Soil Biology and Fertility (NRM-213)

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Chemistry of Nutrient Elements in Soil

Nitrogen

- Study of soil N has been started as early as 1804 by De'saucer who proposed that N come from atmosphere and soil

- In 1840, Van Liebig was of the opinion that N present in atmosphere is plenty and plants use elemental N from atmosphere.
  So N may not be critical or limiting.

- Laws and Gilbert 1843 stated that soil should provide the form of N required by plants for their growth

- Boussingault and few others had also worked on these aspects.

- Soil contains 200 - 4000 ppm N with an average of 1500 ppm. The soil nitrogen is distributed as

  a) organic form (90-95% of total N)
  b) Inorganic form (5 - 10% of the total N)

- All the N present in the soil is the combined form and no free nitrogen is found occurring in soil. The N will be either in the oxidized form or reduced form.

- **Atmosphere contains 78.09% N by volume or 78% by wt**
- **The entire quantity of N in atmosphere is in elemental form**
- **N_2 occurring in the atmosphere is highly inactive form, unutilized mostly except by microbes**
- **Scientists are trying the isolate microbes which can develop on leaf surface and inturn the leaves can utilize the microbial fixed N**
- **The amount of N present in the universe is found to be plenty**
- **Donald (1960) had assessed the approximate quantity of nitrogen present in different components of the universe**

Total N content in plant kingdom	: 1×10^{9} tons
Total N content in Animal Kingdom	: 6×10^{7} tons
Total N content in Soils	: 15×16^{10} tons
Total N content in atmosphere	: 3.7×16^{15} tons

The quantity of N over one acre of land = 35,000 tons.

The minor quantity of soil N which is in organic form consists of

a) **Protein**

b) **Degraded protein compounds (Amino acids, peptides etc.,)**

c) **Non protein compounds (hydroxylamine etc.,)**

The inorganic form of N constitutes mainly of

a) Nitrate - N

b) Nitrite - N

c) Ammonium – N

***d) N_2O (Nitrous oxide)**

***e) NO (nitric oxide)**

***f) N_2O_3 (Dinitrogen trioxide)**

***g) N_2O_4 (Dinitrogen tetroxide)**

***h) N_2O_5 (Dinitrogen pentoxide)**

(* The inorganic forms listed above (d-h) are highly unstable are rapidly converted to other stable forms or escape into atmosphere)

The organic N compounds serves as the store house of N in soil, and are mostly insoluble in water

The ionic forms of nitrogen present in the soil are:

i) NH_4^+ forming NH_4OH

ii) NO_3^- forming HNO_3

iii) NO_2^- forming HNO_3

Sources and losses of N in Soil

Sources

i) Soil organic matter contributing 50% of soil total N
ii) N fixed by microbes
a) Symbiotic - legume : 50 - 300 kg N/ha / yr
- Non legume : 50 - 100 kg N/ha / yr
b) Non symbiotic : 30 - 50 kg N/ha / yr
c) BGA, Azolla etc. : 30 - 60 kg N/ha /yr
iii) Atmospheric discharge in rains :

$$N \xrightarrow{(O)} NO_2$$ **: 30 - 80 kg N / ha / yr**

iv) Atm. discharge as industrial wastes given out as NO, NO_2 : 15 – 25 kg N/ha /yr

v) Artificial N fertiliser sources

B) Losses of Nitrogen

i) Crop removal : 30%

ii) Leaching loss :
iii) Volatilization Loss :
iv) Dentrification Loss :
v) Erosion - removal of surface soil :

} **Highly variable depending upon condition, environment and management practices**

In a cultivated soil, the soil will try to attain equilibrium between these two aspects viz., sources (gains) and losses.

Transformation of N:

The transformation processes that are taking place in soils include..

i) Mineralisation (Ammonification)
ii) Immobilisation
iii) Nitrification
iv) Denitrification
v) Fixation of N - Clay fixation
- Atmospheric N fixation by microbes and photochemical fixation

The details of these transformation processes are given in "N" cycle

Nitrogen Cycle

Though nitrogen is present in abundant quantities in atmosphere (70%), its availability to crop plants is limited since the plants are wholly dependant on soil nitrogen (NO_3 and NH_4) for their nitrogenous constituents.

Animals inturn depend on plants for their energy and synthetic processes.

When animals and plants remains are added to the soil, their nitrogenous constituents undergo numerous changes / transformations, many of them are biologically opposed.

The net result is that only a small proportion of the total N in soil is present in an available form at any one time.

Ammonification

A large proportion of the nitrogenous materials found in the soil (or) added to the soil as plant and animal residues are in organic combination

In order to be utilized by the plants / microbes, these organic residues must be degraded and converted to NH_3 by the process of mineralization

Nitrification

The nitrogen (NH_4-N) mineralized by microbial decomposition / mineralization of organic N compounds is subjected to so many changes *viz.,*

a) adsorbed by clay complex / or fixed
b) absorbed by plant sp.
c) subjected to losses by volatilization
d) Nitrified by nitrifying bacteria

The oxidative sequence involved in the conversion of ammonia to nitrate is termed as nitrification

In soil, generally brought about by two groups of aerobic autotrophic bacteria which derive their energy from the oxidation of their specific N compounds

Denitrification

The processes in which nitrates are utilized by microorganisms fall into two general classes:

a) Nitrate assimilation / assimilatory NO_3 reduction
b) Nitrate respiration / dissimilatory NO_3 reduction

- Nitrate assimilation denotes the biological reduction of nitrate to the ammonia or amino level with the products being used for the biosynthesis of N containing cellular constituents

- In nitrate respiration, nitrate is used as an electron acceptor under anaerobic condition

- NO_3 being reduced to NO_2 and further to nitrous oxide and di nitrogen gas

Immobilisation

- It is the incorporation / conversion of inorganic N to organic N fractions in the microbial cells
- All microbes in soil whether aerobic / anaerobic, are in want of free mineral N for their growth / activity / multiplication
- The absorbed ammonia / nitrate by the microbes get converted to amino acids and latter to protein by the process called immobilization

Chemical nature of Soil Nitrogen

- In wetland rice cultivation, the significance of soil nitrogen is apparent from the fact that 60-80% of N absorbed by the crop is derived from the native nitrogen pool

- As in dryland soils, a major portion of the N in wetland soils occurs in the organic pool, whose chemical nature is not completely known

- There are various fractions of inorganic nitrogen in wetland soil which represent a small part of the total soil N

- These forms constitute an extremely dynamic N system in the soil and therefore is affected by physical, chemical and microbiological reactions

- **The predominant form of inorganic N in the wetland soil is NH_4^+**

- **Nitrification - denitrification is considered to occur in the aerobic-anaerobic soil layer of the wetland soil**

- **However, the amounts of NO_2-N and NO_3-N found are practically insignificant in a continuously flooded soil because of their high instability**

The nitrogen transformation in a wetland soil can be studied under the following aspects.

A) Physical and physico chemical N transformation processes:

i) Transport
ii) Sorption - Adsorption
iii) Ammonia volatilization

B) Biochemical N transformation processes:

i) Ammonification - Immobilisation
ii) Nitrification - Denitrification
iii) Urea hydrolysis

Ammonia Volatilization

Conditions in the wetland rice field are conducive to ammonia volatilization loss

The following physico chemical and biological factors of a flooded soil - water - atmosphere system and others simultaneously influence ammonia volatilization from wetland rice soils

Soil parameters

- Soil pH
- Salinity and alkalinity
- $CaCO_3$ content
- CEC
- Predominant Exchangeable ions
- pH buffering capacity
- Partial pressure of CO_2
- Microbial activity

Flood water parameters:

- pH
- Conc. of NH_3 (NH_3 aq. + NH_4^+, NH_4OH)
- Total alkalinity
- pH buffering capacity
- Temperature
- Water movement
- Algal growth or activity
- Depth
- Conc. of P
- Use of pesticides

Atmospheric parameters:

- Air temperature
- Solar radiation
- Wind velocity
- Partial pressure of NH_3 (PNH3)

Other parameters:

- N management
- Water management
- Plant canopy

All these factors presumably operate simultaneously

Most of the studies, however, suggest ammonia volatilization to be less than 20% of the applied N

During the process of volatilization, gaseous ammonia is formed

$$(NH_4 \rightleftharpoons NH_3 + H^+)$$

Bio-chemical N transformation

i) Urea Hydrolysis:

- **Urease activity is common in wetland soils.**
- **Oxidized surface soil - urea hydrolysis is faster than the underlying reduced soil from the same field.**
- **In wetland soils, urease activity may be influenced by soil pH, temperature and organic manure content.**
- **Urea hydrolysis was recorded over a pH range of 6-9, with a max. at pH 8.0.**
- **In the wetland field, urea should be incorporated before transplanting or top dressed, when soil is normally reduced and when the pH is stabilized in the 6.5 - 7.2 range.**
- **The pH values of the wetland soils per se, except those of acid sulphate or sodic soils may not, therefore, exert a marked effect on urea hydrolysis.**
- **The optimum temperature for the conversion of urea to ammonium seems to be in the 30-40°C range.**

Urea derivatives like Isobutylidine diurea (IDBU), urea form and glycoluril hydrolysed at much slower rates than urea and in the case of glycoluril, a lag period of 8-16 days occurred before hydrolysis began.