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Commentary

Impact of Agricultural Practices on Nitrogen Fixing Microorganism Diversity in Soils

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INTRODUCTION

Soil fertility is crucial for sustainable agricultural productivity and one of the key processes contributing to soil fertility is nitrogen fixation. Nitrogen is an essential nutrient for plants, but it often exists in the atmosphere as an inert gas (N_2) and is not directly usable by most plants. Nitrogen-fixing microorganisms such as certain bacteria and archaea play a critical role in converting atmospheric nitrogen into forms that plants can absorb, such as Ammonium (NH_4^+) and Nitrate (NO_3^-). These microorganisms are vital for maintaining soil health and ensuring crop growth without the excessive reliance on chemical fertilizers.

DESCRIPTION

Nitrogen fixation and its role in agriculture

Nitrogen fixation is a biological process in which nitrogen-fixing microorganisms convert atmospheric Nitrogen (N_2) into bioavailable forms of nitrogen. These microorganisms are broadly categorized into free-living nitrogen fixers and symbiotic nitrogen fixers:

Symbiotic nitrogen fixers: These microorganisms, primarily rhizobia and frankia, form mutualistic relationships with leguminous plants (such as peas, beans and clover) and some non-legumes. The bacteria fix nitrogen within specialized structures called nodules on plant roots, providing the plant with nitrogen while receiving carbohydrates and other nutrients in return.

Free-living nitrogen fixers: Certain bacteria, such as *Azotobacter, Clostridium* and some species of *Cyanobacteria*, fix nitrogen independently of plants. These organisms can be found in the soil or in aquatic environments, contributing nitrogen to the soil as they die or are consumed by other organisms.

Agricultural practices and their impact on microbial diversity

Agricultural practices vary widely depending on the region, crop type and farming system. However, certain practices tend to have a more consistent impact on soil microbial diversity, including nitrogen-fixing microorganisms. Below, we explore some of the most influential agricultural practices and their effects.

Use of synthetic fertilizers: The widespread use of synthetic nitrogen fertilizers has been one of the most significant changes to agricultural systems over the past century. While these fertilizers provide plants with readily available nitrogen, they can also have several negative impacts on nitrogen-fixing microorganisms.

- **Reduced microbial activity:** High levels of synthetic nitrogen can suppress the activity of nitrogen-fixing microorganisms in the soil. This is because when excess nitrogen is available, plants may reduce their dependence on nitrogen-fixing bacteria, leading to lower colonization rates and reduced fixation activity. Studies have shown that over-fertilization with nitrogen fertilizers can reduce the diversity of nitrogen-fixing microorganisms by favoring fast-growing, non-fixing microbial species.
- **Shift in microbial composition:** The excessive use of chemical fertilizers can alter the microbial community composition in soils. Research indicates that high nitrogen levels can lead to a decline in the abundance of certain beneficial microbes, including those involved in nitrogen fixation. For example, some species of Rhizobia and *Azotobacter* may be outcompeted by nitrogen-loving bacteria, disrupting the nitrogen cycle and reducing the soil's natural fertility.

Monoculture and crop rotation: Monoculture farming, the practice of growing a single crop species over large areas, can have significant impacts on nitrogen-fixing microbial diversity in soils. The following effects are commonly associated with monoculture.

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- **Reduced soil health:** Continuous monocropping can lead to the depletion of certain nutrients in the soil, particularly nitrogen. This depletion can affect the diversity of microorganisms, including nitrogen fixers. In some cases, monoculture can reduce the diversity of Rhizobia in the soil, as different plant species (such as legumes) support distinct groups of nitrogen-fixing bacteria.
- **Increased pest and disease pressure:** Monoculture systems are more vulnerable to pests and diseases that target a single crop species. Pesticides and herbicides used to control these threats can negatively affect the soil microbiome, including nitrogen-fixing microorganisms. Additionally, the lack of crop rotation can reduce the availability of diverse root exudates that support different microbial communities, leading to lower microbial diversity overall.

Tillage and soil disturbance: Tillage or the practice of plowing or turning the soil to prepare it for planting, can have significant effects on the soil microbiome, including nitrogen-fixing bacteria.

- **Soil disruption:** Tillage disrupts the soil structure, destroying soil aggregates and reducing the habitat available for soil microorganisms. This disruption can damage the physical environment of nitrogen-fixing bacteria, leading to a reduction in their numbers and diversity. Tillage can also expose microorganisms to excessive moisture and oxygen, both of which can harm certain species of nitrogen-fixing microbes.

Irrigation practices: Irrigation is another agricultural practice that can influence nitrogen-fixing microorganisms. While irrigation is necessary for crop growth in many regions, improper or excessive irrigation can have detrimental effects on microbial communities.

- **Waterlogging:** Over-irrigation or poor drainage can lead to waterlogged soils, which create anaerobic conditions that are harmful to certain nitrogen-fixing bacteria, especially those that are free-living or symbiotic. For example, *Azotobacter* and other free-living nitrogen fixers require well-aerated conditions to thrive and waterlogged soils can cause them to die off.
- **Salinity:** Irrigation practices that lead to the accumulation of salts in the soil can reduce microbial diversity, including nitrogen-fixing bacteria. High salinity can directly affect the growth and survival of nitrogen fixers, leading to a shift in microbial community composition.

CONCLUSION

The diversity of nitrogen-fixing microorganisms in agricultural soils plays a crucial role in maintaining soil fertility and supporting sustainable crop production. However, conventional agricultural practices, including excessive use of synthetic fertilizers, monoculture cropping, tillage and poor irrigation practices, can negatively impact the diversity and abundance of these essential microbes.