اسمدة متقدم 4

Soil and Fertilizers Nitrogen L3

* Nitrogen is the most important plant nutrient for crop production. It is a constituent of the building blocks of almost all plant structures. It is an essential component of chlorophyll, enzymes, proteins , etc. Nitrogen occupies a unique position as a plant because rather high amounts are required compared to other essential nutrients. It stimulates root growth and crop development as well as uptake of other nutrients . Therefore, plants, except legume which fix N_2 from atmosphere , respond quickly t N applications.

* The ultimate source of N used by plants is the inert gas N_2 , which constituents about 78% of earth's atmosphere. In this form, however, it is useless to higher plants.

* The primary path-ways by which N is converted to forms usable by plants are these :

1- Fixation by Rhizobia and other microorganisms which live symbiotically on the roots of legumes and certain nonleguminous plants .

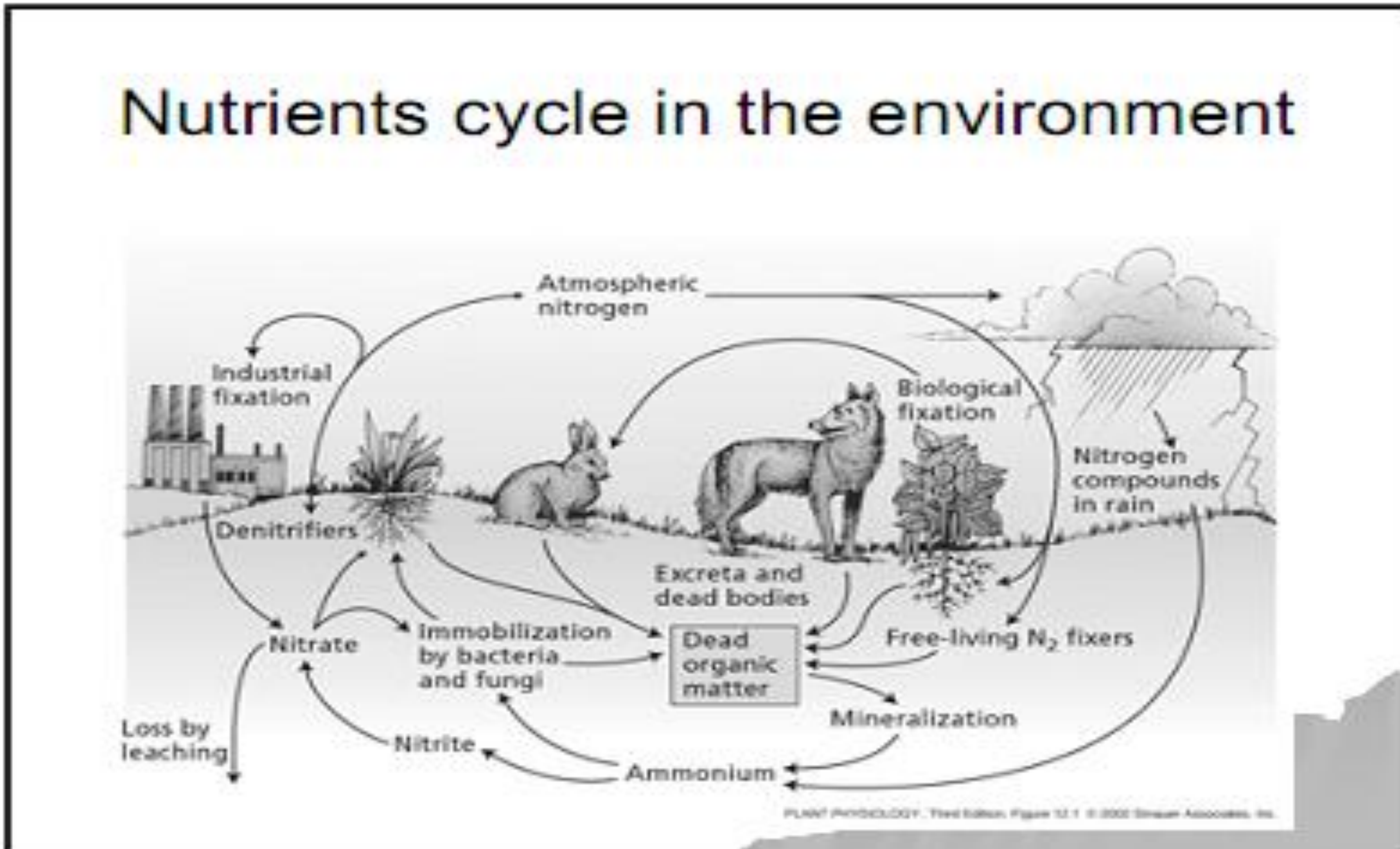
2- Fixation by free- living soil microorganisms and perhaps by organisms living in root zone of tropical plants.

3- Fixation as one of the oxides of nitrogen by atmospheric electrical discharges (lightning).

4- Fixation as ammonia, NO_3 , or CN_2 by any of the various industrial processes for the manufacture of synthetic N fertilizers.

The supply of elemental nitrogen is for all intent and purposes inexhaustible . This inert N is in dynamic equilibrium with the various fixed forms.

N CYCLE


Nutrients cycle in the environment
Atmospheric nitrogen
Industrial fixation
Biological fixation
Nitrogen compounds in rain
Denitrifiers
Excreta and dead bodies
Nitrate
Immobilization by bacteria and fungi
Dead organic matter
Free-living N_2 fixers
Mineralization
Loss by leaching
Nitrite
Ammonium

	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

* Forms on nitrogen in soil L4

1- organic N 2- inorganic N

- organic N : most of the N in a surface soil is present as organic

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.

2- Inorganic N forms :

from NH_4^+ to NO_3^- depending on redox potential of soil
(-3) (+5)

Nitrogen fixation (biological fixation):

$$N_2 + 8e^- + 16\ ATP \xrightarrow{\text{Nitrogenaes}} 2NH_3 + H_2 + 16\ ADP + P_I$$

- nitrogen gains from biological N_2 fixation

Ecosystem	range of fixation (Kg ha$^-$)
Arable land	7 — 28
Pasture (non legume)	7 — 114
pasture (legume)	73 — 865
Forest	58 — 593
Paddy (rice)	13 — 99
water	70 — 250

* Types of biological N fixation

a- non – symobtic fixation (free N fixing bacteria)

- Azotobactor , Beijerinckia , Spirillum and Enterobacter
- Cyanophycea: Nostoc and Anabaena

In general amount of fixed N is small in range of 5 to 50 Kg ha^- $year^-$.

However, is being used in rice fields in Japan and other countries

yield increase %	area	inoculation
2 — 20	Japan	Toly pothrix tenuis
114	India	A. Fertilissima
30	India	mixture
24	Asia	Anabana azotica

b – sybmbotic fixation

- Rhizobium and legumes are the most important

  Clover + lucerne in which N fixation is active can fix from 100 to 400 Kg ha^- $year^-$

- about 12000 verities of legumes can fix N , but only 200 verities are used as economical crops

* The species of the genus Rhizobium are numerous and required certain host plants. For example the bacteria that live symbiotically with soybean will not do so with alfalfa.

Rhizobium species	Host genra	legumes
R. meliloti	Medicago	Alfalfa
	Melilotus	sweet clover
R. trifolii	Clover	Clover
R. phaseoli	Bean	Bean
R. japonicum	Soybean	Soybean
	Cowpeas	Cowpeas

- Numerous legume tree species, widely distributed throughout the tropical and temperate zones of the world, fix appreciable amounts of nitrogen.

* Some nonleguminous plants also fix nitrogen by a mechanism similar to that of the symbiotic relationship between legumes and Rhizobia.
* Legume fixation of nitrogen is at max. only when the level of available soil nitrogen is at minimum. It is advisable to include a small amount of nitrogen in fertilizer of legume of crops at planting. Large or continued application of nitrogen , however, reduce activity of the Rhizobia and therefore are generally uneconomic.

Data from ISU (USA)

N	inoculation	soybean yield (bu/A)
0N	-	41
ON	+	49
60N	-	45
60 N	+	50

* Nitrogen Transformations in Soil

The principle forms of N in the soil are NH_4^{+}, NO_3^{-} and organic N compounds. At any time, the inorganic N in the soil is only a small fraction of total N in soil. Most of the N in surface soil is present as organic N. It consists of :

- protein 20 — 40 %
- amino sugar 5 — 10 % (as hexosamine)
- purine and pyrimidine derivates 1% or less
- rest complex unidentified compounds formed by reaction of NH_4 with lignin, polymerization of quinones with N compounds and condensation of sugars and amine.

These different N fraction are susceptible to various transformation processes.

L4 * Mineralization / Immobilization

Plants absorbed most of their N in the NH_4 and NO_3 forms. The quantity of these two ions presented to the roots of plants depends on the amounts of supplied as nitrogen fertilizers and released from organically bound soil nitrogen. The amount of released from organic source depends on the balance that exist among the factors affecting N mineralization , immobilization , and losses from soil. By way of definition , mineralization :

organic N → inorganic N ($NH_{4,}$ $NO_{2,}$ NO_3) + energy

↑ Heterotrophic microbes

Immobilization :

inorganic N → organic N

↓

* Factors effect mineralization / immobilization

- C/N ratio

if the decomposing organic residue has small amount of N in relation to C (wheat straw, mature corn stalks ,.....etc) the microorganisms will utilize any NH_4 and NO_3 present in soil to further the decomposition. This N is needed to permit rapid growth of the microbes pop. which accompanies the addition to the soil of a large of carbonaceous material (priming effect).

if, on other hand, the material added contains much N in proportion to the C present (legume residue), there will be no decrease in the level of mineral N in the soil. There may even increase, fairly rapid increase in this fraction of soil N, caused by its release from decomposing organic material.

as general role

C/N ratio > 30 → immobilization

C/N ratio = 20-30 → neither one

C/N ratio < 20 → mineralization

in assumption 40% of plant dry weight is C

if % N in plant tissue > 1.8 → mineralization

% N in plant tissue < 1.2 → immobilization

C/N ratio usually decreases with time in soil.

C/N ratio of the undisturbed top soil in equilibrium with its environm-ent is about 10 or 12 to 1.

* Mineralization of organic N compounds L4

involves 3 steps:

- **Aminization** : the pop. of heterotrophic soil micro-organsims is composed of numerous groups of bacteria and fungi each of which responsible for one or more steps in the numerous reactions in organic matter decomposition. The end product of the activity of one group furnish the substrate for the next, and so on down the line until the material is decomposed one of the final stage is termed aminization and is a function of some heterotrophic organisms . It is represented as following:

$$\text{protein} \longrightarrow R\text{-}NH_2 + CO_2 + \text{energy} + \text{other products}$$

- Ammonification

The amines and amino acids so released are further utilize by still other groups of hertreotrophs with release of ammoniacal compounds :

$$R\text{-}NH_2 + HOH \longrightarrow NH_3 + R\text{-}OH + \text{energy}$$

$NH_3 \rightleftarrows (NH_4)$

$(NH_4) \rightarrow$ nitrification

$(NH_4) \rightarrow$ absorbed by plants

$(NH_4) \rightarrow$ immobilized

$(NH_4) \rightarrow$ fixed

- Nitrification

Why interest in nitrification ?

- effect of nitrification on nitrogen nutrition of plants

NH_4^+ VS NO_3^-

- NO_3^- leaching.
- denitrification of NO_3^- .

Nitrification is a mixed blessing and possibly, a frequent evil.

The biochemical RX.

1^{St} Step :

$$NH_4 + 1/2O_2 \rightarrow H_3NO + 1/2O_2 \rightarrow HNO \rightarrow NH_3O_2 + 1/2O_2 \rightarrow HNO_2$$

hydroxyl amine (I) nitroxyl (II) dihydroxyamine (III)

compounds I & II & III unstable in soil , so

$$NH_4^+ + ½\,O_2 \rightarrow HNO_2 + 2H_2O + 2H^+$$

- Conversion to nitrite is brought about largely by a group of obligate autotrophic bacteria :

Nitrosomonas , Nitrosocous , Nitrosolobus

Nitrosomonas → most common

Nitrosolobus → more specific in growth requirements

- it has been shown that numerous heterotrophic organisms can convert nitrogen compounds to nitrite (bacteria, actino, and fungi)

2^{nd} step

HO–N= O ⟶ NH_3 O_3 ⟶ HO—N(=O)—O

autotrophic bacteria :

Nitrobacter , Nitrospira , Nitrococcus

Nitrobacter → most common

Nitrosomonas + nitrobacter = Nitrobacteria

the two steps

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

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

$$\text{net: } 2NH_4 + 4O_2 \longrightarrow 2NO_3^- + 4H^+ + 2H_2O$$

$$NH_4 \xrightarrow{X} NO_2 \xrightarrow{3X} NO_3$$

NO_2 ↓ toxic to plants & microbes

		ΔG
$NH_4 \longrightarrow$	NO_2	-65
$NO_2 \longrightarrow$	NO_3	- 20

- the rate of NO_2^- formation is equal to or greater than that of formation of NH_4^+

Factors affecting nitrification : As a general rule of thumb, the environmental factors favoring the growth of upland plants are those favor the activity of the nitrifying bacteria.

1- supply of NH_4^+ ion

$$\uparrow NH_4 \longrightarrow \uparrow \text{nitrification}$$

2- population of nitrifying bacteria

The presence of different – sized pop. of nitrifiers under field condition conditions would probably results in differences in the lag time between the addition of NH_4 and the build-up of NO_3 in the soil.

3- pH

- 5.5 to about 10 , with optimum around 8.5
- some time it takes place at pH values of 4.5 and even at pH 3.8
- at high pH > 8.5 Nitrosomans activity > Nitrobacter activity

4- soil aeration

The nitrobacteria are obligate autotrophic aerobes . Max. nitrification occurred at 20% oxygen.

5- Temp.

- opt. temp. between 30- 35^{o} C . , however, it could take places at 2^{O} C
- nitrification opt. at 25^{o} C, while ammonification at 50^{o} C .