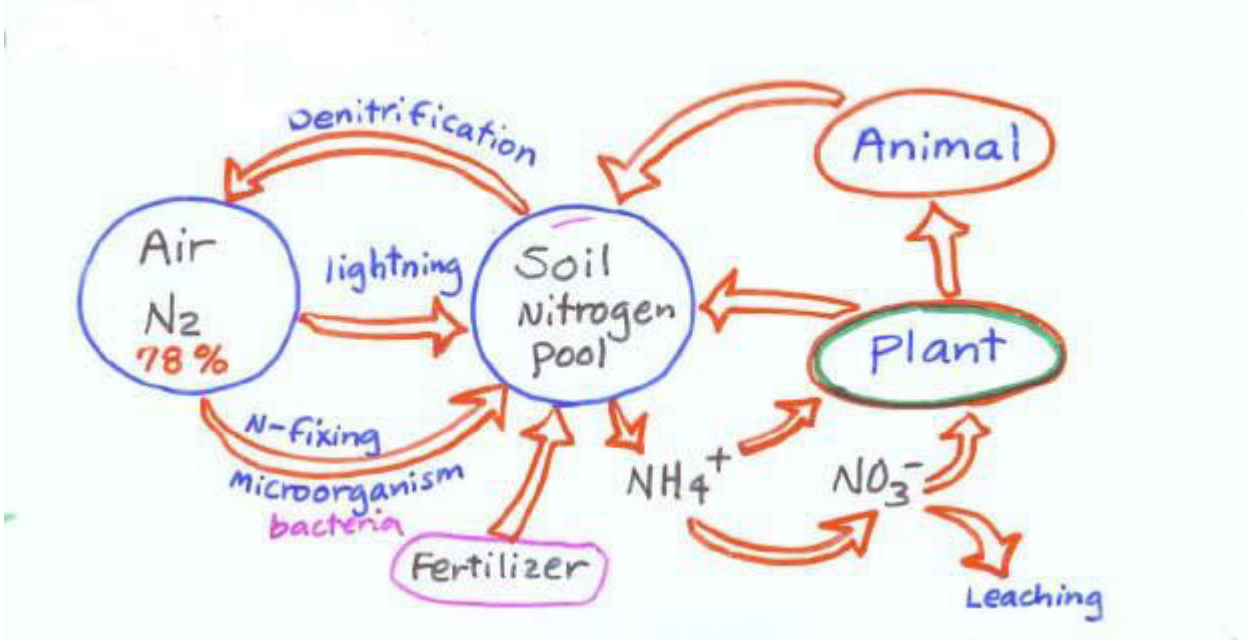
Plant Nutrition

1. **Plant Nutrients**
   - Macronutrients
   - Micronutrients
2. **Chemical Fertilizers**
   - Commercial Analysis
   - Elemental Analysis
3. **Fertilizer Concentration Calculations**
   - ppm
   - mM
   - Meq/liter
4. **Fertilizer Application**
   - Preplant Application
   - Top Dressing
   - Liquid Feeding

Macronutrients

a. Nitrogen (N)

1) Soil Nitrogen Cycle



A. Nitrogen (N)

1) Soil Nitrogen Cycle

a) Nitrogen Fixation

-Transformation of atmospheric N to nitrogen forms available to plants

- Mediated by N-fixing bacteria:

Rhizobium (symbiotic) found in legumes (bean, soybean)
Azotobacter (non-symbiotic bacteria)

b) Soil Nitrification

- Decomposition of organic matter into ammonium and nitrate

- Mediated by ammonifying and nitrifying bacteria

Ammonifying bacteria (*Actinomycetes*) Nitrifying bacteria (*Nitrosomonas*) (*Nitrobacter*)

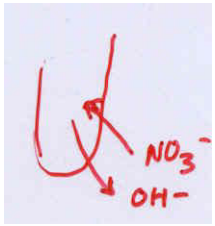
$$\text{Plant residue} \rightarrow NH_4^+ \rightarrow NO_2 \rightarrow NO_3^-$$

(Protein, aa, etc) Ammonium Nitrite Nitrate

2) N Functions in Plants

- Component of proteins, enzymes, amino acids, nucleic acids, chlorophyll
- C/N ratio (Carbohydrate: Nitrogen ratio)
  - High C/N ratio → Plants become more reproductive
  - Low C/N ratio → Plants become more vegetative
- Transamination
  - NO_3^- → NH_2 → Glutamic acid → Other amino acids (a.a.) → Protein

Enzymes



- Essential for fast growth, green color

3) Deficiency and Toxicity Symptoms

Deficiency: - Reduced growth
- Yellowing of old leaves

Toxicity (excess): - Shoot elongation
- Dark leaves, succulence

4) Fertilizers

- Ammonium nitrate (NH_4NO_3)
  - Calcium nitrate [$Ca(NO_3)_2$]
  - Potassium nitrate (KNO_3)
  - Urea [$CO(NH_2)_2$]
- Most plants prefer 50:50 NH_4^+ : NO_3^-

  NH_4^+-form of N → lowers soil pH

  NO_3^--form of N → raises soil pH
- Organic fertilizers (manure, plant residue) - slow acting
- N can be applied foliarly

Nitrogen (N) Deficiency Symptoms

Yellowing of mature lower leaves- nitrogen is highly mobile in plants

B. Phosphorus (P)

1) Soil Relations

- Mineral apatite [$Ca_5F(PO_4)_3$]
- Relatively stable in soil
- Has a low mobility (top dressing not effective)

2) Plant Functions

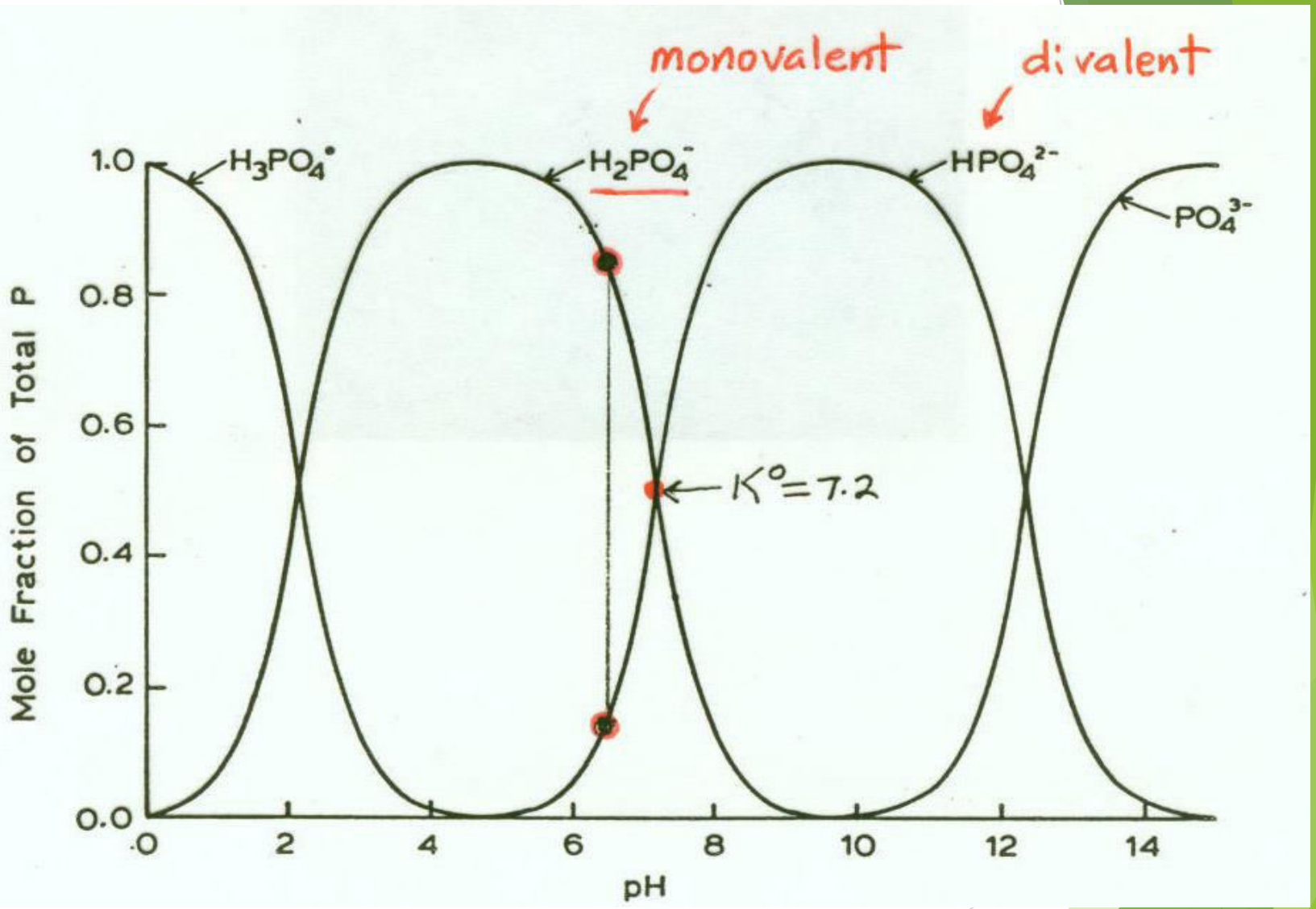
- Component of nucleic acid (DNA, RNA), phospholipids, coenzymes, high-energy phosphate bonds (ADP, ATP)
- Seeds are high in P

3) Deficiency and Toxicity

- P is mobile in plant tissues (Deficiency occurs in older leaves)
- Deficiency: dark, purplish color on older leaves
- Excess P: causes deficiency symptoms of Zn, Cu, Fe, Mn

4) Fertilizers

- Superphosphates (may contain F)
  - Single superphosphate (8.6% P): $CaH_4(PO_4)_2$
  - Triple superphosphate (20% P): $CaH_4(PO_4)_2$
- Ammonium phosphate: $(NH_4)_2PO_4$, NH_4HPO_4
- Bone meal
- Available forms: PO_4^{3-}, HPO_4^{2-}, $H_2PO_4^-$
  - P absorption influenced by pH



Influence of pH on different forms of phosphorus (P)

C. Potassium (K)

1) Soil Relations

- Present in large amounts in mineral soil
- Low in organic soils

2) Plant Functions

- Activator of many enzymes
- Regulation of water movement across membranes and through stomata (Guard cell functions)

3) Deficiency and Toxicity

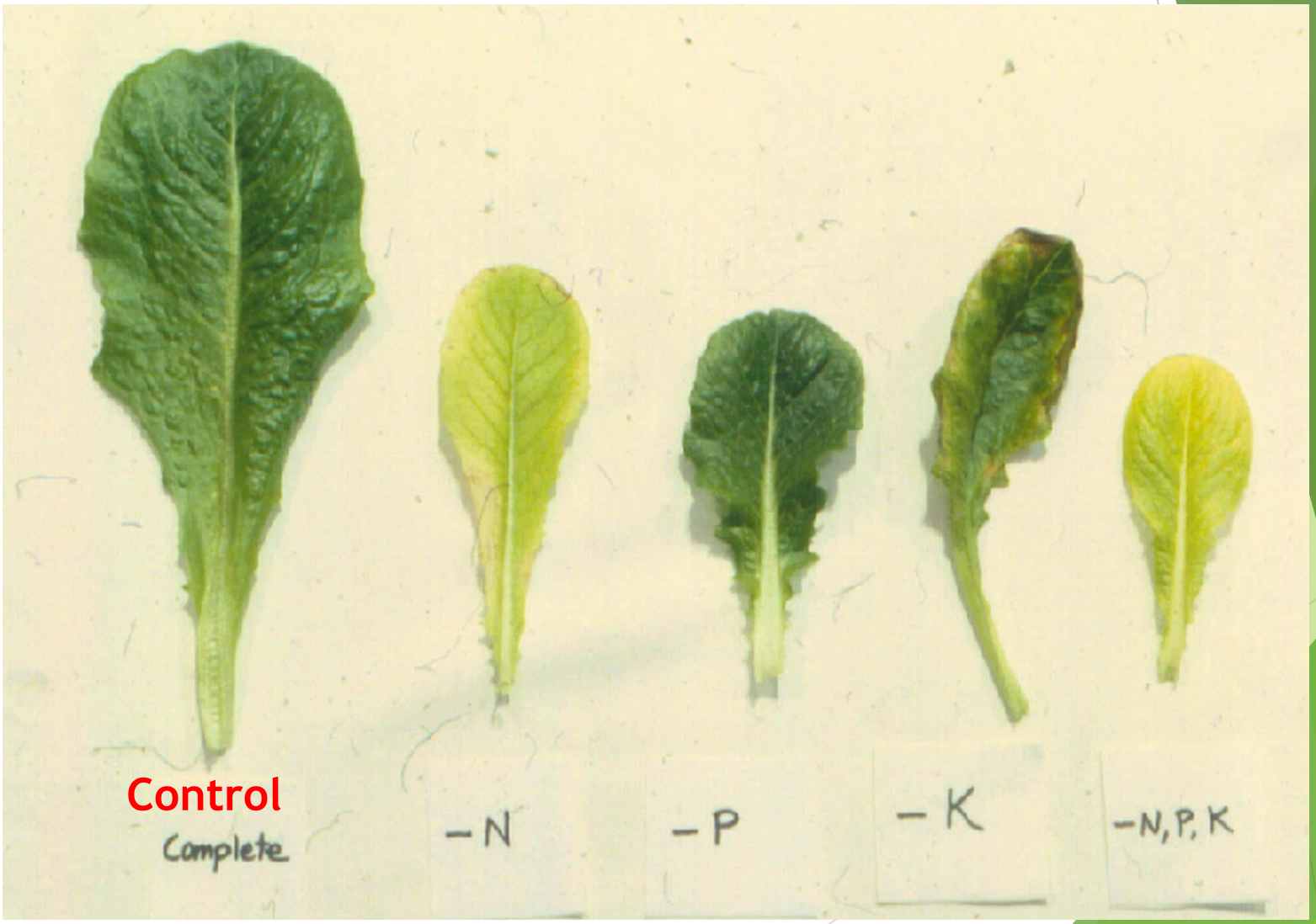
- Deficiency: Leaf margin necrosis and browning
  Older leaves are more affected
- Toxicity: Leaf tip and marginal necrosis

4) Fertilizers

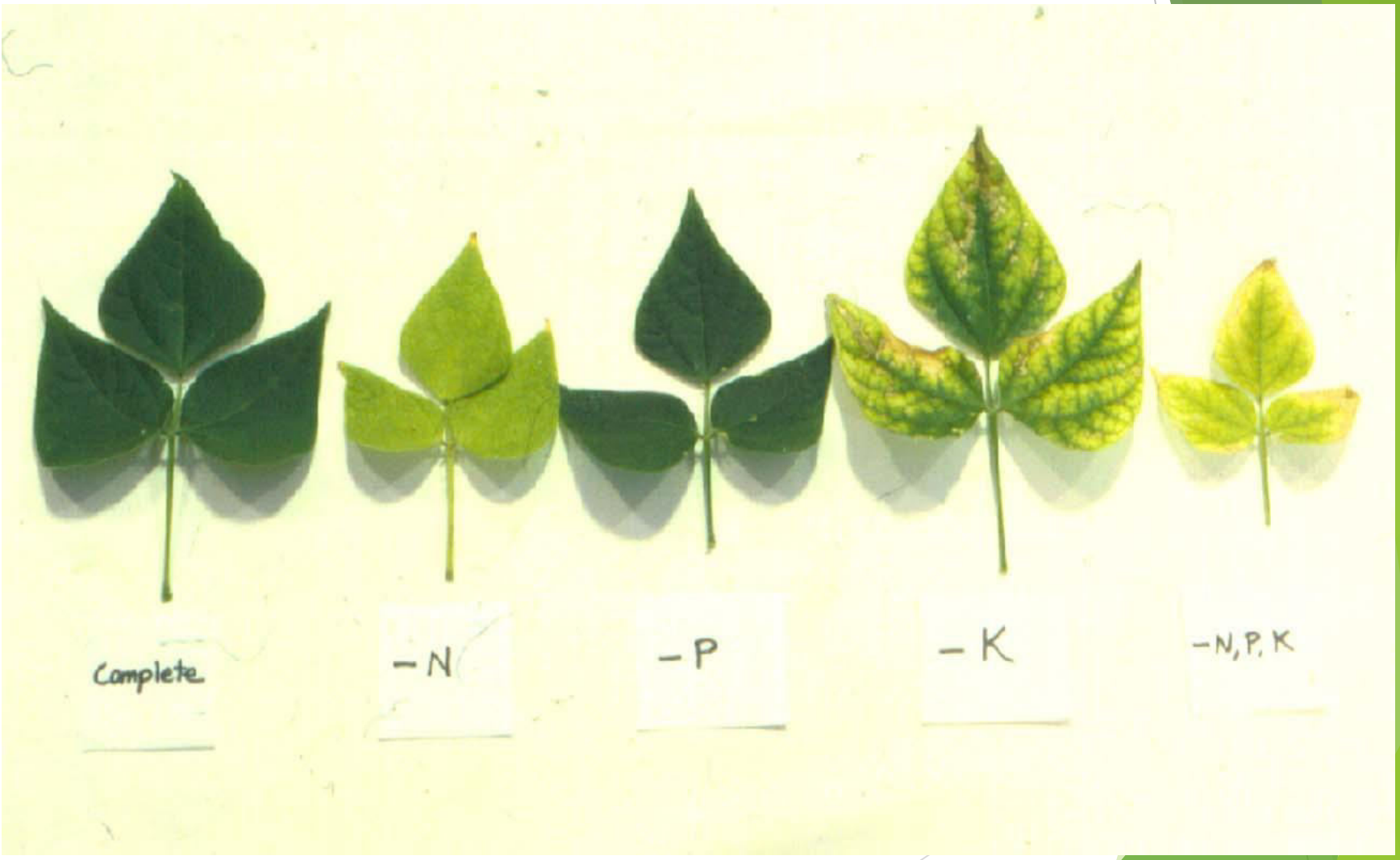
- Potassium chloride (KCl)- murate of potash
- Potassium sulfate (K_2SO_4)
- Potassium nitrate (KNO_3)

Leaf Margin Necrosis in Poinsettia
Potassium (K) Deficiency

Macronutrients N, P, K Deficiencies Leaf Lettuce



Macronutrient Deficiencies
Beans



D. Calcium (Ca)

1) Soil Relations

- Present in large quantities in earth's surface (~1% in US top soils)
- Influences availability of other ions from soil

2) Plant Functions

- Component of cell wall
- Involved in cell membrane function
- Largely present as calcium pectate in meddle lamela

  Calcium pectate is immobile in plant tissues

3) Deficiency and Toxicity

- Deficiency symptoms in young leaves and new shoots (Ca is immobile)

  Stunted growth, leaf distortion, necrotic spots, shoot tip death

  Blossom-end rot in tomato

- No Ca toxicity symptoms have been observed

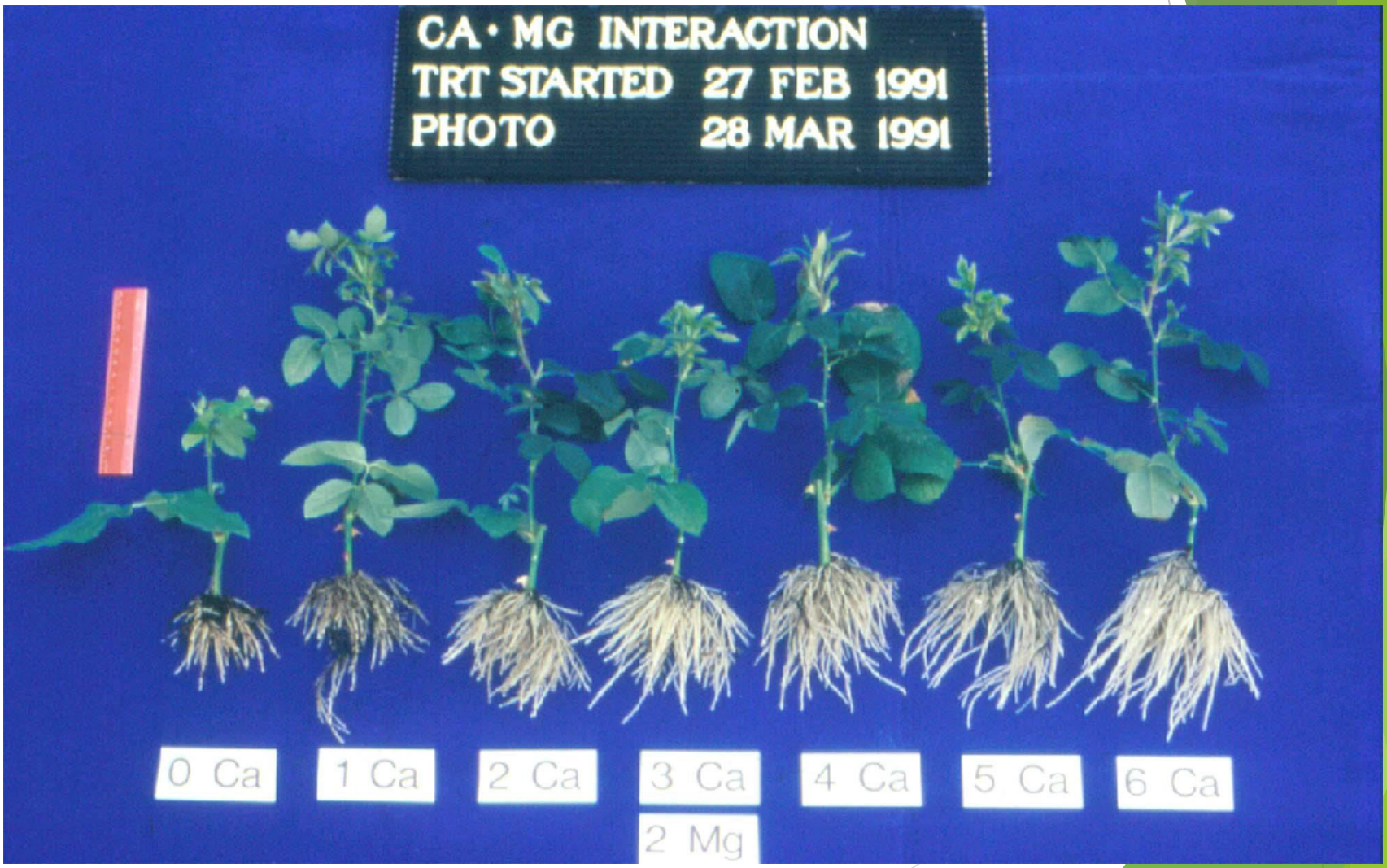
4) Fertilizers

- Agricultural meal (finely ground $CaCO_3 \cdot MgCO_3$)
- Lime ($CaCO_3$), Gypsum ($CaSO_4$)
- Superphosphate
- Bone meal-organic P source

Blossom End Rot of Tomato
Calcium Deficiency

Right-Hydroponic tomatoes grown in the greenhouse, Left-Blossom end rot of tomato fruits induced by calcium (Ca^{++}) deficiency

Influence of Calcium on Root Induction on Rose Cuttings



E. Sulfur (S)

1) Soil Relations

- Present in mineral pyrite (FeS_2, fool's gold), sulfides (S-mineral complex), sulfates (involving SO_4^{-2})
- Mostly contained in organic matter
- Acid rain provides sulfur

2) Plant Functions

- Component of amino acids (methionine, cysteine)
- Constituent of coenzymes and vitamins
- Responsible for pungency and flavbor (onion, garlic, mustard)

3) Deficiency and Toxicity

- Deficiency: light green or yellowing on new growth (S is immobile)
- Toxicity: not commonly seen

4) Fertilizers

- Gypsum ($CaSO_4$)
- Magnesium sulfate ($MgSO_4$)
- Ammonium sulfate [$(NH_4)_2SO_4$]
- Elemental sulfur (S)

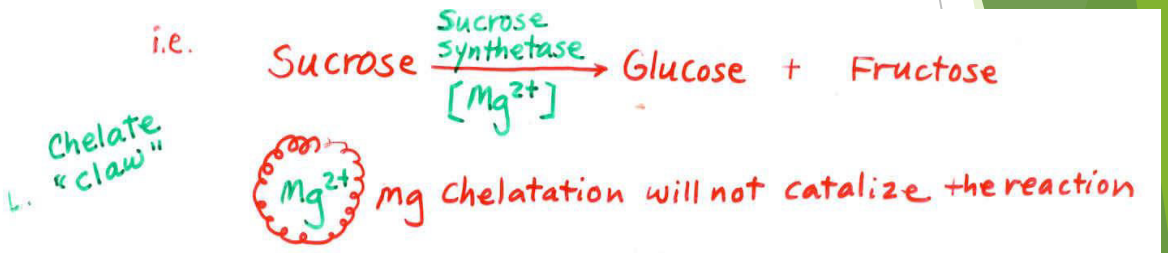
F. Magnesium (Mg)

1) Soil Relations

- Present in soil as an exchangeable cation (Mg^{2+})
- Similar to Ca^{2+} as a cation

2) Plant Functions

- Core component of chlorophyll molecule
- Catalyst for certain enzyme activity



3) Deficiency and Toxicity

- Deficiency: Interveinal chlorosis on mature leaves
  (Mg is highly mobile)
- Excess: Causes deficiency symptoms of Ca, K

4) Fertilizers

- Dolomite (mixture of $CaCO_3 \cdot MgCO_3$)
- Epsom salt ($MgSO_4$)
- Magnesium nitrate [$Mg(NO_3)_2$]
- Magnesium sulfate ($MgSO_4$)

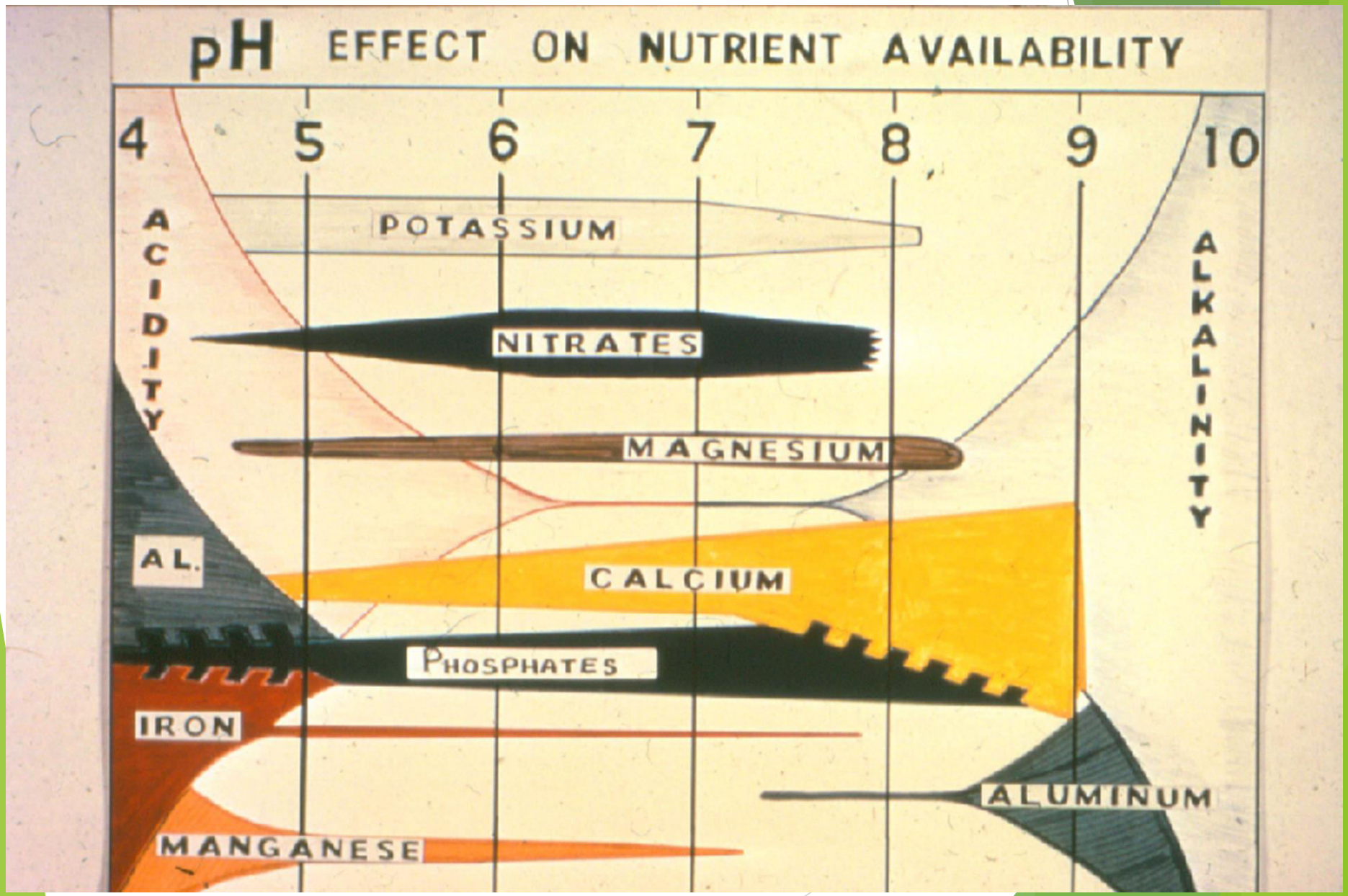
Magnesium (Mg) Deficiency on Poinsettia

Interveinal Chlorosis on Mature Leaves

Micronutrients

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

Influence of pH on Nutrient Availability



3. Micronutrients

A. Iron (Fe)

- Component of cytochromes (needed for photosynthesis)
- Essential for N fixation (nitrate reductase) and respiration
- Deficiency

Symptom: Interveinal chlorosis on new growth

Fe is immobile

Iron chlorosis develops when soil pH is high

Remedy for iron chlorosis:

1) Use iron chelates

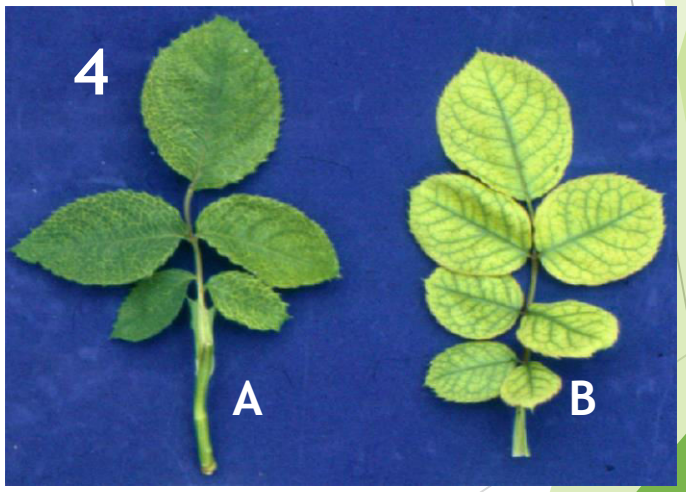
FeEDTA (Fe 330) - Stable at pH < 7.0

FeEDDHA (Fe 138) - Stable even when pH > 7.0

2) Lower soil pH

Iron is in more useful form (Fe^{2+})

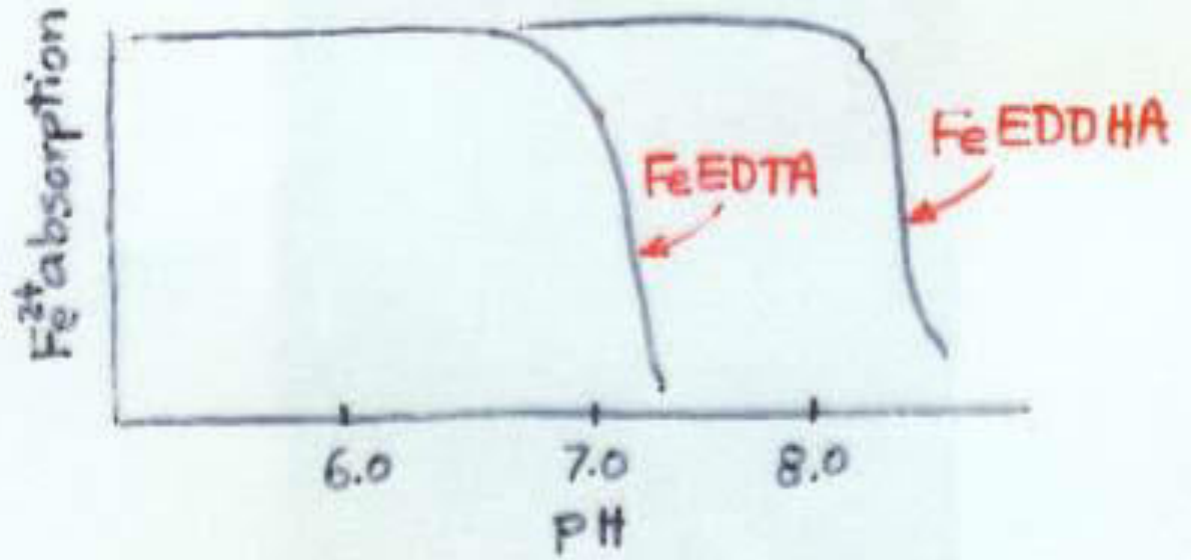
Iron (Fe) Deficiency Symptoms



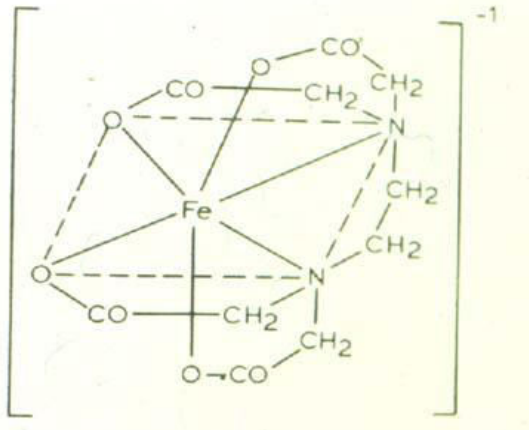
1-Piggyback Plant, 2- Petunia, 3-Silver Maple, 4-Rose (A-normal, B-Fe-deficient)

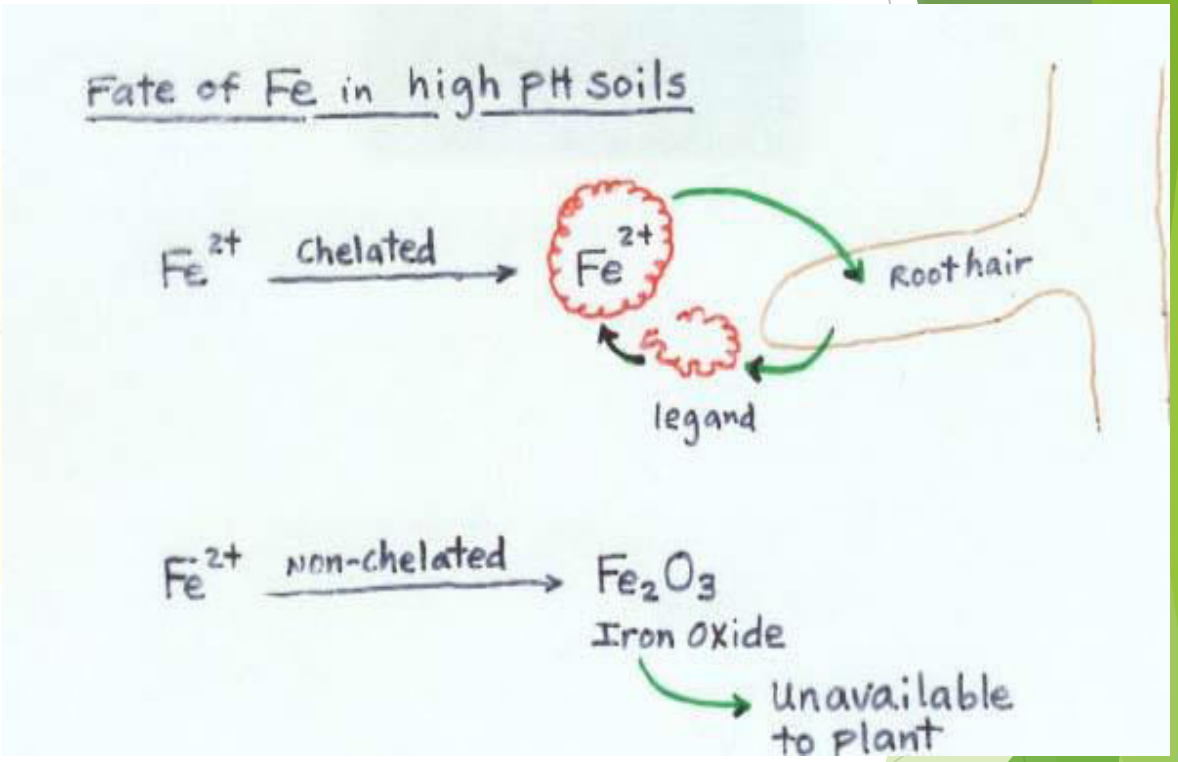
Iron Chelates

EDTA - Ethylene diamine tetraacetic acid
EDDHA - Ethylene diamine dihydroxy phenylacetic acid



Iron (Fe) Absorption by Plants





B. Manganese (Mn)

- Required for chlorophyll synthesis, O_2 evolution during photoshynthesis
- Activates some enzyme systems
- Deficiency: Mottled chlorsis between main veins of new leaves
  (Mn is immobile), similar to Fe chlorosis
- Toxicity: Chlorosis on new growth with small, numerous dark spots
  Deficiency occurs at high pH
  Toxicity occurs at low pH
- Fertilizers: Manganese sulfate ($MnSO_4$)
  Mn EDTA (chelate) for high pH soils

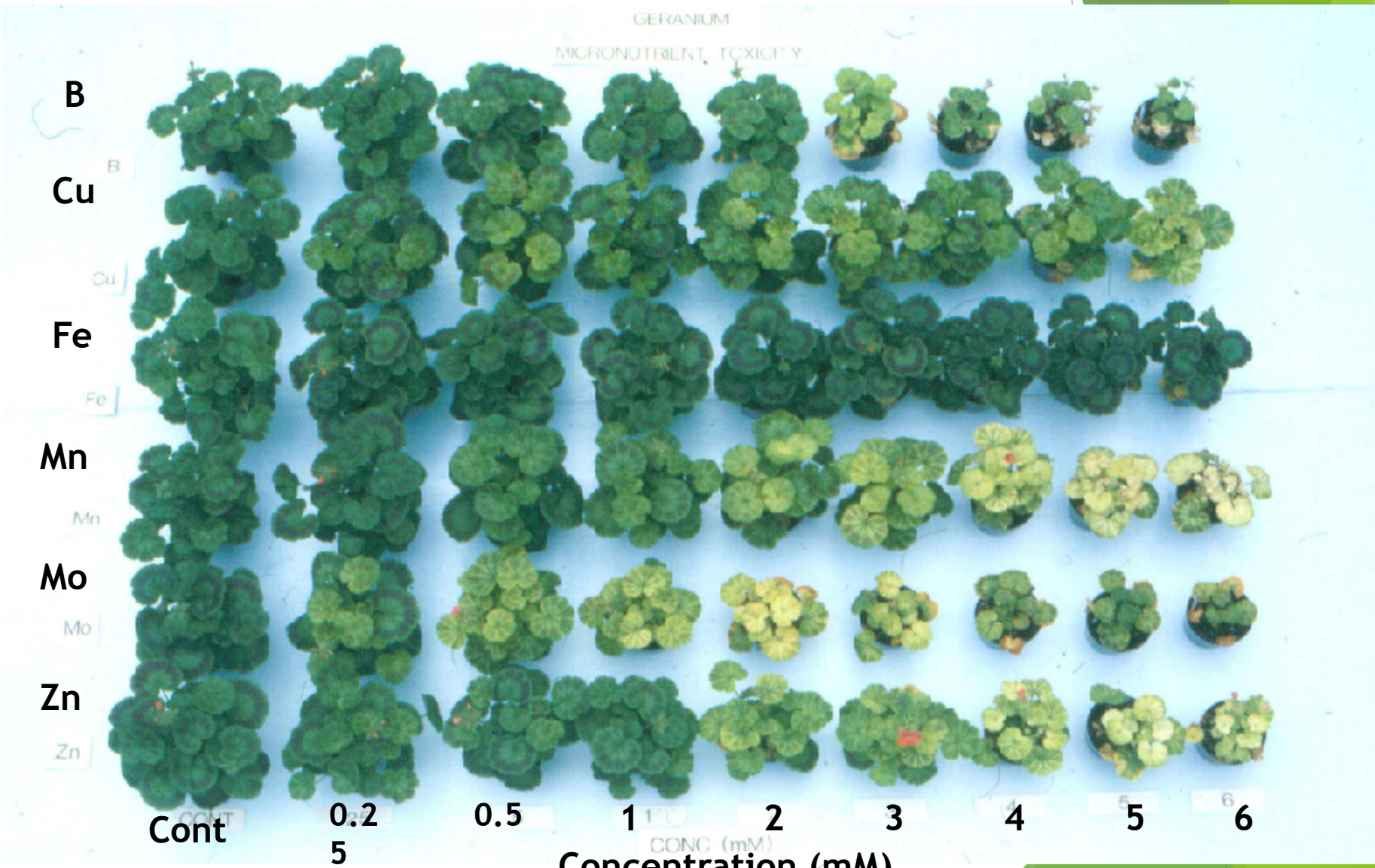
C. Boron (B)

- Involved in carbohydrate metabolism
- Essential for flowering, pollen germination, N metabolism
- Deficiency: New growth distorted and malformed, flowering and fruitset depressed, roots tubers distorted
- Toxicity: Twig die back, fruit splitting, leaf edge burns
- Fertilizers: Borax ($Na_2B_4O_710H_2O$), calcium borate ($NaB_4O_7\ 4H_2O$)

D. Zinc (Zn)

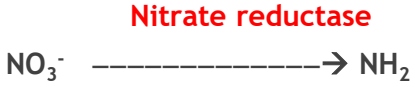
- Involved in protein synthesis, IAA synthesis
- Deficiency: (occurs in calcarious soil and high pH)
  Growth suppression, reduced internode lengths, rosetting, interveinal chlorosis on young leaves (Zn is immobile in tissues)
- Toxicity: (occurs at low pH) Growth reduction, leaf chlorosis

Micronutrient Toxicity on Seed Geranium



E. Molybdenum (Mo)

- Required for nitrate reductase activity, vitamin synthesis



Root-nodule bacteria also requires Mo

- Deficiency: Pale green, cupped young leaves (Mo is immobile)

  Strap leafe in broad leaf plants

  Occurs at low pH
- Toxicity: Chlorosis with orange color pigmentation
- Fertilizer: Sodium molybdate

F. Copper (Cu)

- Essential component of several enzymes of chlorophyll synthesis, carbohydrate metabolism
- Deficiency: Rosette or 'witch's broom'
- Toxicity: Chlorosis
- Fertilizers: Copper sulfate ($CuSO_4$)

G. Chlorine (Cl)

- Involved for photosynthetic oxygen revolution
- Deficiency: Normally not existing (Only experimentally induced)
- Toxicity: Leaf margin chlorosis, necrosis on all leaves
- Fertilizer: Never applied

  (Cl^- is ubiquitous!)

Molybdenum Deficiency on Poinsettia