Chemistry of Micronutrients in the Soil

Risikesh Thakur

Assistant Professor (Soil Science), College of Agriculture, Balaghat
Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur – (M.P.)

Introduction :-

Of the 17 elements known to be essential for plants, eight are required in such small amounts as to be called micronutrients. Micronutrient elements include five cations ie. manganese (Mn), iron (Fe), copper (Cu), Zinc (Zn) & nickel (Ni) and three anions i.e. boron (B), molybdenum (Mo) & chlorine (Cl). The term micronutrients does not imply that all of these elements would occur in minute quantities in the lithosphere or in soils. In fact, two of the micronutrient elements, Fe and Mn, are among the 12 most abundant elements in the lithosphere. The remaining micro nutrients occur at concentrations of less than 0.1 % in the lithosphre and may be referred to as minor or trace elements.

The occurrence of micronutrients in soils generally reflects the influence of type and age of the parent materials, climatic conditions during weathering and soil formation, vegetation, and other soil-forming factors. Locally, micronutrient contents of soils may be affected by mining or industrial activities. In agricultural lands, micronutrient contents may be influenced by the application of fertilizers, such as phosphates, containing traces of micronutrients. In the tropics, where levels of fertilizer application are generally low, fertilization is not presently considered a major contributor to micronutrient contents of soils. The relationships between total and plant-available micronutrient contents of soils are rather complex, and they differ among the micronutrient elements. Total contents of micronutrients, which reflect the influence of parent materials and soil formation, are quite stable in time. Available micronutrient contents in soils are more dynamic; they depend on soil and climatic conditions during the growing season and may change with time and depth in the soil profile.

Sources of micronutrients in soils :-

Micronutrient	Name of minerals with formula
Zinc (Zn)	Sphalerite (ZnS) Smithsonite ($ZnCO_3$)
Copper (Cu)	Chlcocite (Cu_2S) Covellite (CuS) Cuprite (Cu_2O)
Iron (Fe)	Hematite (Fe_2O_3) Geothite ($FeOOH$) Pyrite (FeS_2)

Manganese (Mn)	Pyrolusite (MnO_2) Manganite (MnOOH)
Nickel (Ni)	Serpentine [$(Mg,Fe,Ni, Mn,Zn)_{2-3}(Si,Al,Fe)_2O_5(OH)_4$] Olivine [$(Mg^{2+}, Fe^{2+})_2SiO_4$], Manganese (Mn) and nickel (Ni) commonly are the additional elements in olivine
Boron (B)	Borax ($Na_2B_4O_7$* $10H_2O$) Kernite ($Na_2B_4O_7$* $4H_2O$) Tourmaline [$Na(Mg, Fe)_3Al_6(BO_3)_3Si_6O_{18}(OH)_4$]
Molybdenum (Mo)	Molybdenite (MoS_2) Powellite ($CaMoO_4$)
Chloride (Cl)	Potassium chloride (KCl) Sodium chloride (NaCl)

Factors affecting the availability of micronutrients :-

The effect of soil environment on micronutrient cations are different from those of anions. So, the effect of soil factors on the availability of micronutrient cations and anions will be discussed separately.

Effect on Cations –

1. **Soil pH –** It is the most important factors which regulates the solubility and availability of micronutrient cations in soil. A very low pH indicates highly acidic soil reaction in which all the micronutrients cations occur in soil solution. Under such condition, certain micronutrient cations may become toxic to common plants and one dominant ion in soil solution may hinder the absorption of other micronutrient cations, if the latter occur in low concentration. On the other hand, if the pH of the soil is higher than 7.0, the micronutrient cations get precipitated as insoluble hydroxides. Under alkaline condition, the micronutrient cations are changed largely to their oxides or hydroxides of comparatively lower solubility.

$$Fe^{2+} + 3(OH^-) \longrightarrow Fe(OH)_3$$
$$Cu^{2+} + 2(OH^-) \longrightarrow Cu(OH)_2$$
$$Mn^{2+} + 2(OH^-) \longrightarrow Mn(OH)_2$$
$$Zn^{2+} + 2(OH^-) \longrightarrow Zn(OH)_2$$
$$Ni^{2+} + 2(OH^-) \longrightarrow Ni(OH)_2$$

2. **Oxidation state of micronutrient cations –** Lower oxidation states of Fe, Mn and Cu (reduced state) are more soluble than higher oxidation states at the normal pH range of the soils. The reduced states are encouraged by poor oxygen supply under submerged condition. The presence of easily decomposable fresh organic matter in soil encourages

anaerobic conditions at higher moisture levels due to microbial activity which get energy (Chemoautotrophs) directly from oxidation of inorganic ions. For example, oxidation of Mn^{2+} to Mn^{3+} by certain fungi and bacteria.

In well drained aerated calcareous soils, micronutrient cations exist in the oxidized state and their availability become very low and therefore, plants suffer from micronutrient deficiency, although the total content of all micronutrient cations may be very high. Under such conditions, the hydroxides and carbonates of high valent forms ate too insoluble to meet the plant needs. Zinc is divalent cations but at high pH it forms zincate ions [$Zn(OH)_4^{2-}$]

3. **Interaction of micronutrient cations with other soil constituents –** The availability of micronutrient cations is highly affected by inorganic ions in soil solution, soil solid constituents, especially free oxides of Fe and Al, soil organic matter, fertilizers and amendments applied to soil.

   The presence of CO_3^{2-} and HCO_3^- ions in soil due to sodicity or over liming reduces the availability of micronutrient cations to field crops as well as orchard crops, which suffer most from Fe deficiency.

   Low temperatures also interfere with the availability of micronutrient cations in soil. The deficiency of micronutrient cations in soil at low temperatures is mainly caused by the decreased solubility of native micronutrients.

   The ability of soil organic matter to hold micronutrient cations in stable combinations is well established. Numerous organic compounds are involved, including humic and fulvic acids and a number of organometallic compounds having different solubilities. Some of the metal ions are held as insoluble complexes, such as the humic acid complexes become unavailable to plants.

Effect on Anions –

1. **Chloride (Cl) –** Among the three anions, Cl is absorbed in large quantities by plants and its availability in soil is not affected by any soil properties as most of the chloride compounds are soluble in water. A substantial amount of Cl is added to soil through rain water.
2. **Boron (B) –** The availability of B in soil is affected considerably by soil pH. At low pH, most of the B compounds are soluble and thus B remains available to plants as boric acid. Availability of B in acid soils is lower as compared to that in alkaline soils. Generally, at higher pH values, availability of B increases. Liming reduces B availability temporarily due to lime-induced B-fixation by freshly precipitated Al and

Fe hydrous oxides. Boron occurs mostly in organic matter in the surface soil and down the profile B content decreases mineralization of organic matter releases B to be absorbed by plants.

3. **Molybdenum (Mo)** – Mo chemistry largely resembles that of P in soils. All soil factors which increase availability of P in soils, enhance the availability of Mo as well. For example, Mo availability is very low in acid soils, Mo gets fixed in Fe and Al compounds as well as on silicates at low pH. The fixed Mo can be made available to crops by phosphate application to soil which reduces fixed molybdate ions by anion exchange. Liming the acid soils increases the availability of native Mo.