V. NITROGEN

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Outline

- 5.1 Introduction
- 5.2 N cycles
- 5.3 Functions & Forms of N in Plants
- 5.4 Soil N resources
- 5.5 Soil N availability
- 5.6 Agronomic role of N
- 5.7 Nitrogen Management

5.1 INTRODUCTION

- Nitrogen is macro nutrient (essential and required in high amount)
- Nitrogen in soil as limiting factor for high crop productivity.
- Productivity of many ecosystems (managed & unmanaged) is limited by nitrogen availability:
- So, N prequently added as fertilizer
- Consequences : Eutropication, GHG, etc.
- How to manage N?

5.2 NITROGEN CYCLE

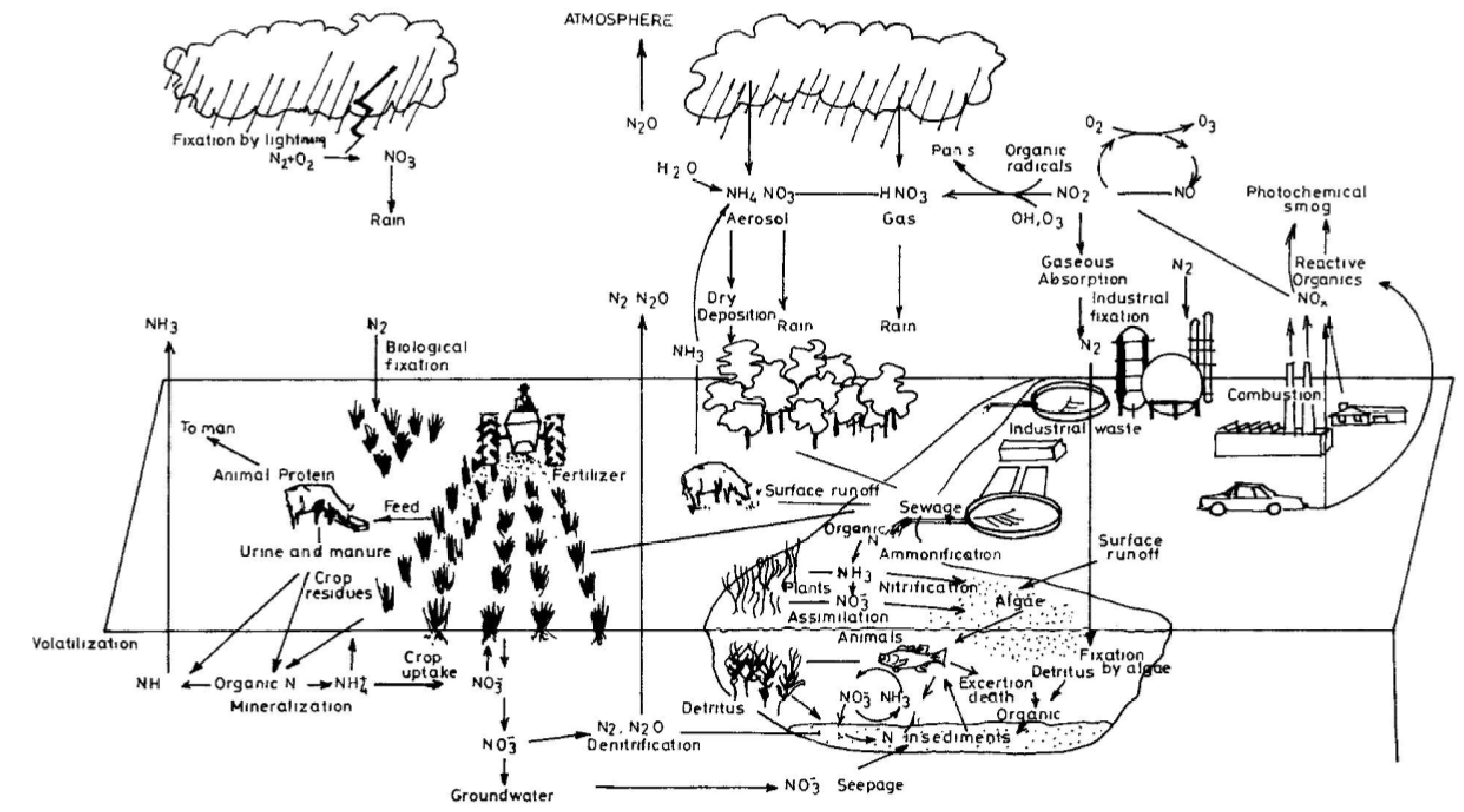
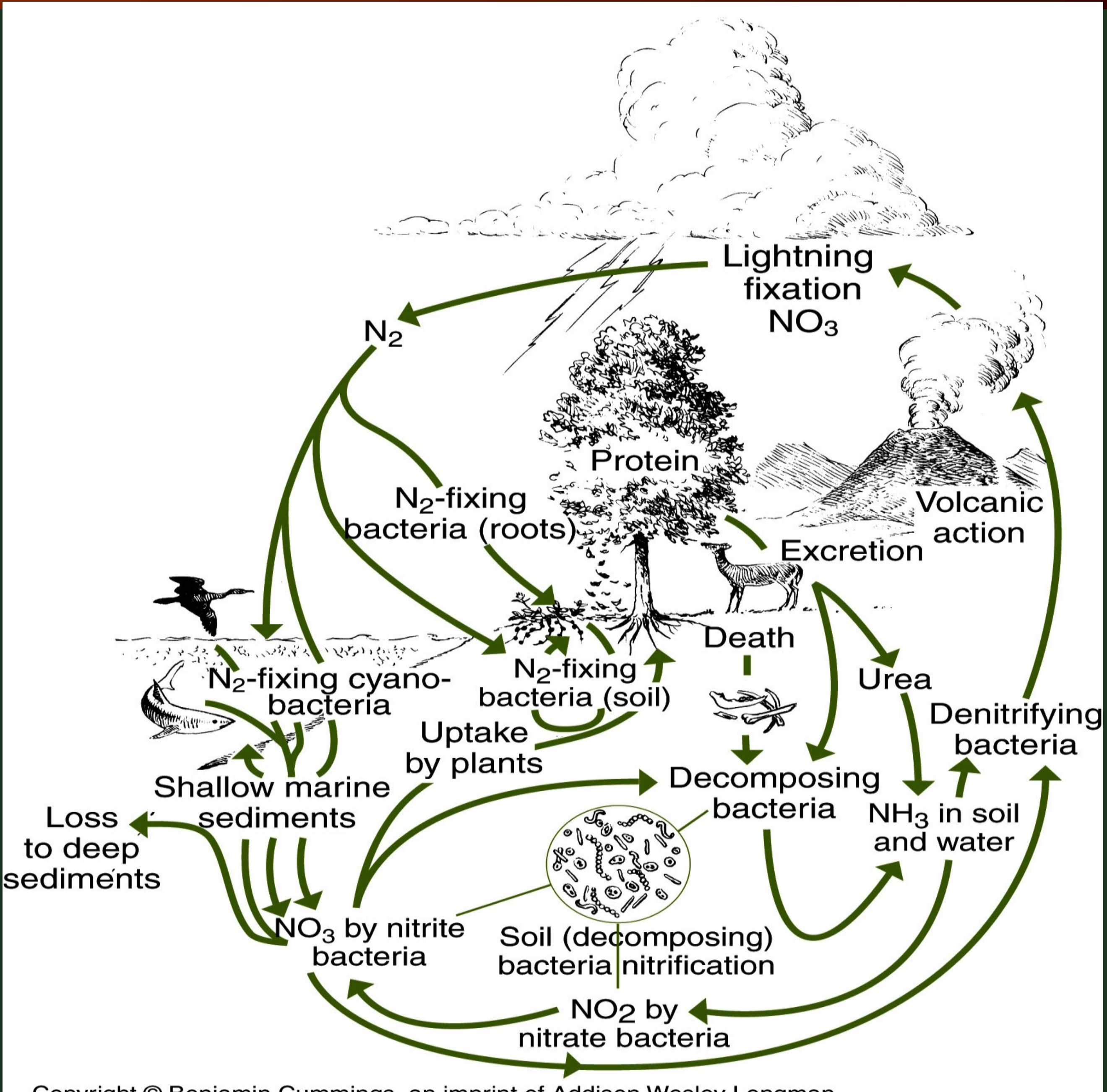
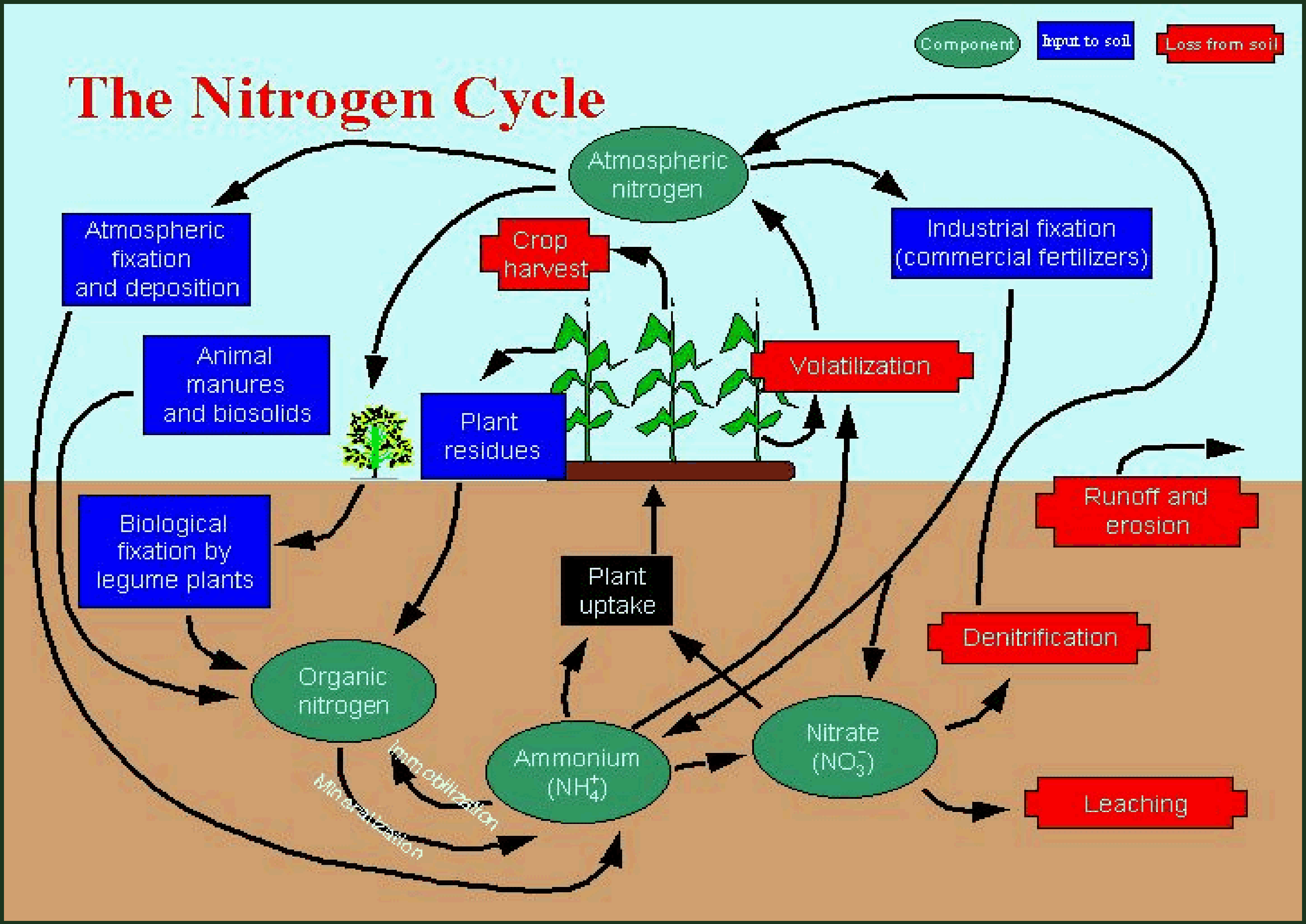


Figure 8.1. Schematic representation of the nitrogen cycle, emphasizing human activities that affect fluxes of nitrogen. (From NAS, 1978.)

The nitrogen cycle, showing major sources, compartments, and processes.



5.2 NITROGEN CYCLE



The Nitrogen Cycle

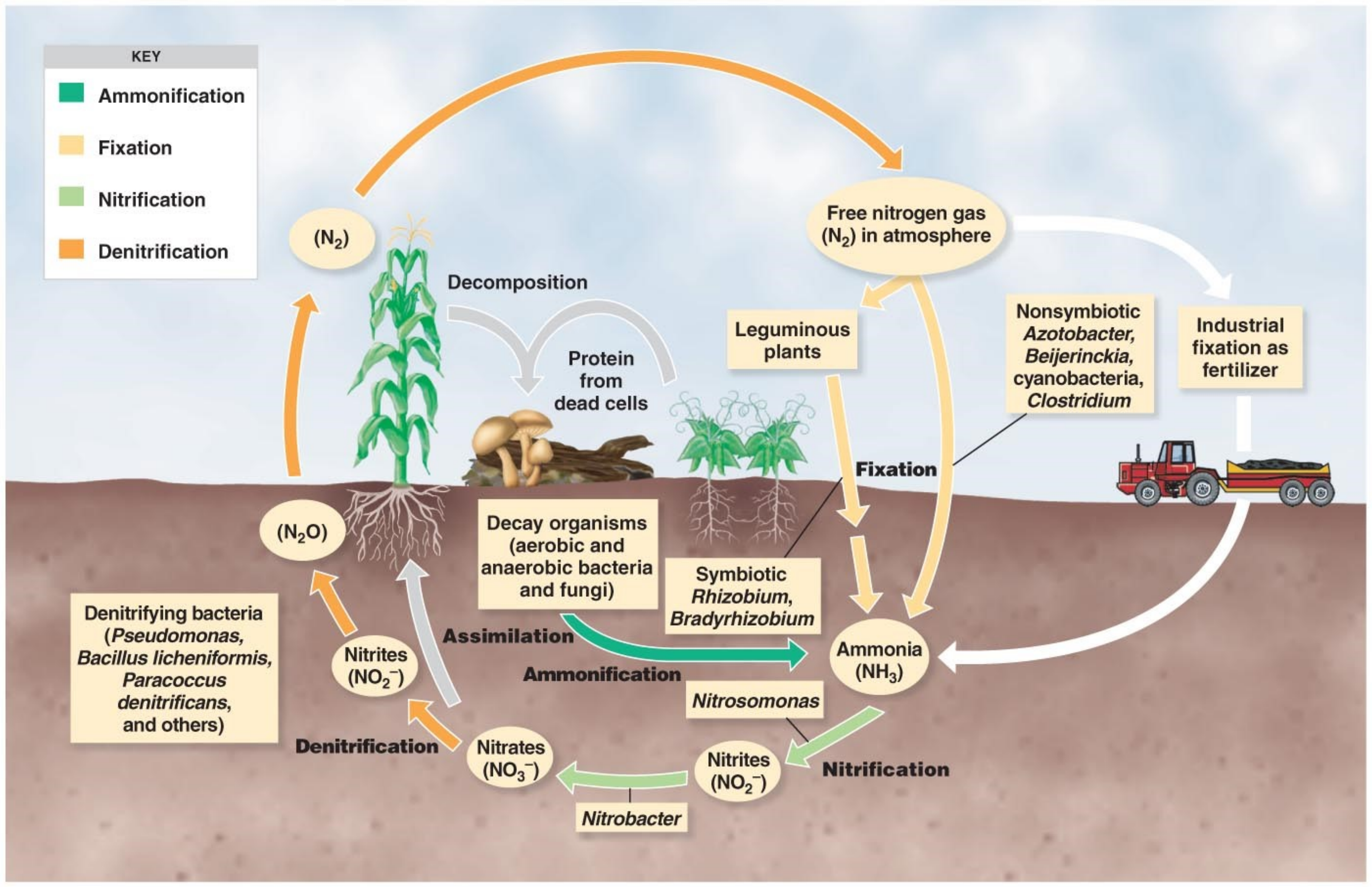
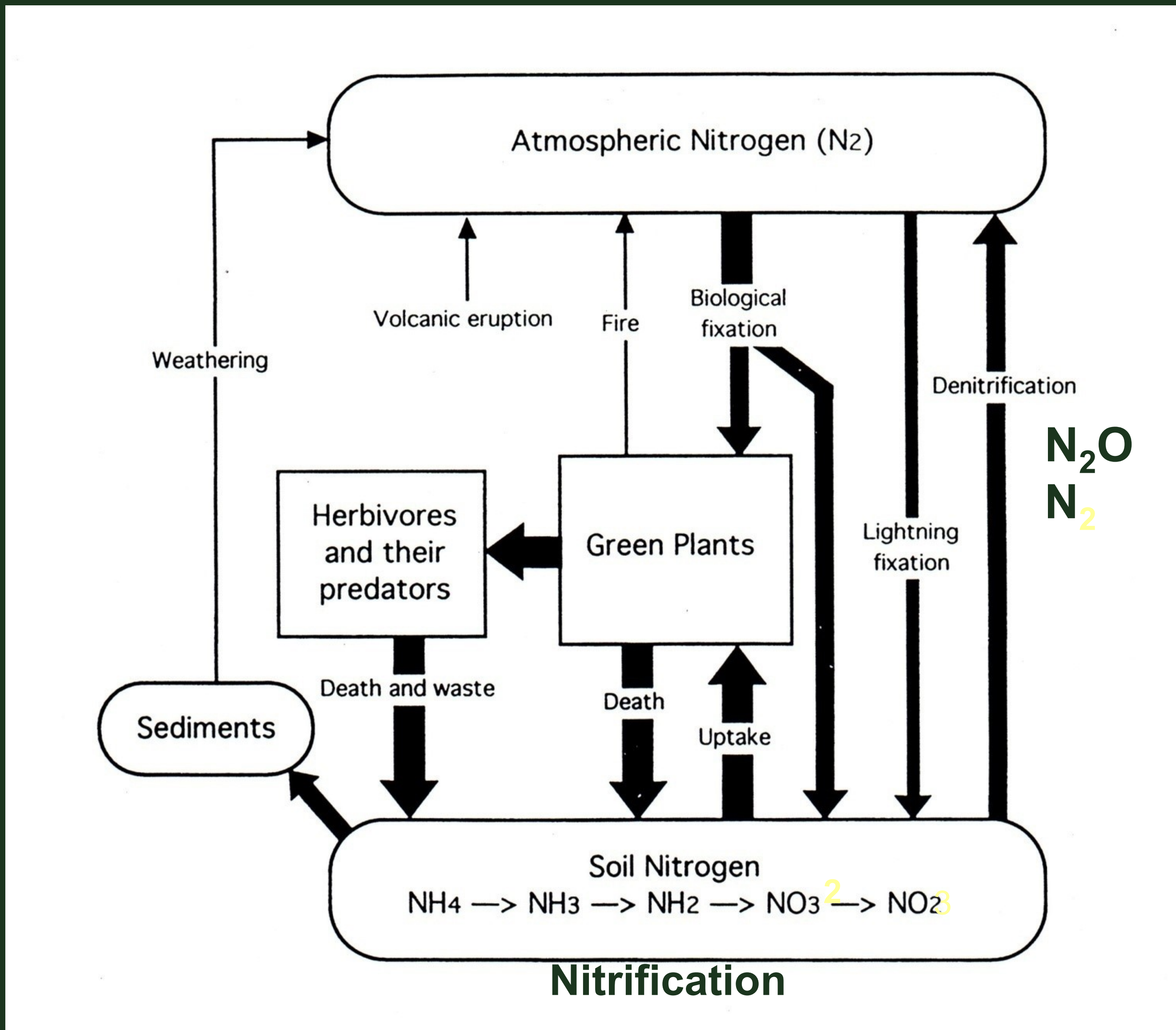


Figure 27.4

Nitrogen cycle



Gliessman, 1998 modified

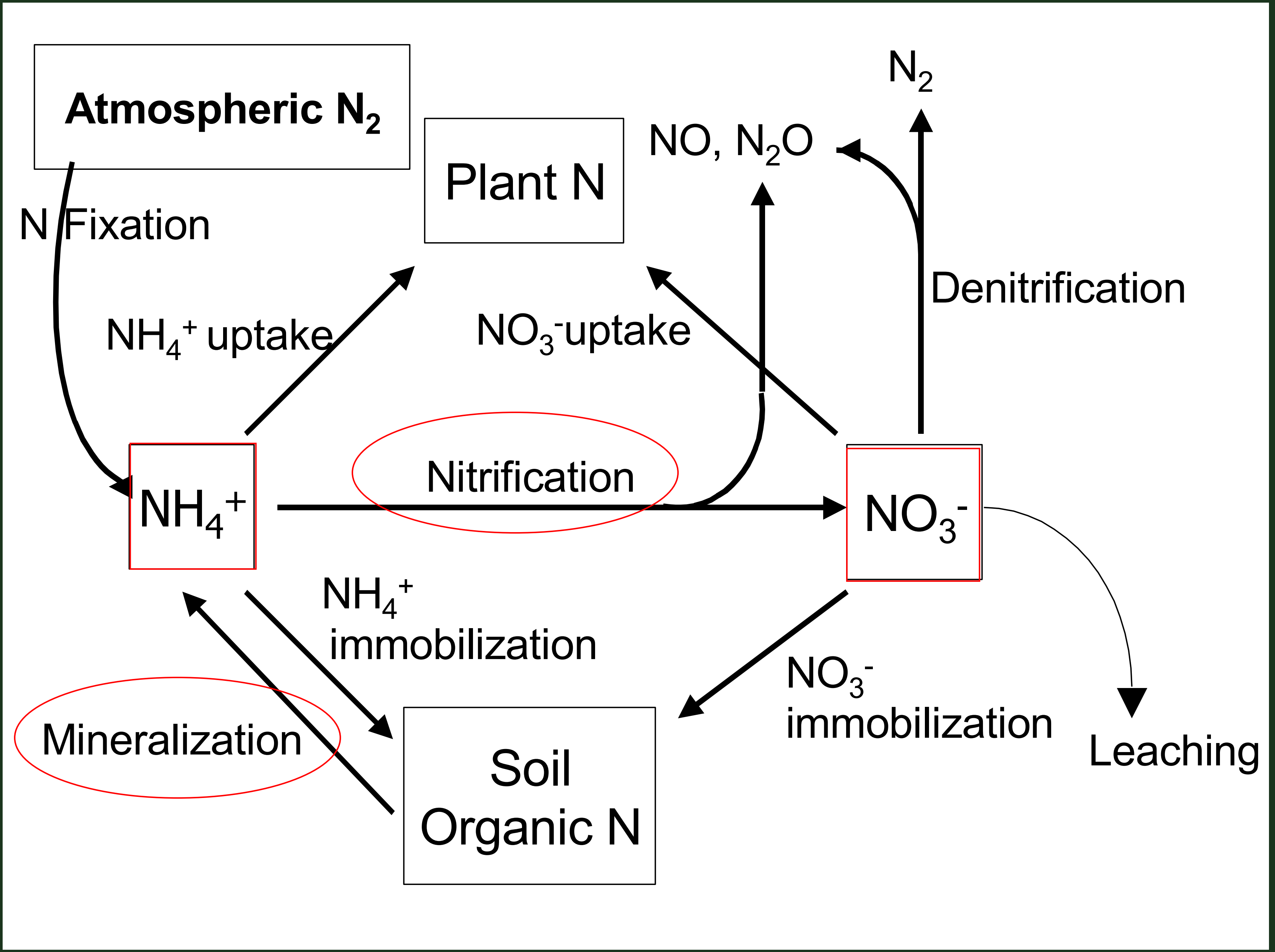

Atmospheric N_2
Plant N
NO, N_2O
N_2
N Fixation
Denitrification
NH_4^+ uptake
NO_3^-uptake
Nitrification
NH_4^+
NO_3^-
NH_4^+ immobilization
NO_3^- immobilization
Mineralization
Soil Organic N
Leaching

Table 8.1 Global Inventories of Nitrogen in the Biosphere (Million Mg N)

Terrestrial	
Plant biomass	$1.1–1.4 \times 10^4$
Animal biomass	2×10^2
Litter	$1.9–3.3 \times 10^3$
Soil organic matter	3×10^5
Soil insoluble inorganic	1.6×10^4
Soil soluble inorganic	3×10^2
(Soil microorganism included in total soil organic matter)	5×10^2
Oceanic	
Plant biomass	3×10^2
Animal biomass	1.7×10^2
Dissolved organic matter	5.3×10^5
Particulate organic matter	$0.3–2.4 \times 10^4$
N_2 dissolved	2.2×10^7
N_2O dissolved	2×10^2
NO_3^- dissolved	5.7×10^5
NO_2^- dissolved	5×10^2
NH_4^+ dissolved	7×10^2
Atmospheric	
N_2	3.9×10^9
N_2O	1.3×10^3
NH_3	0.9
NH_4^+	1.8
NO_x	1–4
NO_3	0.5
Organic N	1

From Winteringham, F.P.W. 1980. *Soil N as Fertilizer or Pollutant*. With permission of IAEA.

5.3. FUNCTIONS & FORMS OF N IN PLANTS

Established date for essentiality/researchers:

- 1802 (de Saussure) and 1851–1855 (Boussingault)

Functions in plants:

- Found in both inorganic and organic forms in the plant
- Combines with C, H, O, and sometimes S, to form amino acids, amino enzymes, nucleic acids, chlorophyll, alkaloids, and purine bases
- Organic N predominates as high-molecular-weight proteins in plants
- Inorganic N can accumulate in the plant, primarily in stems and conductive tissue, in the nitrate (NO_3^-) form

FORMS OF N IN PLANT

TABLE 2.2

Approximate Fractions and Common Ranges of Concentrations of Nitrogen-Containing Compounds in Plants

Compound	Fraction of Total Nitrogen (%)	Concentration (µg/g Dry Weight)
Proteins	85	10,000 to 40,000
Nucleic acids	5	1000 to 3000
Soluble organic	<5	1000 to 3000
Nitrate	<1	10 to 5000
Ammonium	<0.1	1 to 40

FORMS OF N IN PLANT

TABLE 2.1
Amino Acids Occurring Regularly in Plant Proteins

Alanine	Glutamic acid	Leucine	Serine
Arginine	Glutamine	Lysine	Threonine
Asparagine	Glycine	Methionine	Tryptophan
Aspartic acid	Histidine	Phenylalanine	Tyrosine
Cysteine	Isoleucine	Proline	Valine

Source: From McKee, H.S., *Nitrogen Metabolism in Plants*, Oxford University Press, London, 1962, pp. 1–18 and Steward, F.C. and Durzan, D.J., in *Plant Physiology: A Treatise. Vol IVA: Metabolism: Organic Nutrition and Nitrogen Metabolism*, Academic Press, New York, 1965, pp. 379–686.

FORMS OF N IN PLANT

TABLE 2.3
Concentrations of Total Nitrogen in Plant Parts

	Concentration of Total Nitrogen (% Dry Weight)	
Plant Part	Range	Optimum
Leaves (blades)	1 to 6	>3
Stems	1 to 4	>2
Roots	1 to 3	>1
Fruits	1 to 6	>3
Seeds	2 to 7	>2

TABLE 2.4
Concentrations of Nitrogen in Leaves of Various Crops Under Cultivated Conditions

Type of Crop	Diagnostic Range (% Dry Mass of Leaves)		
	Low	Sufficiency[a]	High
Agronomic Crops			
Grass grains	<1.5	1.8 to 3.6	>3.6
Legume grains	<3.6	3.8 to 5.0	>5.0
Cotton	<3.0	3.0 to 4.5	>5.0
Tobacco		4.1 to 5.7	>5.7
Rapeseed		2.0 to 4.5	>4.5
Sugarbeet		4.3 to 5.0	>5.0
Sugarcane	<1 to 1.5	1.5 to 2.7	>2.7
Bedding Plants		2.8 to 5.6	
Trees			
Conifers	<1.0	1.0 to 2.3	>3.0
Broadleaf	<1.7	1.9 to 2.6	>3.0
Cut Flowers	<3.0	3.1 to 4.7	>5
Ferns		1.8 to 2.9	
Potted Floral		2.5 to 4.2	
Forage Crops			
Grasses	<1.5	2.0 to 3.2	>3.6
Legumes	<3.8	3.8 to 4.5	5 to 7
Tree Fruits and Nuts			
Nuts	<1.7	2.0 to 2.9	>3.9

Type of Crop	Diagnostic Range (% Dry Mass of Leaves)		
	Low	Sufficiency[a]	High
Citrus	<2.0 to 2.2	2.3 to 2.9	>3.3
Pome	<1.5 to 1.8	2.1 to 2.9	>3.3
Stone	<1.7 to 2.4	2.5 to 3.0	>3.8
Small Woody	<1.5	1.5 to 2.3	>4.5
Strawberry	<2.1	2.1 to 4.3	>4.3
Banana		3.0 to 3.8	
Pineapple		1.5 to 2.5	
Foliage Plants		2.2 to 3.8	
Herbaceous Perennials	<2.2	2.2 to 3.2	>4.0
Ornamental Grasses	<1.6	1.6 to 2.5	>3.0
Ground Covers			
Herbaceous-broadleaf	<2.0	2.0 to 3.9	>4.0
Herbaceous-monocot	<1.5	1.6 to 2.4	>4.0
Woody		1.5 to 2.5	
Turfgrasses		2.6 to 3.8	
Vegetables			
Broadleaf	<2.6	3.5 to 5.1	
Sweet corn		2.5 to 3.2	
Forest and Landscape Trees	<1.9	1.9 to 2.6	
Woody Shrubs			
Palms		2.1 to 3.2	

Note: Values with few exceptions are mean concentrations in mature leaves. 'Low' is value where symptoms of deficiency are showing. 'Sufficiency' is mean range of lower and upper concentrations commonly reported in healthy plants showing no deficiencies. 'High' is a concentration that might represent excessive accumulation of nitrogen.

[a]Optimum or sufficient values for maximum yield or for healthy growth of plants will vary with species, age, and nutrition of plant, position of organ on plant, portion of plant part sampled, and other factors.

Source: Adapted from Chapman, H.D., *Diagnostic Criteria for Plants and Soils*, HD Chapman, Riverside, Cal., 1965, pp. 1–793; Mills, H.A. and Jones, J.B. Jr., *Plant Analysis Handbook II*, MicroMacro Publishing, Athens, Ga., 1996, pp. 155–414; Goodall, D.W. and Gregory, F.G., Chemical composition of plants as an index of their nutritional status, Technical Communication No. 17, Imperial Bureau of Horticulture and Plantation Crops, East Malling, Kent, England, 1947, pp. 1–167; Weir, R.G. and Cresswell, G.C., *Plant Nutrient Disorders 1. Temperate and Subtropical Fruit and Nut Crops*, Inkata Press, Melbourne, 1993, pp. 1–93; Weir, R.G. and Cresswell, G.C., *Plant Nutrient Disorders 3. Vegetable Crops*, Inkata Press, Melbourne, 1993, pp. 1–104; Walsh, L.M. and Beaton, J.D., *Soil Testing and Plant Analysis*, revised edition, Soil Science Society of America, Madison, Wis., 1973, pp. 1–491; and from other sources cited in references.

5.4. SOIL N RESOURCES

5.4.1 Symbiotic N fixation

5.4.2 Non symbiotic N fixation

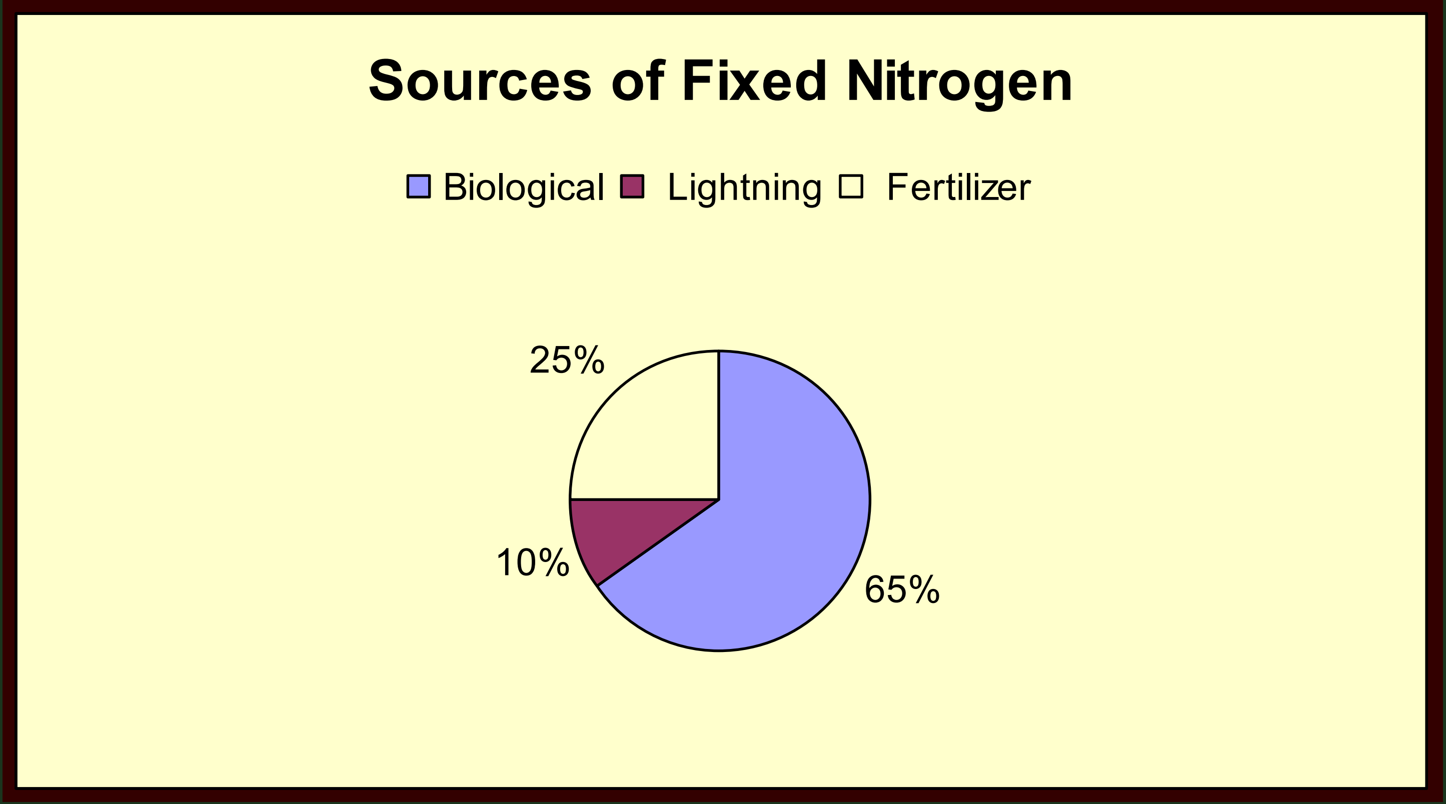
5.4.3 Abiotic N fixation

5.4.4 Organic matter

5.4.5. Fertilizer N

Beneficial root-microbe interactions

- Atmosphere contains 10^{15} tons N_2 gas
  - Biological nitrogen fixation
  - Minimum of 70 million tons N fixed/year



5.4.1Symbiotic N fixation

- Symbiotic Relationships
  - Both host and parasite benefit
  - Ex. Rhizobia (Symbiont) and **Legumes** (Host)
  - Rhizobia: sugars, proteins, and oxygen
  - Plant: usable nitrogen

N-fixation

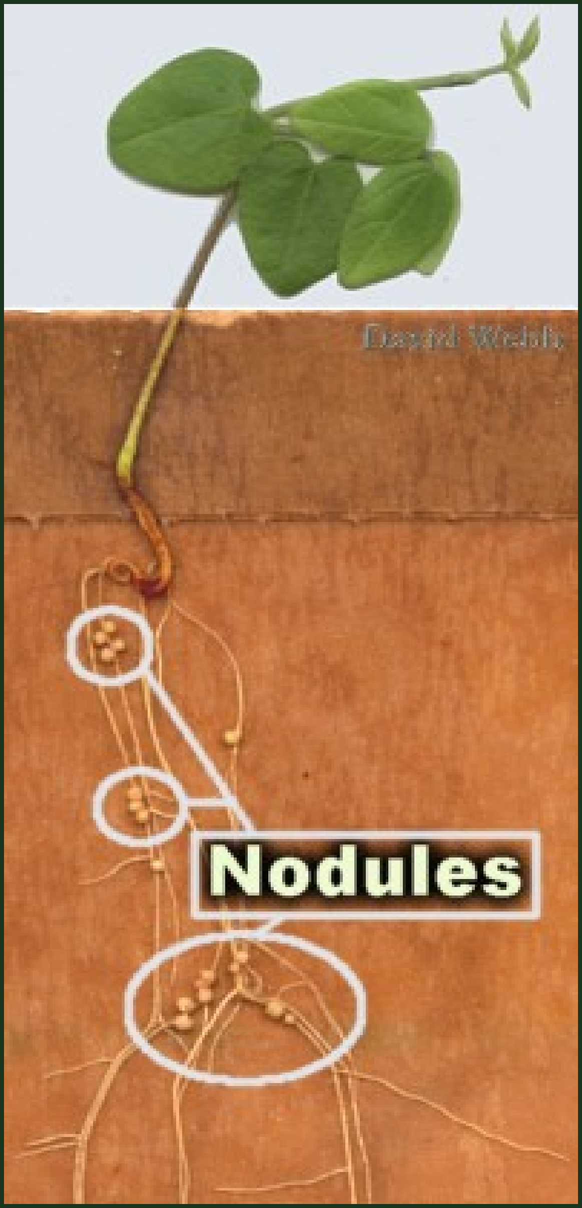
- Legumes
  - Preserve the nitrogen balance in the soil
  - Two Types
    - Legumes
    - Non-Legume
  - Release flavonoids

Importance of legume-rhizobia symbiosis

TABLE 18.3 Estimated Average Rates of Biological N_2 Fixation for Specific Organisms and Associations

Organism or system	Dinitrogen fixed (kg/ha/yr)
Free-living microorganisms	
Cyanobacteria ("blue–green algae")	25
Azotobacter	0.3
Clostridium pasteurianum	0.1–0.5
Grass–bacteria associative symbioses	5–25
Plant–cyanobacterial associations	
Gunnera	12–21
Azolla	313
Lichens	39–84
Legumes	
Soybeans (*Glycine* max L. Merr.)	57–97
Cowpeas (*Vigna, Lespedeza, Phaseolus,* and others)	84
Clover (*Trifolium hybridum* L.)	104–160
Alfalfa (*Medicago sativa* L.)	128–300
Lupines (*Lupinus* sp.)	150–169
Nodulated nonlegumes	
Alnus (alders, e.g., red and black alders)	40–300
Hippophae (sea buckthorn)	2–179
Ceanothus (snow brush, New Jersey tea, California lilac	60
Coriaria ("tutu" in New Zealand)	60–150
Casuarina (Australian pine)	58

Symbiotic N-fixation



1. SYMBIOTIC RELATIONSHIPS

Symbiont	*Host*
Rhizobia (bacterium)	Legumes
Frankia (actinomycete)	Nonlegume
Anabaena (cyanobacterium)	Azolla (fern)

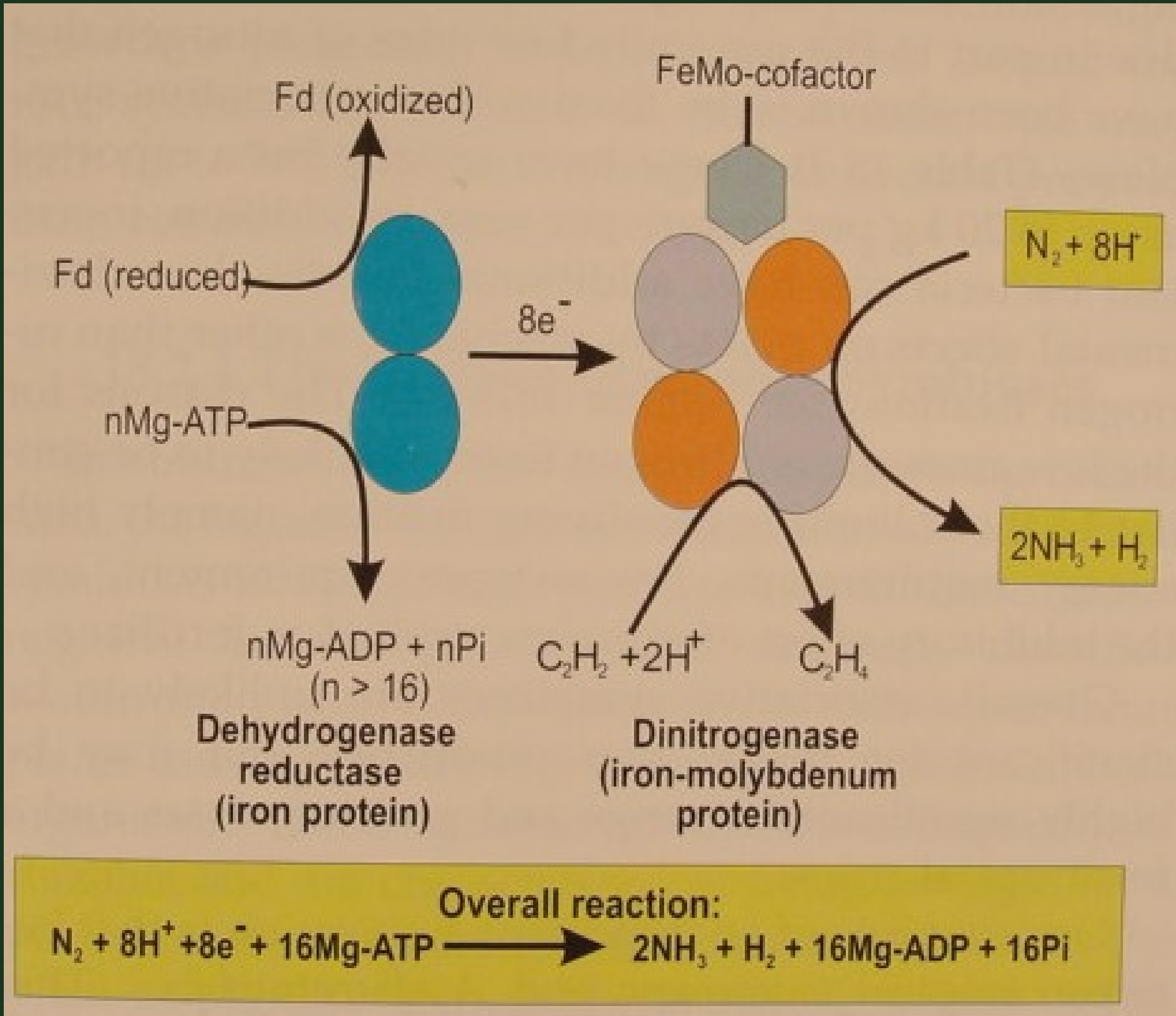
2. ASSOCIATIVE SYMBIOTIC RELATIONSHIPS INVOLVING FREE-LIVING DIAZOTROPHS

Microbe	*Benefitting crop*
Acetobacter	Sugarcane
Azotobacter	Tropical grasses

Beneficial root-microbe interactions

- Biological nitrogen fixation

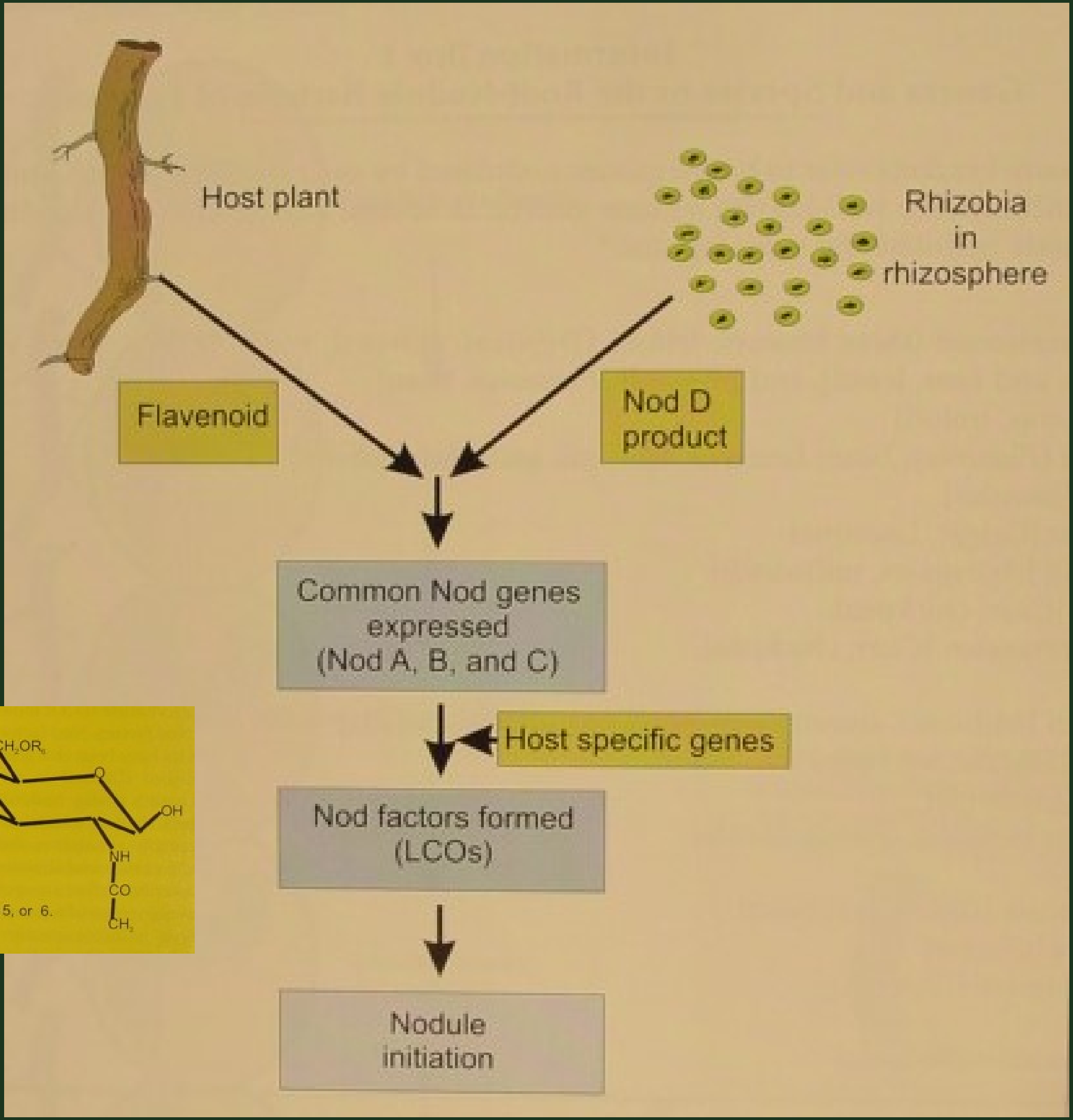
$N_2 + 3H_2 \rightarrow 2NH_3$

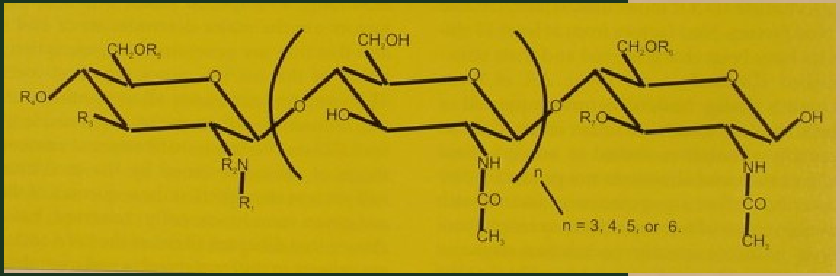


Root Nodule Initiation

- Two types of Nodule
  - Effective
  - Ineffective
- Two groups of Genes Necessary
  - Common Nodulation Genes (*nodABCD*)
    - *nodD* only gene expressed in absence of a suitable host
  - Host Specific Nodulation Genes
- Legumes release flavonoids
- Triggers production of Nod Factors (Lipochitooligosaccharide) by bacteria
- Flavenoids interact with *nodD* product
- Expression of *nodABC* genes

Plant-rhizobia genetic interactions



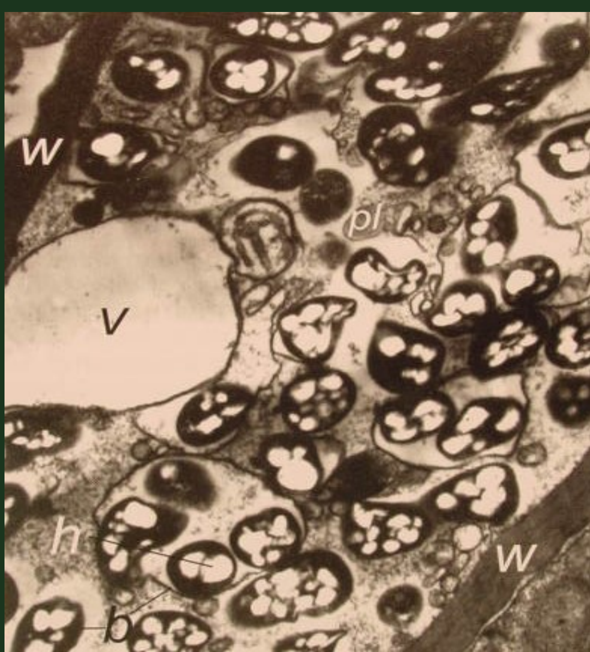


Poly-N-acetyl-glucosamine

Root Nodule Development

- Nod factor sensed by root
- Cell division occurs
- Rhizobia attach within minutes
- Root hair curling begins
- Rhizobia travel along an infection thread
- As infection thread penetrates the root cortex, Rhizobia are released

Nodule initiation and development



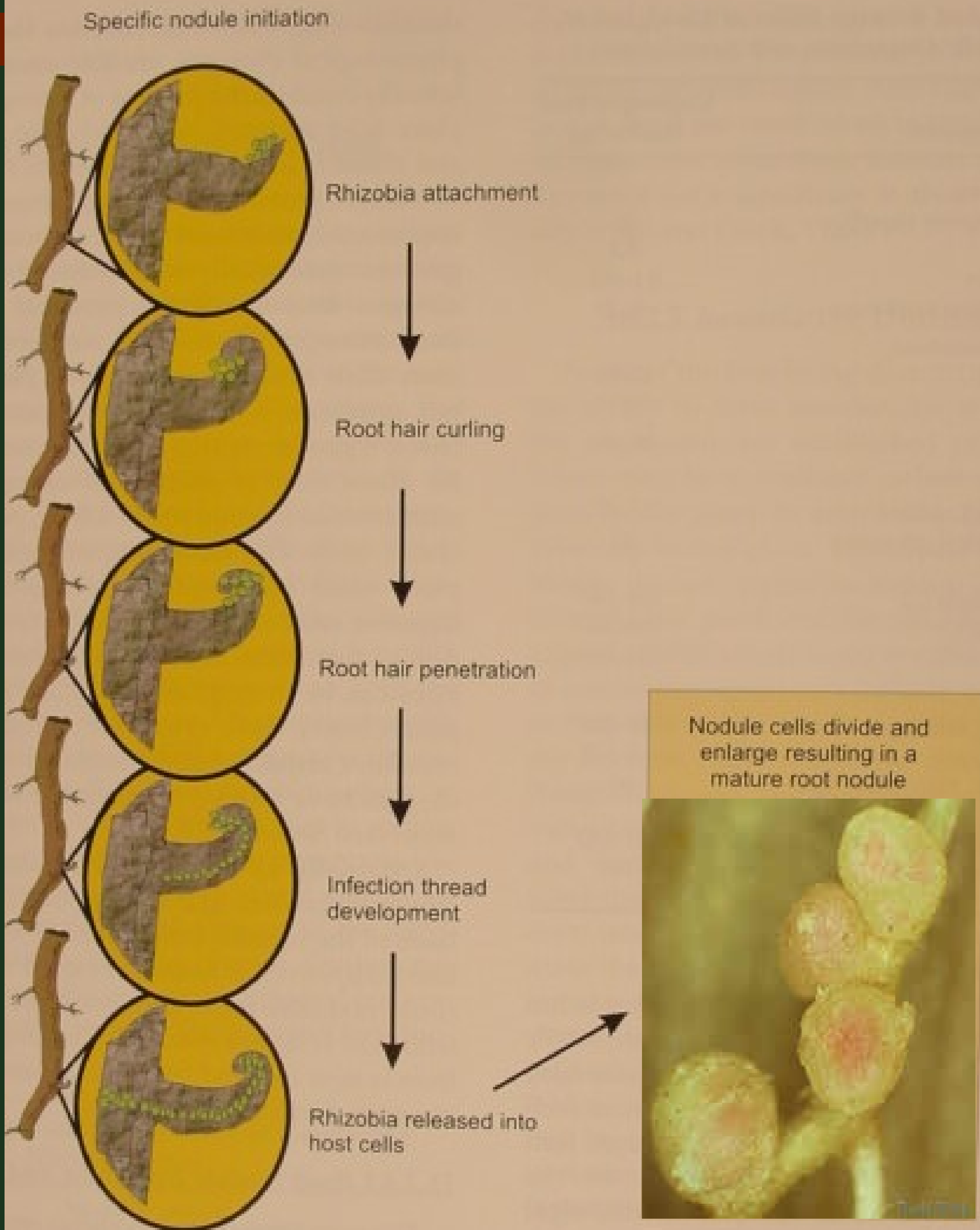


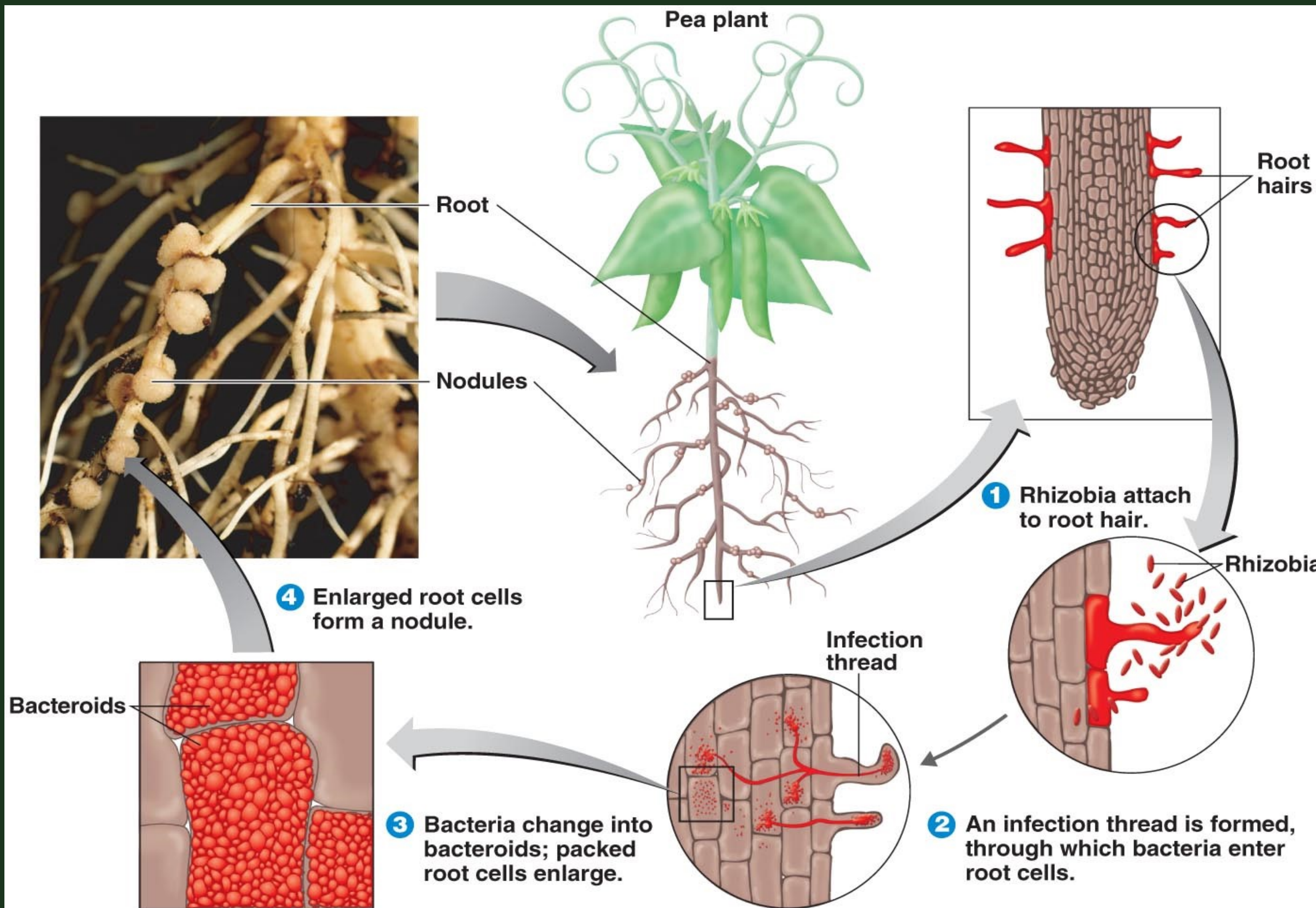
FIGURE 18.6 Nodule initiation and development.

Nitrogen Fixation

- In **root nodules**
  - *Rhizobium*
  - *Bradyrhizobium*
  - *Frankia*

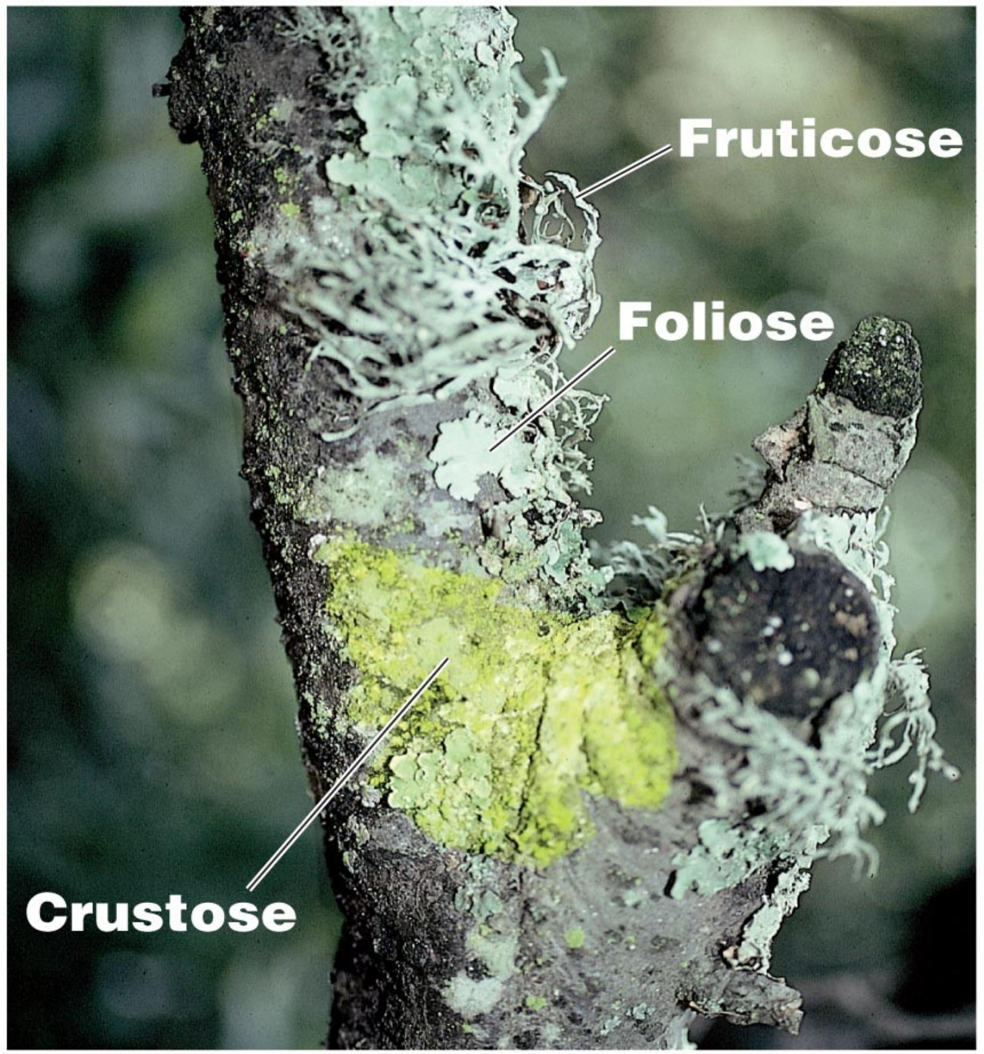
Figure 27.5

The Formation of a Root Nodule



Nitrogen Fixation

- In **lichens**
  - Cyanobacteria



(a) Three types of lichens

Figure 12.9a

Root Nodule Function

- Nodule forms 1 to 2 weeks after infection
- Two types of Nodules
  - Determinate
  - Indeterminate
- Rhizobia enlarge approx. 5 times
- Change physiologically to form bacteroids

Root Nodule Fixation

- Nodulins produced during maturation include:Leghemoglobin (protects nitrogenase enzyme) and also nitrogenase and gluatmine synthetase
- Fixation usually occurs after about 15 days
- Indeterminate
  - Fixation: ammonia Exported: asparagine
- Determinate
  - Fixation: ammonia Exported: purine

Enhancing the Symbiosis

- Natural symbiosis is reasonably effective
  - Free-living nitrogen fixation gives 25kg/hectare/year
  - Symbiotic nitrogen fixation gives 100kg/hectare/crop
- Current enhancements
  - Application of rhizobial inoculants
    - Peat-based carrier with 10^9 rhizobia/gram of peat
      - Application directly to seeds, then planting
    - Application to seed furrow
    - Crop rotation/breeding

FACTORS AFFECTING N FIXATION

- Soil pH
- Mineral nutrient status
- Photosynthesis and Climate
- Legume Management

Table 8.3 Global Rates of Nitrogen Fixation

Process	Amounts (million Mg yr^{-1})
Terrestrial biofixation	
Legumes	36
Rice paddies	4
Other crops	5
Grasslands[a]	45
Forests[a]	40
Others	10
Total	140
Oceanic biofixation	20–120
Industrial fixation (including fertilizers)	89
Terrestrial combustion processes	19

[a] Would also include legumes.

From Winteringham, 1980. *Soil N as Fertilizer or Pollutant*. With permission of IAEA.

Table 8.4 Biological Nitrogen Fixation by Different Organisms/Systems

Organism or system	N-fixed (kg ha^{-1} yr^{-1})
Legumes	
Forage	57–700
Grain	17–270
Nodulated nonlegumes	
Alnus	40–300
Hippophae	2–179
Ceanothus	60
Coriaria	150
Plant algal associations	
Gunnera	12–21
Azollas	31
Lichens	39–84
Free-living microorganisms	
Blue green algae	25
Azotobacter	0.3
Clostridium pasteurianum	0.1–0.5

From Nutman (1971) and Evans and Barber (1977).

5.4. SOIL N RESOURCES

5.4.2 Non-Symbiotic N fixation

- Biological fixation: but non symbiotic, mainly:
  Free living bacteria and blue green algae
- Blue green algae: autotropic, requiring only light, water, N_2, CO_2, and the essential element.
- Certain N fixing bacteria can grow on root surface, and to some extent within root tissue
- Azospirillum brasilense, Acetobacter (sugarcane), Azotobacter (tropical grasses), Clostridium

5.4. SOIL N RESOURCES

5.4.3 Abiotic N fixation

- Industrial fixation: fertilizer N , High N content, cheap, easy to use and tranport

- Lightning fixation:
  oxidation of N to NO_3, back to earth by rain
  about: 10-20%

5.4. SOIL N RESOURCES

5.4.4 Organic matter

- Organic N: protein (amino acids), nucleic acid, enzime, chlorophyl, etc.
- Form: as amine compound
- Before available to plant, organic N should decompose by soil organism especially microorganism.

TABLE 2.6
Fractions of Nitrogen in Soil Organic Matter Following Acid Hydrolysis

Nitrogen Component	Fraction of Total Organic Nitrogen (%)
Acid insoluble	20 to 35
Ammonium	20 to 35
Amino acid	30 to 45
Amino sugar	5 to 10
Unidentified	10 to 20

Source: From Bremner, J.M., in *Soil Nitrogen*, American Society of Agronomy, Madison, Wis., 1965, pp. 1324–1345 and Stevenson, F.J., *Nitrogen in Agricultural Soils*, American Society of Agronomy, Madison, Wis., 1982, pp. 67–122.

TABLE 2.8
Representative Nitrogen Concentrations and Mineralization of Some Organic Fertilizers

Fertilizer	% N (Dry Mass)[a]	Mineralization[b]
Feather meal, hair, wool, silk	15	Moderate–Rapid
Dried blood, blood meal	12	Rapid
Fish scrap (dry)	9	Moderate–Rapid
Tankage, animal	8	Moderate–Rapid
Seed meals[c]	6	Rapid
Poultry manure	2–3	Moderate–Rapid
Livestock manure	1–2	Slow
Sewage biosolids	1–4	Slow
Bone meal, steamed	1	Moderate–Rapid
Kelp	0.7	Slow
Compost	0.5–1	Slow

[a]Concentrations will vary from these representative values, depending on the handling of the products, nutrition of livestock, and source of materials.
[b]Mineralization rate will vary with the products. Rapid mineralization is more than 70% of the organic N expected to be mineralized in a growing season; moderate is 50 to 70% mineralization; and slow is less than 50% mineralization.
[c]Includes by-products such as cottonseed meal, soybean meal, linseed meal, corn gluten meal, and castor pomace.

5.4. SOIL N RESOURCES

5.4.4 Organic matter

- Protein → Amino acid, by aminization
- Amino acid → Ammonium, by ammonification
- Ammonium → Nitrite, by nitritation
- Nitrite → Nitrate, by nitratation

5.4. SOIL N RESOURCES

5.4.5 N fertilizer

- N fertilizer: Mineral form of N giving to soil for adding N
- High N content, cheap, easy to use and transport, easy to desolve.
- The resources of N fertilizers is amonia (N content: 82%)
- Amonia resulted by Haber-Bosch procces, through N and H reaction.

5.4. SOIL N RESOURCES

5.3.4 N fertilizer

- N fertilizer can be made from amonia:
- $NH_3 + H_2SO_4 \longrightarrow (NH_4)_2SO_4$
- $NH_3 + O_2 \longrightarrow HNO_3 + H_2O$
- $HNO_3 + NH_3 \longrightarrow NH_4NO_3$
- $NH_3 + CO_2 \longrightarrow (NH_4)_2CO_3 + H_2O$
- $NH_3 + H_3PO_4 \longrightarrow NH_4H_2PO_4$
- $2NH_3 + H_3PO_4 \longrightarrow (NH_4)_2HPO_4$

8.8.1. Cyanamide Process

This process was developed by Frank and Caro in Germany in 1898 and involves passing purified nitrogen gas over calcium carbide kept at 1100°C.

$$CaC_2 + N_2 \xrightarrow{\text{heat}} CaCN_2 + C$$

This process is used only on a very limited scale in Germany and other European countries, often for purposes other than making chemical fertilizers. Calcium cyanamide, when used as a fertilizer, has some toxic effects on crop plants, and application is generally recommended 4 to 6 weeks before sowing of a crop. Calcium cyanamide has also been used as a herbicide.

8.8.2. Arc Process

This process involves passing elemental nitrogen and oxygen through an arc that is expanded in an electromagnet to increase the contact with gases.

In nature, lightning also accomplishes this process and therefore is a source of nitrates in rain. The reactions are

$$N_2 + O_2 \rightarrow 2\ NO$$

$$2\ NO + O_2 \rightarrow 2\ NO_2$$

$$3\ NO_2 + H_2O \rightarrow 2\ NHO_3 + NO$$

This process can be used where electrical power is inexpensive.

8.8.3. Haber-Bosch Process (Ammonia Synthesis)

Ammonia synthesis by the Haber-Bosch process is one of the few, most significant, scientific discoveries of the early twentieth century, and it led to Haber receiving a Nobel prize for this invention. Ammonia synthesis is based on the reaction of N_2 and H_2 in the presence of a catalyst, the main component of which is magnetite (Fe_3O_4), and at temperatures up to 1200°C. The pressure required varies from 200 to 1000 atm. The basic reaction is

$$3\,H_2 + N_2 \rightarrow 2\,NH_3$$

Furthermore, anhydrous ammonia when reacted with carbon dioxide yields urea, which is an important N source in many Asian countries, as well as elsewhere in the world. The reactions are

$$2\,NH_3 + CO_2 \rightarrow NH_2COONH_4$$

$$NH_2COONH_4 \rightarrow NH_2CONH_2 + H_2O$$

(Urea)

Table 8.7 General Composition of Some Common N and NP Fertilizers

Fertilizer	Percent				
	N	P_2O_5	CaO	MgO	S
N Fertilizers					
Ammonium sulfate	21	—	—	—	24
Anhydrous ammonia	82	—	—	—	—
Ammonium chloride[a]	25–26	—	—	—	—
Ammonium nitrate-sulfate	30	—	—	—	5–7
Ammonium nitrate with lime (ANL)/CAN[b]	20.5	—	10	7	—
Calcium nitrate	15	—	34	—	—
Calcium cyanamide	22	—	54	—	0.2
Sodium nitrate	16	—	—	—	—
Urea	45–46	—	—	—	—
Urea-sulfate	30–40	—	—	—	6–11
Urea-sulfur	30–40	—	—	—	10–20
Urea-ammonium nitrate (solution)	28–32	—	—	—	—
NP Fertilizers					
Ammoniated ordinary superphosphate	4	16	23	0.5	10
Monoammonium phosphate	11	48–55	2	0.5	1–3
Diammonium phosphate	18–21	46–54	—	—	—
Ammonium phosphate-sulfate	13–16	20–39	—	—	3–14
Ammonium polyphosphate solution	10–11	34–37	—	—	—
Urea-ammonium phosphate	21–38	13–42	—	—	—
Urea-phosphate	17	43–44	—	—	—

[a] 66% chloride.

[b] Calcium ammonium nitrate in India.

From Tisdale et al., 1993. *Soil Fertility and Fertilizers*, 5th ed., p. 156. With permission of Prentice-Hall, Inc., Upper Saddle River, NJ.

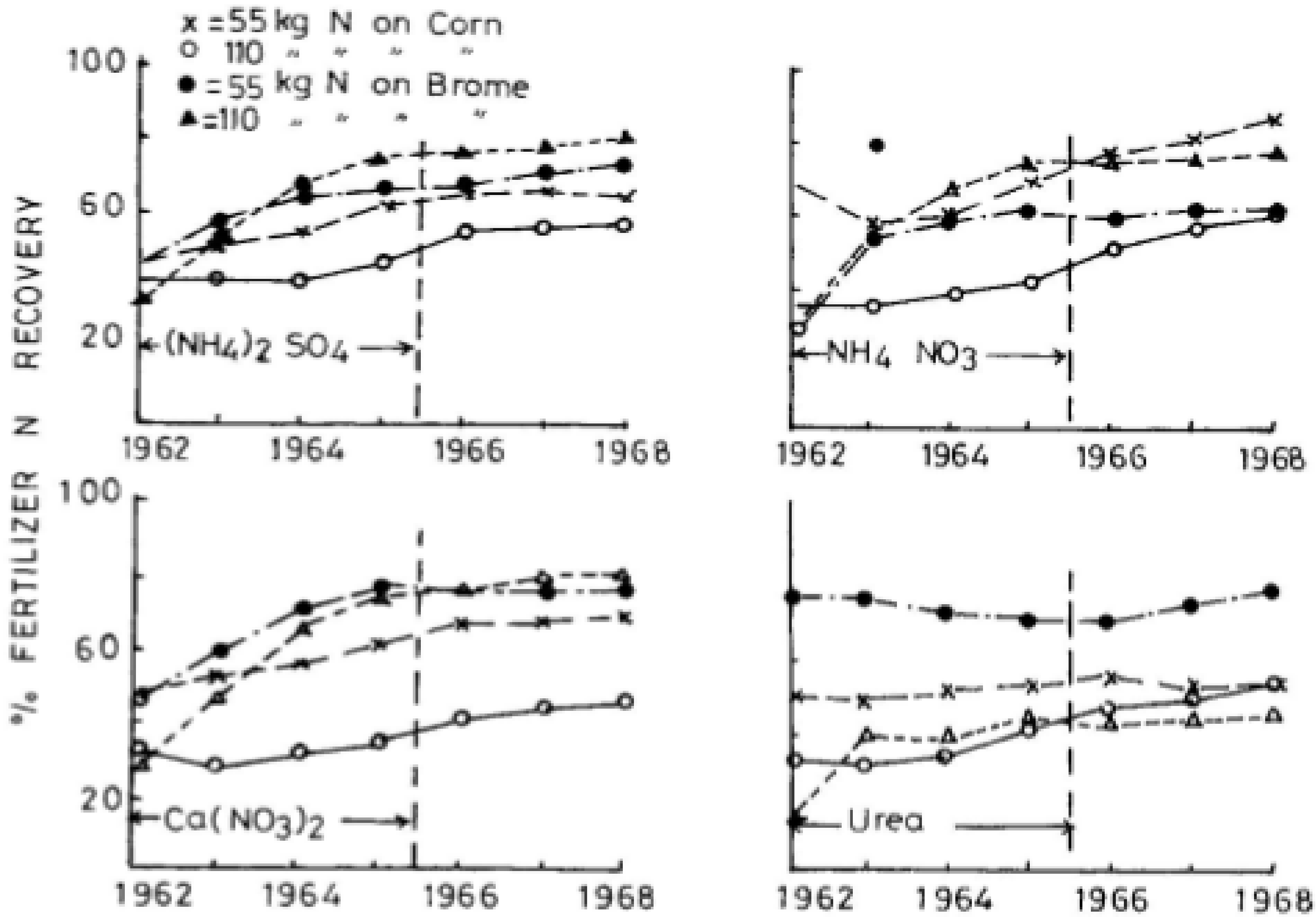


Figure 8.9. Fertilizer N recovery in plant tops from various N sources. (From Power et al., 1973. Agron. J. 65:765–768. With permission of SSSA.)

Efisiensi Pemupukan N

Table 8.8 Total Plant N, Percentage of Plant N Derived from Fertilizer (Ndff), and Percentage of Fertilizer N Recovered by Corn at Maturity on Wood River Silt Loam in Nebraska

Fertilizer N kg ha^{-1}	Total N uptake by plant tops (kg ha^{-1})	Ndff (%)	Fertilizer N recovered (%)
75	87.4	21.2	24.4
150	122	35.0	28.5
225	164	39.8	28.9
300	194	54.5	35.3

From Francis et al. 1993. Agron. J. 85:659–663. With permission of ASA.

Table 8.9 ^{15}N Balance in Rice-Wheat, Corn-Wheat-Mungbean, and Wheat-Mungbean-Corn Rotations (% of Applied N)

kg N ha^{-1} applied to 1st crop	Recovered by 1st crop	Recovered by 2nd crop		Left in soil	Unaccounted N
	Rice	Wheat			
60	35.4	4.1		16.7	43.8
120	31.2	4.6		25.6	38.6
	Corn	Wheat	Mungbean		
120	20.8	7.0	0.8	40.1	31.3
	Wheat	Mungbean	Corn		
90	45.3	2.5	1.5	48.2	2.5

From Goswami et al. (1988) and Subbiah et al. (1985).

SOIL N LOSS

1. Run off and erosion
2. Leaching
3. Volatilization
4. Denitrification

SOIL N LOSS

1. Run off and erosion

Tabel 1. Pengaruh vegetasi dan lereng terhadap erosi dan kehilangan hara.

Perlakuan	Lereng (%)	Erosi (ton/ha)	Aliran Permukaan (mm)	Unsur hara yang hilang (kg/ha)				
				N	P	K	Ca	Mg
Tanah bera, dibajak setiap bulan	22	225.4	1730	25	0.98	24	238	152
Rumput ternak	22	7.1	513	7	0.15	6	25	26
Tanaman kopi muda	45	1.8	190	8	0.04	2	6	7
Kopi muda dengan teras	45	0.2	410	4	0.14	4	8	9
Tanaman kopi tua tanpa konservasi	55	0.6	59	1	0.08	1	2	2

Sumber : Castro dan Rodriguez (1958) dalam Sanchez, 1976.

SOIL N LOSS

2. Leaching

SOIL N LOSS

3. Volatilization

SOIL N LOSS

4. Denitrification

$$2\ HNO_3 \xrightarrow[\pm 2\ H_2O]{+4\ H} 2\ HNO_2 \xrightarrow[\pm 2\ H_2O]{+2\ H} 2\ NO \xrightarrow[\pm H_2O]{+2\ H} N_2O \xrightarrow[\pm H_2]{+2\ H} N_2$$

Table 8.12 Taxonomy of Denitrifying Microorganisms[a]

Organism	Comments
Achromobacter liquefaciens	Oxidizes CH_4 with NO_3^-
Alcaligenes sp.	Oxidizes CH_4 with NO_3^-
Bacillus	Many species known to denitrify
Chromobacterium	
Corynebacterium nephridii	Produces only NO and N_2O
Flursarium spp.	Two species of this fungus reduce NO_2^- (but not NO_3^-) to N_2O
Halobacterium	—
Hydrogenomonas spp. (= *Alkalingenes* sp.)	—
Hyphomicrobium sp.	Oxidizes methanol with NO_3^-
Micrococcus denitrificans	Chemolithotroph; oxidizes H_2
Moraxella	—
Propionibacterium	—
Pseudomonas spp.	Many well-known denitrifying species
Spirillum	—
Thiobacillus spp.	Chemolithotrophs; oxidize S and $S_2O_3^{2-}$ with NO_3^-
Veillonella alcalescens	Strict anaerobe; both assimilatory and dissimilatory NO_3^- reduction
Xanthomonas	—

[a] Not all species within a genus may be capable of denitrification.

From Brezonik. 1977. Progress in Water Tech. 8:373–392. With kind permission from Elsevier Science Ltd., Kidlington, U.K.

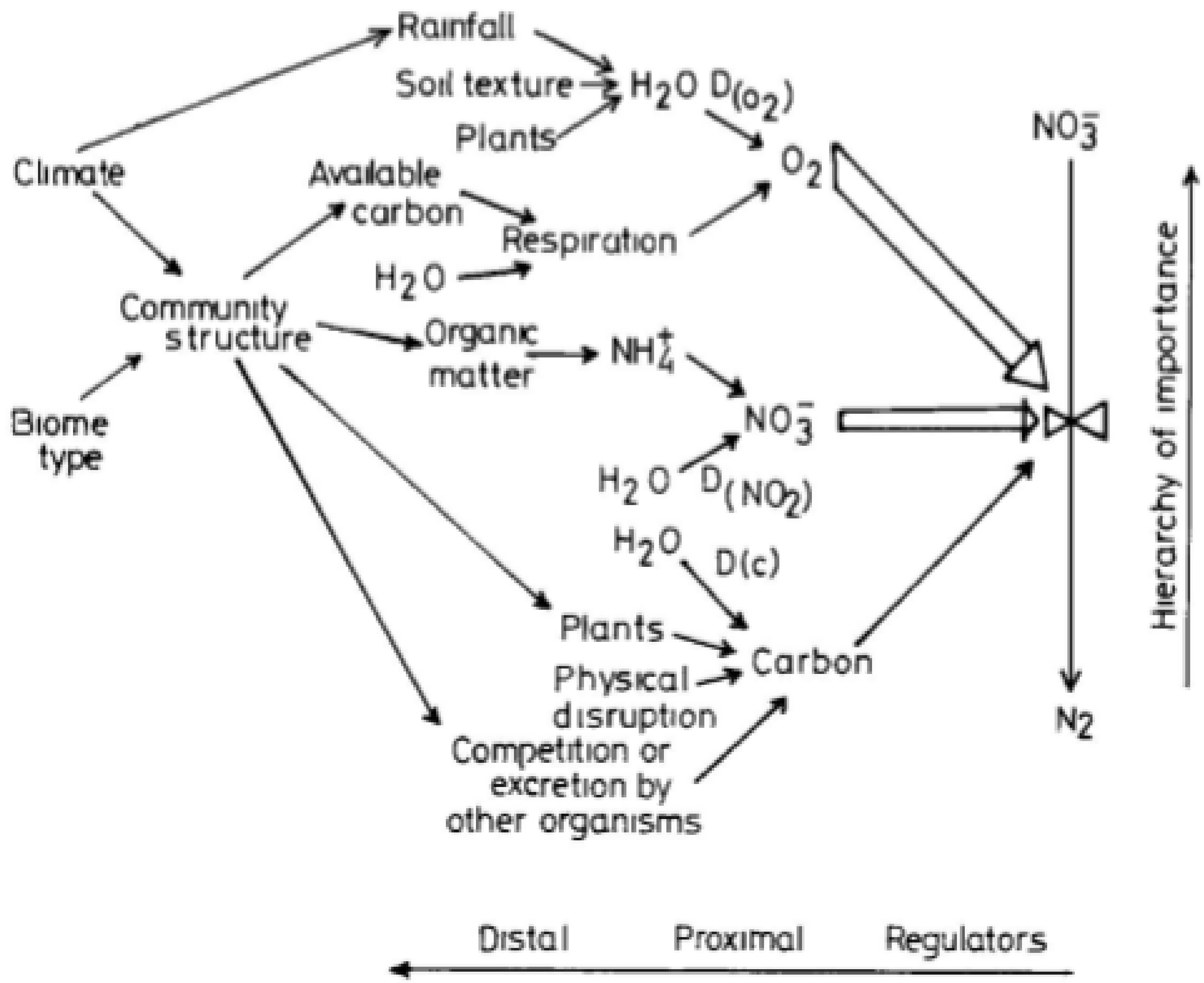


Figure 8.13. **Relationship between proximal and distant controlling factors of denitrification. (From Tiedje, 1987. *Environmental Microbiology of Anaerobes*, Zehnder, A.J.B., Ed. With permission of John Wiley & Sons.)**

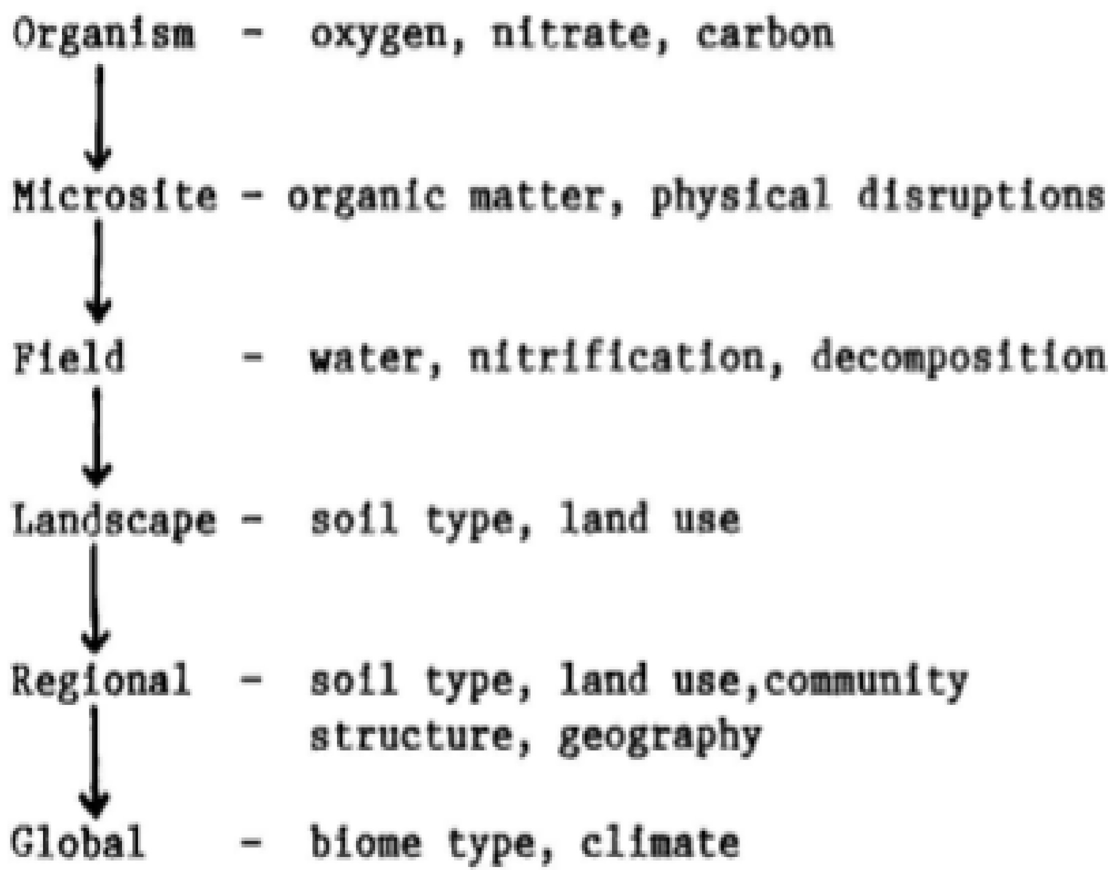


Figure 8.14. Factors controlling denitrification at different levels of investigation. (From Tiedje, 1987. *Environmental Microbiology of Anaerobes*, Zehnder, A.J.B., Ed. With permission of John Wiley & Sons.)

Table 8.13 Nitrate Uptake by a Plant (*Hordeum vulgare*) and Reduction by a Denitrifier (*Pseudomonas fluorescans*) at Different Oxygen Concentrations

Oxygen level (% v/v)	Denitrification ($\mu g\ NO_3^-$-N mg^{-1} biomass h^{-1})	Plant uptake ($\mu g\ NO_3^-$-N mg^{-1} biomass h^{-1})
20	0	1.85
10	0	1.15
5	0	0.52
1	0	0
0.05	0	0
0.01	0.15	0
0	3.5	0

From Wilson, R.J.R., Editor. 1988. *Advances in Nitrogen Cycling in Agricultural Ecosystems*. With permission of C.A.B. International.

Table 8.14 Annual N Loss Due to Denitrification as Affected by Denitrification, Soil Drainage, and Soil Texture for Forested Soils in Michigan

Soil	Denitrification N loss ($kg\ N\ ha^{-1}\ yr^{-1}$)
Sand loam	
Well drained	0.6
Somewhat poorly drained	0.8
Poorly drained	0.5
Loam	
Well drained	10
Somewhat poorly drained	11
Poorly drained	24
Clay loam	
Well drained	18
Somewhat poorly drained	17
Poorly drained	40

From Wilson, R.J.R., Ed. 1988. *Advances in Nitrogen Cycling in Agricultural Ecosystems*. With permission of C.A.B. International.

VOLATILISASI

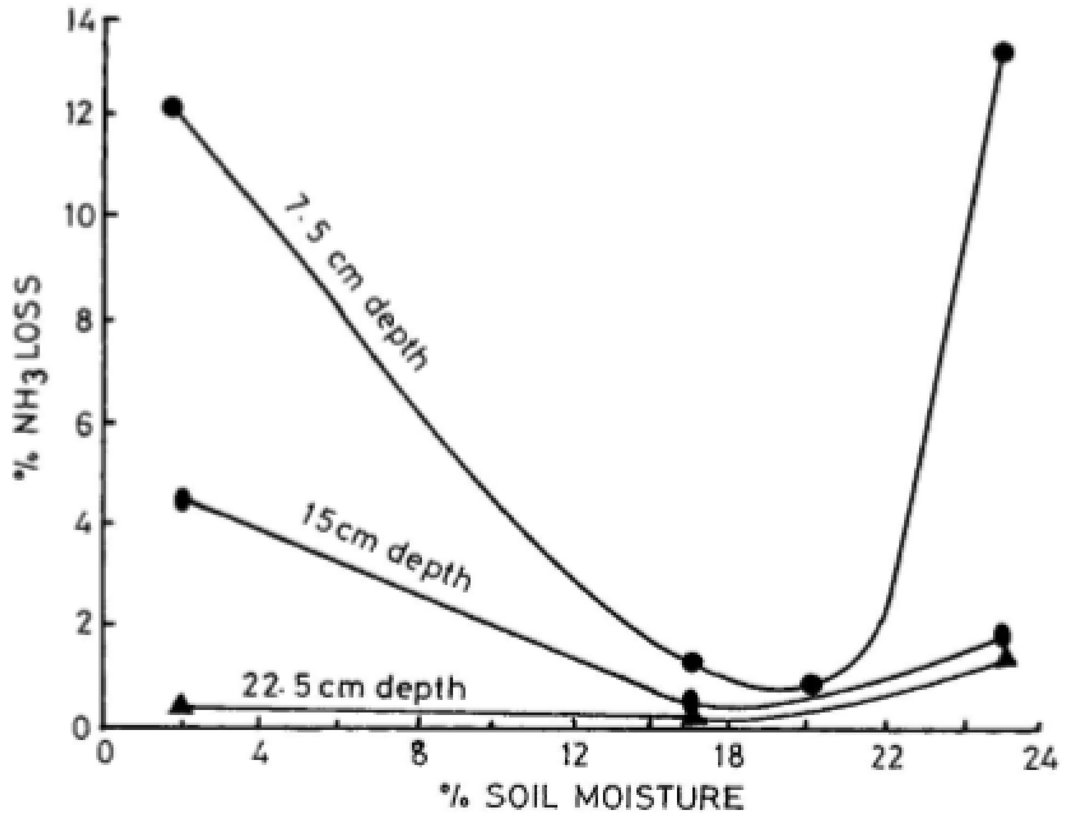


Figure 8.17. Losses of ammonia from a Putnam loam soil as influenced by depth of application and soil moisture. Anhydrous ammonia applied at the rate of 220 kg N ha^{-1} (at 100-cm spacings). (From Stanley and Smith, 1956. Soil Sci. Soc. Am. J. 20:557–561. With permission of SSSA.)

Table 8.15 Measured Site and Land-Use-Specific Nitrate N Input into the Groundwater (Mean Concentration of the Annual Groundwater Recharge)

Soil	Land use (crop rotation, N fertilizer)	Mean nitrate concentration (mg N L^{-1})
Sand	Arable land (cereal-sugarbeet/potatoes-cereal, ≈ 120 kg N ha^{-1} yr^{-1})	25–30
	Arable land (cereal-winter catch crops –sugarbeet/potatoes-cereal, ≈ 120 kg N ha^{-1})	14–16
	Grassland (meadow, ≈ 250 kg N ha^{-1} yr^{-1})	3–7
	Grassland (intensively grazed pasture, ≈ 250 kg N ha^{-1} yr^{-1}; = 2 livestock units ha^{-1}, ≈ 180 grazing days)	14–20
	Field cropping of vegetables, including special crops such as asparagus, tobacco (≈ 300–600 kg N ha^{-1} yr^{-1})	34–70
	Woodland (coniferous tree stands)	2.5
	Woodland (alder tree stands)	10
Loess	Arable land (cereal-sugarbeet-cereal ≈ 150 kg N ha^{-1} yr^{-1})	7–14

Adapted from Strebel et al. (1989).

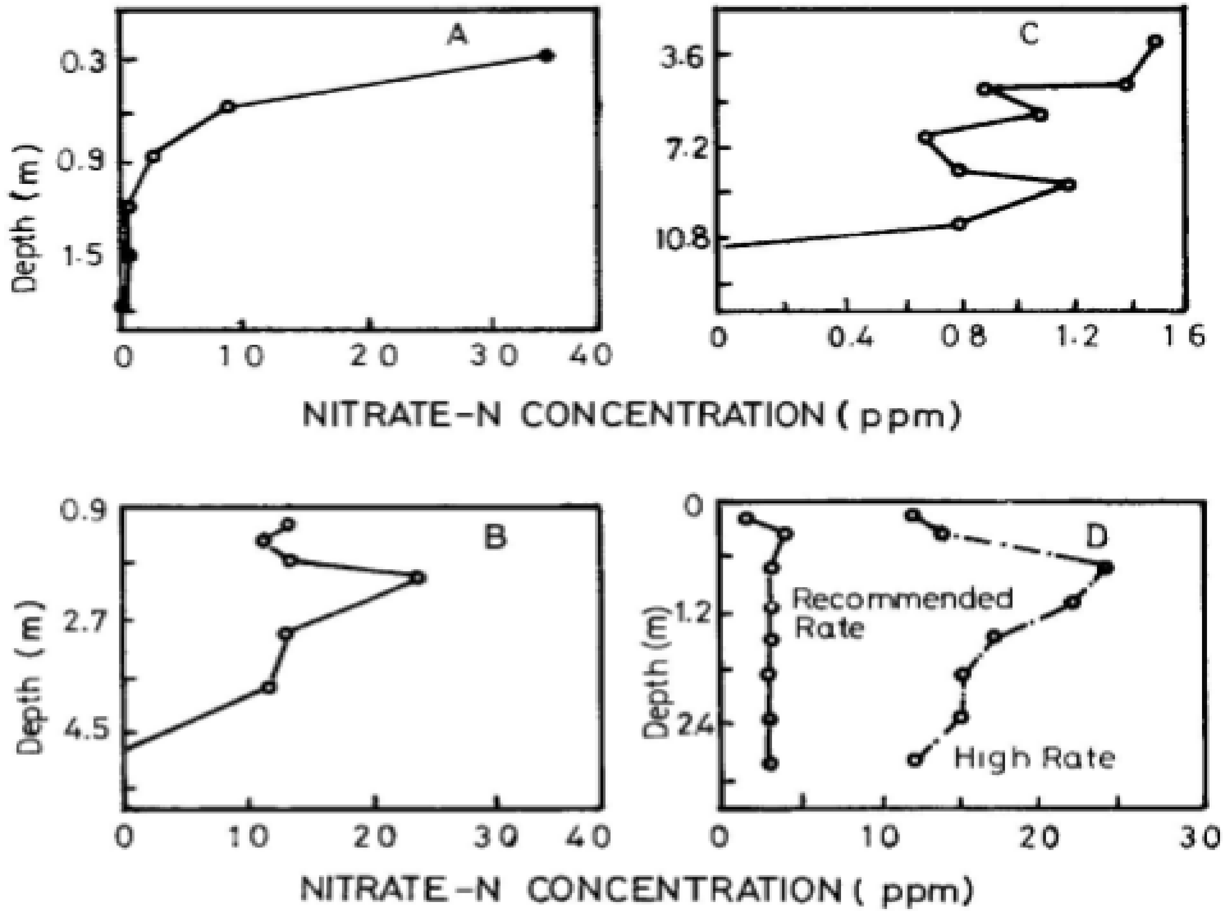


Figure 8.16. Typical nitrate-N profiles in North Carolina soils: A. Soil water NO_3-N in a cultivated, poorly drained, high water table, coastal plain soil. B. Soil water NO_3-N in a cultivated, moderately well drained, coastal plain soil with aquatard between 3 and 3.9 m. C. Soil nitrate-N profile of a cultivated Piedmont soil. D. Soil nitrate-N profile of an area of coastal Bermuda on a coastal plain soil receiving different rates of N. (Adapted from Gilliam, 1991. Better Crops 75:6–8. With permission.)

5.5. SOIL N CONTENT

5.5.1 Factors affecting Soil N content

- Effect of climate and vegetation
- Effect of Topogrphy
- Effect of mineral constituent
- Profil distribution

- Effect of climate

- Effect of temperatur and water supply to plant microbial activity
- Higher temperatur, lower soil N content.
- Higher water supply, higher soil N content

- Effect of vegetation

- Soil N content in grassland higher than forest

- Effect of Topography

- There is relationship between topography and water supply.
- Steeper the slope, soil drier

- Effect of Mineral component

- There is relationship between soil texture and soil N content

Texture	Soil N content (%)
Sand	0,027
Fine sand	0,042
Sandy loam	0,100
Loam	0,188
Silt loam	0,230

- Profil Distribution
- Soil N content in upper layer higher than lower layer

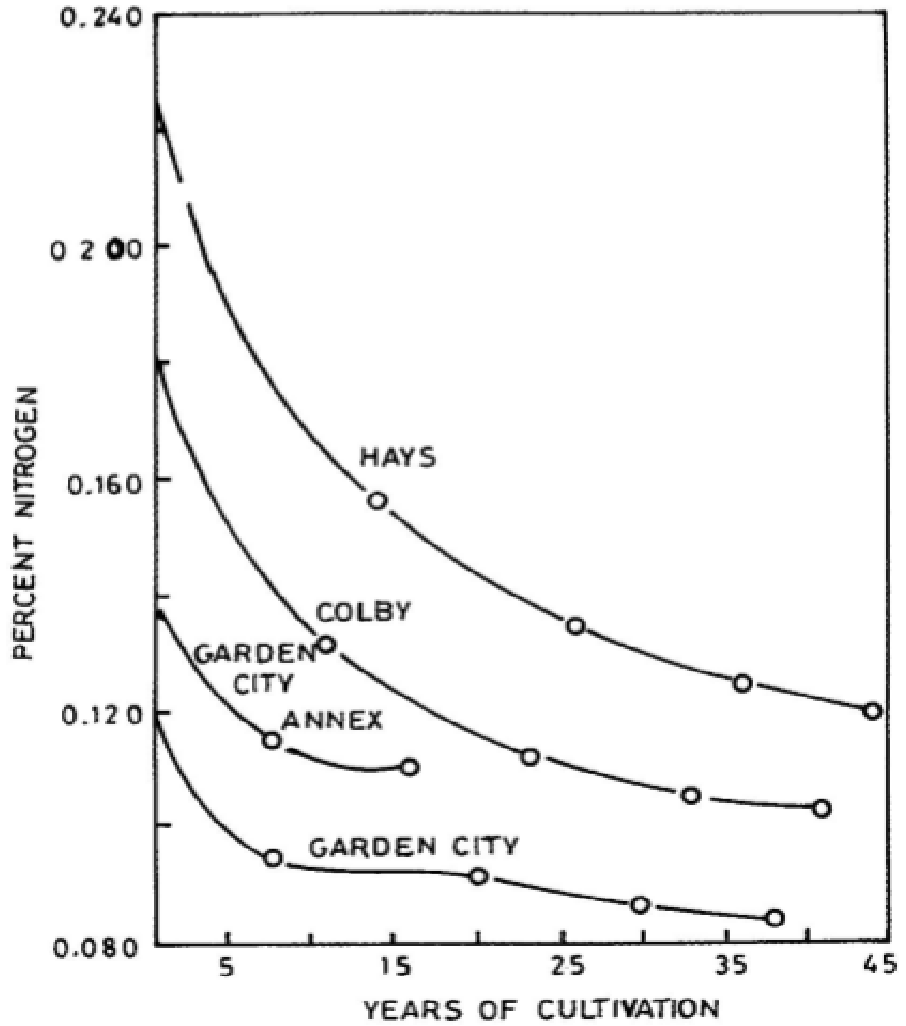


Figure 5.12. Effect of cultivation on nitrogen content of surface soils of Hays, Colby, and Garden City, Kansas. (From Hobbs and Brown, 1957. Agron. J. 49:259. With permission of the ASA, Madison, WI.)

Table 5.4 Effect of Conservation Tillage on Organic C and N in Soil

Location and soil	Annual precipitation (mm)	Soil depth (cm)	Length of study (yr)	Tillage system[a]	Increase (%/yr)	
					C	N
South Africa						
Haploxeralf	412	10	10	TT	5.6	3.4
Haploxeralf	412	10	10	NT	7.3	5.1
Germany						
"Podsol"		30	5	NT	3.2	1.4
"Podsol"		30	5	NT	2.4	1.6
"Podsol"		30	6	NT	1.3	1.3
Australia						
Western						
Psamment	345	15	9	NT	1.6	—
Alfisol	307	15	9	NT	0.7	—
Alfisol	389	15	9	NT	1.4	—
Queensland						
Pellustert	698	10	6	NT	1.2	1.3

Canada						
Saskatchewan						
Chernozem		15	6	NT	6.7	2.8
United States						
North Dakota						
Haploboroll	375	45	25	SM	1.8	1.3
Haploboroll	375	45	25	SM	–0.1	0.1
Argiboroll	375	45	25	SM	0.5	0.4
Kansas						
Haplustoll		15	11	NT	0.7	0.6
Nebraska						
Haplustoll	446	9	15	NT	2.8	2.4
	446	10	15	NT	1.2	1.0
Oregon						
Haploxeroll	416	15	44	SM	0.3	0.4
Washington						
Haploxeroll	560	5	10	NT	1.9	2.0

Table 5.4 Effect of Conservation Tillage on Organic C and N in Soil (Continued)

Location and soil	Annual precipitation (mm)	Soil depth (cm)	Length of study (yr)	Tillage system[a]	Increase (%/yr)	
					C	N
Mean					2.2	1.7
Minimum					–0.1	0.1
Maximum					7.3	5.1

[a]TT, tine-till; NT, no-till; SM, stubble-mulch

Adapted from Rasmussen and Collins (1991).

no-till plots to 1.5 to 1.9% under puddling in a 0- to 5-cm layer of surface soil over 6 years.

5.6. SOIL N AVAILABILITY

5.6.1 N forms in soil

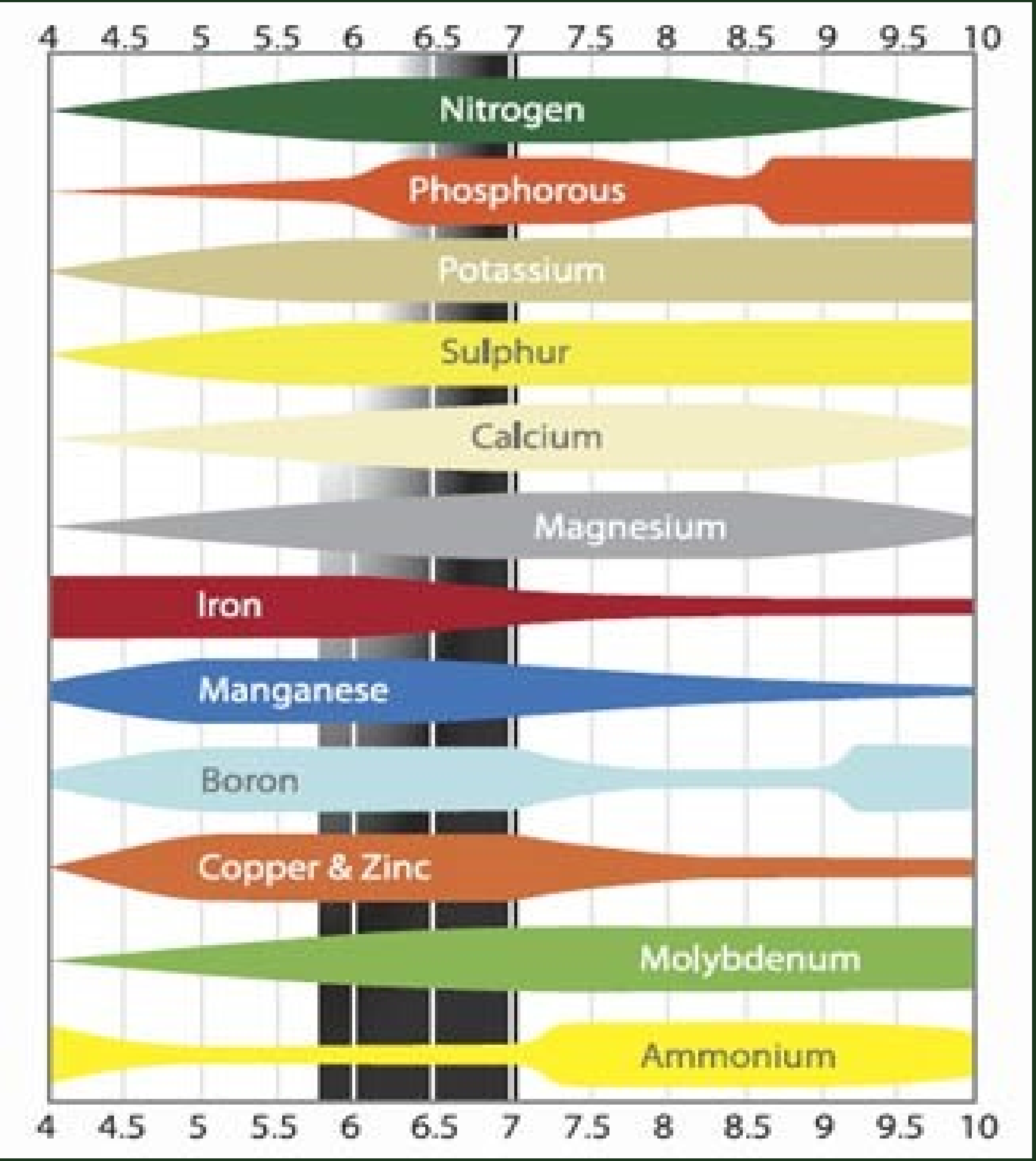
- NH_4^+
- NO_3^-
- NO_2^-
- N_2O
- NO
- N

5.6. SOIL N AVAILABILITY

5.6.2 Factors affecting Soil N availability

- Soil pH
- Organic matter decomposition & mineralisation
  a. OM quality
  b. Decomposer
  c. Environment
- Nitrification
- Mineralisation & immobilization

Soil pH



4 4.5 5 5.5 6 6.5 7 7.5 8 8.5 9 9.5 10
Nitrogen
Phosphorous
Potassium
Sulphur
Calcium
Magnesium
Iron
Manganese
Boron
Copper & Zinc
Molybdenum
Ammonium
4 4.5 5 5.5 6 6.5 7 7.5 8 8.5 9 9.5 10

OM DECOMPOSITION & MINERALISATION

- Organic matter decomposition & mineralisation determine by:

  a. OM quality

  b. Decomposer

  c. Environment

NITRIFICATION

1. Aminisasi
2. Amonifikasi
3. Nitritasi
4. Nitratasi

NITRIFICATION

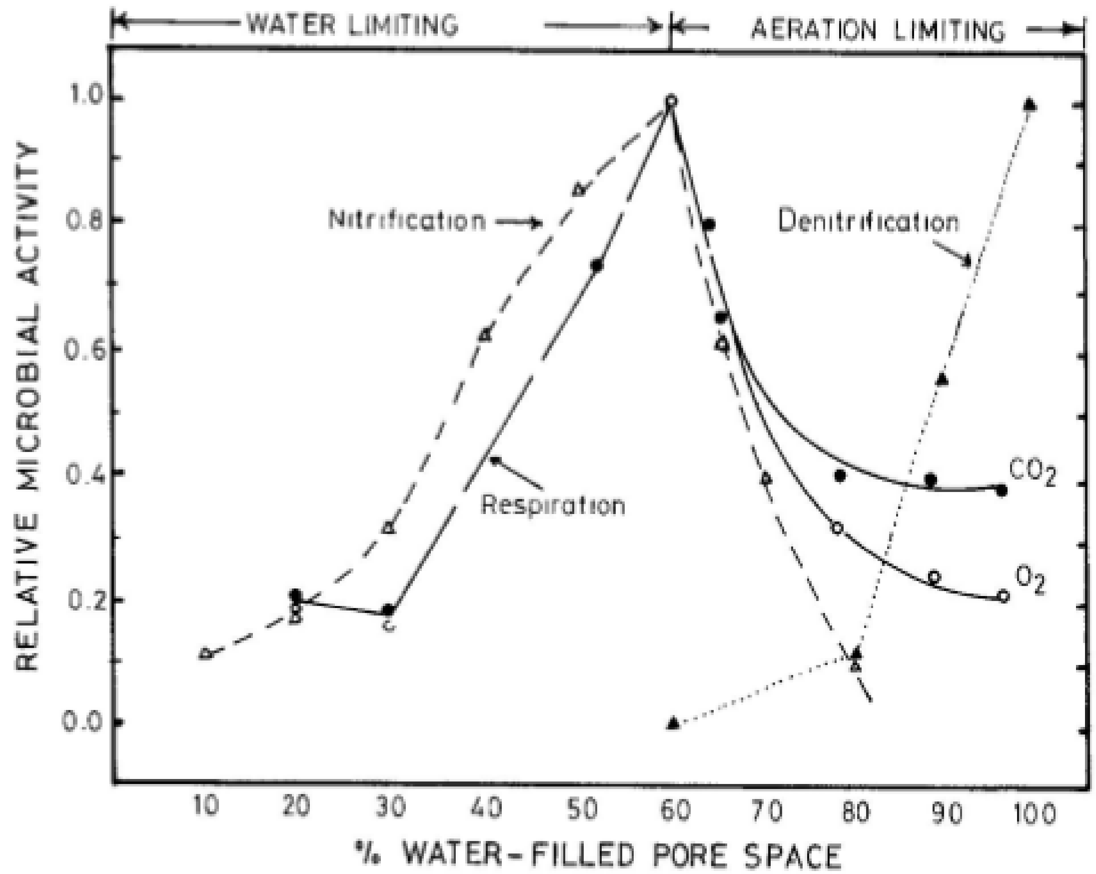


Figure 8.2. The relationship between water-filled pore space and relative amount of microbial nitrification (after Greaves and Carter, 1920), denitrification (after Nommik, 1956), and respiration (O_2 uptake, s–s, CO_2 production, d–d) (Linn and Doran study). Data for nitrification originally expressed as percentage water-holding capacity. (From Linn and Doran, 1984. Soil Sci. Soc. Am. J. 40:1267–1272. With permission of SSSA.)

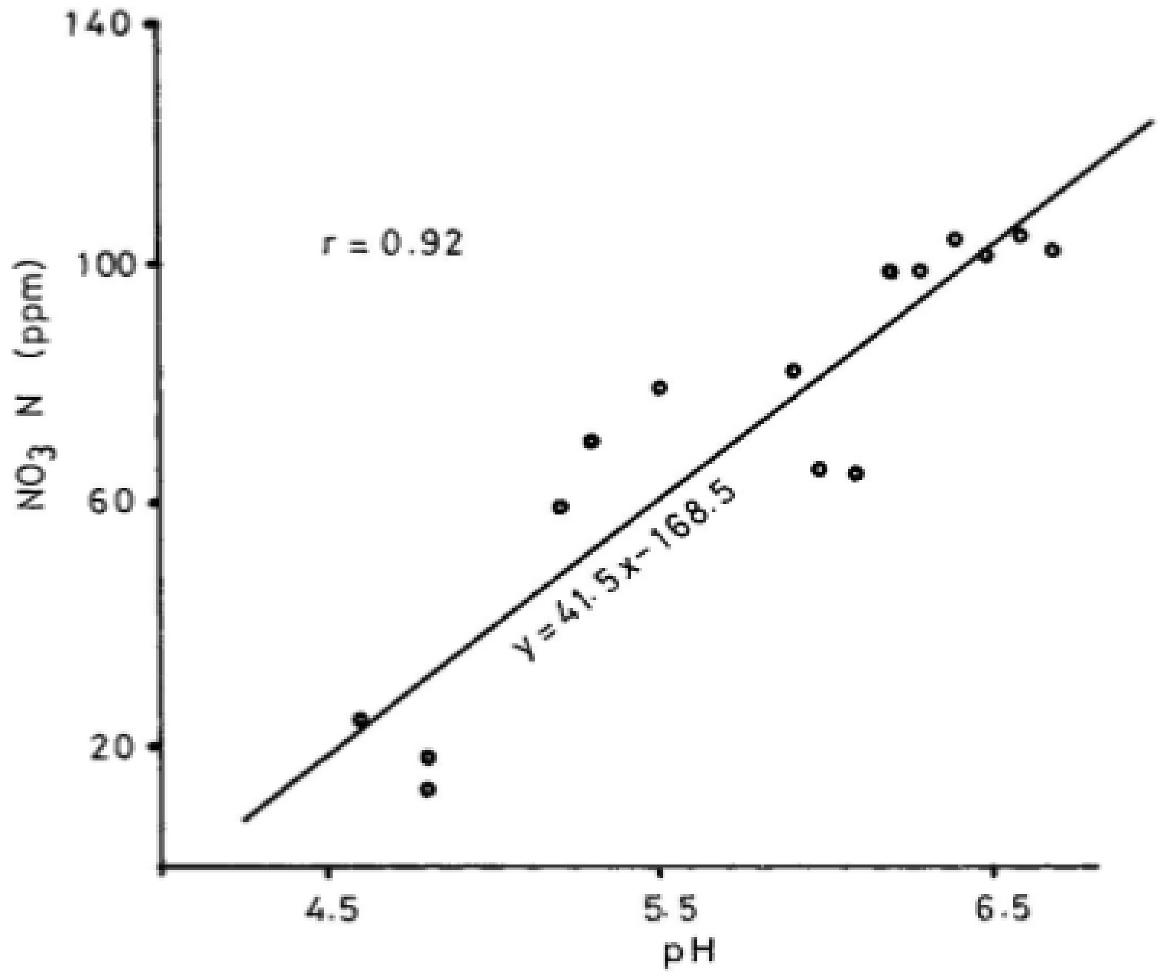


Figure 8.3. Relation between soil pH and NO_3^--N accumulation in soils treated with 100 ppm of NH_4^+-N as $(NH_4)_2SO_4$ and incubated for 15 days at 23°C. (From Dancer et al., 1973. Soil Sci. Am. Proc. 31:67–69. With permission of SSSA.)

NITRIFICATION

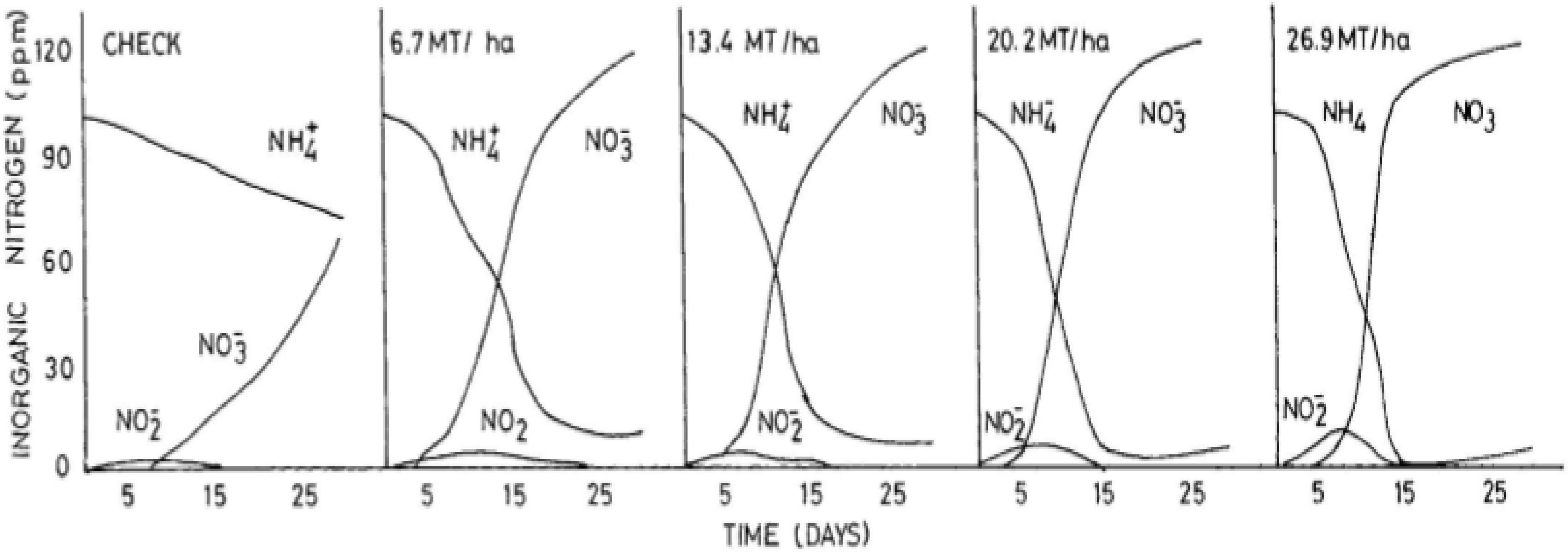


Figure 8.4. Effect of liming and soil pH on the concentration of NH_4^+, NO_2^- and NO_3^--N in soil treated with 100 ppm of NH_4^+-N as $(NH_4)_2SO_4$ and incubated for 30 days at 23°C. Treatments 0, 6.7, 13.4, 20.2, and 26.9 metric tons ha^{-1} of lime correspond to pH values of 4.7, 5.3, 6.0, 6.3, and 6.6, respectively. (From Dancer et al., 1973. Soil Sci. Soc. Am. Proc. 31:67–69. With permission of SSSA.)

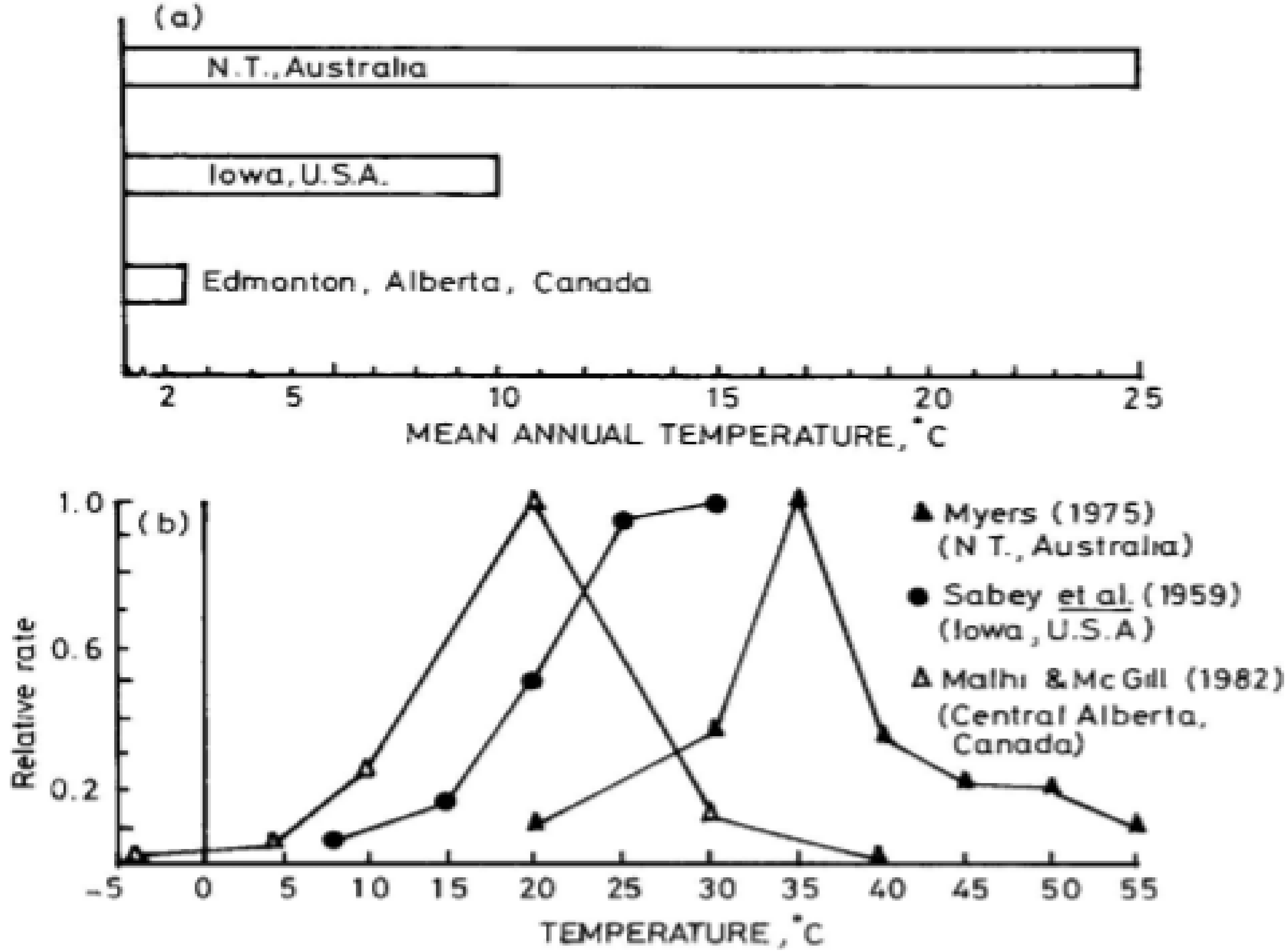


Figure 8.5. The effect of soil temperature on relative nitrification rate at Edmonton compared with published results from two warmer climatic regions: (a) Mean annual temperature for the three locations and (b) Relative nitrification rates. (From Malhi and McGill, 1982. Soil Biol. Biochem. 14:393–399. With permission from Elsevier Science Ltd.)

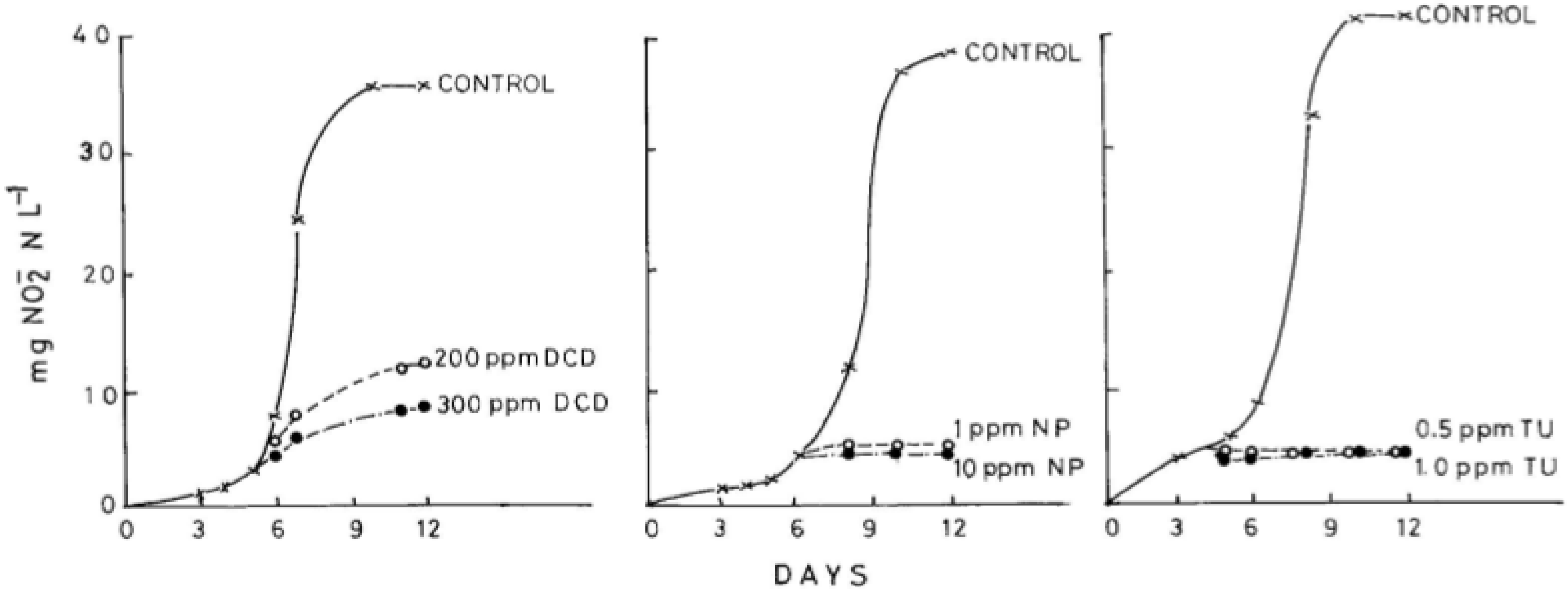


Figure 8.6. Effect of dicyandiamide (DCD), nitrapyrin (NP), and thiourea (TU) on the growth of *Nitrosomonas europea* in pure culture. (From Zacheri and Amberger, 1990. Fert. Res. 22:37–44. With permission of Kluwer Academic.)

MINERALISATION & IMMOBILIZATION

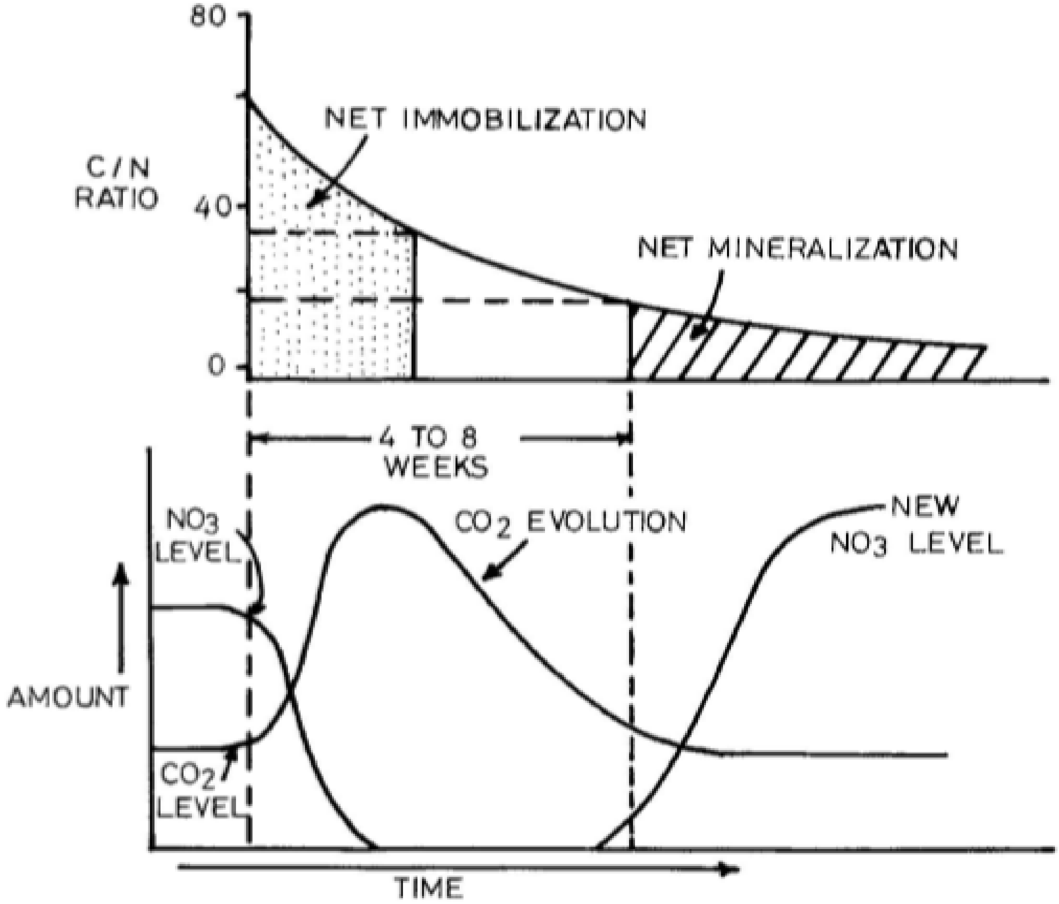


Figure 5.9. Changes in nitrate levels of soil during the decomposition of low-nitrogen crop residues. (From Stevenson, 1986. *Cycles of Soil — Carbon, Nitrogen, Phosphorus, Sulfur and Micronutrients*, pp. 13 and 166. With permission of John Wiley & Sons, New York.)

MINERALISATION & IMMOBILIZATION

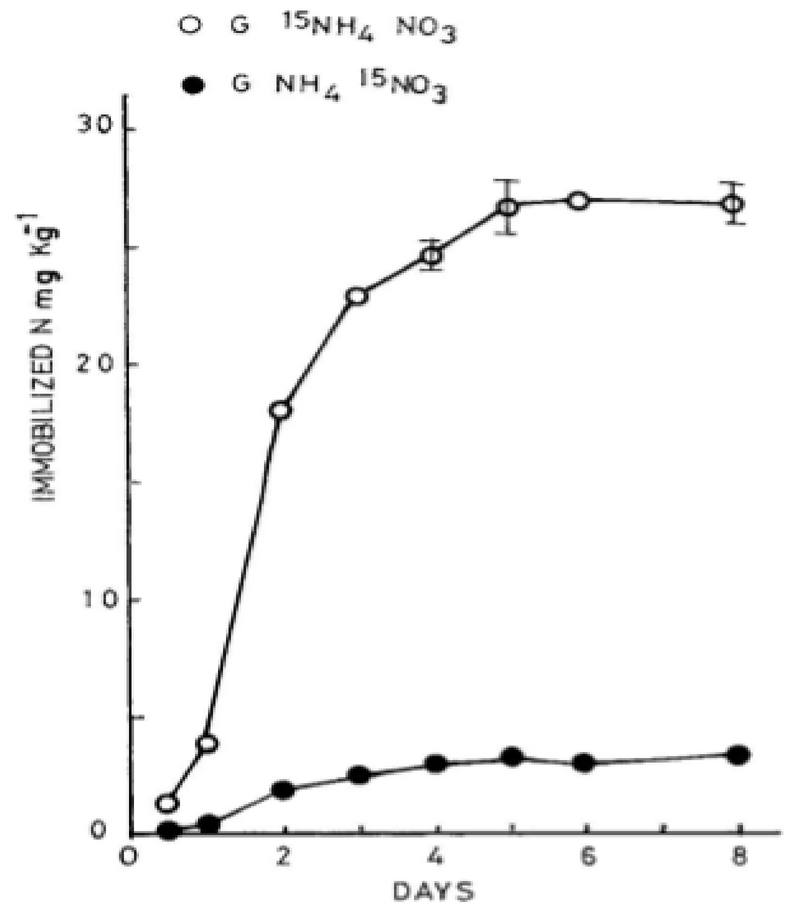


Figure 8.7. Immobilization of N in a loamy soil (soil I) incubated at 10°C with 500 mg C-glucose kg^{-1} soil. 100 mg N kg^{-1} soil applied as $^{15}NH_4 \cdot NO_3$ or $NH_4{}^{15}NO_3$. Values are the mean of two replications. (From Recous and Mary, 1990. Soil Biol. Biochem. 22:913–922. With permission from Elsevier Science Ltd.)

TABLE 2.5
Estimated Content and Release of Nitrogen from Various Soils

	Nitrogen in Soil (kg/ha)	
Type of Soil	**Total[a]**	**Annual Release[b]**
Sands	1400	28
Yellow sandy loam	2200	44
Brown sandy loam	3100	62
Yellow silt loam	2000	40
Grey silt loam	3600	72
Brown silt loam	5000	100
Black clay loam	7200	144
Deep peats	39,000	780

[a]From Schreiner O. and Brown B.E., in *United States Department of Agriculture, Soils and Men, Yearbook of Agriculture, 1938*, United States Government Printing Office, Washington, DC, 1938, pp. 361–376.
[b]Estimated at 2% annual mineralization rate of soil organic matter.

Table 5.1 Carbon and Nitrogen Contents of Soils under Various Moisture-Temperature Interactions[a]

Temperature–moisture interaction zone	Carbon ($Mg\ ha^{-1}\ m^{-1}$)	Nitrogen ($Mg\ ha^{-1}\ m^{-1}$)	Carbon/nitrogen
Boreal dry bush	102	6.3	16
Boreal wet forest	150	9.8	15
Boreal rain forest	320	15.0	22
Cool temperature desert bush	99	7.8	13
Cool temperature grassland	133	10.3	13
Cool temperature wet forest	120	6.3	19
Cool temperature rain forest	200	8.0	25
Warm temperature desert bush	60	3.0	20
Warm temperature moist forest	93	6.5	14
Warm temperature wet forest	270	18.0	14
Warm temperature rain forest	270	7.0	38
Tropical desert bush	10	0.5	20
Tropical dry forest	100	8.9	11
Tropical wet forest	145	6.6	22
Tropical rain forest	180	6.0	30

[a]Adapted from Zinke et al. (1984) and Paul and Clark (1989).

5.5. AGRONOMIC ROLE OF N

5.5.1 Effect of N on growth and production

- N required for formation of protein (amino acids), nucleic acid, enzyme, chlorophyl, ADP, ATP, etc.
- N is a vital nutrient for vegetatif growth

5.5. AGRONOMIC ROLE OF N

5.5.2 N deficiency simptoms

- N deficiency : tumbuh lambat, kurus, pucat
- Kekurangan N membatasi produksi protein dan bahan kering lain yang diperlukan untuk pembentukan sel baru.

N Deficiency Symptom

- Lack of growth or stunted growth. General yellowing of foliage, older leaves first. Loss of leaves under severe deficiency. Purplish colouration due to accumulation of anthocyanin pigments

5.5. AGRONOMIC ROLE OF N

5.5.2 N deficiency simptoms

Corn

Tomato

Cucumber

TYPICAL NUTRIENT DEFICIENCY SYPTOMS SEEN ON PLANT FOLIAGE

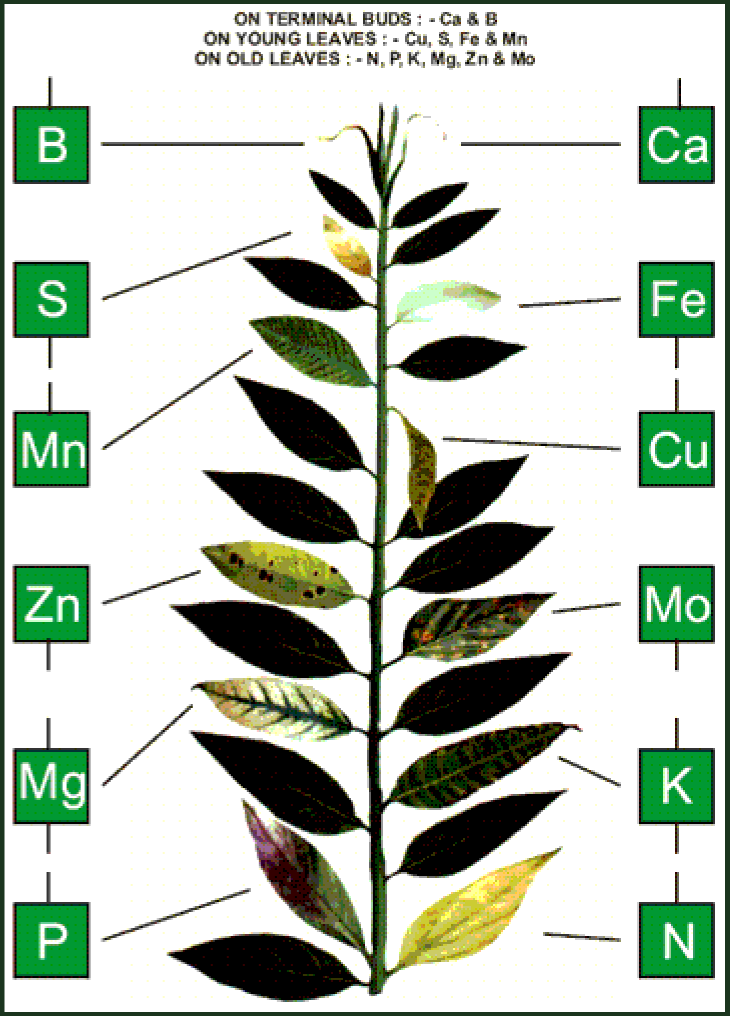


Chart above obtained and used with permission from Micnelf USA Inc.

5.5. AGRONOMIC ROLE OF N

5.5.2 Excess of N

- Kelebihan N : warna lebih gelap, sukulen, pertumbuhan vegetatif hebat, tanaman mudah roboh, mudah rusak karena frost dan pembekuan.

6. NITROGEN MANAGEMENT

6.1 Decreasing N Losses

6.2 Increasing N uptake

6.3 Organic matter management

6.4. Management of N fertilization

6. NITROGEN MANAGEMENT

6.1 Decreasing N Losses

1. Run off and erosion

Tabel 1. Pengaruh vegetasi dan lereng terhadap erosi dan kehilangan hara.

Perlakuan	Lereng (%)	Erosi (ton/ha)	Aliran Permukaan (mm)	Unsur hara yang hilang (kg/ha)				
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Tanah bera, dibajak setiap bulan	22	225.4	1730	25	0.98	24	238	152
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Tanaman kopi tua tanpa konservasi	55	0.6	59	1	0.08	1	2	2

Sumber : Castro dan Rodriguez (1958) dalam Sanchez, 1976.

6. NITROGEN MANAGEMENT

6.2 Increasing N uptake

6.3. Organic matter management

- > 90% N in soil is organic N, so maintaning SOM very important
- Preventing SOM losses
- Adding/giving OM

6. NITROGEN MANAGEMENT

6.4. Management of N fertilization