Popular Article

MANAGING BORON AND ZINC DEFICIENCY IN VEGETABLE CROPS

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ABSTRACT
Among the horticultural crops, vegetables have an important position and are considered as 'protective food'. In recent past the production of vegetables has gone up due to adoption of modern technologies and fertilizer formulation but still productivity is much less than world average. One of the major causes of such situation is the indiscriminate use of major nutrients and giving less importance on micronutrients which are very much necessary for quality vegetable production. Boron and Zinc are the two most important micronutrients which are deficient in soils of several countries of the world including India. Analysis of soil and plant samples has indicated that 49% of soils in India are potentially deficient in Zn and 33% in boron. Crops grown in about half of the country's soils suffer from one or more micronutrient deficiency disorders. The deficiency of these two micronutrients drastically affects the yield and quality of vegetables. So prevention or correction of B and Zn deficiency in crops on deficient soils can have a dramatic effect on yield and quality of vegetables. Selection of proper fertilizer source, application at appropriate rate, using correct formulation, right method of application, timely application and proper balancing of B and Zn micronutrients with other nutrients in soil are some strategies which leads towards more yield and quality production of vegetables. Both soil and foliar application methods of boron and zinc are effective in improving yield and quality of produce.

INTRODUCTION

Boron and Zinc are two most important micronutrients which are found deficient in majority of Indian soils. Analysis of soil and plant samples indicated that 49% of soils in India are potentially deficient in Zn and 33% in Boron (Singh, 2006). Crops grown in about half of the country's soils suffer from one or more micronutrient disorders (Singh, 1991; Takkar *et al*., 1990). Boron is a micronutrient needed by plants. In 1923, it was first reported that boron is essential for cell structure of plants. Boron (B) is a unique non metal micronutrient required for normal growth and development of plants. Boron is involved in cell wall formation, stabilization and lignifications and xylem differentiation. It is needed to ensure normal development of new tissues from roots to flowers and fruit. Boron is responsible for pollen germination and pollen tube formation and activation. The primary function of boron is in regulating the metabolism of carbohydrates in plants. It affects at least 16 functions including flowering, pollen germination, fruiting cell division, water relationships, movement of hormones, cell wall formation, membrane integrity, calcium uptake and movement of sugars (Tiwari *et al*., 2015) When deficient, in general, the terminal bud may die, causing rosette of thick, curled, brittle leaves or brown, discoloured, cracked, fruits, tubers and roots. The other possible roles of boron include sugar transport, lignifications, cell wall structure integrity, Ribose Nucleic Acid (RNA) metabolism, respiration, Indole Acetic Acid (IAA) metabolism, phenol metabolism. It is closely associated with calcium and calcium transport, cell wall formation, cell division in plant growing points, sugar transport in plants, flower and fruit development and plant hormone regulation. Boron minimizes the adverse effects of drought stress in crop plants during dry spell (Tiwari *et al*., 2015).

Zinc has emerged as the most important micronutrient which is deficient in soils of several countries of the world. The essentiality of Zn for higher plants was demonstrated by Somner and Lipman in 1926. Zinc is involved in diverse enzymatic activities i.e. dehydrogenases, phosphodiesterase and the promotion of synthesis of cytochrome C. Zinc is also essential for the metabolism of auxin. Zn is essential for the stability of cytoplasmic ribosomes and root cell plasma membrane, catalyses the process of oxidation, synthesizes protein and indole-acetic acid and involved in the transformation of carbohydrates. Zn can affect carbohydrate metabolism at various levels. The activity of Zn-containing enzyme carbonic anhydrase sharply declines with Zn deficiency and in extreme Zn deficiency net photosynthesis is inhibited, presumably due to chloroplast structure and inhibited photosynthetic electron transfer. Several other enzymes involved in carbohydrate metabolism are Zn dependent and inhibited by Zn deficiency (Shivay, 2013).

Zn deficiency inhibits protein synthesis mainly by a marked decrease in RNA. Zn containing isoenzyme SOD (Cu-Zn-SOD) plays an important role in the detoxification of superoxide radicals and thus protects membrane lipids and proteins against oxidation. Accumulation of tryptophan is reported to be an expression of an inhibited protein synthesis under Zn deficiency. Zn deficiency leads to lower concentration of IAA as well as impaired GA metabolism. Many enzymes contain tightly bound Zn essential for their function (Shivay, 2013).

Soil and climatic conditions favouring boron deficiency

- The deficiency is common in high rainfall areas (over 2500 mm/ year) with high temperature (more than 33^0 C).
- It is also found in areas with high light intensity during dry season, especially in fairly dry areas.
- The deficiency is common in alkaline, calcareous soils (with a pH higher than 8), highly acidic soils (with a pH lower than 4.5) and soils with a very low soil boron content (less than 0.5 mg/ kg hot water soluble B).
- The condition is often found in sandy soils (more than 65% sand content), soils with very low organic matter content (lower than 0.75%) and soils derived from acid igneous rocks (granite).
- Boron deficiency may also be encountered in soils which have been given excessive applications of nitrogen and potassium fertilizers (Tiwari *et al*., 2015).

Boron deficiency has been commonly reported in soils of India which are highly leached and/ or developed from calcareous, alluvial and loessial deposits. It is one of the major constraints to crop production and has been reported in more than 80 countries and for 132 crops over the last 60 years. Boron deficiency has been realized as the second most important micronutrient constraint in crops after that of zinc (Zn). But from the vegetable production point of view, boron deficiency causes more severe crop loss than that of zinc deficiency. Vegetables vary in their boron requirements. Cole crops, turnips, and beets have the highest demands. Even so, recommended rate of application in low boron soils for these high demand crops is only 3 kg/ha. A substantial potential of net economic benefit has been reported from the use of boron fertilizers in boron deficient crops (Tiwari *et al*., 2015).

Deficiency symptoms of boron in different vegetable crops

As boron is immobile in plants, B deficiency in crops growing in soils with marginal boron levels can occur during peak growing periods (vegetative, flowering and seed development stages), so a steady supply of boron throughout the growing season is essential for optimum growth and seed yield. Experiments regarding the effect of boron on yield, mobility and stress tolerance in different crop species revealed that boron significantly enhances yield. In extreme cases, crops on low B soils grow well until flowering when floral abortion or seed set failure can result in severe yield losses. Boron application at the onset of reproductive phase found to be more effective, most likely due to its immobile nature in the plants depending upon the photosynthetic efficiency of the plants. Visible boron deficiency symptoms for many crops are listed below-

Cole crops: Of all the cole crops, cauliflower is the most sensitive to boron deficiencies. Symptoms of boron deficiency vary with crop type. A common boron deficiency in cauliflower is roughened stems, leafstalks and midribs, an interruption in flowering, poor development of curds with brown patches, deformed and discoloured brown heads with an empty space known as “Hollow Heart” resulting in poor yields. In Cabbage, distorted leaves and hollow areas in stems are the characteristic symptoms. Most boron deficient cole crops develop cracked and corky stems, petioles and midribs. Cauliflower curds become brown. This is known as Brown rot/ Browning. Leaves may roll and curl, while cabbage heads may remain small and yellow (Tiwari *et al*., 2015).

Tomato: Tomato plants with boron deficiency have stunted growth and are dwarfed. The leaves are twisted and small in size and may have a variegated appearance. Yellowing and death of fruits are occurred in case of severe deficiency. The young shoots may wither and die. Fruits may be ridged, show corky patches, ripen unevenly and show cracking (Tiwari *et al*., 2015).

Sugar beet: Young plants have distorted crown leaves. The leaf size remains small, become scorched and wilts later on (Tiwari *et al*., 2015).

Turnip: Brown or grey concentric rings develop inside the root (Tiwari *et al*., 2015).

Carrot: Longitudinal splitting of leaves, formation of rough, small roots with a distinct white core in the centre and browning top of plants are the common symptoms. Fruits show blackened spots (Tiwari *et al*., 2015).

Cucumber: Cucumber plants with boron deficiency have abnormal shoots. The apical growing points are stunted and eventually die. Cracks may appear in the stem and the fruits are often deformed. Older leaves of boron deficient cucumber plants develop a yellow border. New leaves are distorted and appear mottled. Fruits abort and show symptoms of twisting and scarring. Longitudinal, mottled yellow streaks develop into corky markings on the skin of cucumber fruits (Vitosh *et al*., 1994).

Pepper: Pepper plants with boron deficiency are stunted or dwarfed. The leaves are small and often become twisted and discoloured. Fruits are twisted and show black spot (Vitosh *et al*., 1994).

Diagnosis of boron deficiency by soil and plant analysis

In soils, concentration of total B is reported to be in the range of 20-200 mg B/ kg and its available concentrations also vary greatly from soil to soil. Boron which is readily available as a nutrient for plants exists in the soil as the water soluble form. For soil diagnosis, a level of less than 0.5 mg/ kg of water soluble boron is low or deficient. A medium or adequate level is 0.5-2 mg/ kg, while soils with more than 2 mg/ kg are considered to have high or excessive boron content. Thus, soils with less than 0.5 mg/ kg hot water soluble boron probably incapable of supplying enough boron to support normal growth and yield. Leaf analysis, supplemented by soil analysis, can differentiate the two conditions.

Boron is absorbed by roots as undissociated boric acid [B (OH) $_3$ or H_3BO_3] which has a strong ability to form complexes inside the plant system. In most crops, boron in plant tissue in the range of 15-100 mg/ kg is considered adequate for normal growth, while more than 200 mg/ kg might be expected to be excessive and have a toxic or depressive effect on crop growth and yields. Concentration of boron in plant tissue below the critical level indicates that growth or yield is not being optimized. Correcting the boron deficiency probably improves both the growth and the yields and more than justify the cost of the applied boron.

Plants are rather exacting in their requirements for boron and the margin between deficiency and excess is particularly narrow. For example, in mini cucumbers, a leaf boron concentration of 30-70 µg/ g is desirable, but deficiency occurs at less than 20 µg/ g and toxicity at more than 100 µg/ g. Boron is not readily moved from old to new tissues, hence continuous uptake by roots is needed for normal plant growth. Boron is important in the regulation of developing cells and in pollination. Seed set and fruit development are affected by deficiency (Tiwari *et al*., 2015).

Interaction of boron with other elements

In most plants, a high potassium concentration due to excessive applications of potassium fertilizers usually induces boron deficiency. A high level of soil calcium depresses the availability of boron in limestone soils. Therefore, in soils with excessive levels of boron, boron toxicity of plants can be avoided by the application of calcium. Zinc application has been found to neutralize toxic effect of boron in some crop plants and subsequently increase the crop yield (Tiwari *et al*., 2015).

Correction of boron deficiency

- The boron deficiency in plants can be easily corrected by applying boron, usually in the form of borax, a white crystalline salt. The quantities needed for the crop are very small. The application of 5-10 kg/ ha can correct boron deficiency.
- Foliar fertilization is also an effective way to supply boron in plants, especially when root activity is restricted and boron deficiency in crop appears under dry soil conditions in the growing season. Foliar spray of 0.2% borax solution can be applied every 10 days until the deficiency is corrected. But it has been found that soil application of boron is superior to foliar sprays (Das *et al*., 2017).
- For calcareous soils, sulphur should be applied at a rate of 2 mt/ ha. This reduces the soil pH to 6.0-7.0 and increases the solubility of boron in the soil solution.
- For hidden deficiency spray 0.2% boric acid or borax at pre flowering or flower head formation stages (Das *et al*., 2017).

Boron application rate generally ranges from 0.25 to 3.0 kg B/ ha, depending on crop requirement and the method of application. Higher rates are required for broadcast applications than for banded soil applications or foliar sprays. One should be very careful when treating a boron deficient crop, as boron is highly toxic to most plants at quite low rates. Care should be taken with soil treatments to ensure an even spread and it must be kept in mind that excess boron can be toxic. An application of 10 kg borax (Granubor) per hectare to deficient soil before planting will prevent boron deficiency. Foliar sprays of borax i.e. Solubor (100 g/ 100 L of water) may also be used (Tiwari *et al*., 2015).

Soil and climatic conditions favouring zinc deficiency

- Scalped or severely eroded soils are more apt to be zinc deficient than well managed soils. Also, sandy, sandy loamy and organic soils are more likely to be zinc deficient than silty or clayey soils. This is due largely to the fact that sandy or organic soils originally contain low total zinc levels. Severe soil compaction can also reduce zinc availability.
- It is found that Zn deficiency manifests under low temperatures in vegetables like beans and potato etc. This could be due to reduced root growth as well as due to lowered absorption and translocation of Zn in plants.
- Under dryland conditions reduced moisture content in the surface layer may reduce Zn absorption and cause Zn-deficiency. Increased soil pH (alkaline soil condition) reduces Zn availability because it increases Fe^{++} and Mn^{++} ion concentration in soil that

suppress Zn uptake and increased HCO_3 concentration detrimentally affects translocation of Zn in plant.
- Reduced light intensity is reported to increase the severity of Zn-deficiency. In India Zn deficiency manifests on a cloudy day (Shivay, 2013).

Deficiency symptoms of zinc in different vegetable crops

Visible zinc deficiency symptoms for many vegetable crops are listed below-

1. **Tomato**: Leaves of the apical portion of the plant become small and thick. Leaves show interveinal chlorosis and lower portion of the individual leaf becomes curly. The curly portion looks like a screw. Mature leaves of basal part of plant turns into brownish orange in colour and dried later on. The plant growth remains stunted (Vitosh *et al*., 1994).
2. **Potato**: Deficiency symptom is found in the young tender leaves. Yellowing starts from apex of the leaf and continue towards leaf margin. Leaf petioles and main stems of individual plant turns into coppery brown colour. The top portion of leaves bend like cup. The whole plants look like a fern. Internodal length remains short and plant shows dwarfism. Potato tubers become fibrous and yield is reduced (Vitosh *et al*., 1994).
3. **Radish**: Chlorosis of leaf is the main symptom. Yellowish dot like spots are found in the leaves. The leaves look skeletonised in the advance stage. The leaves fall down prematurely (Vitosh *et al*., 1994).
4. **Onio**n: Plant growth is stunted. Leaves are converted into yellowish colour from green and looked like bracket (Vitosh *et al*., 1994).
5. **Beetroot**: Leaf apex starts drying. Coppery brown or greyish spots are found in the leaves. Blight like symptoms are found in the leaf margins. Leaves remain undersized. Plants remain dwarf (Vitosh *et al*., 1994).
6. **Chilli, Okra and Cucurbits**: Tender leaves remain small in size. The leaf veins changed into golden yellow or orange colour (Vitosh *et al*., 1994).
7. **Cauliflower**: Leaves remain small in size and leaf number is reduced. Yellow spots are found in the leaves. Leaves show decaying symptoms later on (Vitosh *et al*., 1994).
8. **Pea**: Leaves become thin and pointed. The leaves also bend towards inside. Yellow spots are found in leaves. Apex and leaf margin starts drying. The main stem becomes woody and flower bearing is reduced drastically. Ultimately the pod yield is seriously hampered (Vitosh *et. al*., 1994).
9. **Dolichos bean, French bean and Cowpea**: Interveinal portion of mature leaves show pale green or yellowish orange colour. Gradually, these spots are converted into reddish brown colour patches. The flowers shed upto a great extent and yield is reduced as a result (Vitosh *et al*., 1994).

Diagnosis of zinc deficiency and excess by plant analysis

Lower critical concentration (LCC) in plant tissue at which it shows the deficiency symptoms depends not only on crop and its cultivars but also on the plant part and age of the crop. It is generally agreed that Zn deficiency in vegetable occurs when the Zn concentration is 20 mg kg-1(ppm) or less in plant tissue. It is generally determined from the tissues of top fully opened leaves.

Zn being a micronutrient, its excess uptake results in phytotoxicity which not only results in reduction in crop yield and quality but may also lead to accumulation in food chain and this may impair human and animal health. Zn phytotoxicity symptoms are similar to Fe chlorosis. Once leaf Zn exceeds 400 mg kg-1 DM (Dry matter), toxicity of Zn is to be expected. Tissue Zn concentration (mg kg-1 DM) for plants showing visual toxicity symptoms was: 526 and 523 mg kg-1 DM in tomato and lettuce respectively and causes yield depression. Thus the upper critical limit (UCL) for zinc also varies considerably in crops and depends upon the crop, cultivar and the concentration of other nutrients in plant tissue (Shivay, 2013).

Interaction of zinc with other elements

Zinc interacts positively with N and K and negatively with P. Synergistic effects of Zn x N interaction, are mainly attributed to increased availability of Zn in soils due to acid forming effect of N, while positive Zn x K interaction is attributed to the role of K in Zn translocation in plants. On the other hand Zn in general interacts negatively with P, which depends upon a number of physico-chemical properties of soil. When large amounts of P are applied close to the seed and soil, Zn levels are low and thus Zn deficiency in plants is exhibited.

Zn interacts antagonistically with all the 3 secondary plant nutrients. Higher concentrations of Ca and Mg inhibited absorption and translocation of Zn. Similarly S and Zn interacted negatively.

Most available reports show negative interaction of Zn with Fe, Mn, Cu and Mo. As regards B, it is reported that Zn application created a protective mechanism in root cell micro environment against excessive B uptake (Shivay, 2013).

Correction of zinc deficiency

- There are four classes of Zn sources: inorganic, synthetic chelates, natural organic complexes and inorganic complexes. The inorganic sources are sulphate, chloride, carbonate and oxides of Zn. Of these, sulphate is the most widely used source of

Zn. Of the two sulphates zinc sulphate heptahydrate ($ZnSO_4.7H_2O$) is most widely marketed and used Zn fertilizer in India. Of late ZnO is receiving some attention because of its high Zn content 50-80% as compared to 21% in $ZnSO_4.7H_2O$ and especially in the context of making Zn coated (zincated) urea.

- Methods of Zn application to crops include soil application (broadcast or band placement), foliar application, dusting seeds with Zn powder or soaking them in Zn solution, swabbing foliage with Zn paste or solution, dipping roots of seedlings of transplanted crops in Zn solution or suspension. However, in India mostly soils vs. foliar application have been compared. Although in some studies when a number of sprays were made, foliar applications were equally effective as soil application or did show some advantage over soil application. In other studies soil application was found better than foliar application. Generally 6 kg zinc sulphate applied for foliar spray and 25 kg zinc sulphate applied through soil, but the soil application has advantage of building up soil Zn level and giving residual effects to the succeeding crops, while the continued foliar application results in mining of native soil Zn and over years it may make them Zn deficient.
- Relative efficiency of Zn sources could vary with the method of application. They observed that with soluble fertilizers such as zinc sulphate, band placement was generally superior to broadcast application, while for less soluble fertilizers such as ZnO and Zn frits broadcast application was better.
- Application of $ZnSO_4$ in nursery beds, seedling root dipping in 2-4% ZnO suspension, mid season correction by spraying 0.5% $ZnSO_4$ thrice at weekly intervals are some important measures of preventing deficiency symptoms (Das *et al.,* 2014). Curative measure for correcting are application of 20-25 kg/ha $ZnSO_4$ in acid soil, 22 kg Zn/ha initially followed by 5-10 kg Zn in the later years or 50% gypsum + 10 t GM + 22 kg Zn once in 2-3 years in sodic soils are also very effective (Das *et al*., 2017).

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CONCLUSION

Micronutrient deficiency in crop production is increasing with intensive cultivation of crops. It is very important to identify the micronutrient deficient soils and regions and rectify the problems by applying adequate amount of micronutrients because it is identified as one of the key barriers in augmenting the productivity of vegetable crops. The soils of West Bengal (68%), Bihar (38%), Karnataka (32%), Uttar Pradesh (24%), Madhya Pradesh (22%), Tamilnadu (21%) and Punjab (3%) are mostly deficient in Boron whereas zinc deficient soils are mostly found in Maharashtra (86%), Karnataka (72%), Haryana (60%), Tamilnadu (58%), Odisha (54%), Bihar (54%), Uttar Pradesh (45%) (Singh, 2001). Therefore, a well planned systematic and focused basic and strategic research work is needed to be carried out to suggest its need and judicious use and enhance the use efficiency. Last but not the least, extension workers must come forward to create awareness about the use of micronutrient among the farmers.

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