

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. Their significance at the fundamental level directs the expansion and maturation of plant life over the course of the plants' complete life cycles. Some of the essential micronutrients required for the healthy development of field and vegetable crops are boron, copper, iron, manganese, molybdenum, and zinc. Certain types of plants require just trace amounts of micronutrients like nickel and cobalt. Boron and zinc are of significant importance, however, due to the fact that zinc is the element that is most deficient in the soil of India, followed by boron. 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, according to the findings of this review study.

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

1. Introduction

Micronutrients are essential for the growth of plants and play a vital role in maintaining balanced crop nutrition. The optimal growth and development of plants throughout their life cycle depends on their fundamental importance. 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. 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). Iron (Fe) is critical in cellular redox processes and several enzymes (Kermeur *et al.*, 2023). 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 (Khoshruet *et al.*, 2023). 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

Comment [H1]: Review of literature is essential to know the status of knowledge; while with availability of large number of review articles on micronutrient in general and vegetables in particular, how author distinguish their review is questionable;

Provide section and subsection number to different sections;
Author have to discuss the findings of different workers rather than just enlisting it.
Whether authors have taken permission to copy the figures (figure 1 and 2) from the researchers cited? (see journal policy for copying the figures).

Comment [H2]: Avoid general statements (first two sentences) and focus only on selected group of crops.
Write the significance of use of selected micronutrients (Zn and B) in important vegetables (% increase in yield, increase in concentration, etc. due to application of Zn and B).
Write the concluding remark based on review of literature made by author.

Comment [H3]: Need following information:
1. Introduction to vegetables- Vegetables grown in India, their area and production, their significance and availability per capita, major production constraints and role of micronutrient nutrients in vegetables production (Avoid writing functions of micronutrients written herewith);
2. Introduction to micro-nutrient and their use, significance, constraints for their use in vegetable production in India.
3. Write the need/ scope for reviewing the literature for vegetables and for selected micronutrients. (This will be the research gap)
4. Write the objectives of review clearly (For examples – The present review aims in identifying in the vegetables having positive impacts on Zn and B application in terms of crop growth and yield as well as nutrient enrichment,).

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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). However in the context of India, the micronutrient that exhibits the highest deficiency in soil is zinc (Zn), with boron (B) (Jatav *et al.*, 2022; Tavakoli *et al.*, 2014), so in the paper, we discuss boron and zinc also their impact on vegetables.

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). 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), 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; Sardro *et al.*, 2022 and Matthes *et al.*, 2020). 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, S., and Aasim, M., 2020). 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).

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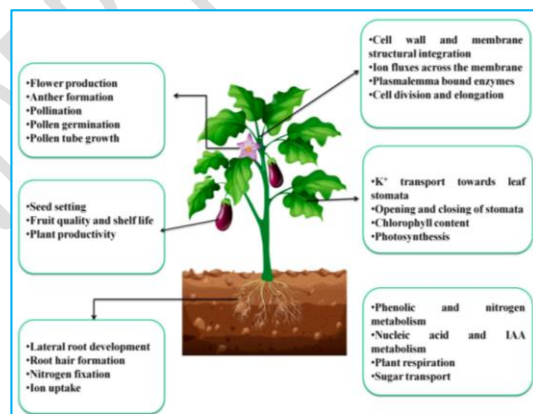


Figure-1 Different functions of Boron (Shireen *et al.*, 2018).

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).

2.1 Impact on vegetables-

2.1.1 Tomato

Rahman *et al.* (2023) 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) revealed that plant height and branch number were not affected by applied treatments. However, the total chlorophyll content of leaves was improved 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 $3.8 \text{ mg} \cdot \text{L}^{-1} H_3BO_3$ 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 (Xuet *et al.*, 2021). The application of 2 kg of ~~Boron-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 (Nazet *et al.*, 2012).

2.1.2 Chili-

Shilet *et al.* (2013) 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-zinc~~ 3 kg/ha; Boron 1kg/ha. Harris *et al.*, (2018) 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 ($MgSO_4 \cdot 7H_2O$) at 100 ppm and the minimum was found in treatment without any foliar spray. Foliar application of Boron (H_3BO_3) + Magnesium ($MgSO_4 \cdot 7H_2O$) at 100 ppm increased yield by three-fold than treatment without any foliar spray. Nawrin *et al.*, (2020) revealed that the highest plant height, leaf number per plant, leaf area, dry

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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 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.

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2.1.3 Cauliflower-

AL-Bayati (2019) 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.*, (2020) 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.

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Discuss the findings of different researchers after mentioned their findings. (Why, How, who much, for selected micronutrients) also mechanism involved.

Comment [H8]: Is it N:P2O5:K2O or NPK? Check it and do needful corrections. Applicable to entire article.

2.1.4 Brinjal

Suganiya and Kumuthini (2014) reported that the foliar application of boron (H₃BO₃) 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-percentage of flower-set, percentage of fruit-set, number of fruits/plant and fresh weight of fruits/plant. Siddiky *et al.*, 2007 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 Güneş (2017) revealed that the highest ratios of linalool were obtained from 80 kg/ha boron application in the Gamze cultivar. Abdallah *et al.*, 2022 showed boron foliar treatment at 150 ppm improved essential oil yield at mild water stress (80% ETC), enhancing fruit quality. Akter *et al.*, 2022 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.

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2.1.6 Radish-

Maurya *et al.* (2019) 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

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2006 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 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 revealed that application of the boron level 3 kg/ha gave the highest seed yield in carrots. Sultana *et al.*, 2015 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; Hacısalihoglu, 2020; Tayyiba *et al.*, 2021). 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).

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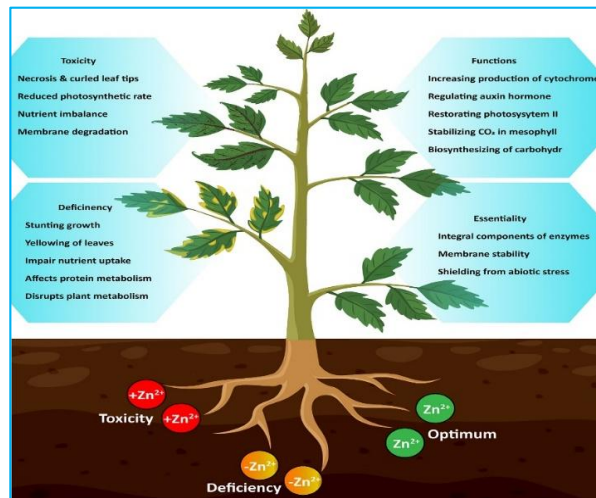


Figure -2 Zn functions, deficiency, and plant toxicity(Hamzah *et al.*, 2022).

3.1 Impact on vegetables:

3.1.1 Tomato

Ahmed *et al.* (2023) 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 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, 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).

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. Kumar *et al.*, 2020 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, 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

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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.

Brinjal-

In their study on brinjal, Raj *et al.*, 2001 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, 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 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.

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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. According to the findings of Bairwa and Khandelwal in 2010, 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.

Broccoli-

According to slosár *et al.*, 2017, 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) 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.

Okra-

An experiment was carried out by Chauhan and Bajapai in 2001, 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, 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 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 shows that increasing zinc levels resulted in increasing height, number of fruits, fruit diameter, and fruit yield.

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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