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IMPORTANCE OF RHIZOBIUM IN DICOT CROP

***Dr. Bahadur Lal**

Associate Professor, Department of Soil Science B.B.D. Govt. College Chimanpura, Shahpura, Jaipur, Rajasthan, India.

Corresponding Author: Dr. Bahadur Lal
Associate Professor, Department of Soil Science B.B.D. Govt. College Chimanpura, Shahpura, Jaipur, Rajasthan, India.

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ABSTRACT

Rhizobium, a genus of nitrogen-fixing bacteria, plays a critical role in the symbiotic association with leguminous plants. This association allows for the conversion of atmospheric nitrogen into a form that is readily available for plant uptake, thereby reducing the need for synthetic nitrogen fertilizers and promoting sustainable agriculture. The importance of Rhizobium in dicot crops lies in its ability to enhance crop productivity, improve soil fertility, and contribute to environmental sustainability. By establishing nodules on the roots of leguminous plants, Rhizobium enables the conversion of atmospheric nitrogen into ammonia through the process of nitrogen fixation. This process not only provides a natural and sustainable source of nitrogen for the associated plants but also enriches the soil with nitrogen, benefiting neighboring plants and supporting ecosystem functioning. The utilization of Rhizobium in dicot crops reduces production costs for farmers, minimizes environmental pollution caused by excessive fertilizer use, and promotes biodiversity by contributing to nutrient cycling in ecosystems.

KEYWORD: Rhizobium, Bacteria, Agriculture, Ammonia, Leguminous.

INTRODUCTION

Rhizobium is a genus of bacteria that forms a symbiotic relationship with leguminous plants, playing a vital role in the nitrogen cycle and nutrient management in ecosystems. This symbiotic association is of significant importance in agriculture due to its ability to fix atmospheric nitrogen and enhance crop productivity. Nitrogen is an essential nutrient required by plants for various physiological processes, and its availability directly affects plant growth and development. However, atmospheric nitrogen is inert and cannot be directly utilized by most plants. Rhizobium bacteria possess the unique ability to convert atmospheric nitrogen into a biologically useful form through the process of nitrogen fixation. The symbiotic association between Rhizobium and dicotyledonous plants involves the formation of specialized structures called nodules on the roots of the plants. Inside these nodules, Rhizobium establishes a mutually beneficial relationship with the plant, supplying it with fixed nitrogen while receiving carbohydrates and other nutrients from the plant. This nitrogen fixation process provides a sustainable source of nitrogen for the associated plants and reduces the reliance on synthetic nitrogen fertilizers. Consequently, the use of Rhizobium in dicot crops offers economic and environmental benefits by reducing production costs for farmers and minimizing the pollution caused by nitrogen runoff into water bodies.

Moreover, the presence of Rhizobium in the soil enhances soil fertility and promotes overall ecosystem functioning. The fixed nitrogen released into the soil by Rhizobium becomes available for other neighboring plants, leading to improved growth and increased biomass production. This, in turn, contributes to the diversity and stability of the surrounding ecosystem. Additionally, the ability of Rhizobium to facilitate nitrogen fixation provides a natural and sustainable approach to nutrient cycling, reducing the need for synthetic fertilizers and minimizing environmental degradation. The importance of Rhizobium in dicot crops extends beyond agricultural benefits. It plays a critical role in maintaining biodiversity by supporting the growth of leguminous plants and providing habitat and food sources for various organisms in the ecosystem. The symbiotic association between Rhizobium and dicot plants exemplifies the intricate interconnectedness of organisms within ecosystems and highlights the significance of microbial contributions to ecosystem functioning. In this study, we aim to investigate the specific mechanisms of Rhizobium-mediated nitrogen fixation and its impact on crop productivity, soil fertility, and environmental sustainability. Understanding the importance of Rhizobium in dicot crops will provide valuable insights into developing sustainable agricultural practices and fostering a balanced and resilient ecosystem.

Characteristics of Rhizobium

Rhizobium, a genus of nitrogen-fixing bacteria, possesses several characteristic features that contribute to its symbiotic relationship with leguminous plants and its ability to fix atmospheric nitrogen.

- Nitrogen Fixation: Rhizobium bacteria have the unique capability to fix atmospheric nitrogen into a biologically useful form. They possess the enzyme nitrogenase, which converts atmospheric nitrogen gas (N_2) into ammonia (NH_3) through a complex biochemical process. This ammonia can be further converted into various nitrogen compounds that are readily available for plant uptake and utilization.
- Symbiotic Association: Rhizobium forms a symbiotic relationship with leguminous plants. It establishes nodules on the roots of these plants, creating a specialized microenvironment. Inside the nodules, Rhizobium and the plant exchange nutrients and metabolites. The bacteria supply fixed nitrogen to the plant, while the plant provides carbohydrates and other necessary nutrients to the bacteria.
- Nodulation: Rhizobium induces the formation of root nodules in leguminous plants. This process involves the recognition and signaling between the bacteria and the plant host. The bacteria release signaling molecules called Nod factors, which trigger the formation of nodules on the root system of the plant. The development of nodules provides a favorable environment for the bacteria to colonize and carry out nitrogen fixation.
- Host Specificity: Different species of Rhizobium exhibit host specificity, meaning that each species has a preference for specific leguminous plant hosts. This specificity is determined by the recognition and compatibility between the signaling molecules produced by the bacteria and the receptors present in the host plant. This specificity ensures the establishment of a successful symbiotic relationship between Rhizobium and its compatible host plants.
- Free-Living Ability: Rhizobium bacteria can exist in the soil as free-living organisms when they are not associated with host plants. They have the ability to survive and grow in the absence of a symbiotic relationship. This free-living ability allows Rhizobium to persist in the soil, waiting for suitable host plants to establish symbiosis.
- Motility: Many species of Rhizobium are motile, possessing flagella that enable them to move in aqueous environments. This motility facilitates their colonization of the root surface and penetration into the root hairs, which is a crucial step in establishing symbiosis with the host plant.
- Genetic Diversity: Rhizobium exhibits significant genetic diversity among its species and strains. This diversity is reflected in their ability to interact with different leguminous plant hosts and adapt to various environmental conditions. It also contributes to the versatility and adaptability of Rhizobium populations in different agricultural and ecological contexts.

Importance of Rhizobium in dicot crops

- Nitrogen Fixation: One of the primary benefits of Rhizobium bacteria is their ability to fix atmospheric nitrogen into a form that is readily usable by plants. Nitrogen is an essential nutrient required by plants for their growth and development. Rhizobium establishes nodules on the roots of leguminous plants and converts atmospheric nitrogen into ammonia through the process of nitrogen fixation. This ammonia is then converted into various nitrogen compounds that the plants can utilize, thereby providing a natural and sustainable source of nitrogen.
- Enhanced Crop Productivity: By forming a symbiotic relationship with Rhizobium, dicot plants can access a direct source of nitrogen without relying solely on synthetic fertilizers. This nitrogen fixation ability reduces the dependence on nitrogen fertilizers, thereby reducing production costs for farmers and minimizing environmental pollution caused by excess fertilizer use. The availability of nitrogen through Rhizobium also enhances plant growth, biomass production, and overall crop productivity.
- Soil Fertility: Rhizobium bacteria contribute to improving soil fertility. The process of nitrogen fixation carried out by Rhizobium enriches the soil with nitrogen, which benefits not only the associated leguminous plants but also other plants growing in the vicinity. Nitrogen is a vital nutrient for plant growth, and the presence of Rhizobium can enhance soil fertility and increase the availability of nitrogen for subsequent crops.
- Environmental Sustainability: The use of Rhizobium in dicot crops promotes sustainable agricultural practices. By reducing the need for synthetic nitrogen fertilizers, the reliance on non-renewable resources is minimized. This leads to reduced energy consumption, lower greenhouse gas emissions, and decreased pollution of water bodies caused by nitrogen runoff. The symbiotic association between Rhizobium and dicot plants offers a natural and eco-friendly approach to nutrient management in agriculture.
- Biodiversity and Ecosystem Functioning: Rhizobium bacteria play a crucial role in maintaining biodiversity and ecosystem functioning. Leguminous plants that form symbiotic relationships with Rhizobium contribute to the nitrogen cycle and nutrient cycling in ecosystems. They enrich the soil with nitrogen, which can support the growth of other plants and provide habitat and food sources for various organisms in the ecosystem.

Rhizobium Bacteria Mechanism

The mechanism of Rhizobium bacteria involves several key steps that enable them to establish a symbiotic relationship with leguminous plants and carry out nitrogen fixation. Chemotaxis and Root Hair Infection: Rhizobium bacteria are attracted to the root exudates of leguminous plants through a process called chemotaxis. The bacteria move towards the root surface using their flagella. Once they reach the roots, they adhere to and colonize the root hairs. The process of infection starts when the bacteria produce specific surface molecules, such as Nod factors, which initiate a signaling cascade in the plant root hairs. Nodulation Signaling: The Nod factors released by Rhizobium bacteria are recognized by specific receptors present on the surface of the plant root cells. This recognition triggers a series of molecular and cellular responses in the plant, leading to the initiation of nodule formation. The plant releases flavonoids, which further induce the expression of bacterial nodulation genes. Nodule Formation: As a result of the signaling between Rhizobium and the plant, specific cells in the root cortex start dividing and form a nodule primordium. Within this primordium, the plant develops specialized structures called infection threads, which provide a pathway for the bacteria to enter the plant tissues. The infection threads grow and extend into the developing nodule, allowing the bacteria to colonize the nodule cells. Bacteroid Differentiation: Once inside the nodule, the bacteria differentiate into specialized forms known as bacteroids. Bacteroids lose their cell walls and transform into elongated, nitrogen-fixing structures. This transformation is facilitated by plant-derived factors and creates an environment favorable for nitrogen fixation. Nitrogen Fixation: Bacteroids within the nodule carry out the process of nitrogen fixation. They possess the enzyme nitrogenase, which catalyzes the conversion of atmospheric nitrogen gas (N2) into ammonia (NH3). Ammonia can be further assimilated into amino acids and other nitrogen compounds that are utilized by the plant for growth and development. Nutrient Exchange: Within the nodule, there is a mutual exchange of nutrients between the plant and Rhizobium bacteria. The plant provides carbohydrates and other necessary nutrients to the bacteroids, while the bacteroids supply fixed nitrogen to the plant. This nutrient exchange sustains the symbiotic relationship and supports the growth and development of both the plant and the bacteria. The mechanism of Rhizobium bacteria involves complex molecular interactions and signaling between the bacteria and the leguminous plant host. Through these interactions, Rhizobium establishes a symbiotic relationship, induces nodule formation, colonizes the nodule tissues, and carries out nitrogen fixation to provide a sustainable source of nitrogen for the host plant. This mechanism is essential for enhancing plant growth, improving soil fertility, and promoting sustainable agricultural practices.

Benefits of Rhizobium

- Nitrogen Fixation: Rhizobium bacteria have the unique ability to fix atmospheric nitrogen into a biologically useful form. They convert atmospheric nitrogen gas (N2) into ammonia (NH3), which can be further assimilated into nitrogen compounds that are readily available for plant uptake. This process provides leguminous plants with a natural and sustainable source of nitrogen, reducing the need for synthetic nitrogen fertilizers and promoting environmentally friendly agricultural practices.
- Enhanced Crop Productivity: The symbiotic association between Rhizobium and leguminous plants leads to increased crop productivity. By fixing atmospheric nitrogen, Rhizobium bacteria provide an essential nutrient required for plant growth and development. This enhances the overall health, vigor, and biomass production of leguminous crops, resulting in improved yields.
- Reduced Fertilizer Dependency: Rhizobium-mediated nitrogen fixation reduces the reliance on synthetic nitrogen fertilizers. Synthetic fertilizers not only contribute to production costs but also have negative environmental impacts, such as water pollution and greenhouse gas emissions. By utilizing Rhizobium, farmers can reduce their fertilizer expenses and minimize the environmental footprint associated with nitrogen fertilizer use.
- Soil Fertility Improvement: The presence of Rhizobium bacteria in the soil improves soil fertility. The process of nitrogen fixation carried out by Rhizobium enriches the soil with nitrogen, making it available to both the associated leguminous plants and other neighboring plants. This enhances the nutrient content of the soil, promotes nutrient cycling, and contributes to overall soil health and productivity.
- Environmental Sustainability: The use of Rhizobium in agriculture promotes sustainable farming practices. By reducing the dependence on synthetic fertilizers, it helps conserve non-renewable resources and mitigates environmental issues associated with fertilizer use, such as eutrophication and air pollution. Rhizobium-mediated nitrogen fixation offers a natural and eco-friendly approach to nutrient management, reducing the ecological footprint of agricultural activities.
- Biodiversity and Ecosystem Functioning: Rhizobium bacteria contribute to biodiversity and ecosystem functioning. The symbiotic relationship between Rhizobium and leguminous plants supports the growth of these plants, providing habitat and food sources for various organisms in the ecosystem. Additionally, by enriching the soil with fixed nitrogen, Rhizobium indirectly supports the growth and diversity of neighboring plant species, thereby contributing to the overall functioning and stability of ecosystems.

CONCLUSION

Rhizobium bacteria are of significant importance in various aspects of agriculture and ecosystem functioning. Their ability to establish symbiotic relationships with leguminous plants and fix atmospheric nitrogen provides numerous benefits. By converting atmospheric nitrogen into a biologically useful form, Rhizobium enhances crop productivity, reduces the dependency on synthetic nitrogen fertilizers, and promotes sustainable farming practices. The nitrogen fixation carried out by Rhizobium not only benefits the associated leguminous plants but also improves soil fertility, supports neighboring plant species, and contributes to overall ecosystem health and biodiversity. Furthermore, the utilization of Rhizobium bacteria reduces environmental pollution associated with excessive fertilizer use and fosters a more balanced and sustainable approach to nutrient management. Understanding and harnessing the importance of Rhizobium in agriculture can lead to increased crop yields, reduced environmental impact, and the preservation of soil and ecosystem integrity.

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