**浙江大学2023–2024学年 春 学期**

**《植物-微生物的相互作用及可持续农业》课程期终论文**

课程号： 16196250 ，开课学院：\_\_\_ 农学院 \_\_\_

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| **得分** |  |
| **评语** |  |
| **评卷人** |  |

**课程论文的任务要求：**

请在以下三个论文选题中自主选择一个题目进行论文写作。

1. What is the importance of Mycorrhiza in Crop Sciences?

Please explain with some examples.

1. Please elaborate the genetic relationship between a

pathogen and a host with examples.

1. Please explain the role of diazotrophs in the Nitrogen

cycle with examples.（I choose this one.）

要求全英文写作，字数不少于2000字。论文具体格式请严格按照浙江大学的课程论文格式要求。请将课程论文打印成纸质版于2024年04月25日（周四）提交。

**A Comprehensive Overview of**

**the Role of Diazotrophs in the Nitrogen Cycle**

**Abstract:**

Diazotrophs, a group of microorganisms capable of fixing atmospheric nitrogen into a form that is usable by plants, play a crucial role in the nitrogen cycle. This paper aims to provide a detailed explanation of the importance of diazotrophs in nitrogen cycling, including some examples of their impact on various ecosystems. The key processes involved in nitrogen fixation, such as symbiotic and free-living nitrogen fixation, will be discussed, along with the ecological significance of diazotrophs in promoting plant growth and soil fertility.

**Keywords:**

Diazotrophs, Nitrogen cycle, Nitrogen fixation, Symbiotic nitrogen fixation, Free-living nitrogen fixation, Plant growth, Soil fertility, Ecosystem diversity

**I. Introduction of diazotrophs and nitrogen cycle**

Before we formally introduce the role of diazotrophs in the nitrogen cycle, let's take a brief look at these two terms: Diazotrophs and Nitrogen cycle.

**I.I Diazotrophs**

“Diazotrophs are bacteria and archaea that fix atmospheric nitrogen(N2) in the atmosphere into bioavailable forms such as ammonia. (From wiki)” And they are able to grow without external sources of fixed nitrogen. This process, known as nitrogen fixation, is essential for the growth and development of plants, because nitrogen is a key nutrient required for plants’ survival.

There are two types of diazotrophs: Free-living diazotrophs and Symbiotic diazotrophs.

1. **Free-living Diazotrophs**

Free-living diazotrophs are a group of microorganisms that have the ability to fix atmospheric nitrogen and grow without relying on external sources of fixed nitrogen. They can independently carry out nitrogen fixation to convert atmospheric nitrogen into a usable form for their growth and metabolism.

1. **Symbiotic Diazotrophs**

While Symbiotic diazotrophs are nitrogen-fixing microorganisms that form a mutualistic relationship with plants. In this relationship, the diazotrophs colonize the roots of the host plant and provide it with fixed nitrogen while receiving nutrients and a suitable environment for growth in return.

**I.II Nitrogen cycle**

The nitrogen cycle is a complex biological and chemical process that involves the transformation of nitrogen between different forms in the environment. It includes a set of complex processes, including nitrogen fixation, nitrification, denitrification, and ammonification, all of which play a crucial role in maintaining the balance of nitrogen in ecosystems. The following is a brief introduction to the processes of nitrogen cycle: Nitrogen fixation, nitrification, denitrification, and ammonification.

1. **Nitrogen fixation**

Nitrogen fixation is the biological process by which certain microorganism convert atmospheric nitrogen gas (N2) into ammonia (NH3) or other nitrogen compounds that can be utilized by plants and other organisms. This process is essential for making nitrogen available in a usable form in ecosystems.

1. **Nitrification**

Nitrification is the biological process in which certain bacteria convert ammonia (NH3) or ammonium (NH4+) into nitrite (NO2-) and then into nitrate (NO3-). Nitrification plays a crucial role in the nitrogen cycle by converting ammonia, a form of nitrogen that can be toxic to plants in high concentrations, into nitrate, which is a form that plants can readily absorb and utilize.

1. **Denitrification**

Denitrification is the process by which certain bacteria convert nitrate (NO3-) or nitrite (NO2-) back into atmospheric nitrogen gas (N2) or other gaseous nitrogen compounds. Denitrification helps to return nitrogen to the atmosphere, completing the nitrogen cycle and preventing the accumulation of excess nitrate in ecosystems.

1. **Ammonification**

Ammonification, also known as mineralization, is the process in which organic nitrogen compounds (such as proteins and nucleic acids in dead plant and animal matter) are converted into ammonia (NH3) by decomposer organisms. Ammonification releases ammonia into the soil, where it can be taken up by plants or further converted into other nitrogen compounds through nitrification and other processes.

These four processes introduced above make up Nitrogen cycle, and the following article will discuss the role Diazotrophs play in Nitrogen cycle, with some examples.

**II. Diazotrophs in Nitrogen Fixation**

In the nitrogen cycle, diazotrophs contribute to the initial step of nitrogen fixation, where they enzymatically convert atmospheric nitrogen gas into ammonia (NH3) or ammonium ions (NH4+). This fixed nitrogen can then be taken up by plants and utilized for their growth. Actually, the nitrogen fixation is one of the core part of the nitrogen cycle, and a few examples of Diazotrophs participating in it are given below:

**II.I Azotobacter vinelandii**

Azotobacter vinelandii is a genus of free-living diazotrophs commonly found in soil. They have the ability to independently fix nitrogen, converting atmospheric nitrogen into a form that is usable by plants. Moreover, because it is a genetically tractable system, it’s also used to study nitrogen fixation in application.

**II.II Trichodesmium**

Trichodesmium, one of free-living diazotrophs, is a genus of marine cyanobacteria that can perform oxygenic photosynthesis and nitrogen fixation. These bacteria form large colonies in the ocean and contribute significantly to the input of fixed nitrogen in marine ecosystems. In fact, Trichodesmium and Cyanothece, are actually major contributors to oceanic nitrogen fixation.

**II.III Nostoc commune**

Nostoc commune, also a free-living diazotroph, is a filamentous cyanobacterium that belongs to the genus Nostoc. The presence of heterocysts in Nostoc commune allows it to fix atmospheric nitrogen, converting it into a form that can be used by the organism itself and potentially released into the surrounding environment. This ability to fix nitrogen contributes to the nutrient cycling and productivity of ecosystems where Nostoc commune is present.

**II.IV Rhizobium**

Rhizobium is a genus of symbiotic diazotrophs that form a mutualistic relationship with leguminous plants (such as soybeans, peas, etc.). The symbiotic nitrogen-fixing bacteria in the root nodules of leguminous plants, such as Rhizobium, can convert atmospheric nitrogen into a form that is usable by plants, providing nitrogen to leguminous plants while receiving the necessary nutrients and growth environment from the plants.

**II.V Frankia**

Just like Rhizobium, Frankia is a gram-positive Bacteria that is found on the roots of plants, and it is found one of symbiotic diazotrophs. The symbiotic relationship between Frankia and actinorhizal plants allows for the efficient fixation of atmospheric nitrogen, providing both the bacteria and the plant with a vital source of nitrogen for growth and development.

**III. Diazotrophs in other nitrogen cycling processes**

Beyond nitrogen fixation, some diazotrophs may also participate in other nitrogen cycling processes such as nitrification, denitrification, and ammonification, further influencing the availability and cycling of nitrogen in the ecosystem, and helping maintain a balanced nitrogen cycle in different ecosystems. Again, some examples are given below:

**III.I Azotobacter**

As said above, Azotobacter is a genus of free-living diazotrophic bacteria that can fix atmospheric nitrogen. But actually, in addition to nitrogen fixation, some species of Azotobacter are also involved in ammonification, the process of converting organic nitrogen into ammonia. This helps release ammonia back into the soil, making it available for plants to use.

**III.II Rhizobium**

Similarly, it had been said above that Rhizobium is a genus of nitrogen-fixing bacteria that form symbiotic relationships with leguminous plants. While besides fixing atmospheric nitrogen in nodules on plant roots, some species of Rhizobium are also capable of participating in denitrification, the process of converting nitrates or nitrites into nitrogen gas. This helps in returning nitrogen to the atmosphere and completing the nitrogen cycle.

**III.III Nitrosomonas and Nitrobacteria**

Nitrosomonas and Nitrobacteria are examples of nitrifying bacteria that are involved in the nitrification process. Nitrosomonas converts ammonia into nitrite, while Nitrobacter further oxidizes nitrite into nitrate. This proves that some diazotrophs may also have the ability to participate in nitrification processes in addition to nitrogen fixation.

**III.IV Pseudomonas**

Pseudomonas species are versatile bacteria found in various environments, including soil and water. Some species of Pseudomonas are capable of denitrification, where they use nitrate (NO3-) or nitrite (NO2-) as electron acceptors in the absence of oxygen. During denitrification, Pseudomonas bacteria enzymatically reduce nitrate or nitrite to produce nitrogen gas (N2) or nitrous oxide (N2O), which are then released back into the atmosphere. This process helps to recycle nitrogen in ecosystems and prevent the accumulation of excess nitrate in the environment.

**III.V Paracoccus**

Paracoccus is another genus of bacteria that can carry out denitrification. Similar to Pseudomonas, certain species of Paracoccus have the ability to use nitrate or nitrite as alternative electron acceptors under anaerobic conditions. By reducing nitrate or nitrite, Paracoccus bacteria help convert these nitrogen compounds back into atmospheric nitrogen gas or other gaseous nitrogen forms. This process is important for maintaining the balance of nitrogen in ecosystems and ensuring the availability of nitrogen for plants and other organisms.

(Special explanation: Although Pseudomonas and Paracoccus are primarily known for performing denitrification, some species have also been found to have the ability to fix nitrogen. Therefore, although their main role is to participate in the denitrification process, in some cases they can also play a role in nitrogen fixation, helping plants obtain nitrogen sources. So they are all considered as diazotrophs.)

**IV. Ecological significance of Diazotrophs**

Since the crucial role the Diazotrophs playing in the nitrogen cycle, Diazotrophs are of a set of ecological significance not only in Nitrogen cycle, but also in other aspects. Here are some points following:

**IV.I Nitrogen cycle**

As mentioned above, Diazotrophs are key players in the nitrogen cycle, helping to recycle nitrogen between the atmosphere, soil, and living organisms. By fixing atmospheric nitrogen and making it available for plant uptake, diazotrophs contribute to the cycling of nitrogen in ecosystems and help maintain nutrient balance. Especially, they are essential for nitrogen fixation process among the nitrogen cycle, fixing the abundant but not readily plant-usable atmospheric nitrogen into a form that plants can absorb and utilize for growth. In this process, Diazotrophs help to increase the availability of nitrogen in ecosystems, supporting plant growth and productivity.

**IV.II Symbiotic relationships**

Besides, symbiotic Diazotrophs form symbiotic relationships with plants, such as legumes, where they colonize the plant roots and provide them with fixed nitrogen in exchange for carbohydrates. This mutualistic relationship benefits both the diazotrophs and the plants, enhancing nutrient availability and promoting plant growth.

**IV.III Soil Fertility**

Moreover, Diazotrophs also contribute to soil fertility by adding fixed nitrogen to the soil through nitrogen fixation. This helps to replenish nitrogen levels in the soil, supporting plant growth and productivity without the need for synthetic fertilizers. Therefore, they have irreplaceable ecological significance in nature.

**IV.IV Ecosystem diversity**

Last but not least, Diazotrophs play a role in maintaining ecosystem diversity by providing a source of fixed nitrogen for a wide range of plants and organisms. This helps to support diverse plant communities and contribute to overall ecosystem health and resilience.

**V. Conclusion**

In the above chapter, the article briefly introduces Diazotrophs and Nitrogen cycle, focuses on the irreplaceable roles played by Diazotrophs in the process of Nitrogen cycle as examples, such as Azotobacter vinelandii, Trichodesmium, and Nostoc commune in nitrogen fixation, or Rhizobium, Nitrosomonas and Nitrobacteria in other processes among nitrogen cycle. It's also mentioned in the article some ecological significance of Diazotrophs.

Based on the content of the above article, we can draw a conclusion:

Diazotrophs, nitrogen-fixing microorganisms, are integral to ecosystem functioning due to their pivotal role in nitrogen cycling, soil fertility, plant growth, and ecosystem diversity. By converting atmospheric nitrogen gas into ammonia or other usable nitrogen compounds, diazotrophs enhance the availability of nitrogen for plants, supporting their growth and productivity. Through symbiotic relationships with plants, such as legumes, diazotrophs provide fixed nitrogen in exchange for carbohydrates, fostering mutualistic interactions that benefit both parties. This process not only enriches soil fertility by replenishing nitrogen levels but also reduces the reliance on synthetic fertilizers, promoting sustainable agricultural practices.

Moreover, diazotrophs contribute to ecosystem diversity by providing a vital source of fixed nitrogen for a variety of plants and organisms, thereby supporting diverse plant communities and enhancing overall ecosystem health and resilience. By participating in the nitrogen cycle, diazotrophs facilitate the recycling of nitrogen between the atmosphere, soil, and living organisms, maintaining nutrient balance and promoting sustainability.

Overall, Diazotrophs are ecologically significant microorganisms that play a vital role in Nitrogen cycle. And the ability of Diazotrophs to fix atmospheric nitrogen and make it accessible to other organisms plays a crucial role in sustaining the productivity and health of ecosystems, highlighting their ecological significance in the natural world.

**References:**

1. The Wikipedia page of Diazotrophs: <https://en.wikipedia.org/wiki/Diazotroph#>
2. Seagrass-mediated rhizosphere redox gradients are linked with ammonium accumulation driven by diazotrophs. Journal | [J] Microbiology spectrum. Volume , Issue . 2024. PP e0333523-e0333523
3. Biological nitrogen fixation, diversity and community structure of diazotrophs in two mosses in 25 temperate forests. Journal | [J] Environmental microbiology. Volume 26 , Issue 1 . 2023
4. Symbiotic diazotrophs in response to yak grazing and Tibetan sheep grazing in Qinghai-Tibetan plateau grassland soils. Journal | [J] Frontiers in Microbiology. Volume 14 , Issue . 2023. PP 1257521-1257521