# Plant Nutrition

# Essential Element

- **Presence** or **concentration** of an element is not a criterion for essentiality of an element to plant

- An element is essential to plants if these three criteria are met
- *A given plant must be unable to complete life cycle in the absence of the element*
- *The function of the element must not be replaced by another element*
- *The element must be directly involved in plant metabolism*

# Essential Elements

- There are 14 essential elements

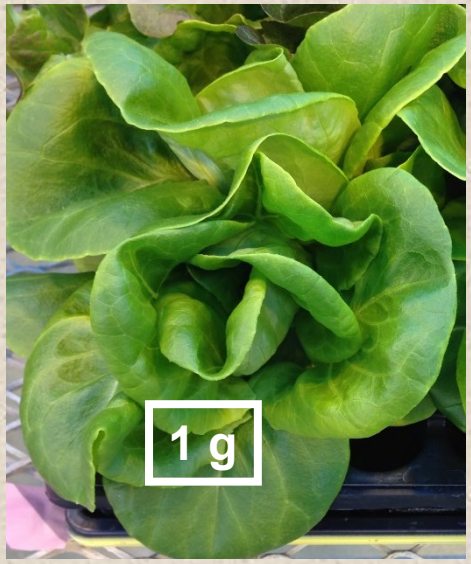
| Primary macro | Secondary macro | Micronutrients |
| --- | --- | --- |
| Nitrogen (N) | Calcium (Ca) | Iron (Fe) |
| Phosphorus (P) | Magnesium (Mg) | Manganese (Mn) |
| Potassium (K) | Sulphur (S) | Molybdenum (Mo) |
| | | Boron (B) |
| | | Copper (Cu) |
| | | Zinc (Zn) |
| | | Nickel (Ni) |
| | | Chlorine (Cl) |

# Composition of elements

*Composition is mg or µg of an element present in 1 g of dry plant*

*It can also be expressed as percentage*

*10 mg/g = 1%*




Percentage of elements in lettuce leaf

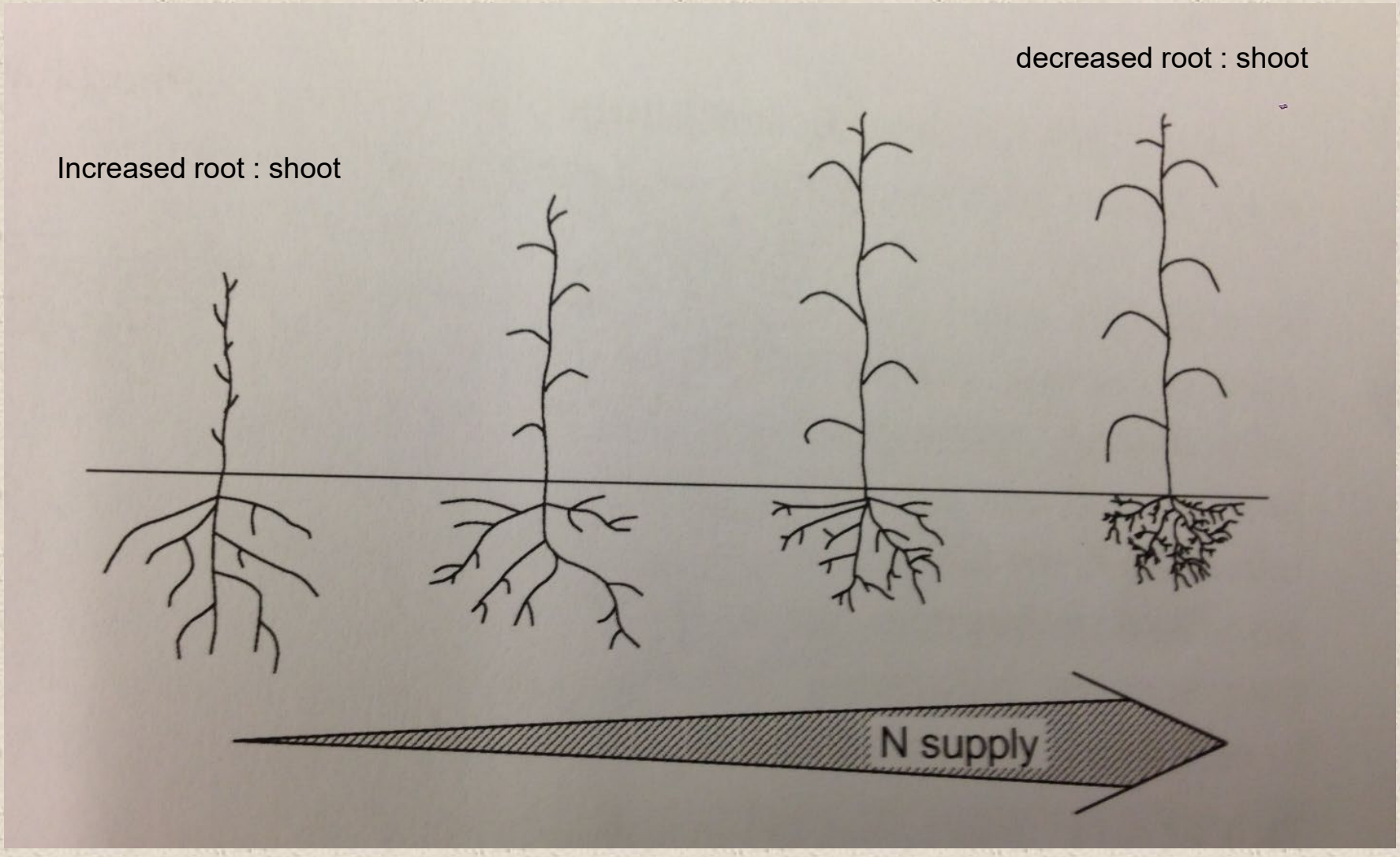
| N | P | K | Ca | Mg | S | Fe | Zn | Mn | B | Cu | Mo, Ni, Cl, |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 4.5 | 0.5 | 5 | 0.5 | 0.3 | 0.3 | 0.0015 | 0.0005 | 0.0005 | 0.0003 | 0.0002 | trace |

# Functions of Macro and Micronutrients

# Nitrogen

- Nitrogen is required for vegetative growth of plants
- When deficient
  - Plants become stunted
  - Older leaves appear yellow and lack chlorophyll


# Root response to N deficiency




*From Marschner's Mineral Nutrition of Higher Plants*

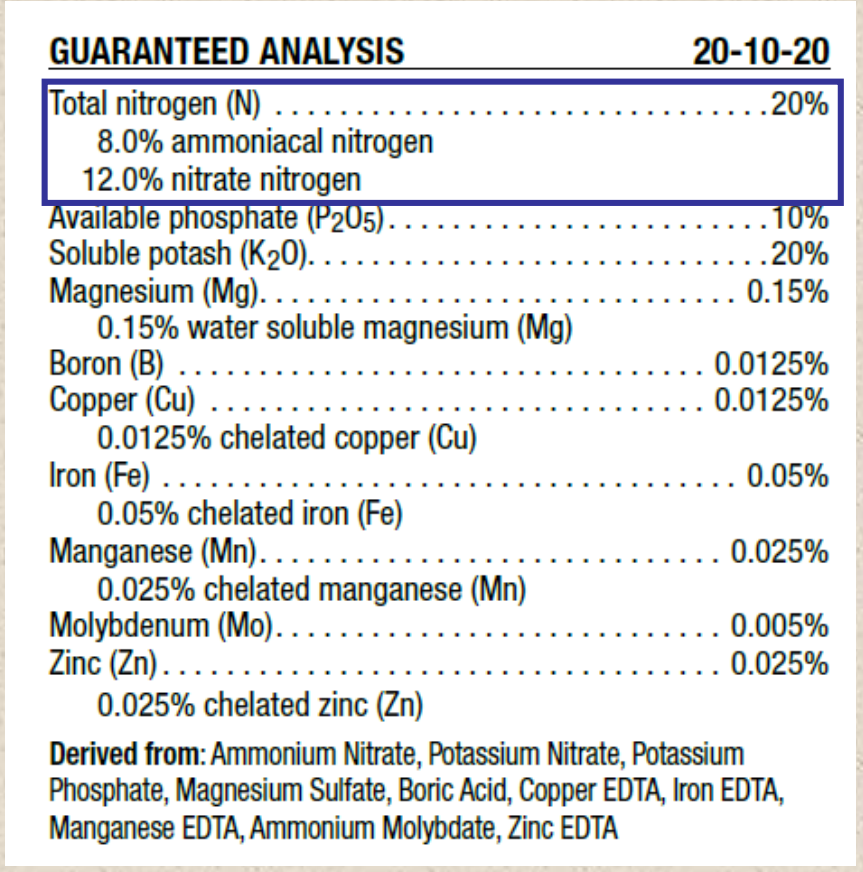
# Facts about Nitrogen fertilizer

- Nearly 80% of air is nitrogen
- Air above an acre of land contains ~75 million pounds of N; not a single pound is useful to plants unless N is fixed into nitrate or ammonium forms
- Lightning and some bacteria can fix atmospheric N; however industrial fixation (Haber-Bosch process) is the main source of nitrogen fertilizer to crops

# Nitrogen fertilizer is applied to crops in different forms

Common forms of nitrogen fertilizer are:

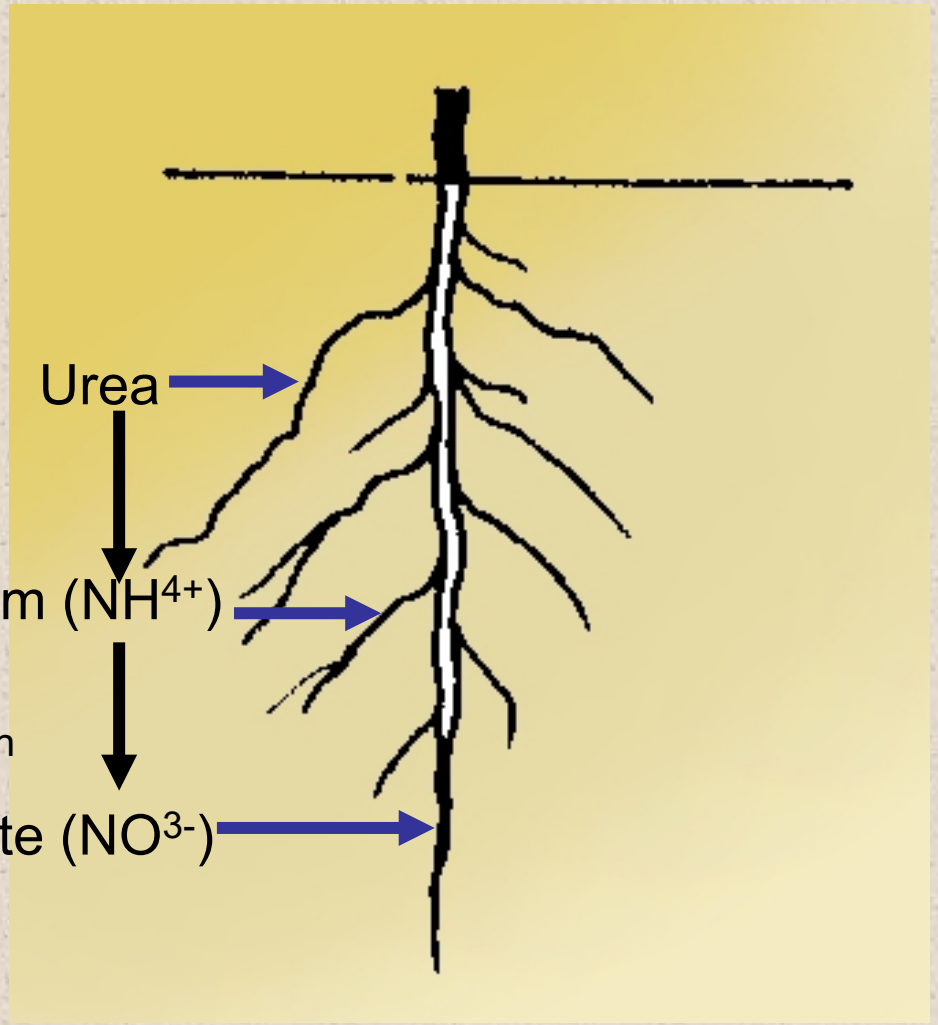
- Urea
- **Ammonium**
- **Nitrate**



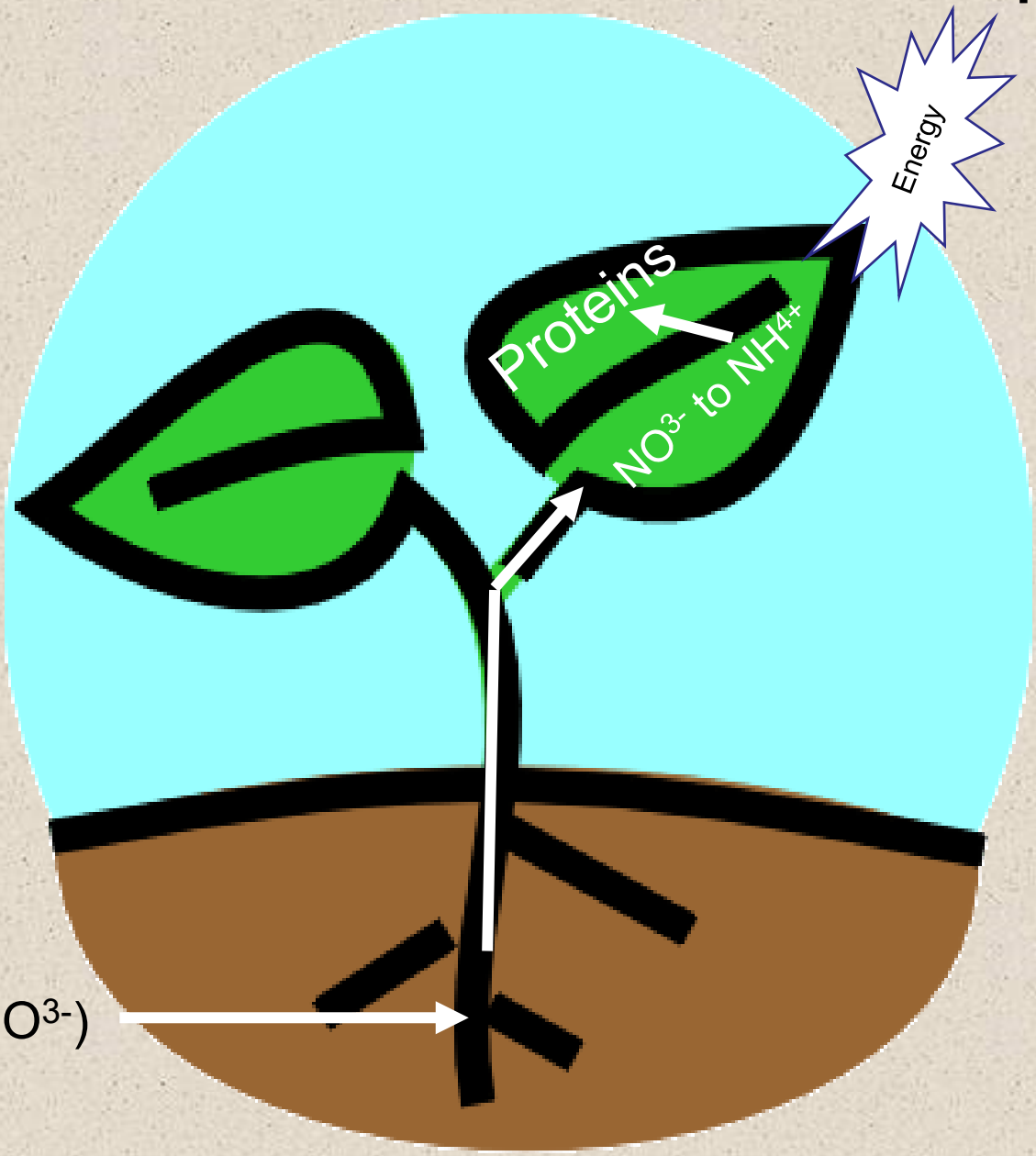
| GUARANTEED ANALYSIS | 20-10-20 |
|---|---|
| Total nitrogen (N) | 20% |
| 8.0% ammoniacal nitrogen | |
| 12.0% nitrate nitrogen | |
| Available phosphate ($P_2O_5$) | 10% |
| Soluble potash ($K_2O$) | 20% |
| Magnesium (Mg) | 0.15% |
| 0.15% water soluble magnesium (Mg) | |
| Boron (B) | 0.0125% |
| Copper (Cu) | 0.0125% |
| 0.0125% chelated copper (Cu) | |
| Iron (Fe) | 0.05% |
| 0.05% chelated iron (Fe) | |
| Manganese (Mn) | 0.025% |
| 0.025% chelated manganese (Mn) | |
| Molybdenum (Mo) | 0.005% |
| Zinc (Zn) | 0.025% |
| 0.025% chelated zinc (Zn) | |

**Derived from**: Ammonium Nitrate, Potassium Nitrate, Potassium Phosphate, Magnesium Sulfate, Boric Acid, Copper EDTA, Iron EDTA, Manganese EDTA, Ammonium Molybdate, Zinc EDTA

# Dynamics of N forms in the substrate



# Dynamics of N forms inside the plant



# Is nitrate form better?

Plus:

- Nitrates are readily available to plants, less fixed by substrate (why?)
- Does not compete with uptake of positively charged ions like K, Ca, Mg
- Increases stress tolerance

Minus:

- Nitrates are stored inside plants (can convert to nitrites upon consumption)
- Requires light energy to convert to amino acids and proteins
- Micronutrient deficiencies due to pH imbalance

# Is ammonium form better?

Plus:

- Ammonium is directly incorporated into amino acids
- Results in large foliage and lush plant growth
- Not easily leached in soilless substrates as nitrates (why?)

Minus:

- Can compete with uptake of positively charged ions (blossom end rot)
- Excess ammonium can cause phytotoxicity

# Ammonium toxicity

Ammonium can accumulate in the substrates under certain conditions when bacterial activity is low:

- Low temperature
- Low pH
- Saturated conditions

Leaching and adding basic fertilizer can aid if toxicity is observed

Source: OSU.edu

# Plugs vs finished plants: which form to use?

Peters® Professional


SKU# E99720*

Classic low-phosphate ratio proven by Florida researches for tropical foliage and hanging baskets. Excellent choice for interiorscapes.

- B (Base) formulation can be used alone or rotated with a C (Customizing) component
- Effective for all Water Types
- Contains a complete range of essential micronutrients

* Available in Canada SKU # E99723

| GUARANTEED ANALYSIS | 24-8-16 |
|---|---|
| Total nitrogen (N) | 24% |
| 7.1% ammoniacal nitrogen | |
| 8.7% nitrate nitrogen | |
| 8.2% urea nitrogen | |
| Available phosphate ($P_2O_5$) | 8% |
| Soluble potash ($K_2O$) | 16% |
| Magnesium (Mg) | 0.35% |
| 0.35% water soluble magnesium (Mg) | |
| Sulfur (S) | 2.0% |

Peters® Professional


SKU# E99340

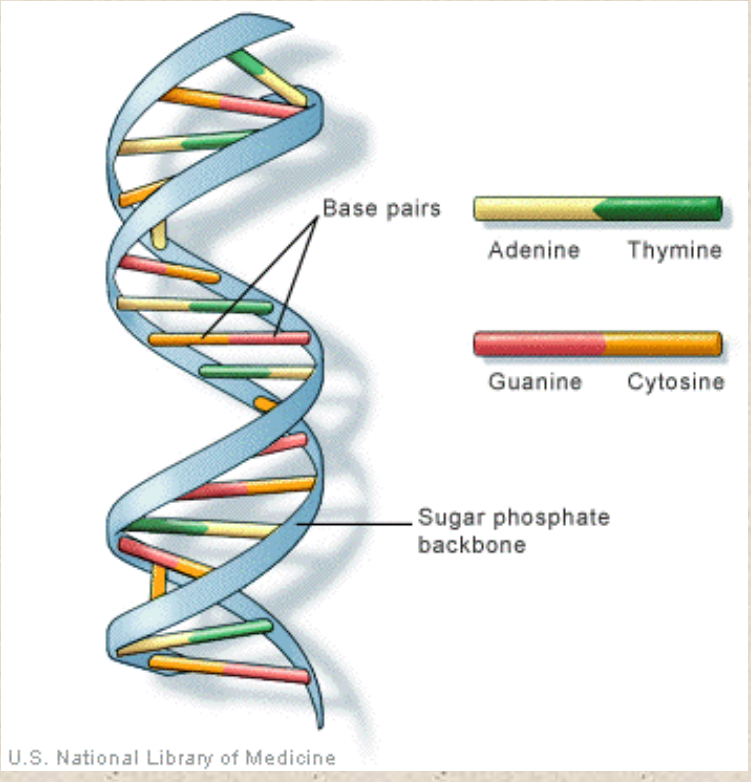
Ideal for plugs, liners, bedding plants and vegetable transplants with high nitrate and low phosphate levels to encourage healthy, compact growth.

- B (Base) formulation for constant, balanced nutrition
- Most effective with Water Types 1 and 2
- Contains calcium and magnesium
- For growers who prefer to add their own micronutrient package

| GUARANTEED ANALYSIS | 13-2-13 |
|---|---|
| Total nitrogen (N) | 13% |
| 0.4% ammoniacal nitrogen | |
| 12.6% nitrate nitrogen | |
| Available phosphate ($P_2O_5$) | 2% |
| Soluble potash ($K_2O$) | 13% |
| Calcium (Ca) | [illegible] |
| Magnesium (Mg) | 3.0% |
| 3.0% water soluble magnesium (Mg) | |

## Phosphorus

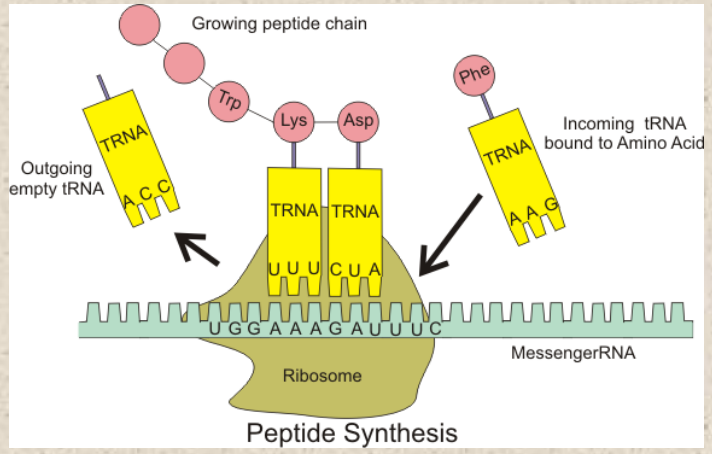
- Structural element of nucleic acids DNA and RNA
- Constituent of ATP (Adenosine Tri Phosphate), energy rich compound needed in metabolism
- Shoot growth decreases and flower initiation delayed under P deficiency
- Purplish margins under P deficiency is associated with starch accumulation in leaves

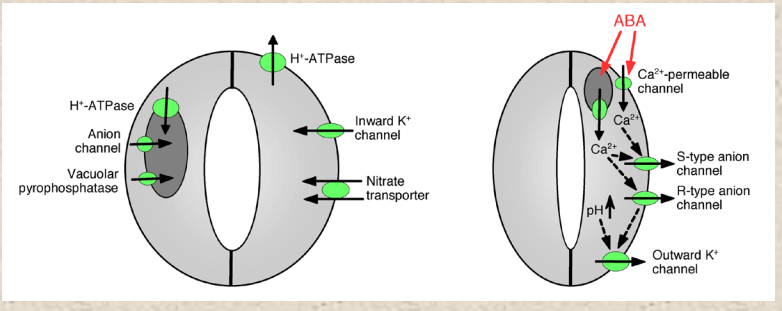


Phosphorus deficiency showing characteristic starch accumulation along margins

# Potassium

- Activates enzymes (ex: starch synthase)
- Involved in protein synthesis, binding of tRNA to ribosomes
- Stomatal regulation and photosynthesis
- Aides in sucrose loading in phloem transport



Potassium deficiency in tomato

## Calcium

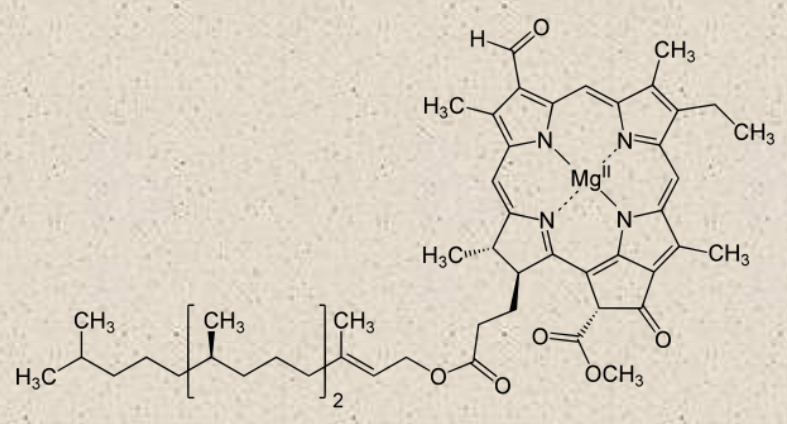
- Cell wall stabilization: Ca-pectate in middle lamella is essential for strengthening cell walls and tissues
- Membrane integrity: Ca deficiency results in leakage of solutes from cells
- Ca as secondary messenger: Calcium channels are activated in response to environmental and developmental signals
- Ca has poor transport through phloem. Fast growth rate sometimes causes imbalance in Ca leading to deficiency symptoms (tip burn in lettuce, blossom end rot in tomato)

Lettuce tip burn

Tomato blossom end rot

# Magnesium

- Central atom of the chlorophyll molecule
- Helps in activation of enzymes (PEP carboxylase, Glutathione synthase)
- Reduction in photosynthesis due to Mg deficiency




Chlorophyll

Magnesium deficiency-interveinal chlorosis

## Sulphur

- Constituent of amino acids cysteine and Methionine
- S deficiency affects chlorophyll concentration
- More uniform chlorosis is observed under S deficient conditions
- Shoot growth is inhibited when deficient

*Outdoor Ag: Industrial pollution leading to increase in $SO_2$ in atmosphere resulted in lower S requirement; however emissions are drastically decreased and S deficiency is becoming widespread*

Sulfur deficiency: uniform chlorosis

# Micronutrients

The name ‘micro’ does not mean that their importance is small, it means that they are required in small quantities.

Micronutrients are part of many enzymes and essential for metabolism

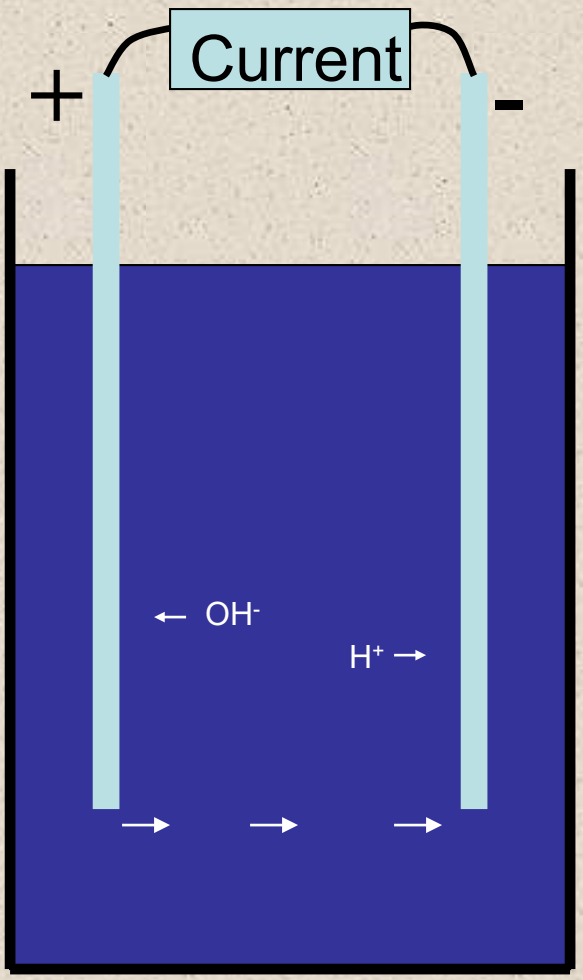
- Mn is an essential component of enzymes
- Fe is required for chlorophyll formation
- Mo is essential for N fixation (Nitrogenase complex)
- Cu is essential for protein and carbohydrate metabolism
- B facilitates translocation of sugars

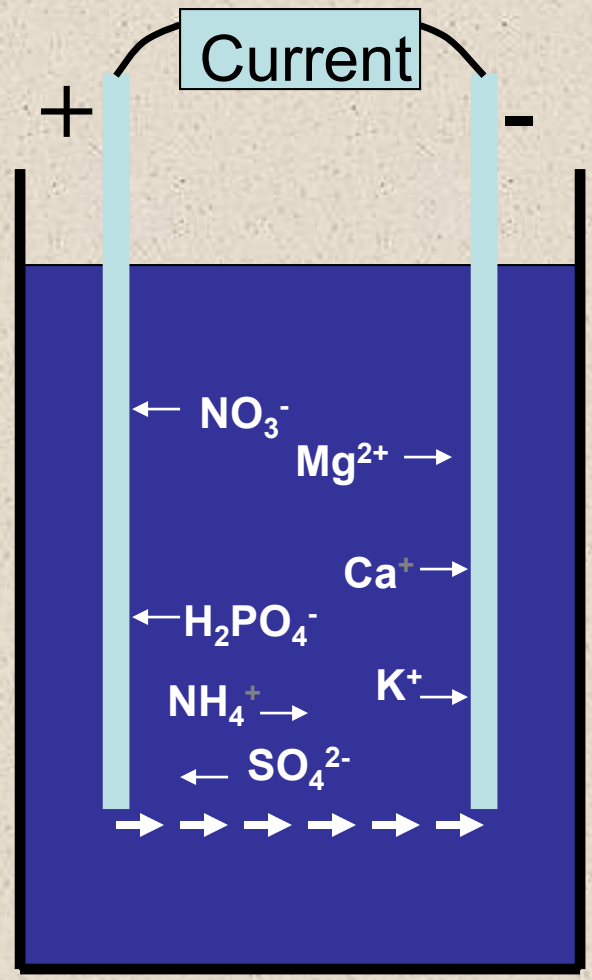
| **Fe level** | **Chlorophyll concentration (mg/cm$^2$)** |
|---|---|
| Optimum | >40 |
| Mild-deficiency | 20-40 |
| Severe deficiency | <20 |

Iron deficiency, note interveinal chlorosis of new leaves

# EC and pH

# Electrical Conductivity (EC)




Salts help conduct electricity

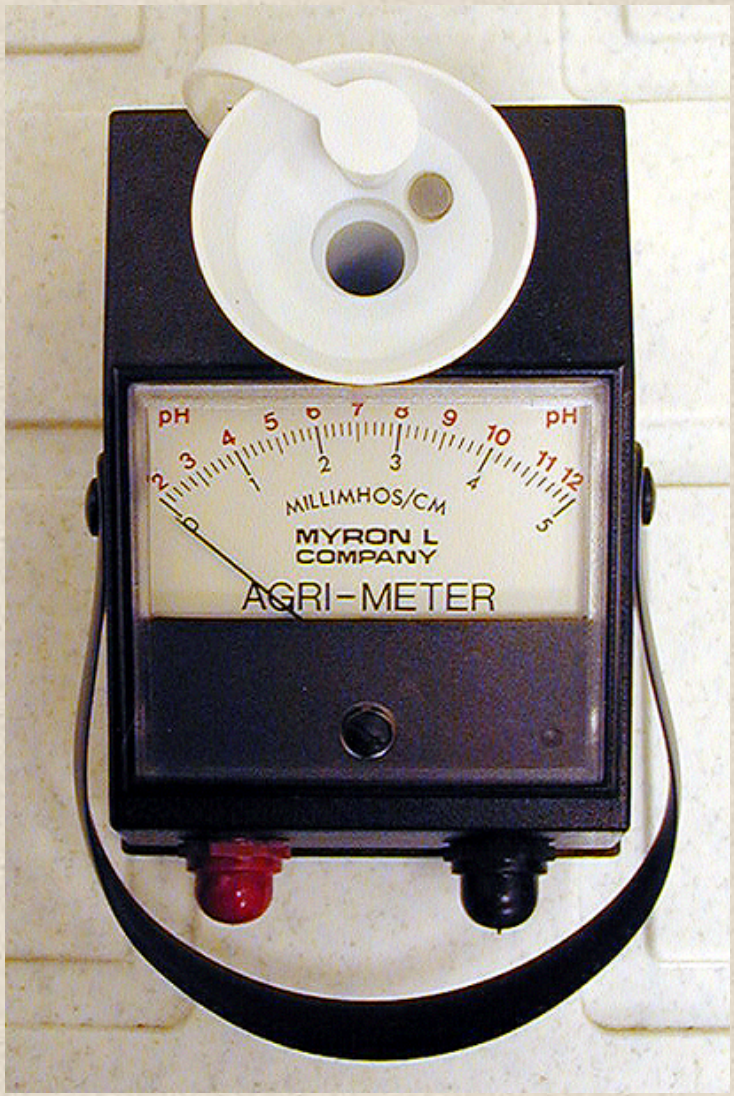
# Electrical Conductivity (EC)

- A measure of the total amounts of salts (fertilizer or non-fertilizer) in the growing medium or solution
- A high EC indicates the presence of a lot of salts (fertilizer)
- Good indicator of the amount of N, P, K, Ca, Mg, and S

# Electrical Conductivity Units

- Siemens (S) is used instead of Mhos
- 1mS/cm = 1 dS/m = 1,000 µS/cm

# Sensors for measuring electrical conductivity






# Calibration

- At least once a week.  If you don't calibrate your meters, there is no need to collect any samples either.

- You will get bad information and **will** make the wrong decisions.

# Fertilizer management of greenhouse plants

- Measure the concentration of fertilizer salts supplied to plants

what we give plants

- Measure fertilizer salts in the root zone of plants

what is available to plants

- Measure nutrients in the leaf / stem tissue

what ends up in the plant

# How to monitor Nutrition for greenhouse plants?

- Measure the concentration of fertilizer salts supplied to plants

what we give plants

- **Measure fertilizer salts in the root zone of plants**

**what is available to plants**

- Measure nutrients in the leaf / stem tissue

what ends up in the plant

# Concentration of fertilizer salts in the root zone (substrate EC)

Depends on :

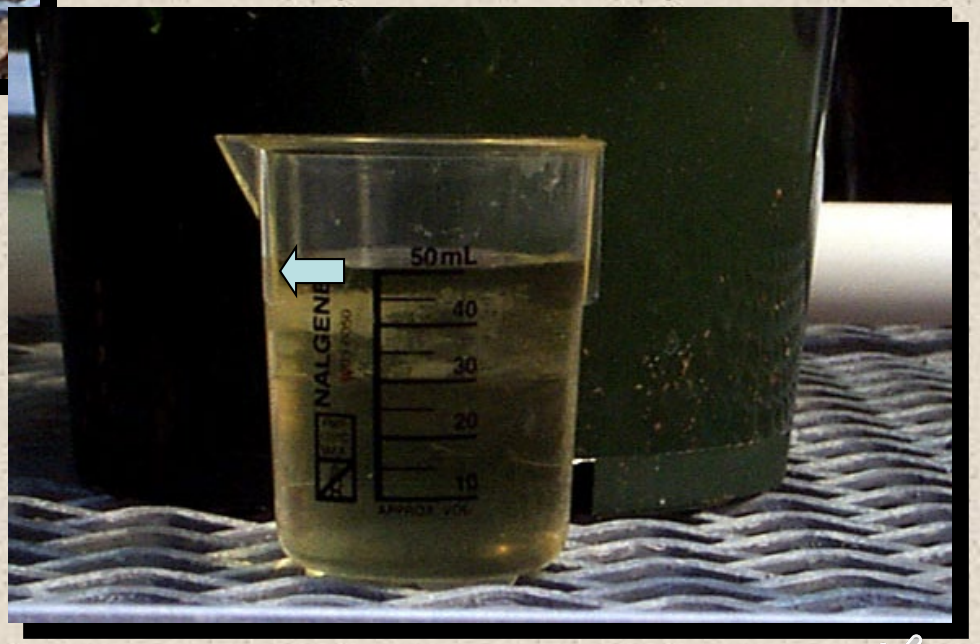
- Substrate composition
- Fertilizer applications
- Irrigation water quality
- Irrigation method (leaching)
- Crop nutrient uptake

# Pour-thru method

Irrigate plants and allow water to equilibrate in the substrate

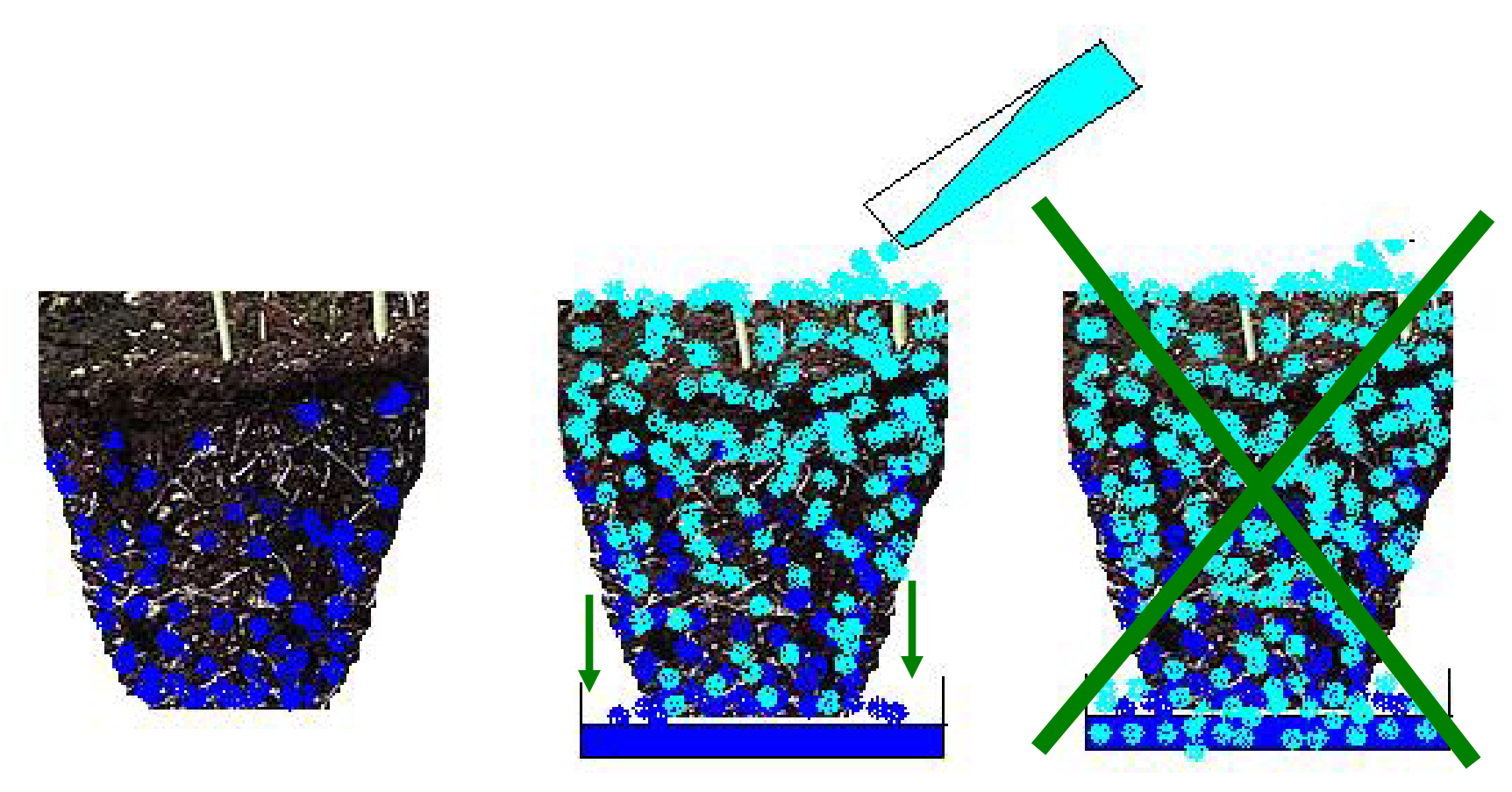
Place leachate collection cups at the bottom

# Add fertilizer water from the top of the substrate




Collect the leachate from the cups into a beaker

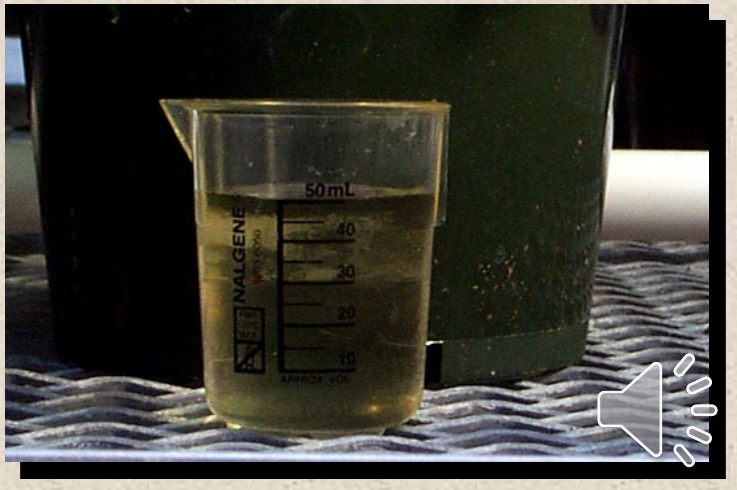
# Pour thru- do’s and don’ts



Too much water added

# Water Volumes for Pour-thru

| Pot Size | ml | oz |
|---|---|---|
| 4 inch | 75 | 2.5 |
| 5 inch | 75 | 2.5 |
| 6 inch | 75 | 2.5 |
| 6.5 inch | 100 | 3.5 |
| 1 Qt | 75 | 2.5 |
| 4 Qt | 150 | 5.0 |
| 12 Qt | 350 | 12.0 |



# Direct substrate EC measurement

**Hanna Soil EC meter**


**Field Scout soil EC meter**

# Growing medium analysis

## Greenhouse Report

**Soil, Plant and Water Laboratory**

| *Grower Information* | *Lab Information* | *County Information* |
|---|---|---|
| Client: | Completed: 02/08/2001<br>Printed: 02/08/2001 | |

**Results**

| Lab | | 21502 |
|---|---|---|
| Sample | | 1 |
| pHw | | 5.00 |
| SS | (mmhos) | 2.450 |
| Ca | (ppm) | 242.1 |
| K | (ppm) | 87.12 |
| Mg | (ppm) | 78.33 |
| NH4-N | (ppm) | 1.000 |
| NO3-N | (ppm) | 170.0 |
| P | (ppm) | 16.97 |

Laboratory methods:

- Saturated Media Extract method
- 1: 2 dilution method

# EC Comparisons in different methods

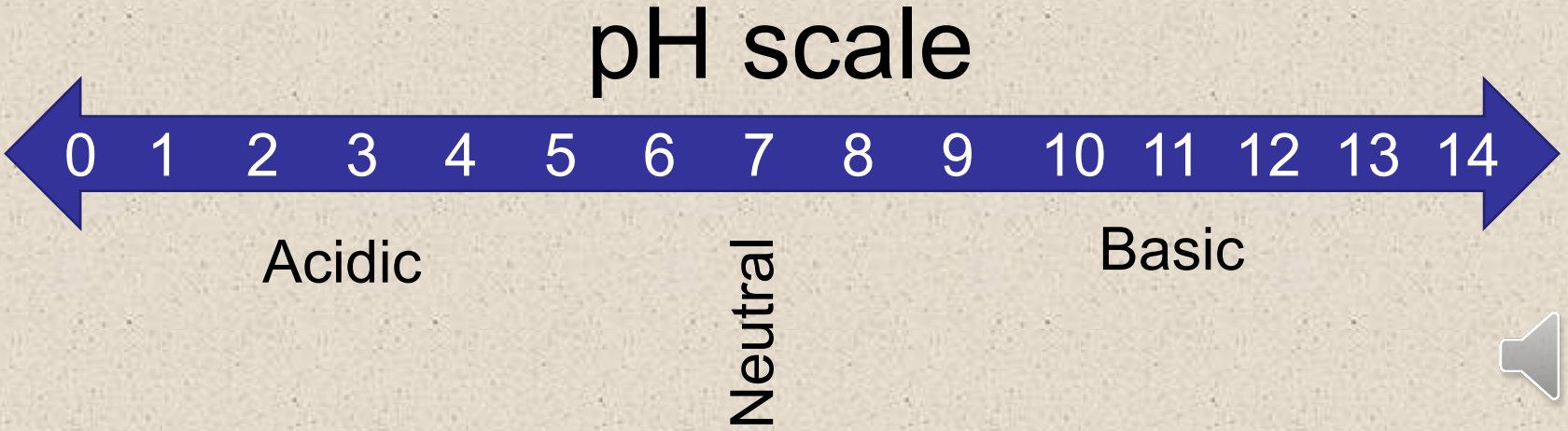
| 1:2 | SME | PourThru | Indication |
|---|---|---|---|
| 0 to 0.3 | 0 to 0.8 | 0 to 1.0 | Very Low |
| 0.3 to 0.8 | 0.8 to 2.0 | 1.0 to 2.6 | Low |
| 0.8 to 1.3 | 2.0 to 3.5 | 2.6 to 4.6 | Normal |
| 1.3 to 1.8 | 3.5 to 5.0 | 4.6 to 6.5 | High |
| 1.8 to 2.3 | 5.0 to 6.0 | 6.6 to 7.8 | Very High |
| > 2.3 | > 6.0 | > 7.8 | Extreme |

# General guidelines for monitoring substrate EC

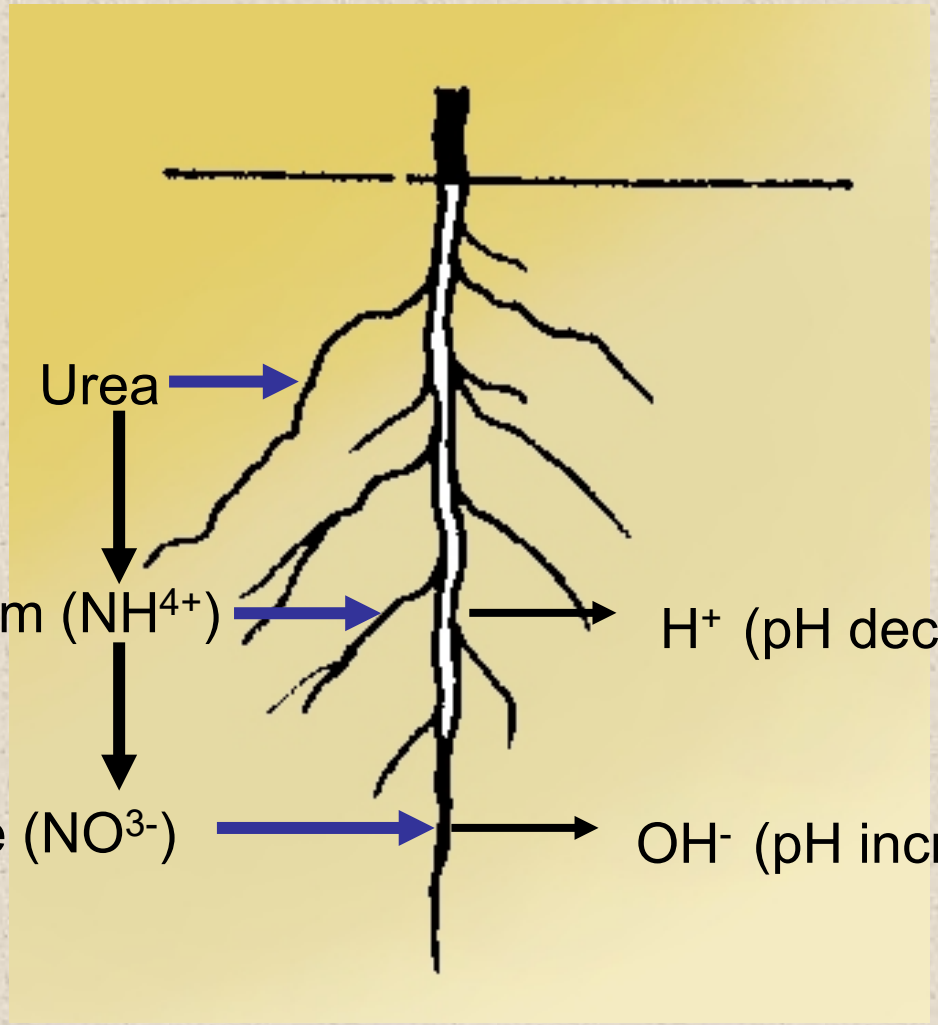
- Sample plants with different requirements separately
- Sample 5 pots or cell packs / 1000
- Randomly select plants
- Select plants from interior of bench
- Account for growth stages
  - establishment, active growth, and bloom

# pH or power of Hydrogen

- pH is negative logarithm of hydrogen or hydronium ion concentration (very confusing!!)
- Low and high pH terms are a bit tricky….low pH actually has high $H^+$ ions!!
- *A low pH of 1 has 10 times more hydrogen ions than pH of 2 and 100 times more hydrogen ions than a pH of 3*



# pH imbalances due to N forms



# Fertilizer effects on pH

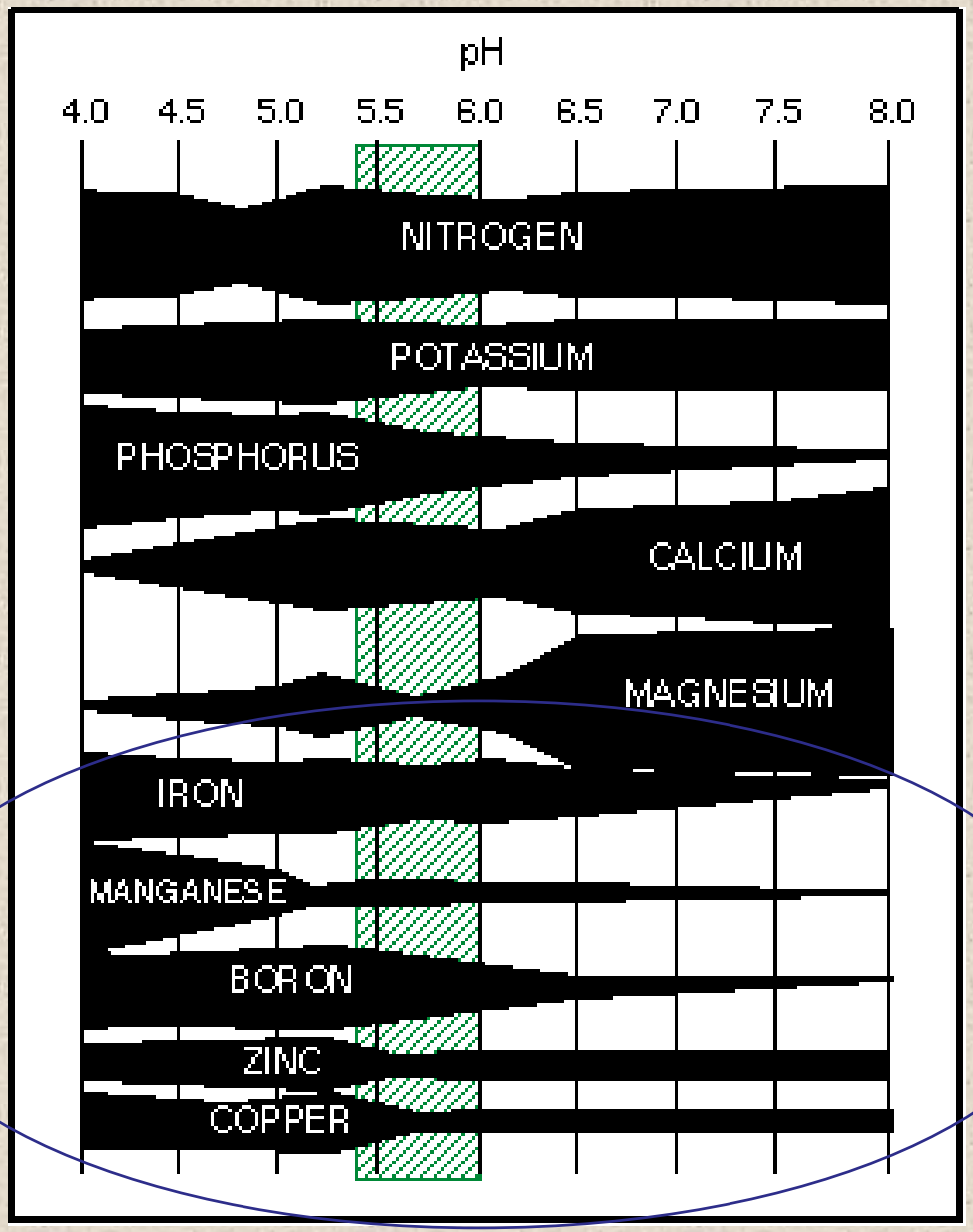
| Fertilizer | $NO_3$ | $NH_4$ [b] | Potential acidity [c] or basicity [d] |
|---|---|---|---|
| Ammonium sulfate | 0 | 100 | 2200 a |
| Urea | 0 | 100 | 1680 a |
| 21-7-7 acid | 0 | 100 | 1539 a |
| 21-7-7 acid | 0 | 100 | 1518 a |
| Diammonium phosphate | 0 | 100 | 1400 a |
| Ammonium nitrate | 51 | 49 | 1220 a |
| Monoammonium phosphate | 0 | 100 | 1120 a |
| 18-9-18 | 47.7 | 53.3 | 708 a |
| 20-20-20 | 27.5 | 72.5 | 532 a |
| 21-5-20 | 62.3 | 37.7 | 407 a |
| 20-10-20 | 59.5 | 40.5 | 404 a |
| 20-10-20 | 60 | 40 | 401 a |
| 21-5-20 | 60 | 40 | 390 a |
| 17-5-17 | 70.6 | 29.4 | 106 a |
| 20-0-20 | 54 | 46 | 0 |
| 15-0-20 | 76.7 | 23.3 | 38 b |
| 15-5-15 | 80 | 20 | 69 b |
| 15-5-15 | 78.7 | 21.3 | 131 b |
| 15-0-14 | 82.7 | 17.3 | 165 b |
| 15-0-15 | 86.7 | 13.3 | 221 b |
| 15-0-15 | 80.8 | 18.8 | 319 b |
| Calcium nitrate | 100 | 0 | 400 b |
| Potassium nitrate | 100 | 0 | 520 b |
| Sodium nitrate | 100 | 0 | 580 b |

Acidic

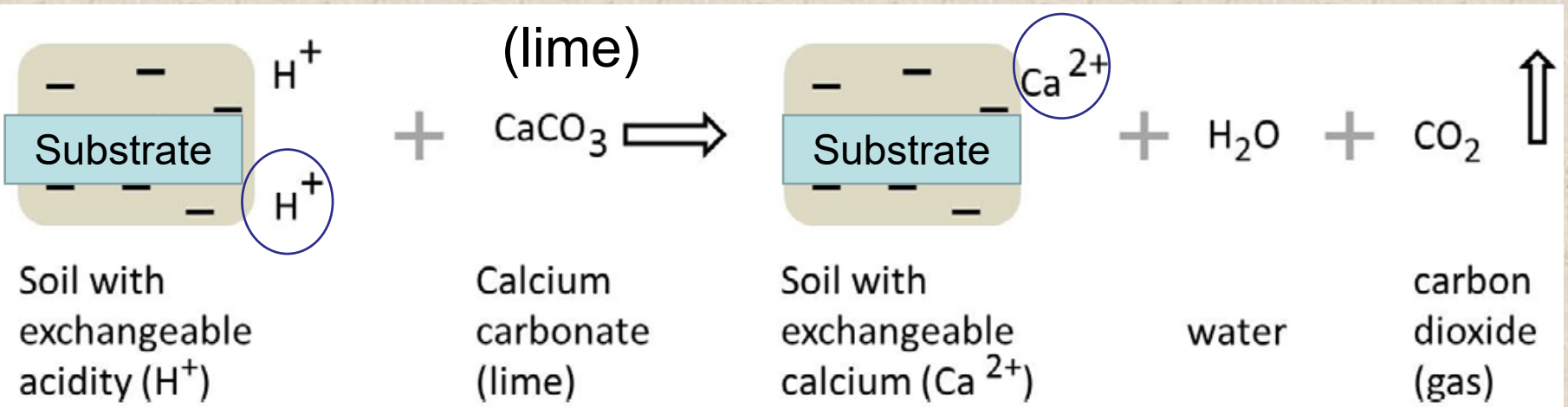
Neutral

Basic

# pH of the substrate and nutrient availability



# Lime for acidic substrates



# Alkalinity effects on pH management