

The Role of Microorganism in Mineral Nutrition

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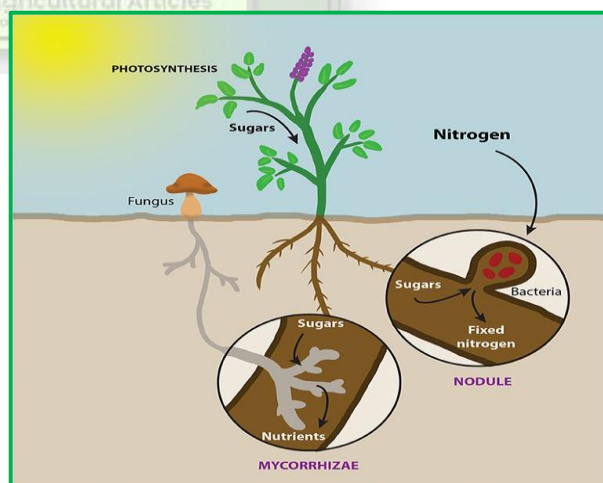
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Abstract

In their natural environment, plants are part of a rich ecosystem including numerous and diverse microorganisms in the soil. It has been long recognized that some of these microbes, such as *mycorrhizal* fungi or nitrogen fixing symbiotic bacteria, play important roles in plant performance by improving mineral nutrition. However, the full range of microbes associated with plants and their potential to replace synthetic agricultural inputs has only recently started to be uncovered. In the last few years, a great progress has been made in the knowledge on composition of rhizospheric microbiomes and their dynamics. There is clear evidence that plants shape microbiome structures, most probably by root exudates, and also that bacteria have developed various adaptations to thrive in the rhizospheric niche. The mechanisms of these interactions and the processes driving the alterations in microbiomes are, however, largely unknown. In this review, we focus on the interaction of plants and root associated bacteria enhancing plant mineral nutrition, summarizing the current knowledge in several research fields that can converge to improve our understanding of the molecular mechanisms underpinning this phenomenon.

Importance

Although plant physiologists sometimes view soil as simply a source of nutrients to plants, it is actually a complex ecosystem hosting bacteria, fungi, protists, and animals (Bonkowski et al., 2009; Muller et al., 2016). Plants exhibit a diverse array of interactions with these soil-dwelling organisms, which span the full range of ecological possibilities (competitive, exploitative, neutral, commensal, and mutualistic). Throughout modern plant science, most interaction studies have focused on alleviating pathogenic effects such as herbivory and infection (Strange and Scott, 2005; Zhang et al., 2013), or attenuating abiotic stress conditions (Yaish et al., 2016; Meena et al., 2017). However, there has also been longstanding interest in characterizing the positive ecological interactions that promote plant growth. For instance, mycorrhizal fungi as well as the bacteria present in nodulated legumes were both recognized as root symbionts from the second half of 19th century (Morton, 1981). Already in the 1950s, crop seeds were coated with bacterial cultures (*Azotobacter chroococcum* or *Bacillus megaterium*) to improve growth and yield (Brown, 1974). By the 1980s many different bacterial strains, mainly *Pseudomonas* but also *Azospirillum*, had



Microbial interaction in mineral uptake

been describes having plant growth promoting effects (Burr et al., 1978; Teintze et al., 1981; Lin et al., 1983). Since the 2000s, research focus has somewhat shifted away from individual microbial strains, and toward documenting the abundance and diversity of the root microbiome through metagenomics. Results from such sequencing studies have shown that the rhizospheric niche is a hotspot of ecological richness, with plant roots hosting an

enormous array of microbial taxa (Bulgarelli et al., 2013).

In the last few years, research has swung toward assembling rationally designed synthetic communities that comprise strains representing the dominant rhizospheric taxa, with the aim of re-capitulating favorable microbial functions under controlled experimental conditions (Busby et al., 2017). A major goal of this research field is to gain a mechanistic understanding of how soil microbes boost plant growth and defense, and then to use this knowledge to inform the optimal design of microbial communities tailored to carry out specific functions.

Microorganisms are classified based on their types:

1. Bacteria - eg. Rhizobium, Azospirillum, Azotobacter, Phosphobacteria
2. Fungi - eg. Mycorrhiza
3. Algae - Blue green algae (BGA) and Azolla
4. Actinomycetes -Frankia
5. Lichens

Rhizobium: Rhizobium forms symbiotic association with roots of leguminous crops forming nitrogen fixing nodules on the root system. Rhizobia enter the roots of legumes either through root hairs or directly at the emergence of lateral roots. They form infection thread through which the bacteria enter the root system.

There are specific Rhizobium for every legume and inoculation with efficient strains of Rhizobia is essential for the nitrogen gains and better crop yields. Inoculation of pulse crop with appropriate cultures can give yield increase of the order of 15-30%.

The rhizobium – legume association can fix upto 100-300 kg N/ha in one crop season.

Application: Seed Inoculant: 20g of Rhizobium culture is required to treat 1kg seed. One packet of Rhizobium culture contains 200g of Rhizobium culture.

- For small seeded pulses like moong, arhar, Lentin, berseem, lucerne, kulthi, 500g of Rhizobium culture is sufficient for seed required to be sown in 1ha i.e. 2.5 packets /ha (since 1packet =200g).
- For Groundnut, 1.5kg of Rhizobium culture for 80 -100kg seeds for 1ha i.e. 7.5 packets/ha.
- For soybean and Bengal gram: 1kg/ ha i.e. 5packets/ha.

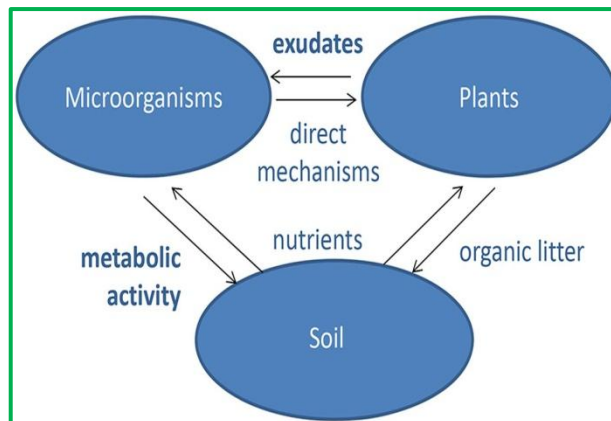


Fig-Microorganism are actively involved in organic matter decomposition and provided mineral nutrition.

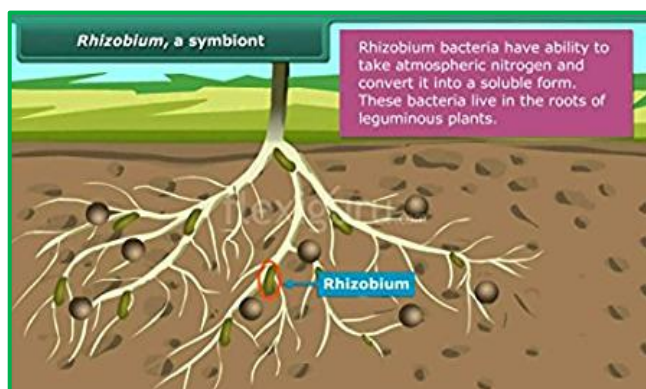


Fig-Rhizobium present as symbiotically in roots of legumes crops to fixed atmospheric nitrogen.

Rhizobium Species Suitable for Different Crops

Host groups	<i>Rhizobium</i> species	Crops
Pea group	<i>Rhizobium leguminosarum</i>	Green pea, lentil, sweet pea, vetch
Soybean group	<i>R. japonicum</i>	Soybean
Lupine group	<i>R. lupine orinthopus</i>	Lupinus
Alfalfa group	<i>R. melliloti medicago trigonella</i>	<i>Melilotus</i> , alfalfa, fenugreek, sweet clover
Beans group	<i>R. phaseoli</i>	Phaseoli
Clover group	<i>R. trifoli</i>	Trifolium
Cowpea group	<i>Rhizobium</i> sp.	Moong, redgram, cowpea, peanut, kudzu
Cicer group (chickpea)	<i>Rhizobium</i> sp.	Bengal gram

Azotobacter: Among the heterotrophic free-living nitrogen fixing bacteria Azotobacter is the most intensive investigated genera. Azotobacter are present in neutral or alkaline soil. *A. chroococum* is the most commonly occurring species in arable soils. Azotobacter is also known to synthesis biologically active growth promoting substance such as indole-acetic acid, IAA, gibberellin and B-vitamins in culture media. The occurrence of this organism has been reported from the rhizobium of a number of crops such as rice, wheat, maize, cotton, sugarcane, bajra, vegetable, and plantation crops.

Azospirillum: Though this organism was first described as *Spirillum lipoferum* by Beijerinck in 1925, its potential to fix nitrogen was realized only in 1975 by Doberiner and Day. Of the two physiological types within the genus Azospirillum, one group has an oxidative metabolism and the other has the ability to ferment certain sugars, producing acid. In addition to their nitrogen fixing ability, certain strains denitrify under anaerobic conditions and could also assimilate NH_2 , NO_3 , NO_2 .

Beijerinckia: Beijerinckia are capable of growing on a wide range of p^{H} from 2.9 to 10.0 and higher population of this organism is reported from soils having a p^{H} 4.9.

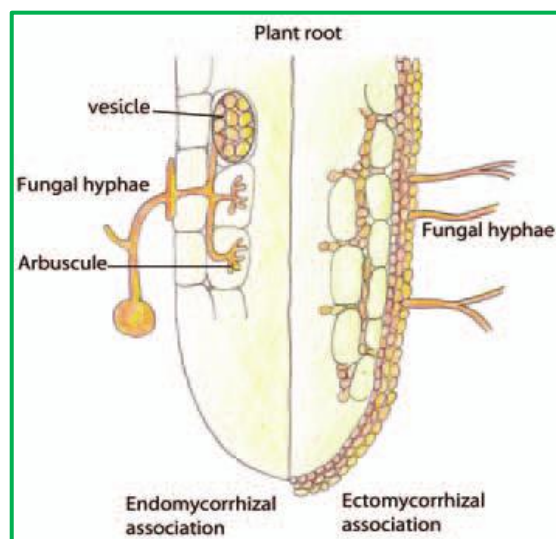
Beijerinckia indica is the dominant species in acidic soils.

Acetobacter: *Acetobacter diazotrophicus* was isolated from certain sugarcane varieties which were capable of obtaining large quantities of nitrogen through biological fixation. The bacterium behaved as an endophyte and possessed unique physiological properties for a diazotroph such as tolerance to low pH, high salt and sugar concentration.

Mychorrhizae: Mychorrhiza (fungus-roots) are symbiotic association between fungi and roots of vascular plants. Two main groups of mychorrhize are recognized:

A. Ectomychorrhizae: In the ectomychorrhizae, the fungal hyphae form a mantle both outside through roots within the root in the intercellular spaces of the epidermis and cortex.

No intracellular penetration into epidermal or cortical cells occurs, but an extensive network called the Harting net is formed between these cells. Ectomychorrhizae are common on trees, including members of the families pinaceae,



(pine, fir, spruce), Fagaceae (willow, poplar, chestnut).

B. Endomycorrhizae: Endomycorrhizae consist of three sub group, but by far the most common are the vesicular arbuscular mycorrhiza (VAM). The fungi present in VAM are members of the Endogonaceae, and they produce an internal network of hyphae between cortical cells that extends out the soil, where the hyphae absorb mineral salts and water.

The VAM are present on most species of herbaceous angiosperms, whether monocot or dicots, annual or perennial crops, or native or introduced species.

Blue Green Algae: Blue green algae form symbiotic association capable of fixing atmospheric nitrogen with fungi, liverworts, ferns and flowering plants. The association between heterocyst forming nitrogen fixing blue green alga – *Anabaena azollae* and the aquatic fern *Azolla* can be a potential source of organic manure and nitrogen in rice production.

The fern forms a green mat over water with a branched stem, deeply bilobed leaves and roots. The dorsall fleshy lobe of the leaf contains the algal symbiont within a central cavity. *Azolla* can be applied as green manure by incorporating in field prior to rice planting. *Azolla pinnata* is indigenous in Asia.

Frankia: Among the nodulated non-legumes, those species which belong to the genus *Casuarina* have the potential to stabilize eroding land surface and to improve the nitrogen status of impoverished soils in addition to providing timber, firewood or charcoal.

Lichens: A lichen is an association between an alga and a fungus, in which the two organisms jointly form a thallus that is distinct from either partner. The fungal partner is known as mycobiont and algal partner as the phycobiont.

Both the partners are benefitted by the association. Such an association is known as symbiosis or mutualism. The fungus derives nutrition from the alga, which, in turn, is protected by the



fungus. The benefited derived by the fungus is more than what it gives to the alga, but it happens in all symbiotic association.

Fig- Lichens (fungal +alga association)

Role of Micro-Organism in Nutrition

- Microbes are the components of soil nutrients cycling.
- Status of soil health and richness of soil nutrients pool depend on structure and functions of soil microbial community.
- Microbes play an important role in nutrients mobilization and uptake.
- They promote plant growth and suppress disease by their various activities.
- Role of microorganisms in sustainable agriculture and environment.
- Microbes are act as major decomposer on earth.
- Micro-organism maintains fertility and improves the quality of the soil.

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