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The Importance of Micronutrients in Agricultural Production

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ABSTRACT

Micronutrients are essential elements that are used by plants in small quantities. Yield and quality of agricultural products increased with micronutrients application, therefore human and animal health is protected with feed of enrichment plant materials. Each essential element only when can perform its role in plant nutrition properly that other necessary elements are available in balanced ratios for plant. Divalent manganese ions (Mn2+) is converted to Mn3+ or Mn4+ easily, therefore in the plant manganese plays an important role on oxidation and reduction processes, as electron transport in photosynthesis. Manganese deficiency has very serious effects on non-structural carbohydrates, and roots carbohydrates especially. Crops quality and quantity decreased due to manganese deficiency, and this is due to low fertility of pollen and low in carbohydrates during grain filling. Zinc uptake of soil solution in divalent cations form (Zn2+); in calcareous soils with high pH zinc uptake may be a valence ion form. In the xylem routes zinc is transmitted to divalent form or with organic acids bond. In the phloem sap zinc makes up complex with organic acids with low molecular weight, and increases its concentration. Zinc deficiency can be seen in eroded, calcareous and weathering acidic soils. Zinc deficiency is often accompanied with iron deficiency in calcareous soils. Iron in the soil is the fourth abundant element on earth, but its amount was low or not available for the plants and microorganisms needs, due to low solubility of minerals containing iron in many places the world, especially in arid region with alkaline soils.

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INTRODUCTION

Micronutrients are essential elements that are used by plants in small quantities. Yield and quality of agricultural products increased with micronutrients application, therefore human and animal health is protected with feed of enrichment plant materials. Each essential element only when can perform its role in plant nutrition properly that other necessary elements are available in balanced ratios for plant. Divalent manganese ions (Mn^{2+}) is converted to Mn^{3+} or Mn^{4+} easily, therefore in the plant manganese plays an important role on oxidation and reduction processes, as electron transport in photosynthesis. Moreover manganese acts as an activator of many enzymes, (more than 35 different enzymes). Manganese has important role on activates several enzymes which involve to oxidation reactions, carboxylation, carbohydrates metabolism, phosphorus reactions and citric acid cycle. Of the most important these enzymes, protein-manganese in Photosystem II and superoxide dismutase can be pointed. There is more than 90% of superoxide dismutase in chloroplasts which about 4 to 5 percent of it is in mitochondria [1,2,3].

Manganese (Mn^{2+}) In terms of biochemical functions is similar to magnesium (Mg^{2+}), both ions connects ATP with complexes enzymes (phosphor transferase· and phosphokinase). Dehydrogenase and Decarboxylase in the Krebs cycle (TCA) are also activated by Mn^{2+}[4,5]. Manganese plays an important role in chlorophyll production and its presence is essential in Photo system II, also involved in cell division and plant growth. RNA polymerase is activated by manganese. Manganese has an effective role in lipids metabolism, and due to effective role of manganese in the nitrate reduction enzymes, nitrate will accumulation in leaves which are facing with manganese deficiency. Moreover amount of lignin in the plant will decline due to manganese

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deficiency, that this reduction is more severe in the roots, this matter is very important especially to reduction resistance the roots of plants to fungi infecting [2,6].

Manganese (Mn) Deficiency:

Manganese deficiency has very serious effects on non-structural carbohydrates, and roots carbohydrates especially. Crops quality and quantity decreased due to manganese deficiency, and this is due to low fertility of pollen and low in carbohydrates during grain filling. Manganese deficiency is similar to magnesium deficiency, because there comes yellow in both intercostals. Manganese deficiency symptoms first appear on younger leaves; because dynamics of these elements in different plant tissues is limited (manganese isn't a mobile element); but the magnesium deficiency symptoms is seen in older leaves primarily [4,7,8]. In dicot plants manganese deficiencies often are known with small yellow spots on leaves, also manganese deficiency symptoms in monocot plants appears as tape and gray-green spots on base of leaves. The major symptom of deficiency is a reduction in the efficiency of photosynthesis leading to a general decline in dry matter productivity and yield. Occurrence and intensity of manganese deficiency is depend to seasonal conditions, as manganese deficiency will be more severe in the cold and wet seasons, due to reduced roots metabolic activity in manganese uptake. Manganese concentrations in plant tissues have been determined 50 to 150 ppm. Manganese critical levels in plant tissues depending on the cultivar, species and environmental conditions and has been reported between 10 to 50 micrograms per gram for dry matter [2,4,9].

Zinc (Zn):

Zinc uptake of soil solution in divalent cations form (Zn^{2+}); in calcareous soils with high pH zinc uptake may be a valence ion form. In the xylem routes zinc is transmitted to divalent form or with organic acids bond. In the phloem sap zinc makes up complex with organic acids with low molecular weight, and increases its concentration. Zinc is in plants only in divalent cation (Zn^{+2}) and does not participate in oxidation and regenerative reactions. The main functions of zinc is tendency to make up tetragonal complexes with nitrogen, oxygen and sulfur, thus zinc have a catalytic, building and activating role in the enzymes. Zinc is main building part of some enzymes and is needed for the plant enzymes formation; in addition, many enzymatic reactions active by zinc [10,11,12,13,14]. 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 [15,16]. Carbonic anhydrase: This enzyme has a zinc atom that catalyzes CO_2 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 [11]. 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 effect on plants tissues due to lipids peroxidation of membrane and increasing its permeability [15,4]. Also zinc is part of some enzymes structure, such as: Alkaline Phosphatase, phosphatides lipase, Carboxypeptidase, RNA polymerase, Dehydrogenase and Aldolase (Pandy *et al*., 2002).

The Role of Zinc on Carbohydrates Metabolism:

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 [15]. 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 [18].

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 [11,4]. In some conditions that plant are in zinc deficient, tryptophan may increase 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 [4,19,20].

Zinc Deficiency:

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. High concentrations of bicarbonate (HCO_3) prevent of zinc uptake by plants shoot [21]. 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. 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. When zinc deficiency developed, the yield is more affected than dry matter. This may is due to damage to the pollen fertility by zinc deficiency. The plants that zinc amount in their tissues is lower than 20ppm, are encountered with zinc deficit [4, 22,23].

Iron (Fe):

Iron in the soil is the fourth abundant element on earth, but its amount was low or not available for the plants and microorganisms needs, due to low solubility of minerals containing iron in many places the world, especially in arid region with alkaline soils. Iron is an importance element in crops, because it is essential for many important enzymes, including cytochrome that is involved in electron transport chain, synthesize chlorophyll, maintain the structure of chloroplasts, and enzyme activity [24,25,26]. Often iron is found in the form of trivalent (Fe^{3+}) in aerobic soils, which has low solubility, and in most cases this is not enough iron to meet the needs of plants. Considering the effect of pH on the solubility of Iron (Fe), in the pH = 7 amount of water soluble iron is about 10^{-18}mol L (moles per liter); while the required concentrations for normal growth of plants is about 10^{-8}mol L. Generally solubility of trivalent iron decreases by increasing pH [27,28].Iron deficiency has a powerful effect on chloroplast protein, so that chloroplast protein is reduced significantly by iron deficiency. In conditions of severe iron deficiency, cell division stops and therefore leaf growth decreases. Iron is needed to produce chlorophyll; hence its deficiency causes chlorosis. For example, iron is used in the active site of glutamyl-tRNAreductase, an enzyme needed for the formation of 5-Aminolevulinic acid which is a precursor of chlorophyll. Iron-deficient fields, when viewed from a distance, exhibit irregularly-shaped yellow areas. Because iron is not translocated in the plant, deficiency symptoms appear on the new growth first. Iron deficiency on individual plants is characterized by yellow leaves with dark green veins (interveinalchlorosis). On corn and sorghum, this gives the plants a definite striped appearance. If the condition is severe, the whole plant may be affected and turn a very light yellow or even white. In many cases where moderate deficiencies occur early in the season, plants tend to recover later [25].

Iron solution concentrations in flooding soils to may be increased several-fold due to low redox potential. In these conditions large amounts of iron may available for plant, and can be toxic to plants. Brown plant tissues, black and soft roots are the iron toxicity symptoms. In addition, at these higher iron (Fe) solution concentrations plants exhibited visual symptoms of possible iron toxicity, including root flaccidity, reduced root branching, increased shoot die-back and mottling of leaves. Plant species in wet regions have mechanisms to oxidize iron in roots areato limit the excessive absorption of iron. Plants in soils aerobic conditions have two strategy-oriented for access to the iron compounds: first siderophore secretion (non-protein amino acid) (This strategy is found in Gramineae family); and second separation iron of soil chelate or restore trivalent iron (Fe^{3+}) to bivalent that occurs through the proton leakage (This strategy can be found in other monocotyledon and dicotyledons plants) [25].

Boron (B):

Boron is mobile in the soil and is subject to leaching, like nitrate and sulphate. Organic matter is the main source of B in western Canadian soils. The vast majority of Saskatchewan soils contain enough organic matter to supply B for crop needs.Boron deficiencies have been suspected in alfalfa and canola on sandy and eroded sandy soils in the Gray soil zone. Boron may be limiting to seed production of alfalfa in these soils. Symptoms that appear in spring under cool and wet conditions tend to go away when soil conditions become warm and drier. Apply B in test strips to confirm economic yield response. Additions of high rates of B on soils where B is not required can result in toxicity and a reduction in yield. There is a narrow range between deficiency and toxicity, so extreme care must be taken to avoid overlap when B fertilizer is applied.

The first symptoms appear in the new growth, as Boron impacts cell development, sugar and starch formation and translocation. Stunted and small plants with misshapen, thick, brittle leaves are common symptoms. Boron is not transferred easily from older to younger (upper) leaves, so younger leaves show symptoms first. In canola, the yellowing of the youngest leaves can be confused with sulphur deficiency. In alfalfa, symptoms include rosetting, yellow top, poor flowering, death of the terminal buds and poor seed set.Boron toxicity is indicated by yellowing, followed by browning of the leaf margins and tips with sharp boundaries between the yellow and/or brown and unaffected green area.Borate and borax forms of B fertilizer are most commonly used. Where B deficiencies have been proven, broadcast rates should not exceed 0.5 lb. actual B/ac. for cereals and 1.5 lb. actual B/ac. for canola. Do not seed-place B when using narrow openers. Boron is toxic when in contact with seed. Use low rates (not to exceed 0.3 lb. actual B/ac.) when foliar applying. Follow label directions for water volumes. Boron is toxic at low levels, resulting in reduced yield. Therefore, extreme care must be taken to apply B uniformly and to avoid overlap [29].

Copper (Cu):

If you suspect a Cu deficiency in wheat, barley or canary seed (crops most sensitive to Cu deficiency) or flax, alfalfa (less sensitive than wheat) based on a soil or tissue sample, consider a foliar application on a test strip. If there is a Cu deficiency in that field, the result will be an economic yield response.Copper is immobile in soil.Solubility and plant availability of Cu is highly dependent on soil pH. Copper solubility increases approximately 100 fold for each unit decrease in soil pH.Copper deficiencies will most likely show up first in wheat, barley, oats or canary seed, as these crops are highly sensitive to Cu deficiency. Canola, rye, flax, and forage grasses are much less sensitive to Cu deficiency. Crop cultivars can differ widely in sensitivity to Cu deficiency. Sandy soils in the Black and Gray soil zones and peaty soils are most likely to be deficient in Cu.Where Cu and Zn are both deficient, they both must be applied to obtain a yield increase.Copper deficiencies usually occur in irregular patches within fields.High levels of soil P can also depress Cu absorption by plant roots creating the Cu deficiency.Avoid blending Cu sulphate fertilizer with other fertilizers. The blend readily absorbs moisture.Copper is involved in several enzyme systems, cell wall formation, electron transport and oxidation reactions. Copper is not readily transferred from older to younger leaves. In cereals, older leaves remain green and healthy with the newer leaves yellowing and wilting, and the leaf tips pig tailing. Excessive tillering, aborted heads, delayed maturity, prolonged flowering period and poor grain filling are also symptoms. These symptoms appear in irregular patches within fields. These patches have a "drought-like" appearance. Copper deficiency is often associated with increased incidence of root rot, stem and head Melanesia (purpling, appears as brown patches in the field at maturity) and possibly may increase the incidence of ergot [29].

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