GreenariA
Go Green, Learn Green
An Agricultural Monthly e-Magazine
Volume 02, Issue 11, 2024
ISSN: 2584-153X
Article ID: G-24-1140

NITROGEN FIXATION IN CYNOBACTERIA

Krishnendu K M
UG Student, College of Agriculture, Vellayani
Corresponding Author Mail ID: krishnendukm99@gmail.com

Introduction

Nitrogen fixation is a vital process that transforms atmospheric nitrogen into ammonia, making it accessible to living organisms. Cyanobacteria play a crucial role in this process, significantly impacting the global nitrogen cycle.Cyanobacteria are commonly referred to as "blue-green algae." While this term is useful for describing self-sustaining organisms found in water, it does not accurately represent any connection between cyanobacteria and other organisms known as algae.Certain filamentous cyanobacteria develop nitrogen-fixing heterocysts, which are specialized cells that create an anaerobic environment, enabling the process of nitrogen fixation to take place.The enzyme nitrogenase, found in the vegetative cells of cyanobacteria, plays a crucial role in the process of nitrogen fixation. Cyanobacteria fix nitrogen and exchange nutrients with host cells through symbiotic associations.

Nitrogen fixing cynobacteria

Anabaena: Anabaena is a filamentous cyanobacterium commonly found in symbiotic relationships with certain plants, such as water ferns (Azolla). It is distinguished by the formation of specialized cells known as heterocysts, which create a low-oxygen environment essential for the activity of nitrogenase, an enzyme critical for nitrogen fixation.

Nostoc: Nostoc is a genus that forms colonies and can be found in various environments, including soil, moist rocks, and in symbiotic relationships with plants, fungi, and lichens. Similar to Anabaena, Nostoc produces heterocysts, which are specialized cells that facilitate nitrogen fixation.

Cylindrospermum: Cylindrospermum is a filamentous cyanobacterium known for its ability to fix nitrogen within specialized cells called heterocysts. This organism is capable of thriving in moist soils and often engages in symbiotic relationships.

Trichodesmium: Trichodesmium is a marine cyanobacterium that plays a significant role as a nitrogen fixer in ocean ecosystems. Unlike most nitrogen-fixing cyanobacteria, Trichodesmium does not produce heterocysts; instead, it is capable of fixing nitrogen during specific periods when oxygen levels are diminished.

Calothrix: Calothrix is a filamentous cyanobacterium known for forming heterocysts at the tips of its filaments. This organism typically inhabits both freshwater and marine environments, playing a significant role in nitrogen fixation within these ecosystems.

Gloeocapsa: Gloeocapsa is a unicellular cyanobacterium known for its ability to fix nitrogen. It is commonly found in terrestrial environments, including rocks, soils, and moist surfaces.

Oscillatoria: Oscillatoria is a filamentous cyanobacterium capable of nitrogen fixation under specific conditions. While it does not form heterocysts, certain species are able to perform nitrogen fixation in low-oxygen environments.

Aphanizomenon: Aphanizomenon is a nitrogen-fixing cyanobacterium commonly found in freshwater ecosystems. It is known to form blooms in lakes and rivers, where it utilizes specialized cells called heterocysts to fix nitrogen within its filaments.

Role in ecosystem

Nitrogen-fixing cyanobacteria play a crucial role in ecosystems characterized by limited nitrogen availability, including nutrient-poor waters, soils, and symbiotic environments. Their capacity to convert atmospheric nitrogen into ammonia significantly enriches these ecosystems, facilitating the growth of other organisms. This process is especially relevant in agriculture, where cyanobacteria such as Anabaena, in symbiotic association with Azolla, are utilized as biofertilizers to enhance soil fertility, particularly in rice paddies.

Enzyme involved

1) Nitrogenase
2) Glutamine Synthetase (GS)
3) Glutamate Synthase
4) Nitrate Reductase
5) Urease
6) Hydrogenase
7) Superoxide Dismutase

Nitrogenase: Cyanobacteria, the key enzyme responsible for nitrogen fixation is nitrogenase. This enzyme facilitates the conversion of atmospheric nitrogen (N_2) into ammonia (NH_3), which the organism can use to synthesize proteins and other essential biomolecules. This process takes place in anaerobic conditions since nitrogenase is extremely sensitive to oxygen.

In cyanobacteria, nitrogenase is usually located in specialized cells known as heterocysts. These cells create an oxygen-free environment essential for the enzyme's activity, as nitrogenase is sensitive to oxygen. The nitrogenase enzyme complex consists of two primary components:

1. Dinitrogenase reductase (Fe protein) – responsible for transferring electrons.
2. Dinitrogenase (MoFe protein) – aids in the conversion of nitrogen to ammonia.

Glutamine Synthetase: This enzyme facilitates the conversion of glutamate and ammonia into glutamine, representing a crucial step in the process of nitrogen assimilation. It plays a vital role in integrating ammonia, a byproduct of nitrogen fixation, into organic molecules.

Glutamate Synthase: Glutamate synthase functions in conjunction with glutamine synthetase to convert glutamine and α-ketoglutarate into glutamate. This process is integral to the GS-GOGAT cycle, which serves as a primary pathway for nitrogen assimilation in cyanobacteria

Nitrate Reductase: This enzyme catalyzes the reduction of nitrite (NO_2^-) to ammonia (NH_3), which subsequently serves as a precursor in the synthesis of amino acids and various nitrogen-containing compounds.

Urease: Certain cyanobacteria possess the ability to utilize urea as a nitrogen source. The enzyme urease catalyzes the breakdown of urea into ammonia (NH_3) and carbon dioxide (CO_2), thereby making ammonia accessible for incorporation into organic molecules.

Hydrogenase: In certain cyanobacteria, nitrogen fixation results in the production of hydrogen (H_2) as a by-product. Hydrogenase enzymes facilitate the recycling of this hydrogen by oxidizing it, thereby generating energy or storing reducing power.

Superoxide Dismutase: Due to the high sensitivity of nitrogenase to oxygen, enzymes such as superoxide dismutase play a crucial role in safeguarding cyanobacteria from oxidative damage. These enzymes convert harmful oxygen radicals, specifically superoxide, into less reactive molecules, such as hydrogen peroxide.

Conclusion

Nitrogen-fixing cyanobacteria are essential contributors to the nitrogen cycle, playing a pivotal role in various ecosystems. By converting atmospheric nitrogen into a biologically accessible form, they enrich both soils and aquatic environments, thereby fostering plant growth and enhancing overall ecosystem productivity. Notable genera such as Anabaena, Nostoc, and Trichodesmium exemplify their significance, functioning in both symbiotic and free-living capacities and substantially contributing to the global nitrogen supply. Their ecological importance underscores their potential as natural biofertilizers, particularly in nutrient-poor conditions, making them valuable assets for sustainable agriculture.

Enzymes are essential to nitrogen metabolism, enabling cyanobacteria to effectively capture, fix, and utilize nitrogen in its various forms. This capability is vital for their survival and underscores their ecological significance.Cyanobacteria play an essential role in the global nitrogen cycle through nitrogen fixation, primarily facilitated by the enzyme nitrogenase, which converts atmospheric nitrogen into a bioavailable form. Supporting enzymes, including glutamine synthetase, glutamate synthase, nitrate reductase, and nitrite reductase, further enhance nitrogen assimilation and utilization within these organisms. Additionally, enzymes such as urease and hydrogenase enable cyanobacteria to exploit alternative nitrogen sources and manage the by-products of nitrogen fixation. Collectively, these enzymes empower cyanobacteria to thrive in various environments and significantly contribute to nitrogen availability within ecosystems.