Dinitrogen fixation: Symbiotic and asymbiotic diazotrophs

By – Dr. Ekta Khare

Department of Microbiology,

Chhatrapati Shahu Ji Maharaj University, Kanpur

Introduction

- **Nitrogen is an element essential for the support of all forms of life.**
- **Nitrogen is the most abundant gas in Earth's atmosphere; it is extremely unreactive.**
- **Most organisms including plants cannot access the atmospheric dinitrogen for metabolic processes.**
- **Plants can utilise only the reduced forms of the nitrogen; hence, nitrogen first must be fixed and converted to a combined form (either ammonia/nitrate) and then trapped by the plants.**
- **Certain microorganisms have the ability to use the renewable source of energy to fix atmospheric nitrogen.**
- **Around 2.5×10^{11} Kg NH_3 is fixed annually by biological means which is a huge amount in comparison to the physical nitrogen fixation.**
- **Biological nitrogen fixation (BNF) is a microbiological process that converts atmospheric di-nitrogen (N_2) into plant-usable form, which offers as an alternative to inorganic fertilizers.**

Biological Nitrogen Fixation

- Works of Atwater, Hellriegel and Wilfaoth published in 1880s – Among the first to provide scientific data supporting the importance of root nodules and bacteria wthin them in the process of nitrogen fixation by clover and other leguminous plants.
- From then concerted efforts determined the symbiotic organisms associated with the root nodules of legumes (or other plants) as well as free living microorganisms capable of nitrogen fixation.
- Symbiotic nitrogen fixing organisms an photosynthetic nitrogen fixers account for most of the atmosphere N_2 assimilated into organic forms in nature.
- With introduction of acetylene reduction technique become possible to check N_2 fixing potential of other organisms.
- Free living N2 fixers though less efficient in N2 fixation but ubiquitous distribution plays major ecological importance.

Diazotrophs

- Those microbes which fix dinitrogen into simple available form (ammonia) are known as diazotrophs, comprises in bacterial and archaeal domains.

Or

- Diazotroph is a microorganism that is able to grow without external source of fixed nitrogen.
- The word diazotroph is derived from the words *diazo* ("di" = two + "azo" = nitrogen) meaning "dinitrogen (N_2)" and *troph* meaning "pertaining to food or nourishment", in summary dinitrogen utilizing.
- The N_2-fixing (diazotrophic) bacteria include heterotrophic, phototrophic-sulfur bacteria, actinomycetes, proteobacteria, cyanobacteria and methanogenic species inhabiting soil, water, animal gut, and in association with plants in varied relationships ranging from colonization of the rhizosphere to complete symbioses.
- Enzymatic conversion of molecular nitrogen to ammonia is catalysed by nitrogenase, an oxygen labile enzyme complex highly conserved in free living and symbiotic diazotrophs.

Diazotrophs

- Biological Nitrogen Fixation is performed by prokaryotes; mainly include :
  - aquatic organisms, such as cyanobacteria,
  - free living soil bacteria, such as *Azotobacter,*
  - bacteria that form associative relationships with plants (colonising the root surface), such as *Azospirillum*
  - Leguminous and actinorhizal plants can obtain their nitrogen by association with rhizobia or Frankia via differentiation on their respective host plants of a specialised organ, the root nodule. Other symbiotic associations involve heterocystous cyanobacteria.
  - endophytic (living in inner plant parts) bacteria eg. *Azoarcus sp., Gluconacetobacter and Herbaspirillum presest*

Symbiotic Nitrogen Fixers

- Symbiotic association of various genera with leguminous plants:
  - *Azorhizobium caulinodans*- tropical legume (*Sesbania rostrata*)
  - *Allorhizobium undicola* – Lotus *(Lotus albicus)*
  - Bradyrhizobium japonicum – *Soybean* (*Glycine max*)
  - *Mesorhizobium amorphae* – false indigo (*Amorpha fruticosa*)
  - *Rhizobium trifolii* – Clover (*Trifolium, Crotalaria*)
  - *Sinorhizobium meliloti* – Alfalfa (*Medicago sativa*)
- Symbiotic association of actinomycetes with angiosperms:
  - *Frankia* sp. with alder (*Alnus*), bog myrtte or sweet gale (*Myrica*)
- Symbiotic association with leaf nodulation plants:
  - *Klebsiella aerogens*

Symbiotic & Associative Nitrogen Fixers

- Symbiotic association of marine bacteria with bivalves:
  - Aerobic, chemoheterotrophic sp. – bivalves (*Teredinidae*)
- Symbiotic association with marine diatoms:
  - *Richelia intracellularis* (cyanobacterium), *Rhizoselenia*
- Associative interaction with grasses:
  - *Azospirillum brasiliense* – tropical grasses
  - *Azospirillum lipoferum* – tropical grasses, maize
  - *Azotobactor paspali – Paspalum notatum*

Free Living Bacteria and Cyanobacteria

- Aerobic, heterotrophic – *Azotobacter, Derxia, Azomonas, Biejerinkia, Nocardia, Pseudomonas*
- Aerobic, phototrophic – *Anabaena, calothrix, Nostoc, Gleotheca, Cylindrospermum, Aphanocapsa*
- Facultative heterotrophs – *Enterobacter cloacae, Klebsiella pneumoniae, Bacillus polymyxa, Desulfovibrio desulfuricans, D. gigas, Achromobacter*
- Anaerobic, heterotrophic – *Clostridium pasteurianum, C. Butyricum, propionispira arboris*
- Anaerobic, phototrophic- *Chromatium vinosum, Rhodospirillum rubrum, Rhodopseudomonas sphaeroides, R. capsulata, Rhodomicrobium vernielli, Rhodocyclus, Chlorobium limocola*
- Nonphotosynthetic autotrophic – *Methanobacterium, Methylococcus, Methylosinus, Methanococcus, Methanosarcina*

Questions

- Write a short note on biological nitrogen fixation.
- Short note on diazotrophs.
- What is biological nitrogen fixation? Diazotrophs can be divided into how many categories? Briefly discuss with example.