Review Article

Management of Zn and Fe in Horticultural Crops of Arid Zone: A Review

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Abstract

Micronutrients are essential for plant growth, but plants require relatively small amounts of them. They include boron (B), copper (Cu), iron (Fe), manganese (Mn), molybdenum (Mo) and zinc (Zn). These elements may also be referred to as minor or trace elements, but "micronutrients" is preferred. Among them iron and zinc plays a very important role for the production of horticultural crops. Horticultural crops suffer widely by zinc deficiency followed by boron, manganese, copper, iron (mostly induced) and Mo deficiencies. Cl, Cu, Fe and Mn are involved in various processes related to photosynthesis and Zn, Cu, Fe, and Mn are associated with various enzyme systems; Mo is specific for nitrate reductase only. B is the only micronutrient not specifically associated with either photosynthesis or enzyme function, but it is associated with the carbohydrate chemistry and reproductive system of the plant. The significance of micronutrients in growth well as physiological functions of horticultural crops are briefed in this review.

Keywords: Management, Zn, Fe, Horticultural crops, arid zone

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Introduction

The occurrence of micronutrient deficiencies in crops has increased markedly in recent years due to intensive cropping, loss of top soil by erosion, losses of micronutrients through leaching, liming of acid soils, decreased proportions of farmyard manure compared to chemical fertilizers, increased purity of chemical fertilizers and use of marginal lands for crop production [1]. Consequently, in addition to nitrogen (N), phosphorus (P) and potassium (K) deficiencies, some other nutrients such as sulphur (S), zinc (Zn), iron (Fe), copper (Cu) and boron (B) deficiencies are observed in many parts of the country [2].The arid region is spread over 38.7 million hectares mainly in the states of Rajasthan. Gujarat, Haryana, Punjab, Karnataka, Andhra Pradesh besides cold arid region situated in Leh, Laddakh and Himachal Pradesh. The region is marked by extreme environmental constraints due to which the cultivation of traditional crops is not economical. In a situation such as this, arid horticulture has ample scope to develop the hot arid and semi-arid regions. Due to extremely light texture, high $CaC0_3$ content, high pH and low organic carbon these soils are deficient in available Zn, Fe, Cu and Mn content [3]. Zinc solubility is highly soil pH dependent and decreases 100-fold for each unit increase in pH, and uptake by plants decreases as a consequence. Soil pH is more important than any other single property for controlling Zn mobility in soils [4]. The low availability of Zn in high pH calcareous soils is due to the adsorption of Zn on clay or $CaCO_3$ [5].In addition, high concentrations of HCO_3^- inhibit Zn uptake and translocation [6].

The role of iron in photosynthesis, nitrite and sulfate reduction and N_2 assimilation is well established. Although it is the 4th most abundant element in soils, yet its deficiency (chlorosis) is wide spread in orchards and is by far the most difficult to correct especially in calcareous soils. The solubility of Fe decreases by~1000-fold for each unit increase of soil pH in the range of 4 to 9 compared to ~100-fold decreases in the activity of Mn, Cu, and Zn [7]. Minimum Fe solubility occurs between pH 7.5 and 8.5, which is he pH range of many calcareous soils of arid region [8].

Roles and management of iron (Fe) in horticultural crops

Iron is an essential micronutrient for almost all living organisms because of it plays critical role in metabolic processes such as DNA synthesis, respiration, and photosynthesis. Further, many metabolic pathways are activated by iron, and it is a prosthetic group constituent of many enzymes. An imbalance between the solubility of iron in soil and the demand for iron by the plant are the primary causes of iron chlorosis. Although abundant in most well-aerated soils, the biological activity of iron is low because it primarily forms highly insoluble ferric compounds at neutral pH levels. Iron plays a significant role in various physiological and biochemical pathways in plants. It serves as a component of many vital enzymes such as cytochromes of the electron transport chain, and it is thus required for a wide range of biological functions. In plants, iron is involved in the synthesis of chlorophyll, and it is essential for the maintenance of chloroplast structure and function [9].

Iron deficiency in fruit plants grown in Punjab is generally seen in orchards established in areas with soils having light texture, alkalinity and high calcium carbonate content. Because it is immobile in plant system, therefore it is not transported from older to younger leaves. As a result of which iron deficiency symptoms generally appears on newly emerging leaves, while the older ones remain green. The affected newly emerged leaves showed a signs of interveinal chlorosis as yellowing of leaves with green veins. The conspicuous symptoms of iron deficiency are therefore, the development of green net-work of veins over light green colored background. However, under acute iron deficient conditions die back of twigs may also start. Even, the new leaves may open/unfold without any green color and later veins may turn green.

Soil treatments usually require applications of iron chelates at a rate equivalent to 0.5 to 1 pound of iron per acre. Often it is difficult to correct iron deficiency with soil applications when soils are alkaline. Soil applications are effective if soils are acid or neutral in reaction. Under alkaline soil conditions, foliage sprays are recommended. Use iron sulfate, iron chelates or iron citrate according to the supplier's recommendations. Iron chelates, though more expensive than iron sulfate, persist longer. Sometimes the best cure for Fe deficiency is to grow varieties that are not sensitive to Fe deficiency. For instance, some soybean varieties are more sensitive to Fe deficiency than others. For bedding plant production, use 1 to 2 ounces of elemental iron per cubic yard of soil mix. To help prevent an iron problem, avoid using excessive amounts of lime or phosphate. Apply chemicals or fertilizers to increase the soil acidity and add organic matter.

For the correction of iron deficiency, inorganic Fe sources have proved non-effective. Efficiency of soil applied Fe-chelates are somewhat effective to prevent chlorosis but it must be supplemented with repeated iron foliar sprays. The 1st report on chlorosis correction was with inorganic Fe salt additions by Gris in France in 1843. Iron-containing synthetic chelates are usually quite expensive, but, generally speaking, they could indeed be effective in correcting leaf Fe chlorosis [10]. However, Fe (II) salts are in many cases as effective as Fe(III) chelates. It is also interesting to mention here that some acidic treatments like 0.5 mM H_2SO_4, citric acid @ 2 g/l can release Fe immobilized within the plant by changing apoplastic pH. Plants evolved on Fe-deficient calcareous soils have natural ability to develop adaptive mechanisms to overcome or minimize the effects of Fe deficiency stress. Marschner and his colleagues have identified two different types of adaptive root responses to Fe deficiency. The first strategy exists in all plant families other than graminaceous family, and is characterized by the mechanisms involving acidification of rhizosphere, activation of a membrane-bound ferric reductase enzyme and the release of reducing substances from roots [11]. These mechanisms are highly inducible in response to Fe deficiency; they improve solubilisation and uptake of Fe from sparingly soluble Fe compounds in soil. The other strategy (strategy II) is confined only to graminaceous species, and characterized by the release of the mugineic acid family phytosiderophores (MAs) to chelate Fe in rhizosphere. The resulting Fe (III)-MAs are taken up into root cells by an inducible specific transporter in the root cell plasma membrane [12].

Roles and management of zinc in horticultural crops

The Zn plays very important role in plant metabolism by influencing the activities of hydrogenase and carbonic anhydrase, stabilization of ribosomal fractions and synthesis of cytochrome [13]. Plant enzymes activated by Zn are involved in carbohydrate metabolism, maintenance of the integrity of cellular membranes, protein synthesis, regulation of auxin synthesis and pollen formation. The regulation and maintenance of the gene expression required for the tolerance of environmental stresses in plants are Zn dependent [14]. Its deficiency results in the development of abnormalities in plants which become visible as deficiency symptoms such as stunted growth, chlorosis and smaller leaves, spikelet sterility. Micronutrient Zn deficiency can also adversely affect the quality of harvested products; plants susceptibility to injury by high light or temperature intensity and to infection by fungal diseases can also increase [14]. Zinc seems to affect the capacity for water uptake and transport in plants and also reduce the adverse effects of short periods of heat and salt stress [15]. As Zn is required for the synthesis of tryptophan which is a precursor of IAA, it also has an active role in the production of an essential growth hormone auxin [16]. The Zn is required for integrity of cellular membranes to preserve the structural orientation of macromolecules and ion transport systems. Its interaction with phospholipids and sulphydryl groups of membrane proteins contributes for the maintenance of membranes [17].

Zinc deficiency in fruit plants appears on newly emerged fully developed leaves as yellowing of areas between mid-ribs called as interveinal chlorosis. However, under acute zinc deficient situations the affected leaves become entirely yellow while the mid-rib, vein sand tissue along-side them remains green. The newly emerging leaves remains small in size and narrow with pointed tips. The growth of twigs is also paused and the inter-nodal distance (distance between the nodes) is reduced, that gave the branch a rosette appearance. With the advancement in deficiency period, the twigs also start dying back. In citrus, fruit bud formation is severely reduced and terminal leaves remained small and narrow under zinc deficient situations. Several zinc compounds can be used to correct a deficiency. Zinc sulfate, zinc oxide, zinc chloride, zinc sulfide and zinc carbonate are common inorganic salts Organic compounds such as zinc chelates (zinc EDTA and zinc NTA) are about five times more effective than inorganic salts with equivalent amounts of zinc. Organic carriers, however, have a lower zinc concentration, ranging from 9 to 14 percent. The zinc concentration of zinc sulfate ranges from 25 to 36 percent, and that of zinc oxide, 70 to 80 percent. In field tests, granular zinc oxide was not as effective as the powdered formulation. The test also showed that mixing the zinc carrier with the fertilizer was more effective than incorporating the carrier in the granule.

Conditions under which fruit trees are most likely to respond to corrective Zn treatments in terms of growth, yield, and fruit quality are not completely understood. In citrus and apples, the occurrence of severe deficiency symptoms appears to be a prerequisite for tree responses. Due to wide occurrence of zinc deficiency in orchards, soil applications are generally recommended. Sometimes soil applications of zinc might not be mucheffective because the roots of some fruit crops occupy deep soil layers and zinc does not easily move in the soil towards beneath layers. The deficiency of micronutrients can better be controlled by making up deficiency doses through soil and later on maintenance doses through foliar feeding. On an average, zinc metal residual effect persists for three years. High rates of phosphatic fertilizers applied to low Zn soils enhances the plant accumulation of P thereby increasing the internal plant Zn requirement because of Zn precipitation [18]. Therefore, high application rates of P fertilizer can induce Zn deficiency (P-induced Zn deficiency) and increase plant requirements for Zn. Inappropriately high P applications have induced Zn deficiency in plants most likely because of increased P uptake and higher shoot growth, which has led to decreased Zn in shoots because of dilution [19-20]. Zinc-deficient plants may also have high and potentially toxic P concentrations, and P toxicity symptoms have sometimes been mistaken for Zn deficiency [21]. High levels of P may also result in increased absorption and retention of Zn in roots and decreased translocation to leaves [22].

Response of Vegetable crops to Fe & Zn application

The plant height of tomato increased significantly with 50 and 75 kg $ZnSO_4$ ha^{-1} in combination with NPK over NPK alone [23]. [24] recorded the maximum plant height (78.53 cm) and number of branches per plant (9.73) in treatment of naphthalene acetic acid (NAA 10 ppm) + urea (1%) + $ZnSO_4$ (0.2%) as compared to control (70.93 cm and 8.13, respectively. The application of NPK 100:100:50 kg/ha +Azospirillum + PSB each @ 125 g/ha as root dipping along with $ZnSO_4$ (0.2%) spray recorded significantly higher plant height, number of branches per plant and number of leaves per plant [25]. In chilli cv. Talhari [26] concluded that with increasing zinc level, the growth and yield contributing traits improved gradually. The highest concentration of zinc at 5 ml/l water resulted in 85.66 cm plant height, 77 cm plant spread, 13 branches per plant and took 56.33 days to flower emergence [27] recorded the maximum growth rate (85.7%) with the application of zinc followed by the application of micronutrients mixture (78.2%) in tomato.

A combined spray of zinc 100 mg/l and iron 200 mg/l on foliage resulted in maximum plant height (124.14 cm) and number of branches per plant (8.36) in tomato [28]. In tomato grown on zinc deficient soils, [29] found that addition of zinc 0.02% to irrigation water increased the yield by 16.3%. [30] reported higher yield of tomato by maintaining 20 ppm or more zinc concentration in the plant. [31] observed that the foliar application of zinc at 5 and 10ppm increased the number of fruits per plant to the tune of 97 and 99% and fruit weight by 25 and 28%, respectively in tomato. The foliar application of $ZnSO_4$ 0.02 or 0.05% at 30, 50 and 70 days after planting had beneficial effect on fruit weight and yield of tomato [32]. [33] recorded the significantly higher yield and yield components of chilli with foliar application of zinc or boron or in combination of zinc, boron and iron each at 0.1% as compared to control. While studying the effect of zinc sulphate on yield of aubergine in calcareous soils, [34] noted that zinc sulphate and copper sulphate at 10 and 20 kg/ha, respectively decreased zinc and copper deficiency symptoms and significantly increased the yield. [35] obtained the heaviest fruits (52.2 g) with soil application of $ZnSO_4$ (25 kg/ha) and the highest yield (27.1 t/ha) and number of fruits per plant (20) with soil application of $ZnSO_4$ (25 kg/ha) in combination with zinc (0.5%) foliar spray 30 days after transplanting in brinjal. [36] obtained the highest marketable tomato yield (285.88 q/ha) when zinc sulphate was applied @ 10 kg/ha. Foliar application of zinc had positive impact on chilli [37]. [38] found significant increase in yield, zinc and iron content of brinjal fruits with the application of zinc and iron either through soil or foliar spray. Among the treatments, soil application of ZnSO4 12.5 kg/ha along with three sprays of $ZnSO_4$ 0.2% and FeSO4 0.5% at weekly interval at later stages recorded significantly highest fruit yield of 37.7 t/ha with 23.6% increased over control in brinjal cv. Bhagyamathi. In chilli, spraying ferrous sulphate 100 ppm significantly increased the number of fruits per plant (49.40) and fruit length (9.10 cm) as compared to control [39]. [26] revealed that zinc at 5 ml/l water resulted in maximum number of fruits per plant (481.33), fruit length (5.50 cm), fresh fruit yield (705 g/plant) and fruit yield (16.35 t/ha). However, the fruit yield (16.350 t/ha) did not increase significantly under concentration of zinc 5 ml/l water when compared with 4 ml/l water, which indicates that zinc at 4ml/l water was an optimum level for obtaining economical fruit yield (16.093 t/ha) in chilli. Similar results have also been reported by [40] from England and [41], from India. Combined application of zinc, iron and boron at 1% as foliar spray was found effective in respect of number of branches per plant (11.2), stem diameter (1.54 cm) and spread of plant (53.54) in chilli [42]. Foliar application of zinc (100 mg/l) + iron (200 mg/l) resulted in maximum number of flowers per cluster (18.14), fruits per cluster (8), fruits per plant (90.14), fruit weight (95.14g) and yield (25.14 t/ha) in tomato [28].

The soil application of zinc sulphate 20 kg/ha + $ZnSO_4$ 0.5% foliar spray before flowering showed significant increase in seed yield and its components in chilli [43]. In bell pepper, [44] noticed lower germination (64.81%), root length (4.86 cm) and shoot length (5.95 cm) with the application of $ZnSO_4$ (0.2%) at pre-flowering stage of bell pepper as compared to control (64.91%, 4.25 cm and 5.22 cm, respectively). [44] recorded the maximum mean seed germination (64.81%), root length (4.86 cm) and shoot length (5.95 cm) when the plants were sprayed with ZnSO4 (0.2%) at pre-flowering stage of bell pepper. [39] reported that the foliar application of zinc sulphate 100 ppm significantly increased the number of seeds per fruit (128.43). In chilli (Capsicum annuum L.) cv. ByadagiKaddi, [45] recorded higher seed yield (248.26 kg/ha) with increased quality parameters by foliar spray of $ZnSO_4$ (0.1%) at flowering stage as compared to control. The maximum number of seeds per fruit (57.93) was recorded, when FeSO4 was applied at 0.25% in chilli [45]. [39] stated that foliar spray of ferrous sulphate 100 ppm significantly increased in the number of seeds per fruit (128.26) as well as the seed yield (136.48 kg/ha) of chilli.

Response of Fruit crops to Fe & Zn application

[46] showed that application of micronutrients Zn, Fe, Mn and Cu @ 15 kg ha-1 each at the of planting followed by Zn+Fe @ 15 kg ha-1 each at the of planting alongwith recommended dose of NPK gave higher yield and helpful in the production and quality of mateera in the sandy soils of hot arid region. Imran Arshad and Wajiha Ali pointed out that Zinc foliar application remarkably increase the yield and quality of Guava fruit. Amongst different concentration of Zinc, Zn (0.5%) was ob served to be more suitable and economical dose as the fruit yield in terms of plant height (3.111 m), length of fruit (6.989 cm), breadth of fruit (6.070 cm), weight of fruit (111.555 gm), number of fruits per plant (379.679), fruit yield (41.935 kg/plant) was recorded maximum [47] found that the zinc availability is responsible for better growth and development of the shoot. [48] reported a significant increase in fruit retention in kinnow by foliar application of 1% zinc sulphate twice i.e. in April and September. [49]observed an increase in the plant height and plant spread of mandarin orange with an application of 0.5% zinc. Similarly, [50] observed that the plant height of young tree of Washington Navel orange, Valencia orange and Balady mandarin was increased with the application of 0.4% zinc sulphate spray. [51] recorded highest plant height and plant spread of acid lime when foliar spray of nitrogen at 1.5 % + zinc sulphate at 0.5% was applied. [52]observed a significant decrease in the fruit drop (80.46 %) of ber with the foliar spray of 0.6% zinc sulphate. [53] recorded a decrease in fruit drop with the foliar spray of zinc alone or in combination with gibberellic acid as compared to control in washington Navel orange. [54] observed a significant increase in number of fruits per tree by spraying Zinc sulphate (0.5%) during February, April and October in Blood Red and Mosambi sweet oranges. [55] Observed significant increase in the number of fruit per plant at 0.05, 0.10 and 0.15% zinc concentration.An improvement in the number fruits per plant in mandarin orange with application Zinc (0.5%) as compared to control. [56] Observed that number of fruits per trees in Kinnow remain unaffected by foliar application of zinc sulphate. [57] Reported an improvement in the number of fruits of kinnow mandarin with the foliar spray of 0.6% of zinc sulphate, one percent Zinc concentration, sprayed in early March and September, increased the fruit weight significantly in sweet orange. [54] observed a significant increase in fruit weight in sweet orange (cvs. Blood Red and Mosambi) through foliar spray with Zinc sulphate (0.5%) + urea (1.0%) thrice i.e. in the February, April and October. The increased average fruit weight of Nagpur orange tress receiving the highest zinc + low iron rate as compared to control. Wali and Sharma (1997) observed that foliar application of $ZnSO_4$ (0.75%) had highest fruit weight (123g) in kinnow. [49] Observed an increase in individual fruit in mandarin orange with the foliar spray of Zinc (0.5%). [50] Observed that the fruit weight of Washington Navel Orange, Valencia orange and Balady mandarin was increased with the application of 0.4% zinc sulphate spray. [52] Observed a significant increase in the fruit weight (21.54 g) of ber with the foliar spray of 0.6% zinc sulphate.

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