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Mycorrhiza and its features

The Experimental Department of the Plant Breeding and Acclimatization Institute in Grodkowice

ARID Association

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Biofertilizers are substances containing live microorganisms (bacteria, algae, fungi) that have beneficial properties for plant growth and development. Microbial strains use different mechanisms to increase nutrient uptake, improve soil fertility and increase yields. These mechanisms include nitrogen fixation, potassium and phosphorus solubilization, phytohormone excretion, production of phytopathogen-inhibiting substances, protection of plants against abiotic and biotic stresses, and detoxification of underground pollutants. Biofertilizers contain one or more microorganisms.

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Biofertilizers are considered a promising and non-toxic alternative to synthetic agrochemicals, combating pathogenic fungi and minimizing mycotoxin contamination. The role of biofertilizers in agriculture is of particular importance, especially in the current context of the increase in the costs of artificial fertilizers and their harmful effect on the condition of soils.

Among the so far well-known microorganisms used in bio-fertilization and biocontrol, the following can be distinguished:

- plant growth-promoting rhizobacteria (PGPR)
- root-nodule bacteria
- mycorrhizal fungi
- endophytic fungi
- rhizospheric fungi
- mycoparasitic and entomopathogenic fungi

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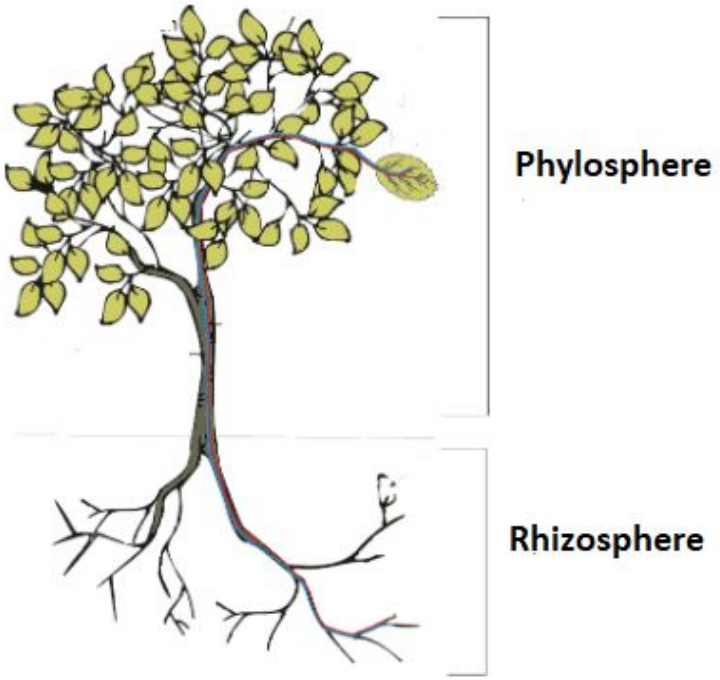
Plant growth-promoting rhizobacteria (PGPR)

- The most commonly used.
- They colonize the rhizosphere of plants, i.e. the soil layer directly adjacent to the plant roots and exert a significant influence on the development of the root, its physiological processes and, above all, the uptake of water with nutrients.
- PGPRs have a beneficial effect on the host (plant) by increasing plant growth, reducing susceptibility to diseases caused by pathogens such as nematodes, fungi, bacteria and viruses.



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- They increase the seed germination rate, root growth, have a positive effect on yield, leaf surface, chlorophyll content, nutrient uptake, protein content, hydraulic activity, tolerance to abiotic stress, shoot and root mass, and delay aging.

- Inoculation of plants with microorganisms belonging to PGPR, especially with bacteria of the genus Pseudomonas, allows to alleviate the stresses caused by abiotic factors and contribute to an increase in the yield of plants by up to 144%. The presence in the rhizosphere of nitrogen-fixing microorganisms, introduced in the form of a vaccine, increases the yield of plants, even with relatively high fertilization.

- Many species of bacteria produce a broad spectrum of antibiotics. Currently, there are products based on PGPR used for biocontrol and containing bacterial strains controlling, for example, net blotch and streaking of barley leaves, fusarium, powdery mildew on apples, grapes, peaches or lettuce rot.

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Root-nodule bacteria

A group of bacteria that coexist with legume plants. Due to them, warts are formed on the plant roots. Bacteria enter the root cells through a special structure called the infectious thread. Infection with these bacteria stimulates the host cells to grow rapidly, which leads to the formation of warts.

Color of warts - pink indicates the nitrogen fixation process. The greatest intensity of nitrogen fixation can be observed before flowering. The N2-binding bacterium converts it into NH3 or the amino acid glutamine. The nitrogen processed in this way is transferred to the plant cells. The role of the plant in the symbiosis process is to provide bacteria with carbon compounds and to provide conditions for development. Part of the nitrogen assimilated by bacteria feeds the soil, which is why legume plants are an important element in crop rotation. Root-nodule bacteria can bind as much as 200-300 kg nitrogen/ha.

Root warts on soybeans

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Endophytic fungi

- They colonize the roots of, among others barley and corn.
- They are responsible for phosphorus and sulfur uptake, increase biomass production and promote early flowering and seed production.
- They help the host plant to overcome the stress of drought, temperature and excessive salinity.
- They induce resistance to toxins, heavy metals, insects and pathogens.

A well-known group of endophytic fungi are also grass endophytes, which activate the regeneration of damage after a prolonged drought, have an economical effect on nitrogen management and better phosphorus absorption. Grasses with endophytes are resistant to pests, nematodes and some diseases, show more abundant tillering, durability and competitiveness in relation to grasses not inhabited by these fungi.

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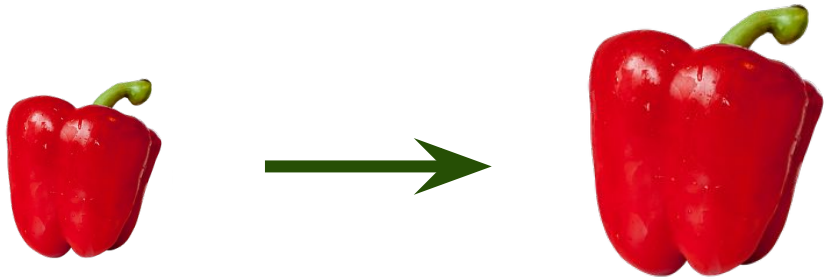
Rhizospheric fungi

- They help the plant to absorb phosphate.
- They are used in many products due to their ability to reduce abiotic and biotic stress on host plants by combating plant pathogens and nematodes.
- Some rhizospheric fungi are capable of producing auxin-like compounds that are able to increase the growth of zucchini, lettuce, pepper, melon and tomato by up to 56-167%. Other rhizospheric fungi can induce growth, flowering and secondary metabolism of the host plants.



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Mycoparasitic fungi

- Mycoparasitism is a phenomenon where a mycoparasitic fungus (parasite) is parasitized on another fungus.

- Mycoparasites reduce infections caused by powdery and downy mildew, rusts, leaf blotch, and stem and tuber rot. They can also be used to control pathogenic insects such as whitefly, thrips, mites, aphids and their various development stages.

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Mycoryza as bio-fertilizer

- Mycorrhizal fungi are involved in mineral balance and the distribution of carbon from photosynthesis. They enable the absorption of phosphorus, nitrogen and micronutrients unavailable to plants. At the same time, they take advantage of the assimilates produced by the green parts of the plant.
- In recent years, so-called organic or ecological cultivation is propagated. The principles of this type of cultivation are based on a significant reduction or even elimination of chemicals, including mineral fertilizers. However, nutritional deficiencies in the plant cannot be allowed to occur. In this case, mycorrhiza plays a significant role.

It has been proven in many experiments that the desired plant growth can be obtained by lowering the recommended doses of fertilizer, even by 25%, and the fertilizer utilization ratio can increase 4-5 times. Mycorrhizal fungi activate phosphorus and microelements, including nitrogen, from inaccessible forms. It is also difficult to cultivate plants in poor, acidic and very acidic soils with very low mineralization. The role of mycorrhizal fungi is an enzymatic decomposition of organic matter, thanks to which mineral forms of nutrients are available to plants: nitrogen from the organic substrate or phosphorus released from chelated forms of iron and aluminum.

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The main purpose of using bio-fertilizers is:

- providing a source of nutrients and good soil conditions for the growth of crops,
- reducing the amount of chemical fertilizer used while maintaining yield,
- reducing the negative effects caused by the use of chemical fertilizers,
- increasing the growth of plant roots, and thus increasing the possibility of water and nutrient uptake,
- extension of root life,
- neutralization and degradation of harmful substances accumulated in the soil,
- reducing the negative effects (neutralizing stress) of transplanting seedlings and shortening the time needed for flowering.

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Mycorrhiza

The term mycorrhiza was first used in 1885 by a German phytopathologist dealing with forestry, A. B. Frank. Mycorrhiza is a symbiosis between plant roots and non-pathogenic, specialized fungi living in the soil. The name mycorrhiza comes from the Greek words: mykes - fungus, rhiza - root. Mycorrhizal fungi live in symbiosis with almost all plants. Research shows that about 80-90% of the land plants are mycorrhizal. The number of fungi entering into mycorrhizal relationships with plants is estimated at about 5,000 - 6,000 species.

Types of mycorrhiza:
- external mycorrhiza (ectomycorrhiza),
- internal mycorrhiza (endomycorrhiza),
- ectendomycorrhiza
- peritrophic mycorrhiza.

mykes – gr. fungi

rhiza – gr. root

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Ectomycorrhiza (external mycorrhiza)

This type of mycorrhiza occurs in approx. 10% of gymnosperms and angiosperms.

In ectomycorrhiza, fungal hyphae penetrate between the walls of the crumb cells of the primary root bark, entangle them and form a system of intercellular connections, the so-called Hartig's network. In angiosperms, this network consists of a layer of cells that do not cross the epidermis, while in gymnosperms, the fungal cells reach deep into the root.

In the area of the Hartig network, mineral and organic compounds are exchanged between the two symbionts: the fungus transfers to the plant, among others, mineral salts, water, hormones and vitamins, and mainly receives sugars, which due to the lack of chlorophyll - it cannot produce itself. The hyphae of the fungus cover part of the root forming a so-called mycelium muff.

Under the influence of mycorrhiza, plant roots change their shape and it is easy to distinguish them from non-mycorrhizal roots. The color and structure of the mycorrhizal muff may vary and depend on the type of symbiotic fungi. The hyphae extend deep into the soil from the muff, creating a network called extrametric mycelium, often of considerable length. They can create connections between the root systems of various plant species, which enables the exchange of organic, inorganic substances and water between plants.

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Colonization with mycorrhizal fungi can take place at an early stage of the seedling when the first lateral roots are formed. The source of the mycelium inhabiting the roots may be the hyphae present in the soil, spores or mycorrhiza present on older roots. Mycelium growth can be stimulated by substances secreted by the plant roots. There are plant species that do not develop properly without mycorrhiza, e.g. beech, oak, pine, spruce. On the other hand, in optional plants, such as birch, willow, and alder, the development of mycorrhiza depends on environmental conditions.

Most ectomycorrhizal fungi are non-plant specific and form mycorrhiza with many host species, while fungal species are found that come into contact with only one plant species.

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Endomycorrhiza (internal mycorrhiza)

It is also called arbuscular mycorrhiza. Fungal hyphae penetrate through the cell walls of the crumb of the primary root bark and create a mass of twisted hyphae inside the cell. Hyphae do not penetrate the cell membrane, which creates multiple dents around them, thereby increasing the contact surface. Sometimes the hyphae form bubbles filled with an oily substance, most likely of a reservoir nature. Mycorrhizal fungi do not penetrate deeper than into the crumb of the primary root bark. In this type of mycorrhiza, the hairs do not disappear and a muff is not formed.

The roots of plants with endomitosis have hairs and outwardly do not differ in any way from non-mycorrhizal roots, and its presence can be found only in microscopic examination. Endomycorrhiza is the most common mycorrhiza. Approx. 250,000 plant species worldwide are capable of producing endomycorrhizae. It is most often found in green plants and fruit trees.

The vast majority of plants form only one type of mycorrhiza - ectomycorrhiza or endomycorrhiza. However, some plants are able to form both types of symbiosis at the same time.

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Ectendomycorrhiza

Ectendomycorrhiza shows both ecto- and endomycorrhizal features. In this type of mycorrhiza, the muff is thin and poorly developed, the Hartig network is well developed, and fungal hyphae are found inside the cells of the primary cortex.

Perrythrophic mycorrhiza

It belongs to the loosest type of symbiosis. The fungi that make up this type of mycorrhiza exist only in the root zone and on the root surface and do not penetrate the primary root bark. The presence of these fungi influences the chemical composition of the root environment, most often they act as soil buffers.

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Advantages of the existence and use of mycorrhyza

- The positive influence of microorganisms is important in order to improve the conditions for the growth and development of plants in areas degraded or contaminated by human activity. Mycorrhizal fungi overgrow the substrate surrounding plant roots, increasing stabilization by creating hyphae, secreting a substance that binds soil particles.

- The presence of mycorrhiza in the areas of volcanic activity, deforestation, the formation of industrial heaps, post-mining pits, agricultural production with too intensive fertilization and in areas heavily contaminated with heavy metals is extremely important. In these cases, the presence of mycorrhiza works well as a method of reducing the toxicity of compounds.

- Properly developed mycorrhiza increases plant survival in difficult conditions by increasing the availability of nutrients, reducing the stress of water unavailability, increasing resistance to pathogens, increasing the production of phytohormones and improving the structure of the substrate.

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- Mycorrhiza is also useful in the process of soil reclamation by **retaining pollutants in the roots** of selected plant species. This process takes place by adsorption on the surface of the roots, adsorption to the interior and precipitation in the root zone. The root system immobilizes the soil and the contaminants it contains, preventing air and water erosion, which prevents contaminants from moving to the deeper layers of the soil profile.

- Mycorrhizal fungi can be useful in **determining the toxicity** of the substrate by replacing the chemical toxicity assessment, especially when there are more stressors. In contaminated areas, the use of mycorrhizal fungi as a cheap and quick method of monitoring will play an important role.

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- **The uptake of nutrients and water and their transport to the host cells** is the main role of mycorrhizal fungi. This phenomenon occurs due to the increase in the absorbent area of the plant roots. The absorbent area of ectomycorrhizal plants is approximately 1000 times greater than that of non-mycorrhizal roots. Properly developed mycorrhiza increases plant survival in difficult conditions by increasing the availability of nutrients. In return, the plant provides the fungi with nutrients, mainly carbohydrates, produced by photosynthesis.

- **The protection of plant roots against attack by pathogens** is considered a fundamental ecological role of mycorrhiza. Ectomycorrhizal fungi reduce the incidence of root diseases by creating a barrier that protects the root against infection caused by pathogens. Some species of mycorrhizal fungi produce antibiotics or stimulate the plant to produce and secrete substances that inhibit the growth and development of pathogens. Mycorrhizal fungi reduce the number of pathogens by competing with them for nutrients.

- Some mycorrhizal fungi **produce plant growth stimulants**, mainly plant hormones from the auxin group. The type of fungus symbiotic with the plant, as well as the type of the plant itself, may decide on the scale of the benefits resulting from mycorrhiza.

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Production and Commerce of Mycorrhiza in Europe

The use of biological preparations in agricultural production is not yet widespread, but it may turn out to be necessary for the face of climate change, including the implementation of the principles of the European Green Deal. The awareness of the use of biopreparats, including preparats with mycorrhiza, is gradually increasing every year. On the one hand, it is awareness resulting from personal beliefs, but also from increasing scientific knowledge about them.

The development and use of microbiological preparations are increasing worldwide due to the recognition of harmful effects on the environment caused by excessive or inappropriate use of chemical fertilizers and a better understanding of the relationship between the plant and microorganisms present in the rhizosphere.

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Often in terms of nomenclature, preparations with mycorrhiza are called bio-fertilizers, biostimulants, biopesticides, microbiological preparations. Therefore, it is not possible to present reliable information on the consumption of individual bio-fertilizers classified in this study.

The legal definition of a product such as a bio-fertilizer is crucial for producers who wish to commercialize it. **In the European Union (EU) and the USA, there are currently no legal definitions of the term "bio-fertilizer" and no specific legal provisions specifying their characteristics**. In the EU, microorganisms (bacteria, viruses and fungi) are included as a possible contribution to organic production, but only for biological pest and disease control. Therefore, they are classified as biological control agents. In Italy, only inocula with mycorrhizal fungi are included in the group 'Products with an effect on soil' and in the category of miscellaneous 'Products with a specific effect'.

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The main limitations of the industry result from the lack of awareness of what bio-fertilizers are, including mycorrhizal products and the low rate of adoption by farmers.

Biopreparat with Hebeloma crustuliniforme fungus stored in the cold store of the Kostrzyca Forest Gene Bank

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