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Dynamics of Micronutrients in Agricultural Soil as Influenced by Organic Matter Build-up

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INTRODUCTION

The word micronutrient refers to elements that are required in small levels (0.5g per kg plant dry matter) but are important for plant growth. These micronutrient elements are equally essential as macro (primary and secondary) nutrients. The micronutrients are mostly found in soils as their oxides, sulfides, and silicates and are passed down from the rocks and minerals that compose the soil through a transformation at different stages of soil development. The significance of soil organic carbon (SOC) plays in enhancing physical, chemical, and biological qualities make it the most crucial element in sustaining soil quality. The use of fertilizers containing nitrogen, phosphorus, and potassium (NPK) causes the Green Revolution, which has increased agricultural production in many parts of the world. Along these lines, creative fertilizing has become increasingly important in recent years to maintain soil sustainability (Bindraban *et al*., 2015).

Micronutrient dynamics – The majority of micronutrients in soil are found in primary and secondary minerals, adsorbed to the surfaces of minerals and organic matter, incorporated into organic matter and microorganisms, and in soil solution. The parent materials, which are regulated by edaphic (pH, redox potential, interaction with coexisting ions) and biological factors, control the dynamics of micronutrients (Zn, Cu, Fe, Mn, B and Mo) availability in soil (organic matter and soil microbial activity). Different physicochemical processes that affect the availability of micronutrients are known to be modified by soil organic matter (SOM). Due to weathering and decomposition, soil minerals and organic matter are the main sources of micronutrients. The key mechanisms that affect the cycling of micronutrients in soil include mineralization, immobilization, dissolution, precipitation, adsorption, and desorption. The amount of minerals and organic matter in the soil generally determines which micronutrients are available to plants.

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Organic matter is decomposed by microbes, and even the chemicals inside it are then oxidized into forms that plants can readily use. Micronutrients are supplied in solution by primary and secondary minerals dissolving. These micronutrients are then adsorbed on mineral and organic matter surfaces, absorbed into microbes and complexed by soluble organic compounds. Diffusion to plants is aided by a sizeable reservoir of micronutrients that have been organically complexed and are in equilibrium with those in solution.

Factors affecting the availability of micronutrients

(1) Soil pH – The most vital factor governing the availability and solubility of micronutrients in soil is the pH of the soil. The presence of all the micronutrients in soil solution implies a highly acidic soil reaction by the extremely low pH. The micronutrient cations precipitate as insoluble hydroxides when the pH of the soil is greater than 7. $Fe^{2+} > Fe^{3+}$ in oxidized, well-drained soil. When soils are flooded with water, soluble Fe^{2+} significantly increases. Fe^{3+} concentration decreases one thousand times with every pH unit increase. As with other divalent cations, Fe^{2+} decreases hundred times for every unit increase in pH. $ZnOH^+$ becomes the most dominant species above pH 7.7. Zn lowers solution Zn^{2+} when it precipitates as insoluble, amorphous soil Zn at high pH. Liming acid soils, especially those low in zinc, will decrease Zn^{2+} uptake because pH has an impact on the solubility of Zn^{2+}. Solution Cu concentration is typically low, ranging between 10^{-6} and 10^{-8} M, and Zn^{2+} adsorption on surfaces of $CaCO_3$, clay minerals, Al/Fe oxides, and organic matter also reduces solution Zn^{2+}, which increases with increasing pH. Cu^{2+} at pH 7 and $Cu(OH)_2^0$ at pH > 7 are the two most predominant species in solutions. Mn^{2+} is the most prominent form in soil solution, similar to other divalent metal cations, its concentration reduces one hundred times for every unit increase in pH.

(2) Oxidation states - Lower oxidation states of Fe, Cu, Mn, and Zn (reduced state) are more soluble than higher oxidation states in soils with normal pH ranges. Oxidation at high pH encourages the reduction of micronutrient cations at low pH. Micronutrient cations are found in the oxidized state and have a relatively low availability in well-drained, aerated calcareous soils, which causes plants to have micronutrient deficiencies.

(3) Over liming – In the presence of carbonates and bicarbonate ions, overliming decreases micronutrient availability in soil.

(4) Soil organic matter – It is generally known that soil organic matter can retain micronutrient cations in stable combinations. Some organic ligands can sustain the micronutrient cation as soluble chelates and these are plant accessible. However, many organic compounds are associated with humic and fulvic acids and a huge number of organo-metallic complexes, such as the humic acid complexes. The availability of insoluble micronutrients to plants is increased by the chelating agent's capacity to convert solid phase micronutrient cations into soluble metal complexes.

5) Type of soil - In sandy soil with a low pH, B is lost down the profile by leaching when rainfall is excessive, but in clay soil, leaching is not a major problem if the soil is not very low in pH. Although there is less B available in acidic soil than in alkaline soil, most B compounds are still soluble at low pH levels.

Micronutrient interactions - The influence of one element on another in regard to plant growth and yield is referred to as interaction. Some interactions are positive (synergistic) and others are negative (antagonistic). A synergistic relationship is one where the elements involved help each other by aiding uptake or utilization. In contrast, an antagonistic relationship means the elements hinder each other in uptake or utilization. The use of iron and manganese, for instance, is aided by sufficient potassium, but the use of magnesium, boron, nitrogen, phosphorus, and calcium is hindered (antagonized) by excessive potassium. Although an antagonistic

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element may be present in sufficient amounts, the plant cannot access it because of the high potassium levels. There are several ways that antagonistic elements can function. If there is an excess of calcium, it may simply compete with other elements for uptake sites on the roots, such as potassium and magnesium, or it may alter soil composition by raising pH levels to the point where iron and boron are no longer available.

Chelate dynamics - The word "chelate" comes from a Greek word that means "claw". Fe^{3+} and other micronutrients can be complexed or chelated by a variety of soluble organic molecules in the soil. Natural organic chelate-Fe complexes in the soil can significantly increase the concentration of solution micronutrient (Fe) and Fe transported to the root by diffusion. Chelated micronutrients are more concentrated in the bulk solution than at the root surface during plant uptake; as a result of the concentration gradient, they diffuse to the root surface. Through interactions between the chelate and organic cell wall components at the root surface, Fe^{3+} dissociates from the chelate. A concentration gradient will cause the "free" chelate to diffuse away from the root and return to the bulk solution when Fe^{3+} separates from the chelate (free chelate concentration near the root is greater than free chelate in bulk solution). Another Fe^{3+} from the solution is then complexed by the free chelate. As a result of chelation, the concentration of unchelated Fe^{3+} in the solution decreases. To replenish the solution with Fe, more Fe is desorbed from mineral surfaces or dissolves in Fe minerals. An important mechanism in soils that significantly contributes to the availability of Fe and other micronutrients to plants is the chelate micronutrient cycle.

Conclusion - The importance of the organic matter in improving and ensuring soil micronutrient availability cannot be overstated. As they contain some micronutrients and have the capacity to create soluble complexes, organic materials such as FYM, vermicompost, green manures, and even plant residues can be used to improve the soil. The interaction between different essential primary and secondary nutrients with micronutrients and chelate dynamics enhances the availability of micronutrients in the soil.

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