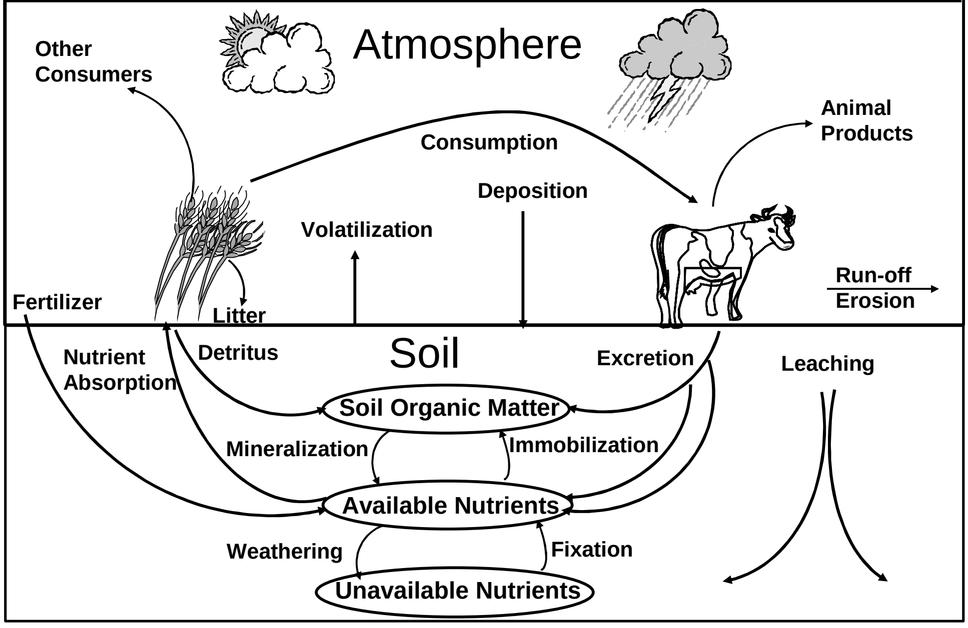
BIOL 695

FERTILIZER APPLICATION

CHAPTER 6
MENGEL et al, 5th Ed

NUTRIENT CYCLING



DECIDUOUS VERSUS CONIFER CYCLING

Nutritional Requirements Relatively High, esp for Ca, Mg

Therefore

Uptake is

Relatively High

MANY Nutrients Returned in Litterfall

DECIDUOUS

Over Time Soil Maintains Relatively High Nutrient Level Due To High Nutrient Cycling Resulting in Moderate Fertility, Moderate pH Soil

Nutritional Requirements Relatively Low, esp for Ca, Mg

Therefore

Uptake is Relatively Low

FEW Nutrients Returned in Litterfall

CONIFEROUS

Over Time Soil Loses Most Nutrients Due To Lack of Uptake and Nutrient Cycling Resulting in Low Fertility, Low pH Soil

DIRECT REASONS FOR NUTRIENT LOSS

- Excessive application
- Wrong time
- Wrong place
- Wrong material

INDIRECT REASONS FOR NUTRIENT LOSS

- Leaching
- Erosion
- Volatilization
- Denitrification
- Fixation by soil (lesser extent)

NUTRIENT REMOVAL BY CROPS

- Varies with crop type, species, portions harvested
- Grain: 70% N, 70% P, 25% K of total aerial portion in cereal crops
- "Improved species" gen increased uptake
- One ton dry matter, leaves & stems:
  20 kg N
  20 kg K
  2 kg P

NITROGEN REMOVAL EXAMPLE

- Data from San Joaquin Valley
  - Vegetables: 43%
  - Low density tree fruits & nuts: 19%
  - Grapes: 37%
  - N removal related to production
  - P & K recovered for several years, N recovery confined to year of application

NUTRIENT REMOVAL BY LEACHING

- Depends upon nutrient & soil type
  (What do we mean by soil type?)
- High leaching potential with high leaching rate
- Sand > silt loam, loam > clay
- N - lost during one year
- P,K - lost over several years
  P - becomes unavailable
- Ca, Mg - generally lime each 4-5 years

NUTRIENT REMOVAL BY LEACHING

- **Behavior controlled by physico-chemical processes:**

  P, K, Ca, Mg, S, micronutrients

- **Behavior controlled by (micro)biological processes:**

  N (NO_3^--N & NH_4^+-N)

- **Rate of loss by leaching:**
  $NO_3^- > Na^+ > Mg^{++} > Ca^{++} > K^+ >> XPO_4$

VOLATILIZATION AND DENITRIFICATION

- **N loss from soil via NH_3**

  $$NH_4^+ \Leftrightarrow NH_3 \Uparrow + H^+$$

  NH_2
  C = O $\Rightarrow$ **$2NH_3 \Uparrow + CO_2$**
  (urea) **NH_2** **(urease enzyme, warm T)**

- **NH_3 loss from leaves in grains, peas**

- **Denitrification: anaerobic conditions**
  - $NO_3^- \Rightarrow N_2 \Uparrow$ & $N_2O \Uparrow$
  - frequently flooded soils: use NH_4^+

SOIL EROSION

- Soil erosion is major problem in city, urban & rural landscapes
- Erosion rate is especially intense in city and urban areas
- Soil is major pollutant worldwide in surface streams
- Topsoil contains most of nutrients & OM
- Major mechanism for loss of soil P

HISTORICAL FOLIAR ABSORPTION

- Fe and S absorbed from smelting
- SO_2 from air pollution
- Occult precipitation from fog
  - S, N, Mg, Fe, Cu
- NH_3 from atmosphere

NUTRIENT SUPPLY BY PRECIPITATION AND FROM ATMOSPHERE

- Near oceans: Na^+ and Cl^-
- Widespread areas: S and N
  - S - may provide sufficient amounts for crops in many areas
  - Forms: H_2SO_4 & HNO_3
  - Soil acidification & plant effects

MINERAL FERTILIZERS

- Most rapidly available forms of nutrients
- Simple salts or treated forms of salts
  KCl, $Ca(NO_3)$, KNO_3
  superphosphate (rock phos + H_2SO_4)
- Analysis: N - K_2O - P_2O_5 i.e., 10-10-10
- Generally wish to decrease solubility of N and increase solubility of P forms

PREVENT LOSS OF NITROGEN

- **Treated fertilizer to reduce potential loss (SLOW RELEASE FERTILIZER)**
- **Control of biol popul responsible for nitrification. Nitrapyrin treatment**
  - **Nitrosomonas**
  - **Nitrobacter**
- **Multiple applications throughout growing season**

SLOW RELEASE ACCOMPLISHED

- **Low soluble material**
  - $Mg(NH_4)_2PO_4$
  - **Isobutylidene diurea**
- **Coating such as**
  - **Plastic polymers**
  - **Sulphur**

ADVANTAGES OF CONTROLLED RELEASE

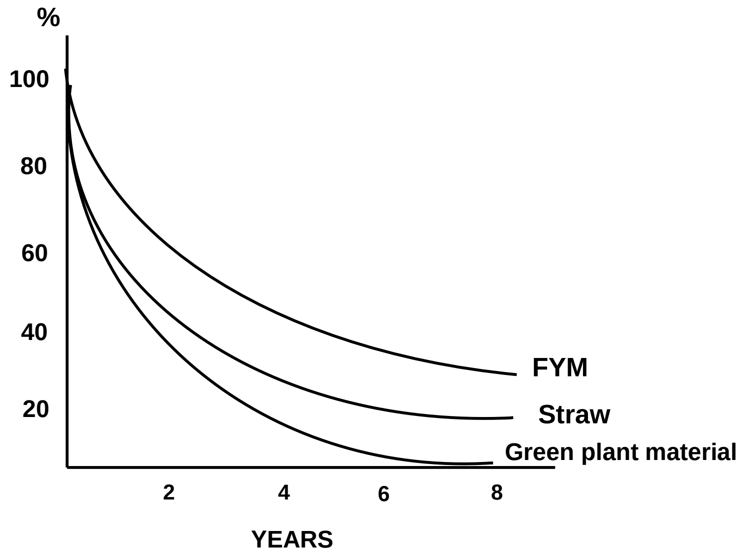
- Efficient - released over long time
- Decreased leaching because availability attuned to plant need.
- Toxicity risk less. Lack of burning from large application.
- Long lasting constant supply

MANURES AND CROP RESIDUES

"organic"	%N-P-K	Availability
cow manure	2-3-3	rapid
chicken manure	2-2-2	rapid (can burn)
compost	1-1-1	slow
bone meal	1-15-1	slow
biosolids	3-2-2	moderate

Many of these are applied as slurries which have highly variable solids (& nutrient) content

RATES OF DECOMPOSITION



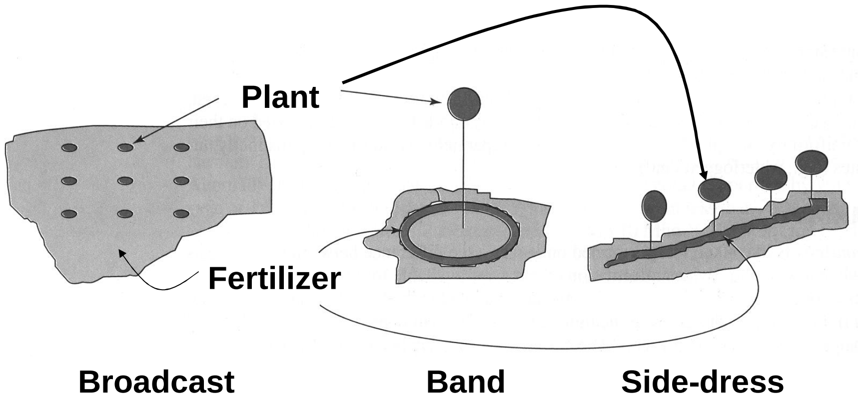
LIQUID FERTILIZERS

- Aqueous NH_3 (NH_4OH) ˜y25% N
- Anhydrous NH_3 - not really a liquid
- Liquid urea, NH_4NO_3 solutions
- Urea+ NH_3+ NH_4NO_3 - 30% N
- N-P solutions
    - superphosphoric acid + NH_4OH
    - 8-24-0
- N-P-K solutions - only low analysis
- Other Soluble mixtures - low analysis

INORGANIC MINERAL FERTILIZERS - APPLICATION

- Dry
  - Broadcast
  - Banding
  - Side-dressing
- Liquid
  - Via irrigation lines
    - Fertigation, Chemigation
  - Foliar spray - concentrations more critical

INORGANIC MINERAL FERTILIZERS - APPLICATION



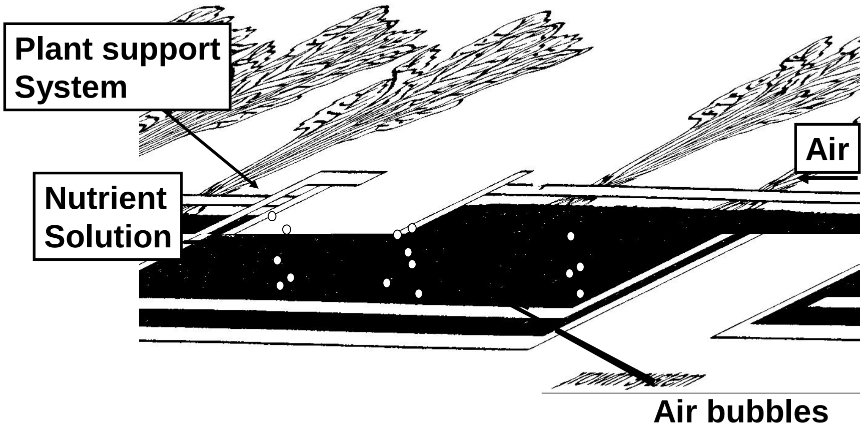
HYDROPONIC SOILESS CULTIVATION

- Demonstrated in early 19 th century
- Best known nutrient solution is Hoagland's (Hoagland & Arnon, 1950)
- No buffering in solutions, need higher conc's of nutrients
- nutrient concentrations change rapidly
- pH fluctuations can be especially rapid & significant

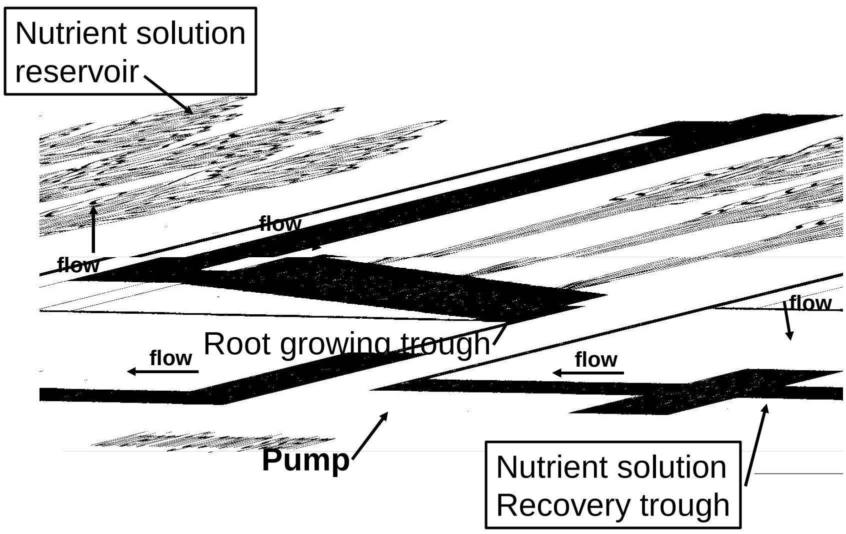
HYDROPONICS SOILESS CULTIVATION

- need to change solutions often or have large volume per plant
- generally need to provide aeration
- used for high value fruits, vegetables & ornamentals
- substrates such as gravel, rockwool & sand may be used
- technique has greatest use in Europe

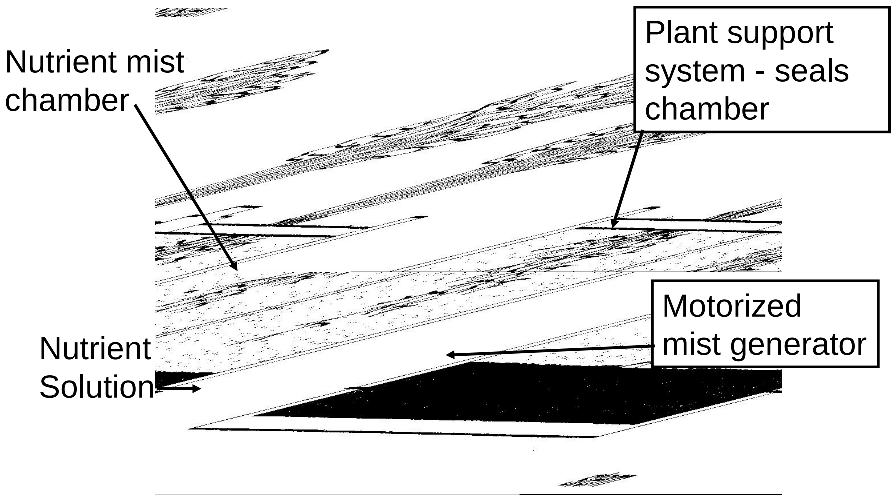
HYDROPONIC: NON-RECIRCULATING



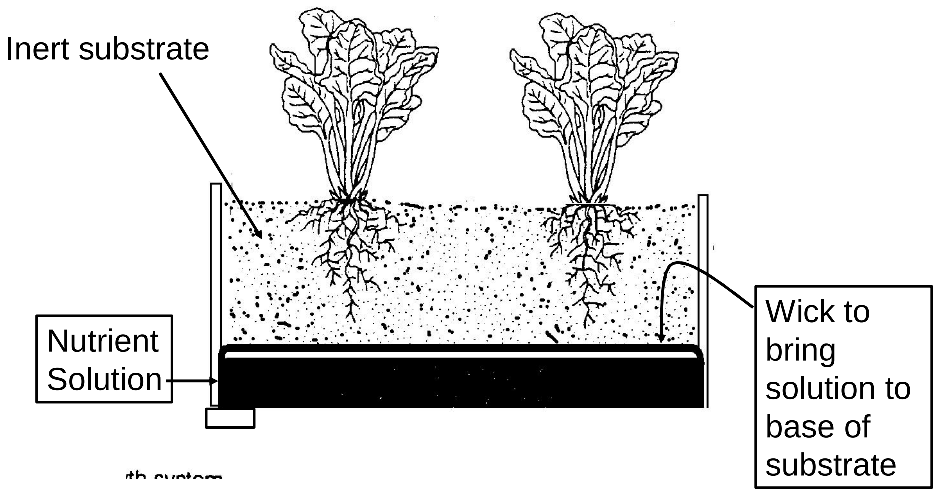
HYDROPONIC:RECIRCULATING NUTRIENT FILM



Hydroponic: aeroponics



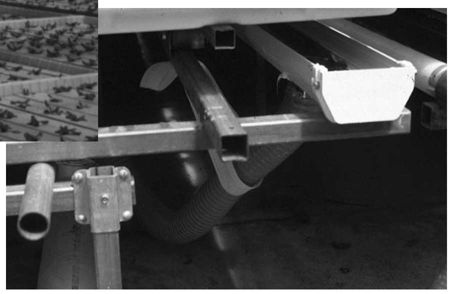
Hydroponic: substrate culture



Commercial Hydroponics: Nutrient Film Technique

Lettuce

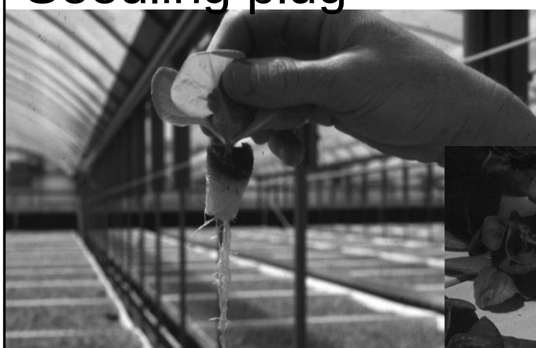
Trough catches
Nutrient solution



Growing trays

Commercial Hydroponics

Seedling plug



First root growth

Commercial Hydroponics

Crop nearly ready for harvest

Commercial Hydroponics

Root systems

Harvest time!

RECOMMENDED N FORMS FOR FERTIGATION

- NH_4NO_3
- $(NH_4)_2SO_4$
- UAN
- Urea
- Not recommended
  - NH_3 and Aqua Ammonia
  - Ammonium Phosphate

P FORMS FOR FERTIGATION

- Inorganic P
  - H_3PO_4 but soil application is less expensive
- Organic P

K FORMS FOR FERTIGATION

- KCl (Muriate of potash)
- KNO_3
- K_2SO_4

MICRONUTRIENTS-FERTIGATION

- **pH 5 - 6**
  - **EDTA**
- **pH 7.5 - 8.5**
  - **EDDHA**
- **Sulfate salts**

CHEMICAL INJECTOR SYSTEMS

- **Differential pressure systems**
  - **Venturi**
- **Positive Pressure pump**
- **Vacuum type injector**
- **Gravity feed injector**

FOLIAR APPLICATION

- Absorption - BIG PROBLEM
- 1/3 of Plant Kingdom
- Two phase environment
  - Roots absorb nutrients
  - Leaves fix CO_2
- Evolution - Roots ability to fix CO_2
  - Leaves retained solute absorb. ability
  - Basis of foliar fertilization

FOLIAR APPLICATION - 2

LEAF STRUCTURE & COMPONENTS:

- Cuticle
- Covers entire surface of leaf
  - Noncellular
    - Outer most layer
      - Long chain fatty acids & wax
    - Second layer
      - Cellulose + cutin & wax

FOLIAR APPLICATION - 3

INNER STOMATAL CAVITY:

- **Cuticular membrane is thinner than outer surfaces**
  - **Gas exchange rapid thru stomates**

FOLIAR APPLICATION - 4

CUTICLE DEVELOPMENT:

- **Continuous deposition epi-cut wax**
  - **During growth of leaves**
  - **Stops with cessation of growth**
- **Thus cuticle**
  - **Hydrophilic in early growth stage**
  - **Hydrophobic with maturity**

FOLIAR APPLICATION - 5

CUTIN LAYER:

- **Below epicuticular wax**
  - **More hydrophilic**
    - **Thus pathways for minerals**
    - **Water goes through**
      - **Foliar absorption**
      - **Foliar transpiration**

FOLIAR APPLICATION - 6

PORES THROUGH CUTICLE:

- **Diameter < 1 nm**
- **Density 10^{10} pores cm^{-2}**
- **Permeable to urea**
  - **But not FeEDTA WHY?**

FOLIAR APPLICATION - 7

UPTAKE THROUGH STOMATES:

- **Sites for exchange of gases**
- **Number of stomates**
  - **Succulents 20 mm^{-2}**
  - **Annuals 100 - 200 "**
  - **Trees 800 "**
- **More abundant on abaxial surface**

FOLIAR APPLICATION - 8

ION UPTAKE BY LEAVES:

- **Most rapid**
  - **Uncharged molecules like urea**
- **Next**
  - **Cations**
- **Slowest**
  - **Anions**
- **No differences at high foliar conc. of N from urea, ammonia, or nitrate**

Positive Correlation Between Number of Stomata & Uptake

- Larger # of pores around stomates and trichomes
  - Also pores have diff permeability
  - Maybe chelate uptake

Unlikely That Solutes Enter Through Open Stomates

- Internal cuticle covers surface of internal cavity
- Ion uptake higher at night when stomates are closed.

UPTAKE BY LEAF CELLS

- Analogous to root cells: Leaf disc studies
  - K, Na, Rb, Fe, Mn, PO_4, Cl uptake
    - –Inhibited by metabolic inhib.
    - –Increased by light
      - »ACTIVE or PASSIVE?
- Root & leaf cell protoplasts = same

SURFACTANTS

- Reduce surface tension -
  - – more contact = more absorption
  - – Except in arid areas
- Stein adjuvants
  - – Glycerol & propylene glycol
- pH also important - optimal pH varies with species and with chemical

RECOMMENDED NUTRIENT RATIOS

See Handout from U Mass - PLSOIL 120

Fertilizer Use & Agriculture Production

- Increased production has depleted soil nutrient reservoirs
- Need increasing amounts of fertilizer for maintaining or increasing prod'n
- Need to increase utilization efficiency
  - Economic & Environment
- Fertilizer use rate in US ranks 8th in world
- What is greatest challenge
  - fertilizer management
  - more efficient crop species

FERTILIZER APPLICATION & ENERGY CONSUMPTION

Table 6.22 Energy output/input ratio of crop and animal products (edible outputs)

FERTILIZER APPLICATION & ENERGY CONSUMPTION

- **In USA, 1 person produces food for 50 others**
- **In UK, agriculture uses 4% of total energy consumption**
- **Crop production is one of few production processes with pos. energy balance**
- **Some plant species are suitable for “energy harvesting” - eucalyptus trees, hybiscus shrubs, Napier grass, sugar cane, cassava**
- **Euphorbiaceae spp contain latex**

DRINKING WATER & FERTILIZERS

- **Major problem is from nitrate - methaemoglobinemia (Ch 5 notes)**
- **Limits in drinking water:**
  WHO - 50 - 100 ppm
  EEC - 50 ppm
  US Publ Health Serv. - 45 ppm
- **Leaching losses about 5-10% of applied**

EUTROPHICATION & FERTILIZERS

- **Eutrophication is natural process, esp in closed water bodies**
- **Eutrophic lake - "good food" - rel shallow, rich in OM & nutrients, very productive, little O_2**
- **Oligotrophic lake - "few food" gen. deeper, steeper sided, narrow littoral zone, poor in nutrients, esp. P, Ca, N**

EUTROPHICATION & FERTILIZERS

- Deep anaerobic zones - little circulation or mixing, high prod'n of algae, etc. at surface provides much OM to anaerobic zone (upper Ches. Bay)
- Productivity limiting factor - very often P
  - P reaches surface waters via erosion
  - P from detergents, urban waste has decreased
- N - leaching of NO_3 can be sig source
- POTWs are sig. source of N & P (improving)

EUTROPHICATION & FERTILIZERS

Some farms, nurseries and golf courses:

- Have surface impoundments to retain surface runoff
- Utilize water hyacinths to reduce nutrient content of water prior to discharge (VA Tech Hort Station Research Project - Laurie Fox)

INORGANIC & ORGANIC FERTILIZERS

- **Plants take up inorganic forms of N, P, K, S, etc. regardless of initial form**
- **Major difference in organic & inorganic sources is availability rate**
- **Organic fertilizer availability depends upon metabolic activities of soil organisms, this depends upon soil conditions, T etc**
- **Some organic sources may release most N late in season (rem Ch 5)**

INORGANIC & ORGANIC FERTILIZERS

- **OM influence on soil properties is important**
- **Plant growth is most important source of soil OM**
- **Need high rates of fertilization for opt. prod'n**
  - **organic sources rarely provide enough**
  - **application rate of some organics limited by N content (biosolids, manures)**
- **Need wise management of all fertilizer use**

SUPPLEMENTING NUTRIENTS

- **In most soils, only N, P, K are added**
- **In greenhouse mixes (completely artificial media without any soil) complex mixtures of many nutrients are added**
- **In hydroponics (water culture) all essential elements must be provided**

CHANGING NUTRIENT AVAILABILITY

- **How much nutrient is in the soil ?**
  - **How change? - add fertilizer**
- **Soil pH (acidity vs. alkalinity)**
  - **How change? - add lime (Ca & Mg) or sulfur**
- **How much organic matter is in soil ?**
  - **How change? - add O. M.**