (11.76 g/plant) were recorded in the application of boron 0.5 kg/ha with vermicompost 5 ton/ha at harvest. Khan *et al.,* (2022) [26] will suggest after an experiment that foliar application of boron significantly influenced all parameters in chili. A maximum number of fruits $plant^{-1}$ (117.01), fruit length (8.98 cm), fruit weight $plant^{-1}$ (622.21 g), yield tons ha^{-1} (2.71 tons), and 1000 seed weight (3.47 g) were observed by the foliar spray of boron at 3 kg per hectares. As per various findings the application of the boron in chilli at the range between 1-3 kg/ha is found beneficial for increase in total yield. It is also reported that the application of boron along with the vermicompost and magnesium is found to be beneficial for achieving the higher yield than the general recommended dosage. However, the application of boron alone and also along with various other nutrients and vermicomposting may be variable from area to area and kind of the soil and their properties.

2.1.3 Cauliflower-

AL-Bayati (2019) [27] reported that the interaction between boron 30 ml/L and humic acid increased plant height, number of leaves per plant, leaf area per plant, curd diameter, curd weight, total curd yield, dry matter percent of curds, and contributed to the highest percent nitrogen and boron in curds. Kumar *et al.,* (2010) [62] conduct an experiment and revealed that borax 20 kg/ha with sodium molybdate 2 kg/ha as soil application in combination with recommended dose of NPK 120: 60: 60 kg/ha gave the maximum height of plant, length of leaf, width of leaf, total weight of plant, width of curd, average weight of curd and yield of curd, while foliar application of boron 100 ppm with molybdenum 50 ppm along with recommended dose of NPK 120: 60: 60 kg/ha gave highest growth and yield among all the foliar application treatments. As per different findings it is noticed that application of the borax in the soil and foliar concentration in different concentration generally 100 ppm will increase the yield significantly and found to be beneficial for good vegetative characters of the cauliflower.

2.1.4 Brinjal

Suganiya and Kumuthini (2014) [29] reported that the foliar application of boron (H_3BO_3) at 150 ppm increased the number of flower buds/plant, number of flowers/ cluster, number of flower clusters/plant, total number of flowers/plant, percentage of flower-set, percentage of fruit-set, number of fruits/plant and fresh weight of fruits/plant. Siddiky *et al.,* (2007) [30] revealed that applying boron on brinjal produced a significantly higher yield, 76.52 t/ha, and a 26% yield increase over control.

2.1.5 Coriander-

Beyzi and Güneș. (2017) [31] revealed that the highest ratios of linalool were obtained from 80 kg/ha boron application in the Gamze cultivar. Abdallah *et al.,* (2022) [32] showed boron foliar treatment at 150 ppm improved essential oil yield at mild water stress (80% ETc), enhancing fruit quality. Akter *et al.,* (2022) [33] revealed that the application of the Zinc 4 kg/ha with Boron 1 kg/ha produced the highest foliage yield, and Zinc 2 kg/ha with Boron 2 kg/ha gave the highest seed yield. The highest zinc and boron contents were found in the Zinc 4 kg/ha Boron 2 kg/ha treatment for both foliage and seeds.

2.1.6 Radish-

Maurya *et al.* (2019)[34] revealed that the maximum plant height, plant spread, number of leaves, fresh weight of leaf, dry weight of leaves, leaf area, leaf area index, root length, root diameter, root-to-shoot ratio, average yield gm. per plant, root yield kg per plot, root yield quintal per hectare TSS, ascorbic acid, and B: C ratio were observed in the treatment with nitrogen 120 kg/ha and boron 10 kg/ha. Tariq and Mott

(2006) [62][revealed that significant effects were found on the growth response of radish plants and maximum yield was recorded with the application 0.5 mg L^{-1} of boron in the radish. Deepika and Pitagi, (2015) [35] showed that the combination of the recommended dosage, $ZnSo_4$ 10 kg ha^{-1}, Borax 0.1% spray at the bud initiation stage was effective in maximum plant height, number of leaves $plant^{-1}$, at the bud initiation stage, length of inflorescence, number of siliqua $plant^{-1}$, siliqua weight $plant^{-1}$, siliqua length, No. of seeds $siliqua^{-1}$, seed recovery percent, seed yield, germination percent, seedling vigor index.

2.1.7 Carrot-

Malek and Rahim, (2011) [36] revealed that application of the boron level 3 kg/ha gave the highest seed yield in carrots. Sultana *et al.,* (2015) [37] depicted that the higher levels of boron, *i.e.,* 1.0 and 1.25 kg $ha^{-1,}$ along with a recommended dosage of fertilizer, resulted in higher yield (14 and 18%, respectively), higher uptake (47.8 and 93.1 g ha^{-1} respectively) and caused a reduction in carrot damage (42 and 39% respectively) in comparison with a recommended dose of chemical fertilizers.

3. Zinc-

One of the essential components that is required for the typical expansion and maturation of plant life is zinc. It is one of the eight critical micronutrients that plants require. In plants, zinc is an essential component of the enzymes and proteins that are involved in the metabolism of carbohydrates, the synthesis of proteins, the expression of genes, the metabolism of auxin (a growth regulator), the formation of pollen, the maintenance of biological membranes, protection from photo-oxidative damage and heat stress, and resistance to infection by specific pathogens (Das and Green 2013; Hacisalihoglu, 2020; Tayyiba *et al.,* 2021) [38,39,40]. Zinc deficiency impairs one or more of the plant's various physiological activities, affecting plant development. Zinc deficiency can cause plant physiological changes, including stunting, interveinal chlorosis, bronzing of chlorotic leaves, small and abnormally shaped leaves, and stunting and rosetting (where the leaves form a whorl on shortened stems). These symptoms vary by plant species and are generally only seen in severely deficient plants. Marginal deficiency can diminish plant production by 20% or more without symptoms (Alloway, 2008; Suganya *et al.,* 2020) [41,42].

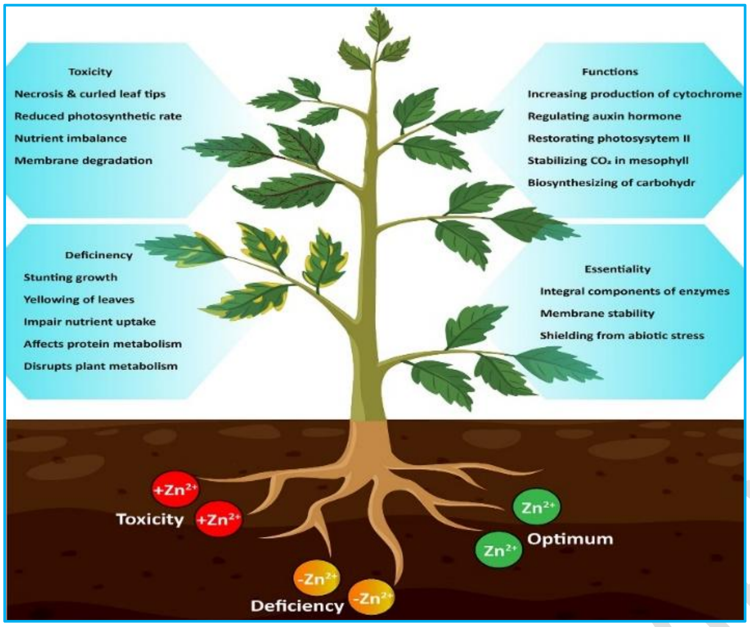

Figure -2 Zn functions, deficiency, and plant toxicity (Hamzah *et al.,* 2022)[60].

3.1 Impact on vegetables:

3.1.1 Tomato

Ahmed *et al.* (2023) [43] reported that tomato growth metrics, physiological features, yield attributes, yield, and quality traits were optimum with foliar spray of 100 ppm ZnO-NPs. The maximum nutrient absorption was achieved with 100 ppm ZnO-NPs. Foliar treatment of 75 ppm ZnO-NPs maximized Zn recovery. Foliar spraying with 100 ppm ZnO-NPs increased yield by 200 percent above control. Haleema *et al.,* (2018) [44] reported that, maximum plant height, number of primary and secondary branches, leaves per plant, leaf area, and fruit per plant were higher with 0.5% foliar Zn application. According to the findings of Ullah *et al.,* (2015) [45], the application of zinc at a concentration of 0.4 percent led to a statistically significant increase in the total number of flowers cluster plants, the total number of flowers within each cluster, the total number of fruits clusters, the total number of plant branches, and the total yield (t/ha). The findings concluded that the application of the zinc as foliar spray of 100 ppm will increase yield around 150-200%. However, this application also gives better vegetative growth and reproductive characters which is directly beneficial to increase the yield of the tomato directly.

3.1.2 Chili-

Foliar application of zinc resulted in a maximum number of fruits per plant (113.99), fruit length (9.45 cm), fruit weight per plant (660.19 g), yield tons ha^{-1} (2.85 tons/ha), and 1000 seed weight (3.54 g) were recorded in the plot to which received zinc of 3 kg per hectares (Akhter., 2021) [46]. Kumar *et al.,* (2020) [28] reported that spraying the crop with a solution containing 0.75 percent zinc and 0.25 percent boron twice, 45 and 65 days after transplanting, resulted in the highest possible green and dry yields. Spraying with zinc at a concentration of 0.75 percent was shown to be helpful in increasing both the growth and yield of the plants. Singh and Singh (2012) [47] reported that the vegetative growth character plant height as well as yield contributing characters viz, number of fruits per plant, fruit length, weight per fruit, the weight of fruit per plant, and fruit yield q/ha was found to be maximum in the foliar application of treatments 0.3 percent zinc and 0.2 percent iron as compared to other treatments. The findings concluded that the application of the zinc on chili in concentration of 0.5 to 0.75 % will significant increase the yield of the chili.

3.1.3 Brinjal-

In their study on brinjal, Raj *et al.,* (2001) [48] found that soil applications of 12.5 kilograms of zinc sulfate per hectare, combined with three sprayings of 0.2 percent zinc sulphate and 0.5 percent iron sulphate at thrice-weekly intervals, resulted in the significantly highest fruit yield of 37.7 tons per hectare, which represented a 23.6 percent increase over the control. According to Tawab *et al.,* (2015) [49] plants treated with 0.2 percent zinc had substantial increases in plant height, the number of leaves produced by each plant, the number of fruits produced by each plant, the weight of the fruits, and the overall yield. It was demonstrated by Abbas *et al.,* (2021) [50] that a soil treatment of humic acid at a concentration of 30 kg/ha combined with zinc sulphate at a rate of 50 kg/ha might be utilized effectively to improve brinjal production.

3.1.4 Bottle gourd-

Zinc application at a rate of 7.5 kilograms per hectare significantly increased vine length, the number of primary branches per vine, the number of nodes per vine, the minimum number of days until the appearance of the first female flower, the node on which the first male and female flowers appeared, the maximum fruit length and girth, and the number of seeds per fruit, according to Bairwa *et al*., (2013) [51]. According to the findings of Bairwa and Khandelwal (2010) [52], the optimal levels of zinc for vine length, fruit girth, number of fruits per plant, seed yield of bottle gourd, zinc content, protein content, and growth and yield of succeeding carrot crop were found to be 5.0 kg zinc per ha and 7.5 kg zinc per ha respectively.

3.1.5 Broccoli-

According to slosár *et al.,* (2017) [53] foliar zinc treatment considerably boosted the sulforaphane content in broccoli florets when compared to the control by around 19.8–32.9 percent at 750 g/ha and by 37.2–49.3 percent when applied at 1.5 kg/ha. It was demonstrated by Ylmaz *et al.* (2013) [54] that the treatment of humic acid and zinc did not have any influence on the height of the plant, the length of the curd, or the dry weight. Significant increases were seen in the leaf number, lateral curd number, and marketable overall yield.

3.1.6 Okra-

An experiment was carried out by Chauhan and Bajapai (2001) [55], and the findings showed that plants given 10.0 mg Zn produced the maximum number of fruits per plant, as well as the highest number of seeds per fruit, the highest weight of fresh fruit, and the highest weight of seeds. According to Sharma *et al.,* (2018) [56], the application of 7.5 kg of zinc per hectare to the soil significantly increased the plant height, the number of branches per plant, the leaf area, the chlorophyll content, the fruit length, the number of fruits per plant, the fruit yield per plant, per hectare, as well as the protein and crude fiber content in fruits. When compared to the control (11 tone/ha), Maliha *et al.,* (2022)[57] found that the zinc and zinc-boron combination produced the maximum yield (17.7 tone/ha). This was in contrast to the results obtained by the control. Naruka *et al.,* (2000) [58] shows that increasing zinc levels resulted in increasing height, number of fruits, fruit diameter, and fruit yield.

4. Conclusion-

The expansion and maturation of vegetable crops are significantly aided by micronutrients like zinc and boron. Because the nutritional content of crops is rapidly becoming a significant concern, the use of micronutrients to preserve soil health and crop production while also preserving the quality of vegetables is of the utmost significance. Zinc and boron application can have positive effects on the growth, yield, and quality of a variety of crops, depending on factors like application concentration, timing, and combination with other nutrients. However, it's important to note that specific results can vary based on soil conditions, climate, crop varieties, and other factors, so local experimentation and adaptation of these findings may be necessary for optimal results.

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