INNOVATIVE ECOLOGICAL TECHNOLOGIES FOR SOIL RESTORATION: BACTERIAL BIOPREPARATIONS

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Abstract
The use of fertilizer products in agricultural crops is a beneficial source of supplementing the nutrients needed for the growth and development of both plants and an increase in agricultural production. However, often the fertilizer doses applied per hectare to agricultural crops are not respected. Failure to comply with the applied fertilizer doses will lead to the occurrence of negative phenomena for soil, environment and agricultural crops, implicitly for human and animal health. Increasing the fertilizer doses per hectare and not respecting them will lead to the occurrence of soil acidification. The decrease of the bacterial colonies in the soil will bring with it a decrease of the humification processes, of the decomposition and solubilization processes of the complex compounds in the soil as well as favoring the leaching and appearance of the complex compounds in the soil (in large quantities). The increase of complex compounds in the soil will lead to a decrease in pH (below pH 7), which will lead to an increase in soil acidity. On acidic soil, crops will not reach their maximum potential in productivity. The use of bacterial biopreparation technologies in agricultural crops plays an important role in plant protection. Some bacterial cultures give plants a protection against pedo-climatic stress, a resistance to the attack of diseases and pests as well as conferring a protection on environmental factors (drought, heavy rainfall, cold, etc.). The use of these bacterial products as fertilizers as well as plant protection products has been shown to have great potential in growing, developing, maximizing agricultural production, in restoring and greening the soil and its beneficial flora, the role of these biological fertilizers being to address a green, sustainable, sustainable agriculture and achieving high, healthy, nutrient-rich productivity, beneficial to human and animal health.

Keywords: *agricultural bacteriology, soil fauna restoration, organic fertilizers, maximizing agricultural productivity, increasing the content of micro / macro elements.*
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Introduction

Soil is the basis of agriculture. The soil is a mediator of processes mediated by microorganisms, both at the surface of the soil and at the root system of plants. The rhizosphere is the area of maximum activity of microorganisms. At this level, the activity of bacterial cultures is carried out in optimal parameters, the rhizosphere being the part of the soil that includes the surface of the root to the top of the absorbent hairs. The rhizosphere is an appropriate environment for the growth, development and interactions of microorganisms with soil, plants and the environment (Figure 1A) (Stammen ,, 2005). At the rhizosphere, plants through the roots, more precisely at the pylorus (calytra) release a range of phytohormones that are involved in the process of fusion with soil microorganisms (beneficial soil microorganisms communicate with plants based on phytohormone emission, transmission, recovery, decoding and response from both parties involved - plants and microorganisms) (Vary et.al., 2007). The role of soil bacteria is to recolonize the bacterial fauna of the soil, to increase plant growth, increase agricultural production and ensure protection against diseases, pests, abiotic stress and fluctuations in soil and climate conditions. The mechanisms of action of bacterial cultures involve processes of availability of nutrients derived from genetic processes in plants (photosynthesis and chemosynthesis) and other related processes such as biological nitrogen fixation, solubilization of insoluble compounds in soluble compounds, production of siderophores Stefănescu et.al., 2010). Root processes are symbiotic, endophytic and associative processes (Figure 1B) that have the role of colonizing the roots (by bacteria), which creates a favorable environment for development, growth, agricultural productivity and soil greening Alves et al., 2004; Adesemoye et al., 2009; Hungary et al., 2010, 2013).

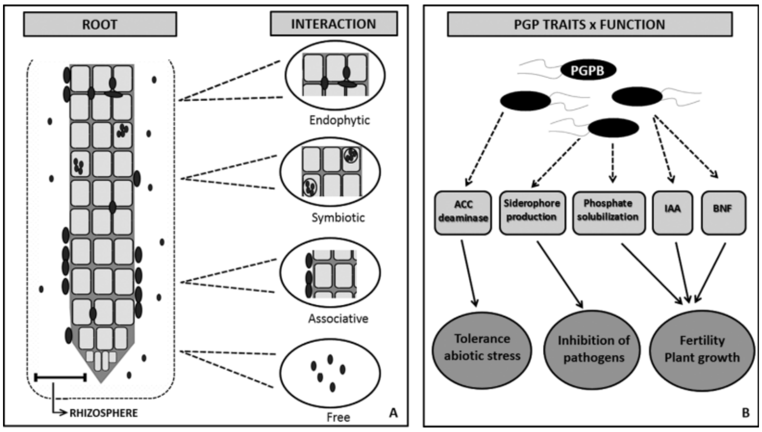

Figure 1A. The interaction between the rhizosphere and soil bacteria
Figure 1B- Colonization and association of bacteria with plant roots

1. Material and methods

In order to prove that agricultural systems can break the dependence on chemical fertilizers as well as plant protection products (of chemical origin), agricultural researchers have tried to maximize bacterial colonies in the soil and provide the main elements necessary for plant growth and development. As research materials, the specialists chose a series of bacterial cultures that are "foldable" for any type of soil, agricultural crop or plant. As research methods, a series of investigation methods were used on soil mapping before and after the application of bacteria, observation methods, methods of collecting and analyzing data related to the activity of bacteria as well as methods to describe the mode of action of each. bacteria in part. As research material, the researchers selected a number of beneficial bacteria for soil, plants and the environment, living bacterial cultures such as: *Bacillus megaterium, Azotobacter chroococcum* and *Azospirillum lipoferum.*

2. Results and discussions

Bacillus megaterium Represents a bacterium that is used on an industrial scale in agriculture (Figure 1). The bacterium has a high capacity to produce exoenzymes. At the same time, the bacterium is a very good host for cloning microorganisms, producing proteins and transmitting a wide variety of plasmids (Vary, 2007). Thus, the bacterium has the role of catabolizing enzymes in the soil, cell division, sporulation and multiplication of bacterial colonies on the soil surface. At the same time, *Bacillus megaterium* gives the plants a resistance to environmental factors as well as to the attack of diseases and pests (Roth, 2005). The role of this bacterium is to spread. It can be used to produce and fix phosphorus and potassium in the soil. At the same time, the bacterium has the role of degrading the inorganic phosphorus in the soil, in organic phosphorus, soluble for plants (Rygus and Hillen, 1991).

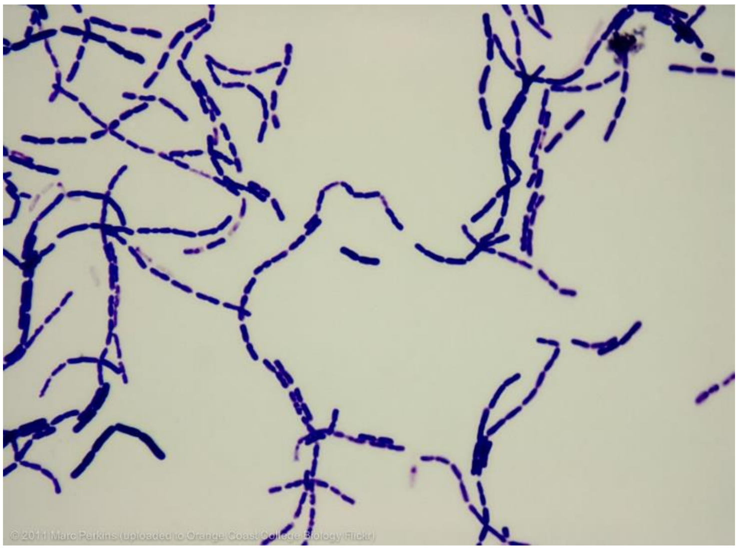

Figure 2. Living culture of Bacillus megaterium

Through the mechanism of action *Bacillus megaterium* has the role of improving the microecological environment of the soil, the dominant bacterial flora in the soil and the constant maintenance of bacterial colonies and the amount of organic phosphorus in the soil. The role of the bacterium is to decompose plant material on the surface and in the soil and convert them into mineral elements necessary for plant growth and development (Pueyo et.al., 2008). At the same time, it reduces toxic soil residues and pesticides leached into the soil structure, converting them into organic matter. The multiplication of this bacterium is rapid, it becomes the dominant bacterium in the soil with an effect on plant nutrition. On the other hand, it has a pathogenic effect for microorganisms that harm soil and plants (Vary et.al., 2007). This microorganism has a positive effect on the thickening of cell walls, role in fibrosing and lignification of relevant plant tissues. It forms a (usually double) layer of silicone over the epidermal layer (a barrier) in order to prevent the attack of diseases and pests (Malten, 2005). Another important process that this microorganism represents is the conversion of insoluble phosphorus into soluble phosphorus, efficient for plant growth, development and productivity, as well as the high rate of phosphorus absorption inside plants (Stefanescu et.al., 2011). The use of bacteria has the role of improving and expanding the efficiency of bacteria as a decomposer, reducing chemical use, crop sustainability, maximizing agricultural production, restoring the ecological balance of the soil, and increasing the quality of agricultural products (Radford, 1967).

Azotobacter chroococcum

Azotobacter (figure 3) is a useful bacterium in agriculture, perhaps the most important bacterium because it has the ability to fix atmospheric nitrogen in the soil. At the soil level, the microorganism forms at the level of the root system of plants certain nodules in which it will store nitrogen (Bashan and Holguin, 1997). The conversion of atmospheric nitrogen into soluble nitrogen, ready for use by plants is a great advantage for farmers because they will no longer use chemical fertilizers. Reducing the amount of chemical fertilizers will lead to a decrease in the intensity of the pollution phenomenon in agriculture (Boddey et. al., 2003). The bacterium can be used as a nitrogen fixer in agricultural crops, as a fertilizer, fungicide, pH indicator, nutrient indicator and soil bioremediation organism. *Azotobacter chroococcum* is a rhizobacterium, which is a microaerophilic plant that has a role in the process of plant growth and development. It is a mesophilic microorganism (grows at moderate temperatures), it has a maximum sporulation on soils with high humidity and moderate temperature (Reinhold et. al., 1986). It can fix atmospheric nitrogen under aerobic conditions. It is independent of the requirements of phosphorus in the soil (to maximize bacterial activity), this bacterium forming a dark brown melanin pigment with a high solubility in water. This pigment is used in plant protection in enzymatic processes of nitrase (Lin et. al., 2015).

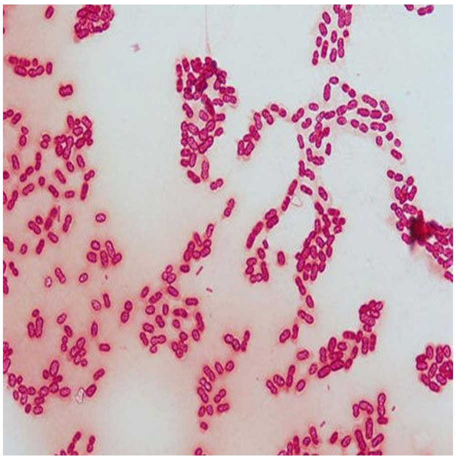

Figure 3. Live culture of Azotobacter chroococcum

The bacterium is resistant to ultraviolet radiation, drought, gamma radiation, which will lead to additional protection of crops. The process of fixing atmospheric nitrogen is based on redox reactions between soil, bacteria and the environment. The fact that the bacterium breathes, this aspect, following the use of some organic compounds in the soil as electron donors and the use of some carbon sources, the *azotobacter* can fix approx. 10 μg of nitrogen per gram of glucose consumed from the soil (Fukami et. al., 2018). The optimal pH for the growth and fixation of atmospheric nitrogen by *Azotobacter* fluctuates between 7.0-7.5, although this increase has been proven at a pH between 4.8 - 8.5. Another important feature of the bacterium that farmers need to know is that the bacterium can also grow in the mixotrophic system (mixed nutrition). Even if there are no glucose reserves in the soil, it can use the hydrogen available in the soil as a source of food and growth (Finkel, 2000). The appearance and formation of nodules in the root system of the plant occur in the absence of elements imported from the soil, elements such as phosphorus, nitrogen or carbon sources. In plant nutrition processes they consume large amounts of mineral elements in the soil (especially nitrogen-consuming plants) (Baniaghil et.al., 2013). By forming intracellular inclusions (at the level of the roots - see example in beans or rape), inside these nodules the bacteria form a series of polyhydroxyalkanoates. In the nitrogen fixation processes, the bacterium produces a series of biologically active substances, substances such as phytohormones (auxins, gibberellins) that have the role of stimulating the growth and development of crop plants. At the same time, the bacterium has the role of bioremediating the soil by breaking down heavy metals (cadmium, lead, mercury), hydrochloric compounds (2,4,6-trichlorophenol, a product used as a bioinsecticide) and other complex compounds that do not pollute the environment, soil and plant (Baniaghil et.al., 2013).

Azospirillum lipoferum

It is a gram-positive bacterium, a microorganism beneficial to soil and plant health (Figure 4). The role of this bacterium is to decompose complex compounds in the soil and convert them into soluble compounds, easily assimilated by plants (Bashan, 1994). The application of live crops of *Azospirillum lipoferum* on the soil surface is an important advantage for farmers because it successfully fights some soil pests, eliminating pathogens, producing plant growth regulators (gibberellins, auxins, cytokinins, etc.) and increasing the amounts of elements necessary for the growth and development of crop plants (nitrogen, phosphorus, potassium, calcium, copper, etc.) (Bashan and Holguin, 1997). The use of this bacterium as a fertilizer in agricultural crops leads to a reduction in the application of chemical fertilizers to agricultural crops, as well as obtaining a high yield of agricultural products obtained.

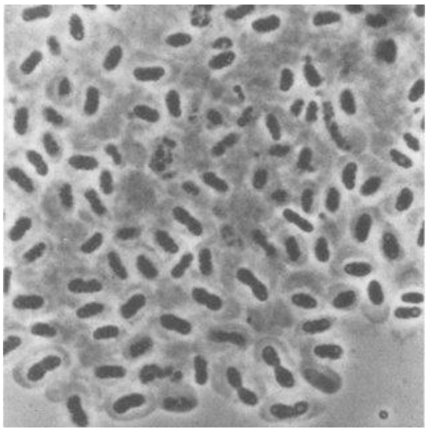

Figure 4. Live culture of Azospirillum lipoferum

The decomposition of complex compounds in the soil leads to an increase and maximization of plant yield. At the same time, the bacterium plays an important role in the development of the root system. The larger the root system, the more plants will have a number of elements necessary for their growth and development (Diamantidis et.al., 2000). Inoculation of the soil with *Azospirillum lipoferum* will lead to an increase in both roots and their weight by about 30% (compared to chemically fertilized lots). The presence of the bacterium in it determined the growth of a well-developed root system, this aspect being identified in all plants fertilized with this bacterium (Reinhold et.al., 1987). The growth of the root system of plants is based on phytohormones. This growth helps the plants to more efficiently acquire the water and nutrients that the plants need in their growth and development. But the main role of this bacterium is the decomposition of complex compounds in the soil into soluble elements. *Azospirillum* has the ability to modify the forms of nutrients (nitrogen, phosphorus) so as to make them as accessible as possible to plants (Hungary et.al., 2010). In addition to the biological fixation in plants of mineral elements resulting from the decomposition of complex compounds in the soil, the bacterium produces a series of antioxidants that have the role of protecting plant roots from stress caused by drought or flooding. At the same time, the bacterium prepares crop plants to withstand a possible attack of pests and diseases, a process called induced systematic resistance (Adesemoye et.al., 2009).

Conclusion

On a global scale, the effects of excessive chemicalization of crops, the application of unsustainable agricultural practices and technologies and the high-dose application of plant protection products can cause serious damage to soil, crop plants, the environment and human and animal health. . Inoculation of soil with live bacterial biopreparation is one of the most important sustainable practices in agriculture, as microorganisms establish associations with crop plants, which will cause a symbiosis between them, while promoting an increase in crop plants and agricultural productivity through several beneficial processes. Endophytic bacteria are suitable for soil inoculation because they reflect their ability to colonize the soil and plant roots, numerous specialized studies demonstrating the specificity and communication between bacteria and host plants (of different species and genotypes). The combination of different crops with these bacteria as well as the bacteria between them, will lead to obtaining large parameters of agricultural crops, parameters imposed by farmers (plant growth, number of bacterial colonies in the soil, identification of beneficial bacteria in the soil, etc.).

Thus, when farmers decide to approach a sustainable, ecological agriculture, they have at their disposal many kinds of living bacterial cultures such as *Azospirillum, Bacillus* or *Rhizobium*, which can be primary candidates for soil inoculation. Finally, the use of bacteria beneficial to the soil and plants is important for the development of new and effective fertilization and plant protection technologies for sustainable agriculture. Also important are investments in technologies that can help increase the efficiency and maximize crop yields as well as the survival rate of bacteria in the soil or the development of new treatments of seed material, which are essential factors for successful inoculation and obtaining the desired results.

Thus, the introduction of beneficial bacteria into the soil tends to be a non-invasive technology that causes less impact on the environment than chemical fertilization, which makes the farmer to practice sustainable agriculture as well as an advantage for it or a way to reduce costs. of production.

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