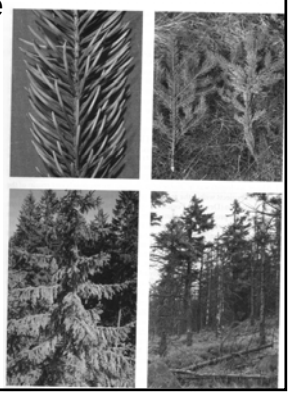
Mineral Nutrition

1. **Which Nutrients are Used For What Functions**

2. How Soils Hold and Release Nutrients

3. How plants obtain Nutrients

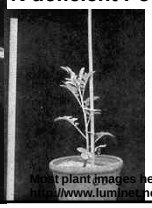
4. How efficiently they use them



Almost all plants and ecosystems respond to nutrient additions – indicating widespread nutrient limitation to productivity

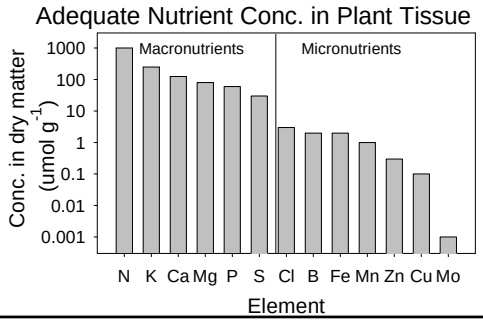
healthy Potato

N deficient Potato



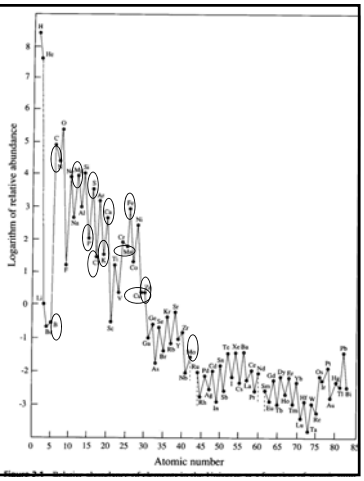
Most plant images here courtesy of: http://www.lumenet/~wenonah/min-def/list.htm

There are 13 nutrients considered 'essential'



Makes sense in terms of cosmic abundances

Mo is a bit of a puzzle – why did plants evolve a need for it? Some suggest this indicates life is of extra-terrestrial origin! (Crick/Orgel)



Deficiency symptoms in any or all of these are complex and overlapping

For example, deficiency in many of the elements causes chlorosis (yellowing)

But the pattern of chlorosis (e.g. young vs old leaves) can give hints about what nutrient(s) might be limiting.

e.g Chlorosis of old/lower leaves first suggests N deficiency, while chlorisis of young leaves first, or all leaves simultaneously, suggests S deficiency. Often a function of translocation mobility.

Let's discuss the role of each

1. Nitrogen:

Constituent of:
Amino acids, proteins, nucleic acids, enzymes, chlorophyll.

Forms taken up as: NO3-, NH4+, organic N

Mobility within plant: High

Deficiency symptoms:
- Stunted growth
- Excess stem woodiness (can't allocate carbon to N compounds)
- Purple coloration (anthocyanin production)
- Chlorosis (yellowing of leaves)

N deficient Oat stalks

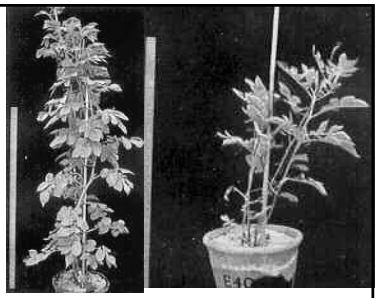
2. Phosphorous:

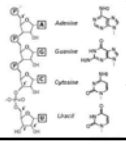
Constituent of:
Sugar Phosphates, ATP, nucleic acids, enzymes, phospholipid bilayers.

Forms taken up as: $PO4^{3-}$, also organic forms

Mobility within plant: High

Deficiency symptoms:
- Stunted growth
- Dark green leaf coloration
- Malformed leaves/necrotic spots
- Purple coloration, no chlorosis
- Delayed maturation





Phosphorus Deficiency — Restricted growth, leaves rolled forward.

Potato Plant in Sand Culture

Growth small and shoots thin; upright habit; leaves slightly pale, with forward roll and scorched margins; defoliation of oldest leaves.

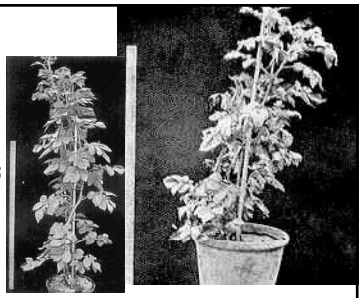
3. Potassium:

Roles:
Maintains electroneutrality in cells; osmotic regulation; cofactor for many enzymes; stomatal regulation

Forms taken up as: K+

Mobility within plant: High

Deficiency symptoms:
- Stunted growth
- Chlorosis (usually mottled)
- Leaf curling/crinkling
- Short internodes
- Root fungal infection vulnerability



Potassium Deficiency — Marginal leaf scorch.

Potato Plant in Sand Culture

Growth fairly good; leaves bluish-green and intervenal chlorosis, spotting and marginal scorch present.

4. Sulfur:

Constituent of:
Amino Acids, Proteins

Forms commonly taken up as: $SO4^{2-}$

Mobility within plant: Somewhat low

Deficiency symptoms:
- Stunted growth
- Chlorosis (but on new leaves as well as old – unlike N deficiency)
- Purple coloration

5. Calcium:

Roles:
Cell signalling, stomatal regulation, cell wall synthesis.

Forms taken up as: Ca^{+}

Mobility within plant: Low (between leaves)

Deficiency symptoms:
- Leaf/bud necrosis at tips of leaves/meristems (where new cell walls formed)
- Growth stunting if meristems die

Calcium Deficiency — Tip leaves small, rolled and scorched.

Potato Plant in Sand Culture

Growth fairly good; young leaves chlorotic forward roll and marginal scorch. This plan failed to form tubers of appreciable size.

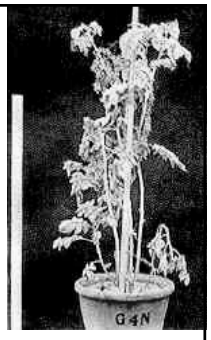
6. Magnesium:

Constituent of:
Chlorophyll, common enzyme cofactor (e.g. activates Rubisco)

Forms taken up as: Mg2+

Mobility within plant: High

Deficiency symptoms:
- Chlorosis (in older leaves first due to high mobility)
- Premature leaf abscission



Magnesium Deficiency — Chlorosis and necrosis of leaves, defoliation.

Potato Plant in Sand Culture

Growth fairly good; foliage chlorotic and with intervenal necrosis; death of older foliage and severe defoliation.

7. Iron:

Constituent of:
Cytochromes (e.g. light rxns), Nitrogenase; generally participates in e- transfers due to variable valence states; needed for chlorphyll synthesis

Forms taken up as: Fe(NO3)2, Fe(SO4), Fe-EDTA, Fe3+, Fe2+

Mobility within plant: Low (gets oxidized/insoluble)

Deficiency symptoms:
- Chlorosis (in younger leaves first due to low mobility)
- Under extreme conditions, leaves turn white

Broccoli Plant — Chlorosis of leaves.

Iron Deficiency

Chlorosis of leaves, beginning as a chlorotic motting.

8. Copper:

Constituent of:
Many enzymes (e.g. plastocyanin in light rxns)

Forms taken up as: CuSO4, Cu2+

Mobility within plant: Low

Deficiency symptoms:
- Dark green spots on tips of young leaves, spotty necrosis
- Twisted, malformed leaves

9. Boron:

Roles:
Not precisely known (nucleic acid synthesis, membrane function, cell wall formation)

Forms taken up as: B3+

Mobility within plant: Low

Deficiency symptoms:
- Black necrosis of young leaves/terminal buds
- Loss of apical dominance – excessive branchiness

Marrow Stem Kale Plant — Distortion of young foliage and crack in stem.

Boron Deficiency

Distortion of young leaves, marginal mottling and external vertical crack in stem.

10. Manganese:

Roles:
Cofactor for lots of enzymes (especially in Krebs cycle); cofactor in photosynthetic H2O splitting

Forms taken up as: MnSO4-H20, Mn ions

Mobility within plant: Not well known

Deficiency symptoms:
- Chlorosis + small necrotic spots
- Can be on younger or older leaves, depends on species

Parsnip Leaf — Intervenal chlorosis.

Manganese Deficiency

Severe marginal and intervenal chlorosis

11. Zinc:

Constituent of: Many enzymes, chlorophyll biosynthesis

Forms taken up as: ZnSo4-7H2O, Zn ions

Mobility within plant: Low

Deficiency symptoms:
- Reduction in internodal growth
- Small, distorted leaves
- Chlorosis

12. Molybdenum:

Constituent of: Nitrogen reductase (N03 -> N02) – essential to Nitrogen assimilation

Forms commonly taken up as: H_2MoO_4

Mobility within plant: High (?)

Deficiency symptoms:

- **Symptoms associated with N deficiency**
- **Older leaves show first symptoms**

13. Chlorine:

Role in: H_2O splitting during photosynthetic light rxns

Forms commonly taken up as: KCl, NaCl
Mobility within plant: High
Deficiency symptoms:

- **Never really deficient in native habitats –usually way more Cl than needed**
- **In lab, Cl starvation leads to leaf chlorosis/necrosis, reduced growth**