Plant Nutrients in Mineral Soils

The Supply and Availability of Plant Nutrients in Mineral Soils

Factors Controlling the Growth of Higher Plants

1. Light
2. Mechanical Support
3. Heat
4. Air
5. Water
6. Nutrients

Principle of Limiting Factors

- The factor which is least optimum will determine the level of crop production

The Essential Elements

- 16 - essential elements
- Must be in farms usable by the plant
- Optimum concentration for plant growth
- Proper balance

Essential Nutrients Elements and Their Sources

Essential Elements Used in Relatively Large Amounts			Essential Elements Used in Relatively Small Amounts	
Mostly from				
Air and Water	From Soil Solids		From Soil Solids	
Carbon	Nitrogen	Calcium	Iron	Copper
Hydrogen	Phosphorus	Magnesium	Manganese	Zinc
Oxygen	Potassium	Sulfur	Boron	Chlorine
			Molybdenum	

Criteria of Essentially

1. A deficiency of the element makes it impossible for the plant to complete the vegetative or reproductive stage of its life.
2. The deficiency can be corrected only by supplying the element
3. The element is directly involved in the nutrition of the plant, quite apart from its possible effect in correcting some micro-biological or chemical condition in the soil.

Essential Plant Minerals

- 16 essential elements
  - C, H, O – air and water, photosynthesis
  - P, K, S, -- major elements
  - Ca, Mg – lime elements
  - Fe, Mn, B, Mo, Zn, Cu, Cl, Na – micro or minor elements
  - I and Co important for animals

Essential Elements from Air and Water

C from CO_2
H from H_2O
O from O_2

$$CO_2 + H_2O \longrightarrow C_6H_{12}O_6$$

94 - 95% of fresh plant tissue

Essential Elements from the Soil

Macronutrients
- N, P, K, Ca, Mg, S - used in large amounts
- N, P, K, S supplied to soil as Farm manure, Commercial fertilizers
- Ca, Mg supplied as lime

Micronutrients- Fe, Mn, Cu, Zn, B, Mo, Cl
- used in small amounts
- this does not mean they are less essential

1) Sandy soil 2) Organic soil 3) Very alkaline soil

The Nutrient Question

1. Amount present
2. Forms of combination
3. Processes of availability
4. Soil solution and its pH

Amount present
- N, P - small amounts in mineral soils
- K, Ca, Mg - small amounts in Acid soil
  - Large amounts in Alkaline soil
- S - small amount present - but more readily available

Forms in which the Macronutrients occur in soils

In general, the nutrients elements exist in two conditions

1. Complex and rather insoluble compounds
2. Simple forms usually soluble in the soil water

Complex - Less active form		Simple - More available	
Nitrogen (N)			
Organic combinations Proteins, amino acids	Nitrogen cycle →	Ammonium salts Nitrite salts Nitrate salts	NH_4^+ NO_2^- NO_3^-
Phosphorus (P)			
Apatite Ca, Fe, Al phosphates nucleic acid		Phosphate of Ca, K, and Mg	$HPO_4^=$ H_2PO_4
Potassium (K)		Potassium ions adsorbed by colloidal complex	
Feldspars, Mica Clays, especially illite		Potassium salts	K^+

Complex - Less active form		Simple - More available	
Calcium (Ca)			
Calcite, Dolomite		Calcium ions adsorbed by colloidal complex Calcium salts	Ca^{++}
Magnesium (Mg)			
Mica, Dolomite, Hornblend		Magnesium ions adsorbed by colloidal complex Magnesium salts	Mg^{++}
Sulfur (S)			
Pyrite and Gypsum Organic forms	Oxidation →	Sulfates Sulfates of Ca, K, and Mg	$SO3^=$ $SO4^=$

Simple available forms

1. disappear in drainage - leaching
2. used by micro-organisms
3. used by higher plants
4. may be converted to the complex form

Organic combinations

1. held in combination with soil organic matter
2. released by organic matter decomposition
3. nitrogen, sulfur and phosphorous

Inorganic Combinations

1. most of the K, Ca, Mg exist in this form
2. wide range in the degree of availability
3. must be converted to an available form

Transfer of Plant Nutrients to Available Forms

Organic Nitrogen (protein, amino acids) → Ammonium NH_4^+ → Nitrite NO_2^- → Nitrate NO_3^-

$Ca_3(PO_4) + 4H_2O + 4CO_2 \rightarrow Ca(H_2PO_4)_2 + 2Ca(HCO_3)_2$

Insoluble Phosphate (Tri Ca Phosphate) → Water Soluble Phosphate + Soluble Calcium Bicarbonate

$2KAlSi_3O_8 + H_2CO_3 + H_2O \rightarrow H_4Al_2Sl_2O_9 + K_2CO_3 + 4SlO_2$

Microcline feldspar; Carbonic Acid → Hydrated silicate + Soluble carbonate

1. Taken up by plants
2. Leached
3. Adsorbed

Transfer of Plant Nutrients to Available Forms

Ca [Colloidal Surface] + $2H_2CO3$ → H / H [Colloidal Surface] $a(HCO_3)_2$

Sulfur

Organic sulfur (Protein) → Sulfides H_2S → Sulfites $SO_3^=$ → Sulfates $SO_4^=$

Forms of Elements Used by Plants

Two general sources of readily available nutrients in the soil.

1. Nutrients adsorbed on the colloids

NH_4 - [ ] -Ca, - Mg, - K

2. Salt in the soil solution

$KCl \longrightarrow K^+ + Cl^-$

Essential element must be in the ionic form

1. Cationic- Positively charged ions
2. Anionic- Negatively charged ions

The more important ions present in the soil solution or on the soil colloids may be tabulated as follows

Elements	Symbol	Form Used by Plants
Sulfur	S	$SO_3^=$, $SO_4^=$
Carbon	C^{++++}	$CO_3^=$, HCO_3^-, CO_2
Hydrogen	H^+	H_2O
Oxygen	$O^=$	O_2
Nitrogen	N	NH_4+, NO_2-, NO_3-
Phosphorus	P^{+5}	$HPO_4^=$, H_2PO_4
Potassium	K^+	K^+
Calcium	Ca^{++}	Ca^{++}
Magnesium	Mg^{++}	Mg^{++}

Cont.

Elements	Symbol	Form Used by Plants
Iron	Fe	Fe^{++}, Fe^{+++}
Molybdenum	Mo^{+6}	$MoO_4^=$
Manganese	Mn	Mn^{++}, Mn^{++++}
Copper	Cu	Cu^+, Cu^{++}
Zinc	Zn^{++}	Zn^{++}
Born	B	$BO_3^=$
Chlorine	Cl^-	Cl^-
Water	H_2O	H^+, OH^-

O_2 and CO_2 come from the soil air or the atmosphere

Inorganic Salts

-Forms in which you buy fertilizer

$KCl \longleftrightarrow K^+ + Cl^-$

$NaNO_3 \longleftrightarrow Na^+ + NO_3^-$

$NH_4NO_3 \longleftrightarrow NH_4 + NO_3^-$

Inorganic Salts

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Other Elements

K^+, Ca^{++}, Zn^{++}, Mg^{++}, Cl^-, only one form present

Fe, Mn and Cu - From depends on the oxidation reduction condition of the soil

$Fe^{+++} + e^- \longleftrightarrow Fe^{++}$

oxidation ⟷ reduction

ic ous

Other Elements

Aerated soils

Fe^{+++}	(Ferric oxides)
Mn^{++++}	(Manganic oxide)

Poor Drainage

Fe^{++}	(Ferrous oxides)
Mn^{++}	(Manganous oxide) Toxic

Micronutrients

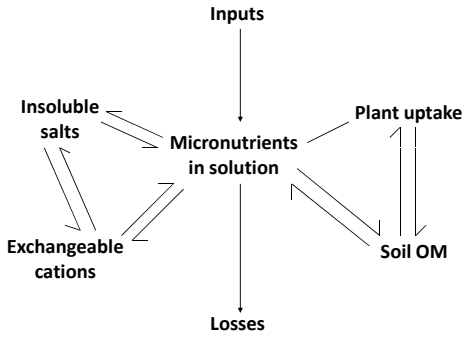
- **Micronutrient elements**
  - **Iron (Fe)**
  - **Manganese (Mn)**
  - **Boron (B)**
  - **Zinc (Zn)**
  - **Molybdenum (Mo) Zinc (Zn)**
  - **Copper (Cu)**
  - **Chloride (Cl)**
- **Usually supplied by irrigation water and soil**
- **Deficiency and toxicity occur at pH extremes**

Cations

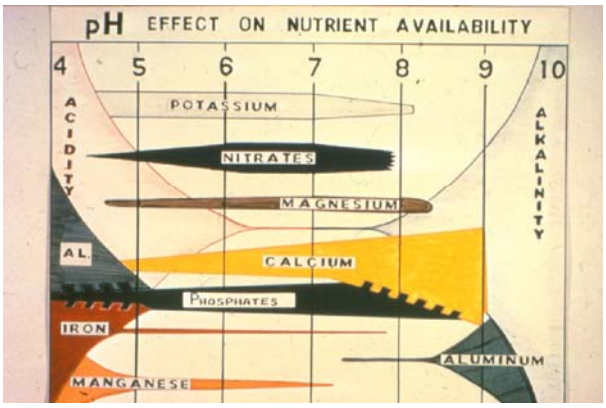
- Copper
- Manganese
- Nickel
- Iron
- Zinc

Anions

- Boron
- Chloride
- Molybdenum



Influence of pH on Nutrient Availability



"Micronutrients"

- as As important macronutrients **in absence of limiting factors such as water or N, can be yield-limiting factor(s)**
- Required in smaller amounts **than macronutrients**
- **Less likely to be deficient than macronutrients, but……**
- Fe, Zn, Cu, Mn **(cationic)**
- **B, Mo, & Cl (neutral or anionic)**
- **Total of 7/ 8*** **** if you include nickel***

Four major forms in soil

- **Soluble**
  -- **"chelators" (plant or microbial) ↑ solubility**
- **Organic pool**
  -- **complexed to O.M. (esp. Zn, Cu, B)**
  -- **contained in crop residues & microbial biomass**
- **"Adsorbed"**
  -- **Zn adsorbed to certain minerals in soil.**
- **Mineral (primary & secondary minerals)**

Factors affecting availability:

1. Soil organic matter
   - storehouse
   - chelation
2. Soil pH
   - Microbial activity
   - Solubility
3. Soil moisture content
   - Oxidation / reduction
   - Microbial activity
   - Root exploration

Factors affecting availability:

4. Soil exchange capacity / leachability
   - Retention vs. loss
5. Ion Interaction
   - Competition
   - Substitution
6. Weather
   - Nutrient absorption
   - Rate of growth

Micronutrients

Element	Main Function	Primary Source	Approx. Conc. in Plants
Iron (Fe)	Chlorophyll synthesis; oxidation-reduction reactions; enzyme activator	Soil minerals	10-1000 ppm
Manganese (Mn)	Oxidation-reduction reactions; nitrate reduction; enzyme activator	Soil minerals	5-500 ppm
Copper (Cu)	Enzyme activator; nitrate reduction; respiration	Soil minerals; soil organic matter	2-50 ppm
Zinc (Z)	Enzyme activator; regulates pH of cell sap	Soil minerals; soil organic matter	5-100 ppm
Boron (B)	Cell maturation and differentiation; translocation of carbohydrates	Soil organic matter; tourmaline	2-75 ppm

Micronutrients in Plant Nutrition

✓Perform enzymatic functions in plants
✓Zn, Mn, Cu, Fe - photosynthesis
✓B - sugar formation translocation
✓Mo - nitrate reductase (legumes)
✓Cl - ionic buffer in plants

Micronutrient Mobility

➢Iron: Not mobile in plants
➢Copper: not mobile in plants
➢Manganese: not mobile in plants
➢Boron, Zinc, and Molybdenum - not mobile