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Importance of micronutrients (Zinc) in crop production: A review

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Abstract

Micro nutrients are designed to supply critically needed nutrients at the most responsive time during the growth cycle and to stimulate and optimize the assimilation and production process in the leaves. Micronutrients are the elements which are essential for the plant growth when roots are unable to absorb sufficient nutrients from soil due to high degree of fixation, losses from leaching, low soil temperature and lack of soil moisture. Zinc (Zn) is one of the eight essential micronutrients. It is needed by plants in small amounts, but yet crucial to plant development. In plants, zinc is a key constituent of many enzymes and proteins. It plays an important role in a wide range of processes, such as growth hormone production and internode elongation. Crop yield significantly increases with the use of micronutrients such as zinc (Zn), iron (Fe), boron (B), copper (Cu), manganese (Mn), etc. Zinc (Zn) has an important metabolically role in plants growth and development and is therefore called an essential trace element or a micronutrient. Zinc is uptake and transfers the form of Zn^{2+} in plants and is an essential nutrient that has particular physiological functions in all living systems, such as the maintenance of structural and functional integrity of biological membranes and facilitation of protein synthesis and gene expression, enzymes structure, energy production and Krebs cycle; also has a positive impact on crops yield; therefore crops quantitative and qualitative yield is strongly dependent on zinc (Zn) in the soil. Calcareous soils with high intake of phosphorus (P) and soils with high pH are confronted with zinc deficiency. Zinc is an active element in biochemical processes and there is chemical and biological interaction between it and some other elements such as phosphorus, iron and nitrogen in plants. Phosphorus and copper have an antagonistic impact on zinc. The Food and Agriculture Organization (FAO) has determined that zinc is the most commonly deficient micronutrient in agricultural soils; almost 50% of agricultural soils are Zn deficient. Plants growing on potentially zinc-deficient soils have reduced productivity and contain very low concentrations of zinc in the edible parts (such as in cereal grains). Therefore, zinc deficiency represents a serious nutritional and health problem in human populations, especially in the developing world where cereal-based foods are the dominating source of diet. Hence, the review.

Keywords: Crop production, micronutrient, quality, zinc

Introduction

Micro nutrients are designed to supply critically needed nutrients at the most responsive time during the growth cycle and to stimulate and optimize the assimilation and production process in the leaves (Brar and Brar, 2004) [7]. Micronutrients are the elements which are essential for the plant growth when roots are unable to absorb sufficient nutrients from soil due to high degree of fixation, losses from leaching, low soil temperature and lack of soil moisture. The use of micronutrients in soil nutrition is the pillars of agriculture in developed countries. Proper plant nutrition is one of the most important factors in improving the quality and quantity of plants product. Zinc is an important component of various enzymes that are responsible for driving many metabolic reactions in all crops. Growth and development would stop if specific enzymes were not present in plant tissue. Carbohydrate, protein, and chlorophyll formation is significantly reduced in zinc-deficient plants. Zinc is required in small but critical concentrations to allow several key plant physiological pathways to function normally (Alloway, 2002; Mousavi *et al*., 2011; Yosefi *et al*., 2011) [4, 29, 18]. With increasing utilization of chemical fertilizer and on the other hand increasing fertilizer prices due to their dependence on fossil fuels, water, air and soil pollution and ignorance in the use of chemical

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fertilizers are problems that must be solved with appropriate methods (Alloway, 2008) [5]. Zinc is essential element for crop production and optimal size of fruit, also it required in the carbonic enzyme which present in all photosynthetic tissues, and required for chlorophyll biosynthesis (Graham *et al*., 2000; Ali *et al*., 2008; Mousavi, 2011; Xi-Wen *et al*., 2011) [21, 3, 29]. In general zinc have main role in synthesis of proteins, enzyme activating, oxidation and revival reactions and metabolism of carbohydrates. By utilizing of fertilizers contain zinc and other micronutrients, performance on quality of crops is increasing and with shortage of this elements due to decline in plant photosynthesis and destroy RNA, amount of solution carbohydrates and synthesis of protein decreased and then performance and quality of crop will be decreased (Mousavi *et al*., 2007; Efe and Yarpuz, 2011) [30, 29]. In plants, zinc plays a key role as a structural constituent or regulatory co-factor of a wide range of different enzymes and proteins in many important biochemical pathways and these are mainly concerned with: carbohydrate metabolism, both in photosynthesis and in the conversion of sugars to starch, protein metabolism, auxin (growth regulator) metabolism, pollen formation, the maintenance of the integrity of biological membranes, the resistance to infection by certain pathogens (Alloway, 2008) [5].

Effect on growth, yield and yield attributes

Nageswara Rao (1976) [32] conducted a field experiment and observed that soil application of 25 kg per ha-1 and foliar spray of 0.5 per cent of magnesium sulphate increased the seed cotton yield by 16 and 25 per cent respectively, over control. Eweida *et al*. (1979) [16] reported that there was significant increase in seed cotton yield with foliar application of 2 per cent magnesium and 0.2 per cent zinc and also with combination of zinc and magnesium. Khodzhaev and Stensyagina (1983) [24] reported that spraying of cotton plants at flowering stage with a mixture of 0.1 per cent Zinc sulphate markedly increased the number of bolls per plant and seed cotton yield per ha.

Raja Rajeshwari (1996) noticed significant increase in number of bolls plant-1 (19.0) and mean boll weight (4.0 g) as well as seed cotton yield (1331 kg ha-1) with the foliar spray of 0.5 per cent ZnSO4 at peak flowering stage compared to control (13.0 bolls per plant-1, 2.7 g boll weight and 891 kg per ha-1 seed cotton yield, respectively). Ikisan (2004) indicated that foliar spray with 5 per cent MgSO4 and 1 per cent urea reduced the leaf reddening and increased the seed cotton yield. Katkar *et al*. (2005) [23] reported that three sprays of MgSO4 (1.0%) + ZnSO4 (0.5%) at square, flowering and boll development stage gave significantly higher seed cotton yield over control. Foliar spray of 0.5 per cent ZnSO4¬ plus 1 per cent MgSO4 plus 0.5 per cent FeSO4 at peak flowering and boll development stages produced higher kapas yield and also improved the quality parameters against control treatment (Anon., 2008). At Nanded, Maharashtra, it was found that foliar feeding of micronutrients with spraying of MgSO4 @ 1.0% + ZnSO4 @ 0.5% gave significantly higher number of bolls plant-1 (41) and boll weight (3.86 g) (Anon., 2009). Amutha *et al*. (2009) [6] studied the effect of foliar nutrition to reduce the boll shedding and square drain in cotton and the results revealed that foliar spray of TNAU formulation (MgSO4, KNO3, Zn, B, Urea and Planofix) proved to be the best treatment with higher mean values in respect of plant height, number of sympodial branches, number of bolls per plant, boll weight per plant and seed cotton yield. Ratna Kumari and Hema (2009) [41] observed that foliar application of different nutrient concentrations (MgSO4 @ 0.5 and 1%, ZnSO4 @ 0.2%, FeSO4 @ 0.2 and 0.4%, MgSO4 @ 0.2 and 0.4%, boric acid @ 0.2%) increased the seed cotton yield significantly compared to control except MnSO4 (0.4%), FeSO4 (0.4%) and water spray.

Zinc deficiency

Zinc is one of the most important micronutrient essential for plant growth especially for rice grown under submerged condition. Zinc deficiency is prevalent worldwide in temperate and tropical climates (Fageria *et al*., 2003; Slaton *et al*., 2005) [46]. Forty seven percent of Indian soils (Takkar, 1996) [48] and fifty percent of Tamilnadu soils (Anon, 2006) are deficient in zinc. Zinc is a major component and activator of several enzymes involved in metabolic activities (Klug and Rhodes, 1987). Zinc deficiency continues to be one of the key factors in determining rice production in several parts of the country (Chaudhary *et al*., 2007) [12]. Many zinc deficiency problems around the world are associated with sandy soils and calcium carbonate-rich soils. Deficiencies of zinc occur in many parts of the world on a wide range of soil types but semi-arid areas with calcareous soils, tropical regions with highly weathered soils and sandy-textured soils in several different climatic zones tend to be the most seriously affected (Alloway, 2008; Akay, 2011) [5, 1]. Zinc deficiency can be seen in eroded, calcareous and weathering acidic soils. Zinc deficiency is often accompanied with iron deficiency in calcareous soils. Zinc deficiency in these soils is related to adsorption of solution zinc in the soil by clay and limestone particles. In eroded soils, zinc deficiency is caused by organic matter deficiency. Also zinc deficiency may be related to weather conditions, zinc deficiency increases in cold and wet weather conditions. It may be due to the limited root growth in cool soils, or reduction activity of microorganisms and reduction the release of zinc from organic materials (Alam *et al*., 2010; Abdou *et al*., 2011, Mousavi, 2011) [2, 29]. High concentrations of bicarbonate (HCO3) prevent of zinc uptake by plants shoot (Gokhan, 2002) [19]. Different crops have a difference relative sensitivity of to zinc deficiency (Table 1) (Alloway, 2008) [5]. Zinc deficiency symptoms appear on the young leaves of plants first; because zinc cannot be transferred to younger tissues from older tissue (zinc isn't a mobile element). Areas between nervure in plants are yellow by zinc deficient (Vitosh *et al*., 1994). In dicot plants internode distance and leaf size will be short and in monocot plants, corn especially, bands comes into the main nervure on both sides of leaves in zinc deficient condition Overall, shoot is more affected than the root growing by zinc deficiency (Boardman and McGuire, 1990; Gokhan, 2002, Mousavi, 2011) [29, 19, 2].

Zinc toxicity

Zinc (Zn) ions have both beneficial and toxic effects on plant cells. It is inimitable in several plant metabolic processes such as enzyme activation like RNA polymerases, superoxide dismutase, alcohol dehydrogenase, carbonic anhydrase, protein synthesis and metabolism of carbohydrate, lipid and nucleic acid. Also Zn ions are integral parts of Zn finger family of transcription factors controlling cell proliferation and differentiation (Valle and Falchuk 1993; Lin *et al*. 2005; Palmer and Guerinot 2009) [50, 26]. Besides these, Zn plays major role in chloroplast development and function, of which most important are the Zn-dependent activity of SPP peptidase and the repair process of photo system II by turning over photodamaged D1 protein (Hansch and Mendel 2009) [22].

When zinc amount is excessive, causes toxicity in plants. Leaf and root growth and development decreased by zinc toxicity. Production of NADPH in plant chloroplasts are decreases with increasing zinc concentration. In addition, production of free radicals will increases in plants. Activity of RUBP carboxylase enzyme and Photosystem II decreases by zinc toxicity. Zinc toxicity reduces ATP synthesis and chloroplasts activity and photosynthesis will decline as a result. Also, large amounts of zinc reduces uptake of P and Fe. More than 300ppm of zinc in plant caused toxicity. (Prasd *et al*., 1999; Vitosh *et al*., 1994; Teige *et al*, 1990; Ruano *et al*., 1988) [39, 49, 42]. Resistance to zinc is differences in various plants, the plants such as beans, corn, onions, sorghum, rice, citrus fruits and grapes have most sensitivity to zinc deficiency, barley, lettuce, potatoes, soybeans, sugar beet and tomato have moderate sensitivity to zinc deficiency and carrots, alfalfa, asparagus, radish, and forage plants are resistance to zinc deficiency (Vitosh *et al*., 1994).

Zinc fertilizers

Three different types of compounds are used in zinc fertilizers. These compounds vary considerably in zinc content, price and effectiveness for crops on different types of soils. The sources of zinc include: (1) inorganic compounds, (2) synthetic chelates and (3) natural organic complexes. • Inorganic sources include: zinc sulphate, zinc oxide, zinc carbonate, zinc nitrate, and zinc chloride. Zinc sulphate is the most commonly used zinc fertilizer worldwide and is available in both crystalline monohydrate and heptahydrate forms. Prevention of deficiencies is the best way to deal with micronutrients deficiencies, choose of resistant plant varieties and cultivars and appropriate management practices can be used to prevent of manganese deficiency occurrence. Soil analysis can be used to diagnose problems in existing crops but is more valuable for enabling deficiencies to be predicted and remedial action taken to avoid reduced yields in subsequent crops (Alloway, 2002; Mousavi *et al*., 2011)[4, 29]. Zinc deficiency related to soils pH and its value is very low in calcareous soils with high pH (Alloway, 2008; Alam *et al*., 2010) [2, 5]. Zinc mobility and uptake in soil is dependent on many factors such as soil acidity, zinc total value in the soil, organic matter and soil type. The most important factors affecting on the zinc usability can be noted as following (Sillanpaa, 1990; Chang *et al*., 2007; Alloway, 2008) [45, 11, 5]: Zinc total value maybe very low in highly acidic soils due to the intense soil leaching. Zinc usability decreases by increasing soil pH, because the minerals solubility reduced and zinc uptake increases by soil colloidal particles such as clay minerals, iron and aluminum oxides, organic matter and calcium carbonate. Zinc usability decreases by decreasing temperature and light intensity due to limited root development. Zinc usability by plants decreases by high levels of phosphorus in the soil. Zinc uptake by plants inhibits by some metal cations such as Cu $^{2+}$ and Fe $^{2+}$ (due to the same carriers for these elements in the plant roots). Three different types of compounds are used as zinc fertilizers and these vary considerably in their zinc content, price and effectiveness for crops on different types of soils. These sources of zinc include: 1- Inorganic compounds include: zinc oxide (ZnO), zinc carbonate (ZnCO3), zinc sulphate (ZnSO4), zinc nitrate (Zn(NO3)2) and zinc chloride (ZnCl2). Zinc sulphate is the most commonly used source around the world and is available in both the crystalline monohydrate and heptahydrate form. 2- Synthetic chelates, which are special types of complexed micronutrients generally formed by combining a chelating agent such as Ethylene Diamine Tetra-acetic Acid (EDTA) with a metal ion and the stability of the metal-chelate complex determines the availability of the metal to plants. 3- Natural organic complexes include those which are manufactured by reacting zinc salts with citrates or with organic by-products from paper pulp manufacture such as lignosulphonates, phenols and polyflavonoids. They are generally less expensive than synthetic chelates such as Zn-EDTA, but are generally much less effective.

Zinc in plants productions

In general, soils used for cereal production in the world containing low levels of plant available micronutrient, reduces not only grain yield, but also nutritional quality. Low fertile soils are brought under cultivation due to high population pressure. Micronutrient deficiency is being paid more attention in recent times in areas where intensive agriculture is practiced. Depletion of micronutrients in soil has been accelerated by increase of intensive cultivation with increased dependence on inorganic fertilizer and decreasing emphasis on the use of organic manures and in addition with use of high yielding varieties. Zinc is one of the most important elements in the carbohydrates metabolism, most enzymes that play a role in carbohydrates metabolism are activated by zinc. In addition Carbonic anhydrase, Fructose-1, 6- bisphosphate and Aldolase enzymes are activated by zinc. These enzymes are active in the chloroplasts and cytoplasm, six-carbon sugar molecule are separated between chloroplasts and cytoplasm by Fructose- 1, 6-bisphosphate and three-carbon sugars molecule in photosynthesis are transported from cytoplasm to chloroplasts by Aldolase. The activity of these enzymes decreased in zinc deficiency condition, in resulting carbohydrate accumulated in plants leaves (Marschner and Cakmak, 1989, Mousavi, 2011; Taheri el al., 2011) [27, 29, 2]. Zinc is essential micronutrients for proteins production in plants; also zinc is main composition of ribosome and is essential for their development. Amino acids accumulated in plant tissues and protein synthesis decline by zinc deficit. One of the sites of protein synthesis is pollen tube that amount of zinc in there tip is 150 micrograms per gram of dry matter. In addition zinc will contribute on the pollination by impact on pollen tube formation (Marschner, 1995; Outten and O'Halloran, 2001; Pandey *et al*., 2006) [27, 34, 36]. Metabolism of plant hormones such as auxin (IAA) and tryptophan decreases in zinc deficiency condition, as a result leaf growth stops. In fact, zinc is essential for tryptophan synthesis, which is a prerequisite for auxin formation, therefore amount of auxin decreases by zinc deficiency (Marschner, 1995; Pedler *et al*., 2000) [27, 37]. In some conditions that plant are in zinc deficient, tryptophan may increased in the leaves as a result in impaired of protein synthesis. Zinc is necessary element for maintain living membranes. Zinc may be connected to membrane phospholipids or constituent groups of sulfhydryl or make up tetragonal compounds with residues of Cysteine polypeptide chains and thus, proteins and lipids were protect against oxidation damage (Salami and Kene, 1970; Domingo *et al*., 1992; Marschner, 1995) [43, 27]. Zinc is main building part of some enzymes and is needed for the plant enzymes formation; in addition, many enzymatic reactions active by zinc (Vitosh *et al*., 1994; Pedler *et al*., 2000; Akay, 2011) [1, 37]. Zinc plays an important role in most of the enzymes that they can point to the following: Alcohol dehydrogenase: this enzyme molecule has two atoms of zinc. One of the atoms has a catalytic and other has a building role. Alcohol dehydrogenase enzyme has a catalytic role in regeneration of acetaldehyde to ethanol. In higher plants, ethanol is making in the root tip meristematic tissue under aerobic conditions, alcohol dehydrogenase enzyme declined by zinc deficiency in plants, as a result root development reduced (Marschner, 1995; Gokhan *et al*., 2003) [27]. Carbonic anhydrase: This enzyme has a zinc atom that catalyzes CO2 hydration. Enzyme activity location is in chloroplasts and cytoplasm and the enzyme activity is dependent to zinc value in the plant. The main functions of this enzyme are: dehydration of carbon dioxide, increasing absorption of carbon dioxide per leaf area unit, increasing in photosynthesis and biomass production. In the plants that are confronted with zinc deficiency activity of this enzyme is stopped (Ohki, 1976; Dell and Wilson, 1985; Marschner, 1995) [33, 27, 13]. Superoxide dismutase zinc-copper: In this enzymes zinc is connected to copper, it seems that zinc has catalytic and copper has building role. Superoxide dismutase activity decreased in zinc deficiency conditions and is associated with increased free radicals oxygen (super oxide), that it's a toxic substance and have a harmful affect on plants tissues due to lipids peroxidation of membrane and increasing its permeability (Marschner, 1995) [27]. According to the plant professional's research, zinc exerts a great influence on basic plant life processes, such as: nitrogen metabolism and uptake of nitrogen and protein quality; photosynthesis and chlorophyll synthesis, carbon anhydrate activity; resistance to abiotic and biotic stresses and protection against oxidative damage. The effect of zinc fertilization were conducted on growth and yield of many plants such as alfalfa, wheat, maize, barley, cotton and potato were investigated in numerous researches and observed increasing in yield with zinc application For millions of people around the world, a few extra milligrams of zinc each day can

Make the difference between illness or death and a healthy, productive life. By ensuring that crops receive an adequate supply of zinc, we can help address this global issue. Adding zinc to crops not only increases crop nutritional value, but also increases crop yield and crop resistance to environmental hazards such as drought and disease. Increased yield leads to increased income for the farmers. Zinc fertilizer is a simple, sustainable solution to zinc deficiency in soils, crops, and humans, which ultimately leads to increased food and nutrition security, higher income for farmers, and a great reduction in death and disease related to zinc-deficiency

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