Review Article

Fungal Bio Fertilizer for Sustainable Agriculture

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Abstract:

Plant roots are the main organ that supplies the plant with the nutrients in the soil, which is reflected on the productivity of the plant. Some of the microorganisms present in the soil are among the factors that may contribute to raising the efficiency of plants in utilizing the nutrients in the soil, therefore there is the need to study on plant interactions with soil microorganisms. However, care must be taken when adding these beneficial microorganisms to the soil as biological fertilizers or pesticides, to reduce the use of chemical fertilizers and pesticides, and to minimize its harmful effects on humans and the environment, on the one hand, and on the other hand, to increase the plant productivity to maintain food security. With the evolution of omic[1] technologies, it became possible to effectively observe rhizosphere microbial community together with their effects on plant productivity, thus maintaining sustainable agriculture. This prompted scientists to discover and develop microbial species that interact positively with plants (Berruti *et al*., 2016).

Key words: Bio fertilizer, AMF inoculation, Plant protection, Sustain agriculture.

[1] The branches of science known informally as **omics,** which are various disciplines in biology whose names end in the suffix *-omics*, such as genomics, proteomics, metabolomics, and glycomics (https://en.wikipedia.org/wiki/Omics).

Introduction:

Agriculture at the present time relies on adding chemical fertilizers in large quantities to obtain high and abundant production. It also depends on the use of chemical pesticides that are harmful to humans, animals and the environment alike (Bhardwaj *et al*., 2014).

Scientists are concern to invest beneficial microbes in agriculture, because of its important role in obtaining a safe, healthy food without chemicals, on the other hand, it is safe for the environment and sustainable crop production (Bhardwaj *et al*., 2014).

An application that has proven to be effective is the use of beneficial and safe microbes, i.e. the plant growth promoting rhizobacteria (PGPRs), endo- and ectomycorrhizal fungi, cyanobacteria and many other useful microscopic organisms led to improved nutrient uptake, plant growth and plant tolerance to abiotic and biotic stress (Bhardwaj *et al*., 2014; Igiehon and Babalola, 2018a).

The fungal interactions of rhizobacterial and mycorrhizal have been studied by many researchers (Song *et al*., 2015; Rasmann and Turlings, 2016). Also, host interactions with viruses are similarly important since virus causes different disease conditions according to the host. This means, that plant interactions with microorganisms could be positive or negative depending on the species involved (Igiehon and Babalola, 2018).

The positive interactions between plant and microorganisms will be reviewed and light will also be shed on the various relationships between different hosts and micoorganisms that can be used as a biological fertilizer in plant nutrition.

Plant-microbial interactions:

So far, this relationship is not clearly understood, therefore, it needs a lot of in-depth studies to understand it, to benefit from it in sustainable agricultural development (Igiehon and Babalola, 2018a).

This interaction between plant and microorganisms takes place in an area called “the Rhizosphere” which can be defined as the zone of soil close to plant roots and has a lot of microorganisms as well as invertebrates (Philippot *et al*., 2013; Mendes *et al*., 2014).

Soil organisms that located in huge numbers affect plant growth and productivity (Philippot *et al*., 2013; Mendes *et al*., 2014).

There are many substances that are secreted by the roots and contribute to the regulation of plant root-microbial interactions i.e. flavonoids, different organic acids and cutin monomers, besides gene expression of microorganisms. These substances secreted from the roots send chemical signals to soil microbial organisms to control and develop them, providing the roots with everything they need (Venturi and Keel (2016).

Many published papers have explained accurately the mechanisms of chemical communication signals that plays an important role in root-microbial interactions (Bednarek *et al*., 2010; Rosier Rosier *et al*., 2016).

Soil organisms do not live in isolation but rather interact with many hosts, and there are several forms of interaction namely: virus versus virus, bacterium versus bacterium, protozoan versus protozoan, fungus versus fungus, bacterium versus fungus, fungus versus plant or animal, bacterium versus plant or animal, virus versus plant or animal, protozoa versus plant or animal, bacterium versus fungus versus plant or animal, in addition to other parasitic and symbiotic associations, that has unique mechanisms that lead to enhanced host plant growth (Igiehon and Babalola, 2018).

Figure (1) is a good example that explains the parasitic interaction between the bacterium *Pasteuria penetrans* and root-knots nematode in the rhizosphere area (Flor-Peregrín *et al*., 2014).

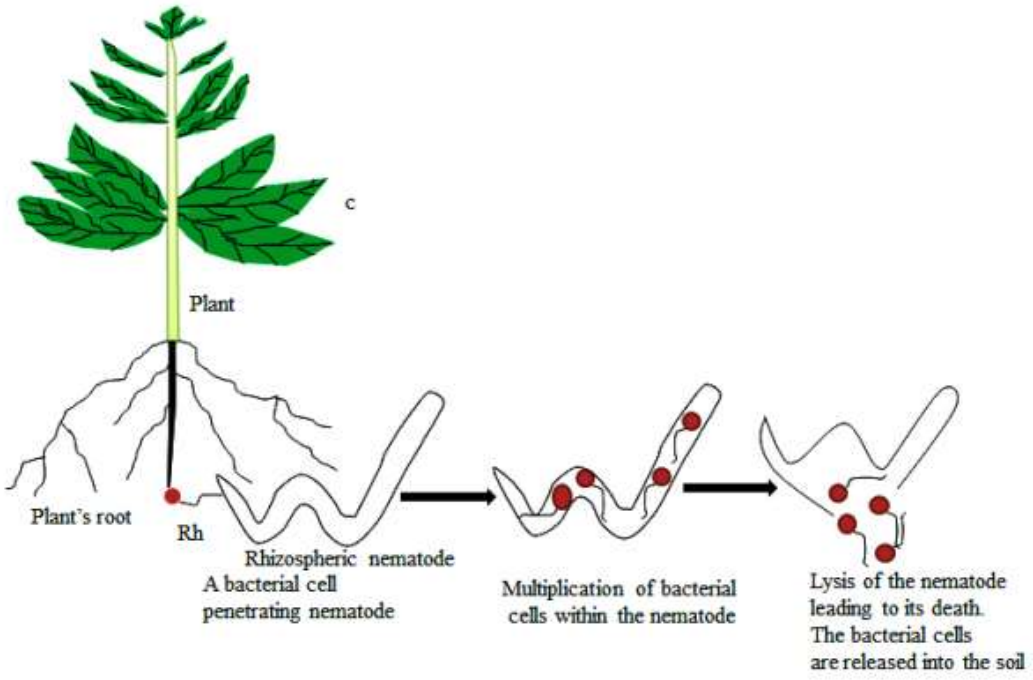

Figure 1. Parasitic interaction between the bacterium *Pasteuria penetrans* and root-knots nematode in the rhizosphere (Flor-Peregrín *et al*., 2014).

Arbuscular Mycorrhizal Fungi (AMF) reciprocates benefits with 80% of plants by forming a group of roots. This fungus provides the plant with water, nutrients, and protection from diseases, and in return it obtains photosynthesis products (Berruti *et al*., 2016).

Also, there is a direct effect of AM fungi in the soil, which is to improve the soil texture (Rillig and Mummey, 2006; Leif heit *et al*., 2014, 2015; Rillig *et al*., 2015)

The phyllosphere is defined as the part of the plant above the soil surface, precisely the part around the leaves. Many studies have demonstrated how the underground interaction (rhizosphere) affects the interaction above ground (phyllosphere) with herbivores and carnivores (Philippot *et al.*, 2013). For example, the two fungi MF, *Bacillus* and *Pseudomonas* have the ability to stimulate systemic plant immunity against many diseases caused by soil microorganisms (Zamioudis and Pieterse, 2012; Philippot *et al.*, 2013). Also, some plants that are attacked by insects excrete Volatile Organic

Compounds (VOCs) generated systemically. These compounds travel in the air as signals to alert other plants to stimulate their immune system to fight these insects, besides these compounds also travel through plant roots to the rhizosphere. For example, the common mycelial networks that motivate the transfer of signaling compounds from the attacked plant to un-infested to be careful of infestation with these insects as shown in Figure (2).

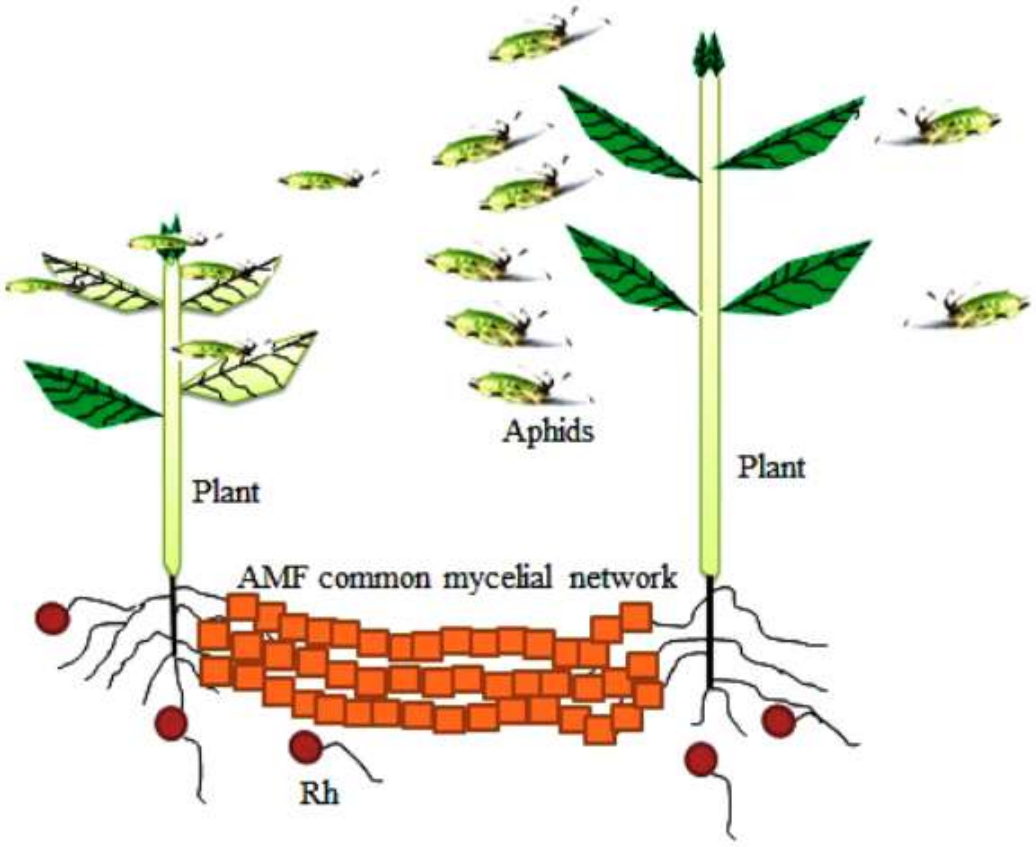

Figure 2. The attacked plants (left) by aphids secrete volatile organic compound that transmitted through common mycelial system to prevent aphids attack on other plants (right).

Future Prospects and Conclusions:

-Due to the positive effect of AMF inoculation into the soil, which helps the plant to take advantage of the nutrients in the soil and prevent many diseases caused by microorganisms in the rizhosphere, thus increasing plant productivity, without adding and somtimes reducing the addition of chemicals that harm the environment, human and

animal health. For these reasons, it is important to expand thoughtfully by adding these AMF in agriculture, after implementing a number of field trials and studying the economic benefit analyses of this technology as presented in Ceballos *et al.,* (2013).

-Since many studies have shown that AMF that existed in each different soil are equally or even better performing than commercial, it is better for the farmers to produce their AMF inocula, to make this technology (bio-fertilizers) available, especially for the third world countries, which need to greatly sustain agriculture.

- There is a need to carry out many studies, as the relationship between plant and microbial species is not yet clear in many cases, as it has been shown by Babalola and Glick (2012).

- Understanding what these interactions are may contribute to develop of microbial inoculants (Babalola, 2010; Alori *et al.,* 2017; Igiehon and Babalola, 2018b). Also, it will reduce the harmful effects of chemicals.

References:

Alori, E.T.; M.O. Dare; and O.O. Babalola (2017). Microbial inoculants for soil quality and plant health. Sust. Agric. Rev., 281-307. [http://dx.doi.org/10.1007/978-3-319-48006-0_9]

Babalola, O.O. (2010). Beneficial bacteria of agricultural importance. Biotechnol. Lett., 32(11): 1559-1570. [http://dx.doi.org/10.1007/s10529-010-0347-0] [PMID: 20635120]

Babalola, O.O.; and B.R. Glick (2012). Indigenous African agriculture and plant associated microbes: Current practice and future transgenic prospects. Sci. Res. Essays. 7(28): 2431-9.

Bednarek, P.; C. Kwon; and P. Schulze-Lefert (2010). Not a peripheral issue: Secretion in plant-microbe interactions. Curr. Opin. Plant Biol., 13(4):378-387. [http://dx.doi.org/10.1016/j.pbi.2010.05.002] [PMID: 20558098]

Berendsen, R.L.; C.M. Pieterse; and P.A. Bakker (2012). The rhizosphere microbiome and plant health. Trends Plant Sci., 17(8): 478-86. [http://dx.doi.org/10.1016/j.tplants.2012.04.001] [PMID: 22564542]

Berruti, A.; E. Lumini; R. Balestrini; and V. Bianciotto (2016). Arbuscular Mycorrhizal Fungi as Natural Biofertilizers: Let's Benefit from Past Successes. Front. Microbiol. 6:1559. doi: 10.3389/fmicb.2015.01559

Bhardwaj, D.; M.W. Ansari; R.K. Sahoo; and N. Tuteja (2014). Biofertilizers function as key player in sustainable agriculture by improving soil fertility, plant tolerance and crop productivity. Microbial Cell Factories. 13(66):1-10. http://www.microbialcellfactories.com/content/13/1/66

Ceballos, I.; M. Ruiz; C. Fernández; R. Peña; A. Rodríguez; and I.R. Sanders (2013). The in vitro mass-produced model mycorrhizal fungus, Rhizophagus irregularis, significantly increases yields of the globally important food security crop cassava. PLoS ONE 8:e70633. doi: 10.1371/journal.pone.0070633

Flor-Peregrín, E.; R. Azcón; V. Martos; S. Verdejo-Lucas; and M. Talavera (2014). Effects of dual inoculation of mycorrhiza and endophytic, rhizospheric or parasitic bacteria on the root-knot nematode disease of tomato. Biocontrol Sci. Technol., 24(10): 1122-1136. [http://dx.doi.org/10.1080/09583157.2014.925091]

Igiehon, N.O.; and O.O. Babalola (2018a). Below-ground-above-ground Plant-microbial Interactions: Focusing on Soybean, Rhizobacteria and Mycorrhizal Fungi. Review article. The Open Microbiology Journal. 12:261-279.

Igiehon, N.O.; and O.O. Babalola (2018b). Rhizosphere microbiome modulators: Contributions of nitrogen fixing bacteria towards sustainable agriculture. Int. J. Environ. Res. Public Health. 15(4): 574-98. [http://dx.doi.org/10.3390/ijerph15040574] [PMID: 29570619

Leif heit, E. F., Verbruggen, E., and Rillig, M. C. (2015). Arbuscular mycorrhizal fungi reduce decomposition of woody plant litter while increasing soil aggregation. Soil Biol. Biochem., 81: 323–328. doi: 10.1016/j.soilbio.2014.12.003

Leif heit, E.F.; S.D. Veresoglou; A. Lehmann; E.K. Morris; and M.C. Rillig (2014). Multiple factors influence the role of arbuscular mycorrhizal fungi in soil aggregation—a meta-analysis. Plant Soil. 374: 523–537. doi:10.1007/s11104-013-1899-2

Mendes, L.W.; E.E. Kuramae; A.A. Navarrete; J.A. van Veen; and S.M. Tsai (2014). Taxonomical and functional microbial community selection in soybean rhizosphere. ISME. J., 8(8): 1577-87. [http://dx.doi.org/10.1038/ismej.2014.17] [PMID: 24553468]

Mendes, R.; M. Kruijt; I. de Bruijn; E. Dekkers; M. van der Voort; J.H.M. Schneider; Y. piceno; T.Z. DeSantis; G.L. Andersen; P. Bakker; and J.M. Raaijmakers (2011). Deciphering the rhizosphere microbiome for disease-suppressive bacteria. Science. 332(6033):1097-1100. [http://dx.doi.org/10.1126/science.1203980] [PMID: 21551032]

Philippot, L.; J.M. Raaijmakers; P. Lemanceau; and W.H. van der Putten (2013). Going back to the roots: The microbial ecology of the rhizosphere. Nat Rev. Microbiol., 11(11): 789-99. [http://dx.doi.org/10.1038/nrmicro3109] [PMID: 24056930]

Rasmann, S.; and T.C. Turlings (2016). Root signals that mediate mutualistic interactions in the rhizosphere. Curr. Opin. Plant Biol., 32: 62-8. [http://dx.doi.org/10.1016/j.pbi.2016.06.017] [PMID: 27393937]

Rillig, M.C.; and D.L. Mummey (2006). Mycorrhizas and soil structure. New Phytol. 171: 41–53. doi: 10.1111/j.1469-8137.2006.01750.x

Rillig, M.C.; C.A. Aguilar-Trigueros; J. Bergmann; E. Verbruggen; S.D. Veresoglou; and A. Lehmann (2015). Plant root and mycorrhizal fungal traits for understanding soil aggregation. New Phytol., 205: 1385–1388. doi:10.1111/nph.13045.

Rosier, A.; U. Bishnoi; V. Lakshmanan; D.J. Sherrier; H.P. Bais (2016). A perspective on inter-kingdom signaling in plant-beneficial microbe interactions. Plant Mol.

Biol., 90(6): 537-548. [http://dx.doi.org/10.1007/s11103-016-0433-3] [PMID: 26792782]

Song, L.; Y. Wang; W. Tang; Y. Lei (2015). Archaeal community diversity in municipal waste landfill sites. Appl. Microbiol Biotechnol., 99(14): 6125-37. [http://dx.doi.org/10.1007/s00253-015-6493-5] [PMID: 25758957]

Venturi, V.; and C. Keel (2016). Signaling in the Rhizosphere. Trends Plant Sci 2016; 21(3): 187-198. [http://dx.doi.org/10.1016/j.tplants.2016.01.005] [PMID: 26832945]

Zamioudis, C.; and C.M. Pieterse (2012). Modulation of host immunity by beneficial microbes. Mol Plant Microbe Interact 2012; 25(2): 139-50. [http://dx.doi.org/10.1094/MPMI-06-11-0179] [PMID: 21995763]