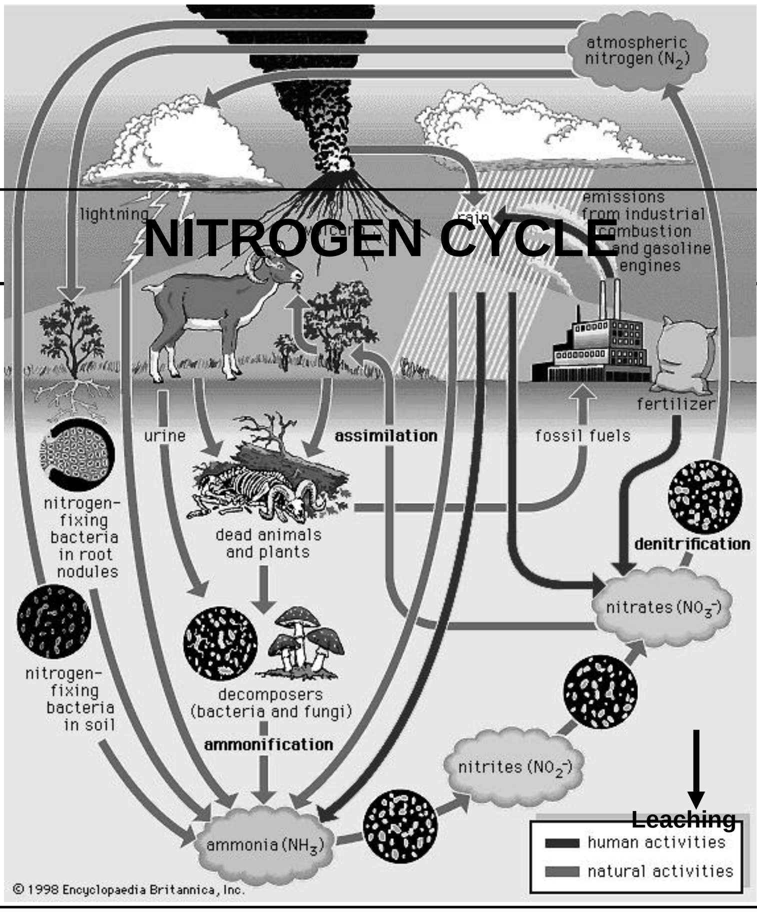
BIOL 695

NITROGEN

Chapter 7
MENGEL et al, 5th Ed

NITROGEN CYCLE



INDUSTRIAL N FIXATION

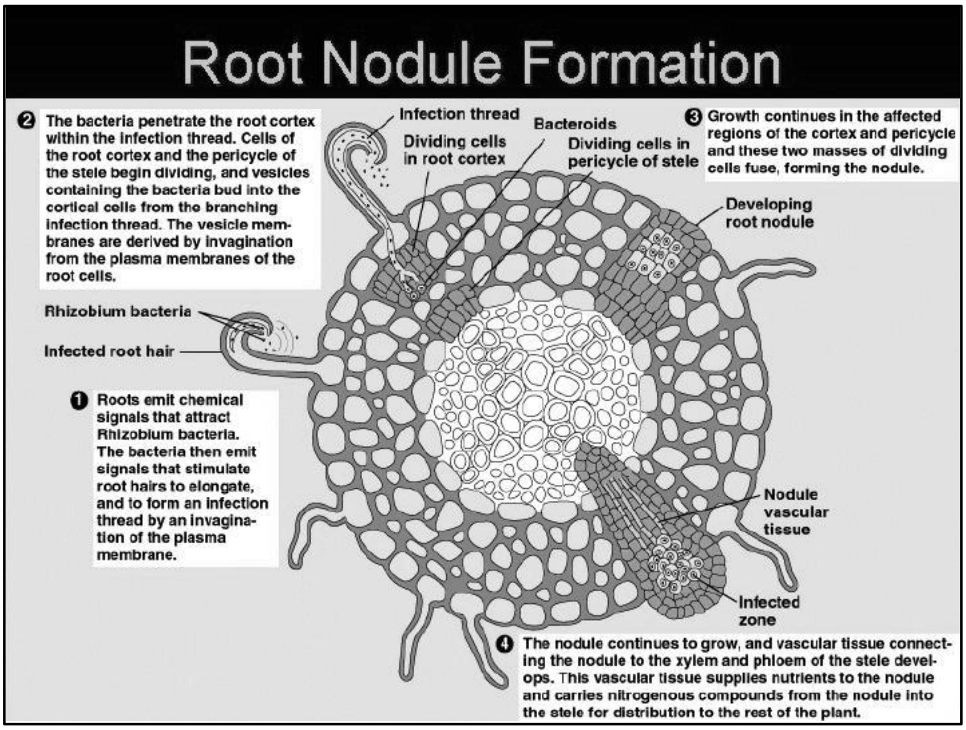
- High energy requirement
  - Haber-Bosch Process
    - Natural gas -
      - High Temperature & pressure
      - $N_2 + 3H_2 \Rightarrow 2 NH_3$

BIOLOGICAL N FIXATION

- Alternative process - saves fossil fuel
- 11 of 47 bacteria families can fix N
  - Eubacteria is significant one.
- Can provide N source for other crops
  - simultaneous
  - sequential

BIOLOGICAL N FIXATION

- Symbiotic Systems:
- Highest fixation capabilities
  - Because plant provides energy
  - Exports red’d N to leaves
  - Rapid transl from bacteria to plant
- *Protobacteria rhizobia*
- *Rhizobium* - fast growing (Legumes)
- *Bradyrhizobium* - slow growing



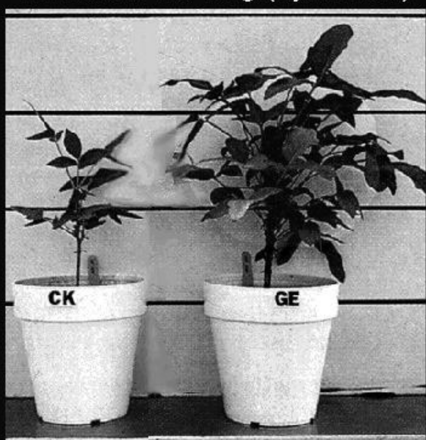
ROOT NODULES

BENEFITS OF RHIZOBIA

Some Fungi are good for the plants: providing nitrogen; or allowing phosphorus uptake

With and without Rhizobia (N-fixing bacteria)

Without and with fungi (Mycorrhizae)



AMMONIFICATION

- Proteolysis - release of amino-N from OM

Soil Org N $\rightarrow$ $RNH_2 + CO_2$ + Add'nl Prod + E

- Ammonification:
  - reduction of amino-N to NH_3

$$RNH_2 + H_2O \rightarrow NH_3 + ROH + E$$

NITRIFICATION

- Biological oxidation of ammonia to nitrate
- A two-step process
- *Nitrosolobus*:

$$2\ NH_4^+ + 3\ O_2 \rightarrow 2\ HNO_2 + 2\ H^+ + 2\ H_2O$$

- *Nitrobacter*:

$$2\ HNO_2 + O_2 \rightarrow 2\ NO_3^- + 2\ H^+$$

Wow!

Net: $2\ NH_4^+ + 4\ O_2 \rightarrow 2\ NO_3^- + 4\ H^+ + 2\ H_2O$

NITRIFICATION

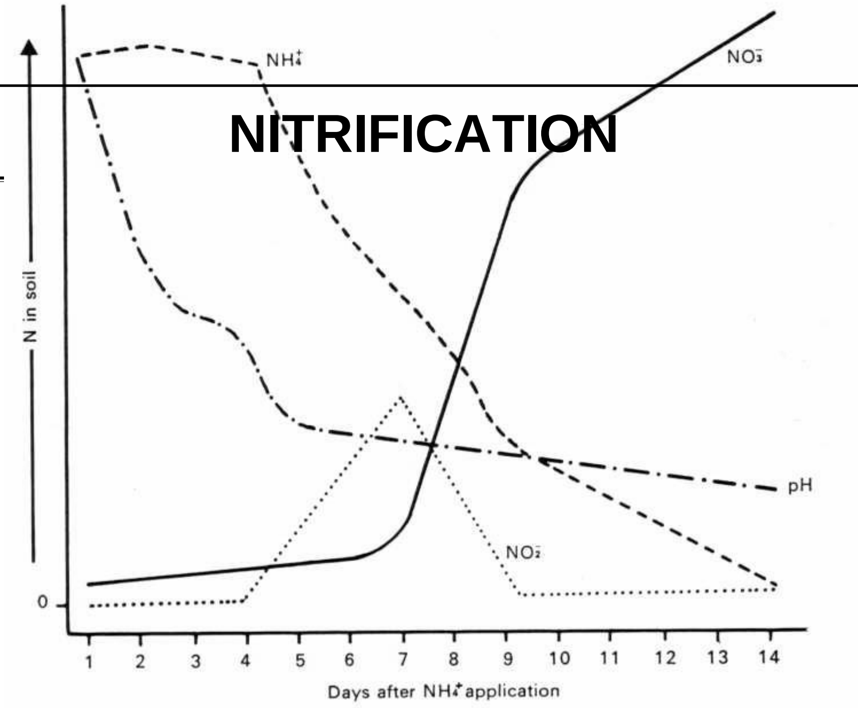


Fig 7.5 Relationship between microbial NH_4^+ oxidation, nitrate formation and soil pH (after DUISBERG and BUEHRER [1954]).

DENITRIFICATION

- $NO_3^- \rightarrow NO_2^- \rightarrow NO \uparrow \rightarrow N_2O \uparrow \rightarrow N_2 \uparrow$
- **Denitrifying bacteria utilize NO_3^- in absence of O_2**
- **Losses can be significant**
  - **promoted by high soil moisture, neutral soil pH, high soil T, low rate of O_2 diffusion, soluble OM, NO_3^-**

NITRIFICATION INHIBITORS

- $NH_4^+ \Rightarrow NO_2^-$ by *Nitrosomonas*, *Nitrosocystus* & *Nitrosospira*
- Add inhibitor to prevent nitrification and avoid major NO_3^- losses
- Nitrapyrin: (2-chloro-6-[trichloromethyl] pyridine)
- Apply in Fall along with NH_4^+ (NH_3) fert
- Variable results with different soils, climates

AMMONIUM FIXATION

- NH_4^+ fixed by soil clays $\Rightarrow$ immobile
- Similar to K^+ fixation by soil clays
- Vermiculite (soil clay) has high fixing cap.
  -other 2:1 clays will fix K^+
- NH_4^+ is initially fixed, later available to plants
- Leaching loss of NH_4^+ 100X < NO_3^-

NITROGEN IN THE SOIL SOLUTION

- May fluctuate rapidly with time & space in soil
- Influenced by temperature & moisture
- Mostly NO_3^- in the soil solution
- Highest concentrations in absence of plants

NITROGEN IN PHYSIOLOGY

- NH_4^+ versus NO_3^- nutrition
- Rhizosphere pH
- Nitrate reduction in cells
- Transport of N-forms
- Energy of N reduction

NH_4^+ vs NO_3^- NUTRITION

- Calcifuges adapted to low soil redox potentials prefer ammonium fertilizer
- Calcicoles preferentially utilize nitrate fertilizer
- However, better to use both
  - NO_3^- & NH_4^+ comprise 80% of ions taken up by plants

NH_4^+ vs NO_3^- NUTRITION

- Strong impact
  - On other cations & anions
  - Cellular pH
  - Rhizosphere pH
    - more acid:

      $3\ NH_4^+ \Rightarrow 3RNH_2 + 4\ H^+$
    - or more alkaline:

      $3\ NO_3^- \Rightarrow 3RNH_2 + 2OH^-$

NITRATE REDUCTION IN CELLS

- NO_3^- + 8 H^+ 8 e^- $\Rightarrow$ NH_3 + $2H_2O$ + OH^-
- Mediated by 2 enzymes
- Diuron effective herbicide
  - inhibits NO_2^- reductase (NiR)
- Both nitrite & nitrate reductase
  - in mesophyll cells of C_4 plants
  - absent in bundle sheath cells

LOCALIZATION

- Most nitrate reduction may occur in roots
- Low nitrate cond - reduction in roots
- Nitrate uptake increases & nitrate conc in xylem increases
- K^+ can accompany NO_3^- & increase nitrate transl in xylem
- Ca & Na inc nitrate reduction in roots

SPECIES DIFFER

- **Temperate perennials reduce nitrate in roots**
- **Tropical perennials & annuals reduce nitrate in shoots**
- **Root reduction is expensive**
  - **No PS to relieve energy drain**

ENERGY REQUIREMENT

- **Red'n 1 mol NO_3^- costs 15 mol ATP**
- **Red'n 1 mol NH_4^+ costs 5 mol ATP**
- **Nitrate red'n in roots req 23% of root respiration**
- **Ammonia red'n req'd only 14% of root respiration**
- **Low light comp betw CO_2 & NO_3 red'n**
- **High light comp may relieve stress**

NITROGEN FRACTIONS IN PLANTS

- Inorganic N ⇒ low MW org compounds
  ⇒ macromolecular org N compounds

- Amino acids (~ 5%)
  ⇒ proteins (80-85%)
  & nucleic acids (10%)

- Common compounds:
  glutamate, glutamine, aspartate

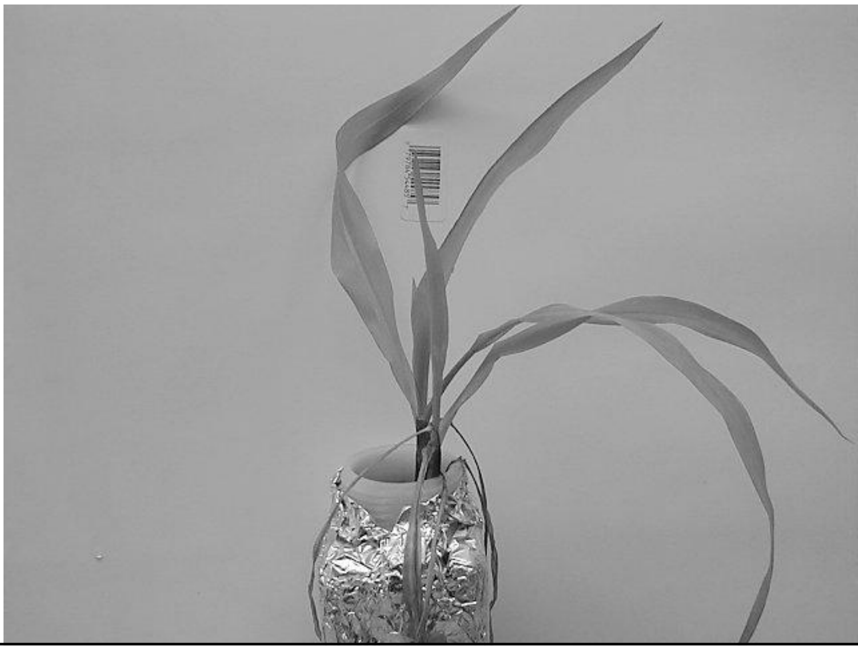
TRANSLOCATION

- Root to shoot through xylem
- NH_4^+ assimilation in roots, translocated as amino acids
- NO_3^- assimil in roots or transl as NO_3^-, depending on species
- N_2-fixing legumes, major transp products are asparagine, ureides, allantoin, allantoic acid

NITROGEN DEFICIENCY SYMPTOMS

- General loss of chlorophyll & disturbance of chloroplast development
- Yellowing of leaves begins with older
- All parts of leaves gradually turn yellow
- Yield is very low if any
- Veg. growth stage may be shortened
- Severe def. gives late stage necrosis

N DEFFICIENCY - CORN



N DEFFICIENCY

Tomato

Ponsettia

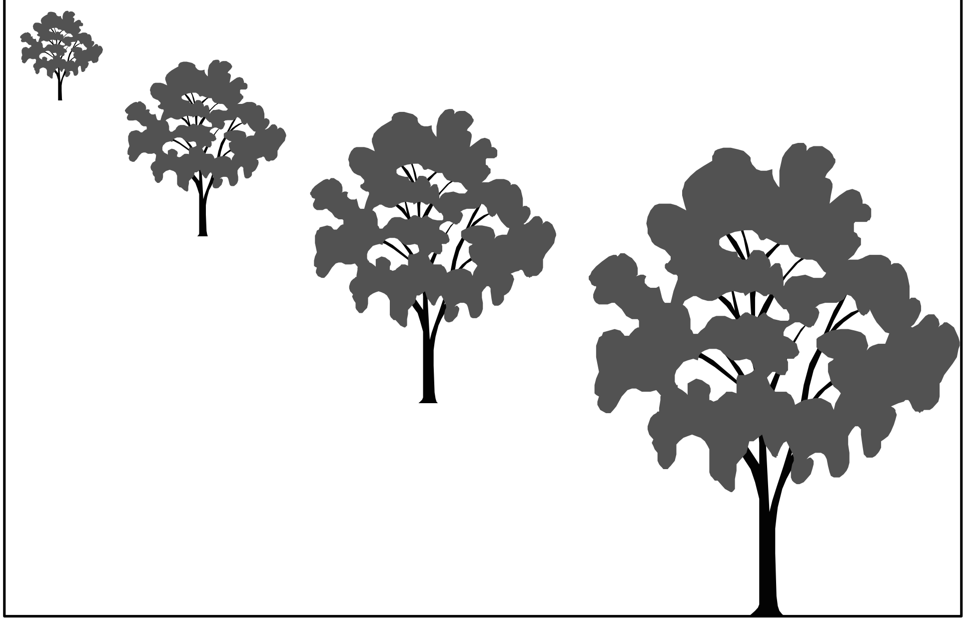
N DEFFICIENCY

Normal

Deficient

Sugar beet

RESPONSE TO N APPLICATION



RESPONSE TO N APPLICATION

- Different soil types - sandy, clayey, high OM
- Different crop requirements (physiology) (different cultivars)
- N appl'n rate compared with P & K rates
- Efficiency calculations, p. 428, note these
- Want some way to compare applied N to uptake amount versus losses

N FERTILIZER APPLICATION RATES

- Depends on plant species & previous soil condition
- Guided by actual uptake amounts
- N from soil OM may allow reduced application
- Some added OM may increase N immobilization (straw)
- Careful not to over-fertilize legumes

MAJOR N FERTILIZERS

- Anhydrous Ammonia (NH_3) (82%N)
- Ammonium Nitrate 34%N
- Urea 46% N
- $(NH_4)_2SO_4$ 21% N 24%S
- $NaNO_3$ 16.9 % N (Alkaline residue)
- $Ca(NO_3)_2$ 15.5 % N (Alkaline residue)
- Urea & NH_4NO_3 solns 28-32% N