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EFFICIENCY OF ZINC IN PLANTS, ITS DEFICIENCY AND SENSITIVITY FOR DIFFERENT CROPS

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ABSTRACT

Optimal crop nutrition is a significant factor in increasing agricultural vintage and quality of products. Zinc (Zn) is an immobile important micronutrient, which is taken up by plants in Zn^{2+} form to complete their life cycle efficiently. It plays a critical metabolic role in plants and is an important constituent of proteins and other large-molecules, and serves as structural and functional unit, or controlling cofactor for a wide range of enzymes. The Zn is needed in small and in appropriate amounts for plants main physiological processes to work normally. These processes play critical roles in photosynthetic activity of plants and forming carbohydrates, synthesis of protein, reproduction and seed development, growth, and disease protection. After Zn deficiency in plants, these physical functions are decreased, and plant health and productivity suffer greatly, subsequent in reduced production or even failure of crops and often bad quality of crop products. Plant Zn deficiencies occur on variety of soils and are severe due to a combination of symptoms like chlorosis, resetting, dieback and suppressed or irregular vegetative development. In addition, various crops require varying amount of Zn. So the knowledge regarding this is not up to date. The present review discusses the Zn importance in plants, its deficiency in soil and required level of Zn for crops.

Contribution/Originality: The present review describes the efficiency of Zn in plants, its deficiency and sensitivity for different crops. This study is one of the very few studies that have investigated Zn importance in growth related processes and its effect on yield.

1. INTRODUCTION

Zinc (Zn) is most essential nutrients that plants require in very small amount, for normal growth and development. It is one of the eighth micronutrients needed by plants. In plants, Zn is taken up and transferred in the form of Zn^{2+}. The Zn with enzymes and proteins play an important role in metabolism of carbohydrates, auxin, protein synthesis, gene expression, pollen production, protection of cell membranes, and provide protection against biotic and abiotic stresses [1-4]. It is needed in small but essential for the normal operation of several main plant physiological paths [5]. Furthermore, it is a necessary component of crop production and fruit size, as well as the carbonic enzyme found in all photosynthetic tissues and compulsory for biosynthesis of chlorophyll [6-8]. In plants, Zn is an important micronutrient for synthesis of proteins; it is also a component of cell organelle like ribosomes and is needed for their formation. Pollen duct is one of the sites for synthesis of proteins, which contains 150 micrograms of Zn per gram of dry matter. Furthermore, Zn aid pollination by influencing pollen tube formation [9, 10]. The Zn can be linked to phospholipids of membranes or important constituent of sulfhydryl groups, or it can form compounds which are tetragonal in nature, with residues of Cysteine polypeptide chain, protecting proteins and lipids from oxidation damage [11].

The Zn is also a vital component of certain enzymes that are involved in the formation of enzymes of plants; additionally, it is involved in a variety of enzymatic reactions [12]. It is also plays a major role in alcohol dehydrogenase enzyme activity which contains two Zn atoms in which one atom play a catalytic role, while the other plays a role in building. This alcohol dehydrogenase enzyme catalyzes the acetaldehyde conversion into ethanol. Under aerobic conditions, higher plants produce ethanol in the root tips of meristematic tissue; however, deficiency of Zn reduces the activity of the alcohol dehydrogenase enzyme, resulting in reduced root growth [13]. The Zn, is an important part of macromolecules, enzymes and proteins, and serves as operational, functional, or regulatory cofactor for an extensive range of enzymes. . It plays an important role in stabilization of RNA and DNA structure, DNA synthesizing enzyme activity maintenance, and RNA degrading enzyme activity regulation. As a result, Zn can play a role in regulation of gene expression [14]. Hence, Zn is a vital nutrient for plants due to its significant role in plant development and development as shown in Figure 1.

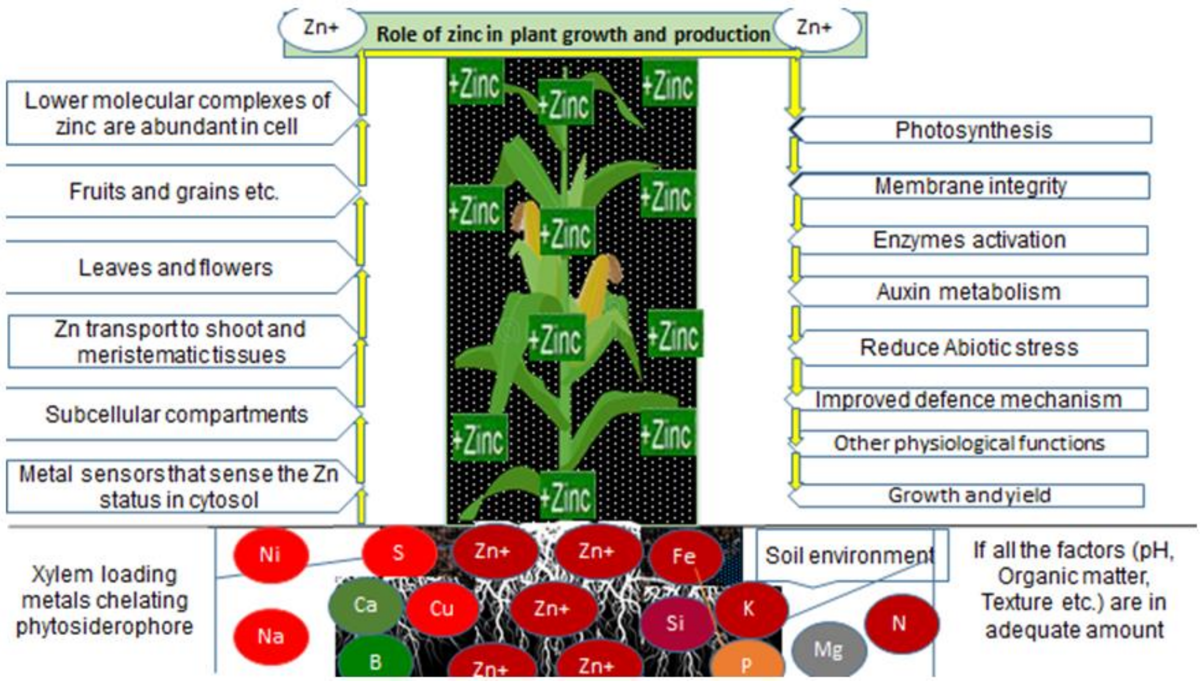

Figure-1. Role of Zn in plants growth.

Very minute quantity of Zn is present in soil and on average it varies between 0.2 - 0.002 µg Zn per gram of soil. Due to fixation, high pH and other factors, its availability to plants is less [15]. In addition, the artificially applied Zn becomes fixed with soil by reacting with soil matrix. Furthermore, chelated Zn EDTA is extremely effective and accessible to maintenance of the plant progress, resulting in advanced production [16].

1.1. Zn Deficiency in Plants

Zn deficiency reduces amino acid accumulation in plant tissues and protein synthesis. Most of the physiological changes are caused by Zn deficiency, which are associated with disturbances in normal enzyme function; hence, Zn deficiency cause photosynthesis suppression accompanied by an activity of essential photosynthetic enzymes has decreased. The Zn shortage also leads to membrane dielectric breakdown by inhibiting the involvement of enzymes involved in the removal of harmful reactive oxygen species [17]. Sorghum plants are particularly vulnerable to zinc (Zn) deficiency, which can cause oxidative stress, increased cellular osmotic potential, and a reduction in colour production and protein synthesis [18]. The Zn is immobile, so the deficiency symptoms occur first on new leaves of plants because it cannot be moved from older to younger leaves [19]. Stunted growth is one of the most common acute zinc deficiency symptoms. Other deficiency indicators of plants exhibit light green color of leaves, yellow, or bleached spots in interveinal parts of older leaves; young leaves are smaller in size, sometimes referred to as "little leaves," and exhibit resetting, in which the intermodal distance becomes so small that all the leaves appear to come out of the same single point [20] and the remaining symptoms and diseases as shown in Table 1.

Table-1. The Zn deficiency symptoms and diseases of various crops.

Crops	Symptoms and Diseases	References
Maize	Chlorosis Rosetting White bud of maize	Alloway [1] McCoy, et al. [21] Ata, et al. [22] Lutts, et al. [23]
Rice	khaira disease Hudda Disease Bronzing	Kushwaha [24] Lutts, et al. [23]
Sorghum, Soybean	Bronzing	Lutts, et al. [23]
Apple	Rosetting/Little leaf	Lutts, et al. [23]
Sugarbeet		Motieeian, et al. [25]
Grapefruit	Mottle-leaf	Freidberg [26]
Tung	Leaf bronzing Necrosis Spotting	Batchelor [27]
Barley	Chlorosis	Yang [28]
Cotton	Leaves chlorotic with necrotic areas	Suvo, et al. [29]
Potato	Leave spot Curling of leaves	Kambale [30]
Broad bean	Leaves and flower buds shed	Demski [31]
Tomato	Leaves mottled and necrotic, leaflets small	Hamid [32]
Garden pea	Lower leaves have necrotic edges and tips; stems stiff and erect; flowers none.	Smith, et al. [33]
Garden bean	Leaves and flower buds shed.	Demski [31]
Oat	Leaves pale green Necrosis extends down leaf, remainder of leaf gray to bronze-green.	Idota, et al. [34]
Squash	Leaves mottled with necrotic areas	Benson and Grimstead [35]

Overall, Zn deficiency has a greater impact on shoot growth than on root growth [2, 7]. Plant hormone metabolism, such as Indole acetic acid and tryptophan, declines in Zn deficiency, due to which leaf development ceases. In fact, zinc is required for tryptophan synthesis, which is required for the formation of auxin; hence, zinc deficiency reduces the amount of auxin [36].

By using fertilizers containing zinc and other micronutrients improves crop production, however when these elements are present in inadequate amount, this cause degeneration of photosynthesis process and the destruction of RNA, carbohydrates solution and protein synthesis decreases, lowering crop productivity and quality [37].

1.2. Zn Deficiency in Soil

Raulin discovered the biological function of Zn in 1869, when he observed that *Aspergillus niger* (a common bread mold) was unable to grow in Zn absence. Soon after, Zn was discovered to be a common part of both tissues of animal and plant. This discovery sparked Zn studies in crops, and in plants the first demonstration of deficiency of Zn occurred in 2021 [38]. Now, Zn deficiency has been most common micronutrient insufficiency in soils and crops around the world, resulting in significant crop losses and nourishing quality degradation. Nearly half of the world's soils are zinc deficient [39]. According to the UN's Food and Agriculture Organization (FAO), 50 percent of the world's cereals growing soils are Zn deficient. It also predicts that by 2050, food manufacture will need to increase by 70% to feed the world's population of over 9 billion people [40]. Mostly Zn deficiency problems are found in calcareous, and weathered acidic soils. In these soils, iron deficiency is often followed by deficiency of Zn. The adsorption of Zn from soil solution by clay and limestone particles causes Zn deficiency in these soils. A depletion of organic matter in eroded soils causes n deficiency. It can also be linked to conditions of weather; more common when weather is cold & wet and may be attributed to a lack of root development in cool soils, as well as reduced microbe activity and Zn release from organic materials [7, 41]. Excessive bicarbonate (HCO_3) concentrations inhibit zinc uptake by plant shoots [42].

1.3. Zn Sensitivity of Different Crops

Numerous plant species, including, maize, bean, rice, wheat, tomatoes and rice, are considered to be less resistant to zinc deficiency and show major crop losses when compared to more tolerant plant species like carrots, rye and peas Table 2 [43]. The relative susceptibility of different crops to deficiency of zinc varies [1].

Table-2. Zn sensitivity of different crops.

Low Sensitive	Medium Sensitive	Highly Sensitive
Asparagus	Alfalfa	Bean
Carrot	Barley	Citrus
Forage grasses	Clover	Cowpea
Mustard	Cotton	Maize
Oat	Sorghum	Millet
Pea	Sugar beet	Onion
Rye	Sugar can	Rice
Wheat	Sunflower	-
Paper mint	-	-

2. CONCLUSION

The Zn is required by plants in smaller amount and allow plants to perform their functions normally, mostly physiological. World's soils are usually deficient in Zn to meet the requirements of plants. To overcome the zinc deficiency there is need to raise awareness among farmers community about its importance with the help of extension workers and trying to correct zinc deficiency would increase yields and farmer income while also enhancing nutritional quality of crops and ultimately human nutrition. For higher crop yields, balanced fertilizer use with micronutrients such as zinc is needed.

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