page 74

ESSENTIAL ELEMENTS, MOBILITY AND pH EFFECT

essential element - an element required by plants for normal growth, development and completion of its life cycle, and which cannot be substituted for by other chemical compounds.

17 ELEMENTS ARE REQUIRED BY PLANTS

3 supplied naturally by air and water - comprise the bulk of the plant
C, H, 0

6 macronutrients - required at 0.1 to 6% of the dry weight of plants
N, P, K, S, Ca, Mg

8 micronutrients - required at 1 to 300 ppm of the dry weight of plants
Fe, Zn, Cu, Mo, B, Mn, Cl, Ni
Cl and Ni are ubiquitous - hence, will not be addressed in detail

The essential elements can be easily remembered by a catch phrase such as
C. HOPKiNS CaFe, CuB, Mn, C.l. MoNiZnsky, Mgr

NUTRIENT MOBILITY

Two directions of movement in plants

1) acropetal - means towards the apex; transport up the in xylem
2) basipetal - means towards the base; transport down in the phloem

Two classifications of nutrient mobility

1) mobile - moves both up and down the plant by both acropetal and basipetal transport (in both the xylem and the phloem).
Deficiency appears on older leaves first.
N, P, K, Mg, S

2) immobile - moves up the plant by only acropetal (in the xylem) transport
Deficiency appears on new leaves first.
Ca, Fe, Zn, Mo, B, Cu, Mn

EFFECT OF pH

The pH determines solubility in the soil

1) more available at low pH (below 5.5), and less available at high pH.
Fe, Zn, Cu, Mn, B

2) more available at high pH (above 6.5), and less available at low pH.
N, K, Mg, Ca, S, Mo

3) more available at intermediate pH (6-7)
P

Ideal pH

slightly acid:

a) around 6.5 for field soil
b) around 5.5-6.0 for artificial growing media made with peat moss or composted bark

---

page 75

FERTILIZER ANALYSIS AND RATIO

FERTILIZER ANALYSIS

analysis - sequence of 3 numbers on the fertilizer label that gives the percent composition of N-P_20_5-K_20 in a fertilizer; required by law to be on the label of every fertilizer sold.

Example: 8-8-8 means the fertilizer contains:

8% N
8% P_20_5
8% K_20
24% total nutrient content

Buy fertilizers by price per pound of fertilizer, not price per bag.

100 lb. of 8-8-8 @ $4.99	**100 lb. of 13-13-13 @ $5.99**
100 lb. @ 24% = 24 lb. of nutrients @ $4.99 = **20.8 cents per lb**	100 lb @ 39% = 39 lb. of nutrients @ $5.99 = **15.3 cents per lb.**

FERTILIZER RATIO

ratio - the relative proportion of N to P_20_5 to K_20 in a fertilizer.

Analysis	Ratio
8-8-8	1-1-1
20-20-20	1-1-1
10-20-10	1-2-1
18-6-12	3-1-2

USING FERTILIZER RATIOS TO MANIPULATE GROWTH

a) to favor vegetative growth

- **use a high N, low P and K fertilizer**
- for example, use a 2-1-1 or 3-1-1 ratio fertilizer (higher 1st number)

b) to favor flowering, root and underground storage organ growth

- **use a low N, high P and/or K fertilizer**
- for example, use a 1-2-2 or 1-3-2 ratio fertilizer (higher 2nd and/or 3rd number)

---

page 76

FUNCTION OF NUTRIENTS

Nutrient	Symbol	Function
nitrogen	**N**	**1)** Component of chlorophyll; amino acids, proteins and enzymes; nucleic acids (RNA and DNA); some auxins and cytokinins.
phosphorus	**P**	**1)** Component of the high energy compounds ATP, NADPH and NADP; nucleic acids (DNA and RNA); and phospholipids.
potassium	**K**	**1)** Needed for protein and enzyme synthesis and activation. **2)** Involved in maintaining proper water balance **3)** Needed for photosynthesis.
magnesium	**Mg**	**1)** Component of chlorophyll. **2)** Activates many enzymes.
calcium	**Ca**	**1)** Ca pectates in middle lamella of cell wall cement cells together. **2)** Required for normal cell division and meristem growth. **3)** Stabilizes membranes
sulfur	**S**	**1)** Component of several amino acids (methionine, cystine, cysteine).
iron	**Fe**	**1)** Required for chlorophyll synthesis. **2)** Component of many enzymes and carriers, especially those of electron transport chain.
zinc	**Zn**	**1)** Required for tryptophan, hence auxin (IAA), synthesis.
manganese	**Mn**	**1)** Required for chlorophyll synthesis. **2)** Activates many enzymes.
copper	**Cu**	**1)** Required for chlorophyll synthesis. **2)** Component of many enzymes and carriers, especially those of electron transport chain.
boron	**B**	**1)** Required for complete flowering and fruit development. **2)** Involved in translocation of carbohydrates and hormones.
molybdenum	**Mo**	**1)** Component of enzymes in N metabolism (nitrate to organic N) **2)** Component of enzymes in nitrogen fixation (N gas to ammonia)
chlorine	**Cl**	**1)** Oxygen evolution in photosynthesis **2)** Stomatal functioning
nickel	**Ni**	**1)** Component of several enzymes, especially urease (breaks down urea)

---

page 77

TISSUE CONCENTRATION, DEFICIENCY SYMPTOMS AND FERTILIZER SOURCES

Nutrient	Tissue Concentration	Characteristic Deficiency Symptom*	Fertilizer Sources
MACRONUTRIENTS			
N	2-6%	older leaves - overall chlorosis	NH4 nitrate, sulfate, phosphate; K, Na, or Ca nitrate; urea
P	0.2-1.2%	older leaves - deep green, purple coloration of petioles	superphosphate; NH4 or K phosphate; phosphoric acid
K	1-6% (luxury consumption)	older leaves - interveinal chlorosis with marginal and tip necrosis	K nitrate, chloride, phosphate, or sulfate; K frit
Mg	0.2-1%	older leaves - interveinal chlorosis and bronze coloration	dolomite (Ca/Mg carbonate), Mg sulfate (Epsom salt)
Ca	0.5-2%	stem tips - die, small leaves	limes (Ca carbonate/hydroxide); Ca sulfate (gypsum) or nitrate; superphosphate
S	0.3-0.7%	all leaves overall chlorosis, on young leaves 1st then progresses to old leaves	sulfate carriers; elemental S; air pollution; superphosphate
MICRONUTRIENTS**			
Fe	50-300 ppm	young leaves - severe interveinal chlorosis	Fe chelate; Fe sulfate; some pesticides
Zn	5-75 ppm	new growth - rosetted growth & small leaves	Zn chelate; Zn sulfate; some pesticides
Mn	30-300 ppm	young leaves - interveinal chlorosis with necrosis when severe	Mn chelate; Mn sulfate; some pesticides
Cu	5-30 ppm	stem tips - die, stunted; leaves small; multiple buds formed	Cu chelate; Cu sulfate; some pesticides
B	30-200 ppm	stem tips - internodes short, thick; leaves thick, brittle, with necrosis	borax; boric acid
Mo	1 ppm	similar to N deficiency, except occurs on young leaves.	Na or NH4 molybdate
Cl & **Ni**	?	virtually never seen in nature	ubiquitous

***chlorosis** = yellowing; **necrosis** = browning; **interveinal** = between the veins
****micronutrients** are often applied as a multi-micronutrient mix; ex. STEM, PERK, Micromax

---

page 78

NUTRIENTS WITH SIMILAR DEFICIENCY SYMPTOMS

Nutrients That Cause Interveinal Chlorosis

	Deficiency Of	
Interveinal Chlorosis Occurs On	With No Necrosis	Plus Necrosis
Young Leaves	Fe	Mn
Old Leaves	Mg	K

Nutrients That Cause Overall Chlorosis

Overall Chlorosis Occurs on	Deficiency Of
Old Leaves	N
New Leaves	Mo
New Leaves, Then Spreading to Old Leaves	S

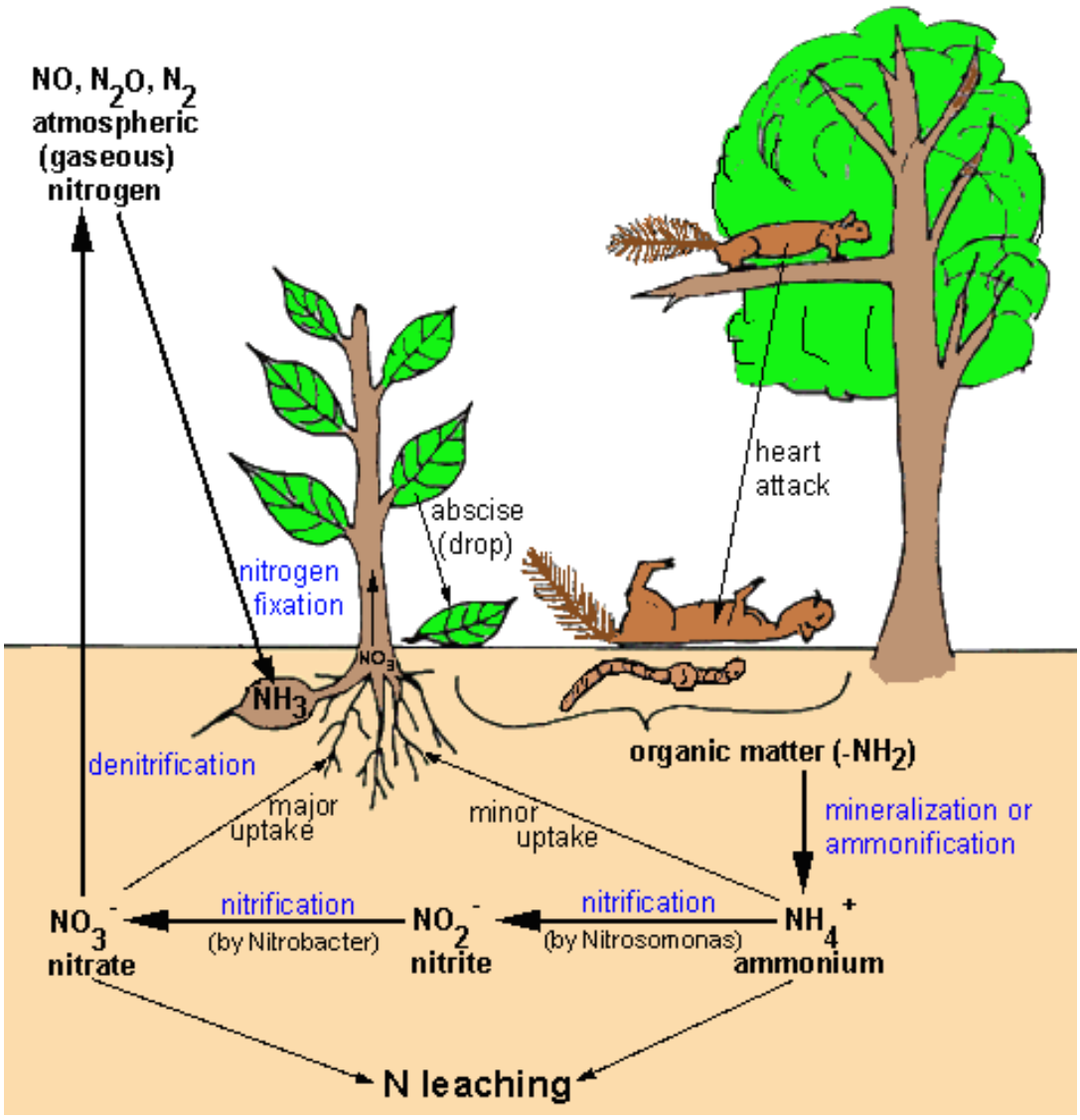
Nutrients That Effect the Shoot Tip

Various Deficiency Symptoms on Growing Point, Emerging Leaves or Shoot Tip	Deficiency Of
Small New Leaves and Rosetted New Growth	Zn
Thick and Brittle New Leaves	B
New Leaves Distorted and Necrotic	Ca
Vague Symptoms: New Leaves Small, Wilted, Translucent or Necrotic	Cu

---

page 79

NITROGEN CYCLE



WAYS IN WHICH NITROGEN IS LOST FROM THE SOIL

1) **leaching** (especially nitrate which is negatively charged)
2) **plant absorption**
3) **microorganisms consume** (see C:N ratio next page)
4) **denitrification**

---

page 80

NITROGEN CONVERSIONS

NITROGEN REACTIONS

mineralization or **ammonification** -the conversion of organic nitrogen (in the -NH2 form) to inorganic nitrogen (in the NH_4 form).
- the speed of conversion depends on the C:N ratio (see below).

nitrification - a two step process converting ammonium to nitrite, then nitrite to nitrate.
- the soil bacterium *Nitrosomonas* converts ammonium to nitrite
- the soil bacterium *Nitrobacter* converts nitrite to nitrate
- this occurs very quickly so little ammonium (which can be toxic if high) and virtually no nitrite (which is highly toxic) accumulates in the soil.

denitrification - the conversion of nitrate in the soil to gaseous nitrogen that escapes into the atmosphere.

nitrogen fixation - the conversion of gaseous nitrogen to ammonia.
- only nitrogen fixing microorganisms can cause nitrogen fixation;
some form symbiotic relationships with plants (see table below)

CARBON:NITROGEN (C:N) RATIOS IN ORGANIC MATTER

C:N Ratio - proportion of carbon to nitrogen present in organic matter.

a) high C:N ratio - wood, sawdust, uncomposted bark
- microbes use up all nitrogen in organic matter when consuming carbon,
- then the microbes use up the nitrogen in the soil

b) low C:N ratio - manure, bone meal, fish emulsion, organic fertilizers
- microbes consume carbon,
- then release excess nitrogen from the organic matter into the soil
- thus, low C:N organic matter acts as an **organic nitrogen fertilizer**

MICROORGANISMS THAT CAN FIX NITROGEN

Type Microorganism	Nitrogen-Fixing Microorganism	Forms Symbiotic Relationship With
1) Bacteria	*Rhizobium*	Legumes (soybean, clover, mesquite)
2) Bacteria	*Azotobacter* *Clostridium*	free living only
3) Filamentous Bacteria	some Actinomycetes	Some woody plants, (*Alnus* and *Elaeagnus*)
4) Blue-green algae	*Anabaena*	*Azolla* and Cycads (can also be free living)