BENEFITS OF APPLYING BIOPRODUCTS FOR IMPROVE SOIL NUTRIENT CONTENT AND FERTILITY IN TOMATO AND SOYBEAN CROPS - MINIREVIEW

Cristina Petrisor, Andrei Chiriloaie-Palade*

Research and Development Institute for Plant Protection Bucharest

*Correspondence address
Research and Development Institute for Plant Protection Bucharest
Ion Ionescu de la Brad 8, CP 013813, Bucharest, Romania
E-mail: crisstop@yahoo.com

Abstract: In recent years, agricultural and horticultural crops are subject to different abiotic and biotic factors, such as low soil fertility, low soil water supply, extreme temperatures and pathogens. Current soil management strategies depend mainly on chemical fertilizers which represents a serious threat to human health and the environment. In this context, for sustainable agriculture, an increased attention was directed to conservation of natural resources, reducing of the environmental degradation, being developed conventional agricultural systems with minimal application of chemical fertilizers and pesticides on different crops. At present, various beneficial microorganisms are used as biofertilizers having a key role in maintaining soil structure and fertility in environmental protection, being a low cost friendly measure and a renewable source of nutrients for plants replacing with successful chemical fertilizers in the sustainable agriculture system. Application of microbial inoculants (biofertilizers) is a promising technology for sustainable agriculture, leading to the high and healthy yield, solving the problem of feeding an increasing human populations under the conditions of the application of some modern agricultural practices. The present study presents the positive effect of applying biofertilizers based on *Trichoderma* spp. in terms of nutrient uptake, increased productivity and crop quality tomatoes and soybean.

Keywords: *biofertilizers, sustainable agriculture, crop improvement*

INTRODUCTION

In recent years, environmental pollution is a serious global problem, and plants are the subject to a variety of stress factors. Among them, the abiotic and biotic factors, such as low soil fertility, drought, extreme temperatures and pathogens are very common. In this context, for sustainable agriculture, increased attention has been directed towards the conservation of natural resources, reducing environmental degradation and decrease of fertilizers price. Thus, lately, conventional farming systems have been developed with minimum application of fertilizers and pesticides to different crops under different agroecological conditions.

Proper management of beneficial microorganisms in agriculture to enable an increase in the assimilation of an appreciable amount of minerals from the soil without loss of production, will leads to a more sustainable production system. General strategy for increasing productivity cultures and maintaining them at a high level should include an integrated approach to soil nutrient management, along with other complementary measures of plant protection.

The optimal growth and development of plants require that nutrients from the soil be available and be in balanced quantities (Chen, 2006). Soil fertility can be restored by application the concept of integrated soil fertility management based on soil nutrient management by conserving natural resources and increasing efficiency of inputs. Biofertilizers (microbial inoculants) play an essential role in soil nutrient management by participating in regulating enzymatic activity followed by nutrient dynamics in the rhizosphere.

Biofertilizers are important components of integrated soil management, they have a key role in maintaining soil structure and fertility in environmental protection being a friendly measure with low costs and a renewable source of nutrients for plants successfully replacing chemical fertilizers in the sustainable agriculture system (Mohammadi & Sohrabi, 2012; Mahanty et al., 2016; Saritha & Tollamadugu, 2019). The interaction with the plants result in a specific balance in soil biocenosis that can be disturbed by a flow of organic matter, chemicals or a sudden change in the physico-chemical properties of the soil.

Biofertilizers (microbial inoculants) are products that contain living or dormant cells belonging to different beneficial microorganisms which, when applied to seeds, plants in vegetation or soil, colonizes the rhizosphere or the interior of the plant and stimulates it plant growth and development by transforming the nutritional elements, nitrogen, phosphorus into assimilable forms through biological processes such as phosphate solubilization (Chen, 2006; Colla et al., 2015; Rakshit et al., 2015; Simarmata et al, 2016). Use of biostimulants for plants including organic substances and substances natural inorganics (humic acids, protein hydrolysates, algae extracts, silicon) but also beneficial microorganisms (fungi of the genus *Trichoderma* spp. and bacteria of the genus *Bacillus* spp. and rhizobacteria) that increase nutrient uptake and crop production can be considered a sustainable and environmentally friendly approach to production stability through the use of some minimal input (Colla et al., 2015; Lorito & Woo, 2015; Rouphael et al., 2015).

Mechanisms of action of biofertilizers. Fungi increase nutrient uptake and can produce phytohormones such as IAA and giberelines that play an important role in stimulating plant growth. *Trichoderma* spp. develops in symbiosis with the plant and has the capacity to increase the vigor of the seedlings, stimulates the development and the forming of the lateral roots so that they are used as biofertilizers (Altomare et al., 1999). Fertility of the soil treated with *Trichoderma* spp. can be significantly improved and has been demonstrated experimentally by increasing the length of the roots, modifying their architecture and so this induces the plant's ability to absorb more water and resist drought (Kapri & Tewari, 2010). Phytase microbes represent a group of enzymes that are able to release soluble phosphates from phytates one of the most abundant forms of organic phosphates found in the environment. (Singh et al., 2013).

The phytostimulation effect due to the application of *Trichoderma* strains has been attributed to some direct or indirect factors such as the release of substances with auxinic activity (indolyl acetic acid) peptides as well as volatile organic compounds, which improve the root system architecture (root length, density and branching) and assimilation / solubilisation of macronutrients (P) but also of micronutrients (Fe, Mn, Zn) enhancing plant growth and development and yield of agricultural crops (Harman et al, 2004; Contreras-Comejo et al., 2009, 2011; Lorito et al., 2010, Colla et al., 2015; Rouphael et al., 2017).

Moreover, the application of microbial inoculants, chemical fertilizers or a combination of organic and chemical compounds could modulate microbial communities in the plant rhizosphere (Mar Vázquez et al., 2000), with an ecological impact on the agroecosystem (Belyaeva et al., 2012; Ventorino et al., 2013, 2016; Gupta et al., 2014, 2016).

Haque et al., (2012) has claimed that *Trichoderma* spp. based biofertilizers enriched with inorganic fertilizers play a significant role in the growth and productivity of tomatoes and mustard plants and can reduce costs with inorganic fertilizers in proportion of 50%. Application of microbial consortia of biofertilizers together with different types of compost is an excellent choice for remedy and improve soil health and increase plant productivity for a sustainable agriculture (Simarmata et al. 2015).

Application of bio-ameliorators as well as of biofertilizers based on *Trichoderma* but also the combination between them increased biodiversity and activity microorganisms in the rhizosphere of rice plants which contributed to the induction of systemic resistance (Simarmata et al., 2016).

Figure 1. Functional characteristics of biofertilizers and biopesticides (source Saritha & Tollamadugu Prasad, 2019)

Trichoderma strains play an important role in the nutrient cycle, helping decomposing organic matter and making minerals available to many plants that are normally inaccessible. Yediddia et al. (2001) argued that the presence of fungi in the genus *Trichoderma* increases assimilation and concentration of many nutrients (Cu, P, Fe, Mn, Na) in the roots of tomatoes grown in hydroponic culture. Different experiments show an increase in productivity > 30% after treatment with *Trichoderma* and promoting plant growth was detectable in different plant species (pepper, beans, green salad, tomatoes, radishes, carrots, peas) (Harman et al., 2004; Gret al., 2007; De Souza et al., 2008).

Studies have shown that the ability to stimulate plant growth by microbial agents beneficial such as *Trichoderma* strains can be very specific for certain plant species, varieties and genotypes. In this regard, Tucci et al. (2011) and Ortega Garcia et al. (2015) showed that inoculation of tomato or onion varieties with *T. atroviride*, T. *harziamum* or *T. asperellum* improve crop performance but are dependent by the genotype used. Also the combined use of biofertilizers and N: P: K chemical fertilizers increased vegetative and reproductive growth, production, nutrition and tomato quality by the slow and stable release of nutrients in the plant, than by exclusive application of N: P: K fertilizer (Molla et al., 2012).

Trichoderma produces gluconic, citric, fumaric organic acids that lower soil pH and allow solubilization of phosphates, micronutrients and cations mineral (Fe, Mn, Mg) used in plant metabolism especially in neutral and alkaline soils. It has also been reported that *Trichoderma harzianum* 1295-22 could improve the efficiency of nitrogen use and solubilize certain low soluble nutrients, such as Mn^{4+}, Fe^{3+} si Cu^{2+} leading to better growth and development of plants (Altomare et al., 1999).

The positive effects obtained in estimating the growth of plants also depend on the way application of fungal inoculum to seed, soil or in vegetation. According to him López-Bucio et al. (2015) *Trichoderma* has acquired a special importance as a microbial biostimulant in horticulture. Therefore it is not surprising that the *Trichoderma* strains were found to be active ingredient in over 200 agricultural products marketed as biopesticides, biofertilizers, biostimulants and used in both organic and conventional agriculture (Woo et al., 2014). In the recent review, Lopez-Bucio et al. (2015) reported that stimulation mechanism induced by *Trichoderma* involves multi-level communication between the root and the plant stem.

Forms and methods of application of biofertilizers. Biofertilizers are formulated so that they are in a viable state and at the same time, have the ability to improve soil fertility, productivity and plant growth.

The process of formulating the biofertilizers is carried out in several stages in which microbial strains are combined with certain additives that protect cells during the storage period. Studies have shown that proper formulation not only increase the number of microbial colonies in the soil, but at the same time increases their biological activity after inoculation of the host plant (Keswani et al., 2016). Improvement of forms based on microbial biofertilizers are necessary for obtaining and marketing new bioproducts which are thus more efficient, more stable having a higher quality for the satisfaction farmers' requirements (Bashan et al., 2014).

The formulations must meet the following characteristics:

- to allow the addition of nutrients, have an adjustable pH, be made from an available and cheap raw material
-to have no harmful effects on the environment to be non-toxic, clean and biodegradable
- to allow the controlled and rapid release of fungi into the soil and to be easily applied with an agricultural equipment
- to be stored for a long time
- to have storage abilities for long time, biofertilizers must be viable for a long time and to have activity in extreme climate conditions

There are 2 types of formulations: liquids, solids (granular and powders):

Liquid formulations are based on liquid microbial cultures, mineral or organic oils, oils in water or polymer based suspensions. Liquid biofertilizers are also easy to use, handled and can be applied to the seed, by soaking the roots of the seedlings at the moment transplants, in soil but also by foliar spraying during vegetation (Reddy & Saravanan, 2013). They usually contain high concentrations of the target microorganisms and allow applying a smaller quantity with a similar efficiency. More than that, unlike solid carrier biofertilizers, liquid formulation allows the manufacturer to include adequate amounts of cellular nutrients and protocols to improve performance (Sahu & Brahmaprakash, 2016). Moreover, it was argued that this is not contaminated, they have a longer life for some formulations, greater protection against aggressive environmental factors, and grown field effectiveness compared to peat formulations.

Biofertilizers based on liquid microbial cultures do not have the protection of the carrier and lose viability on it seed. However, the addition of some components such as sucrose, glycerol and arabic gum they can improve the viability of liquid microorganisms.

The granules can be made of calcium chloride, silicon, which are moistened with an adhesive and reinforced with powder inoculum. Granules are covered or impregnated with target beneficial microorganisms. The size of the granules varies, but the relationship between densities the population of the microbial culture and the quality of the final product is direct. Granular formulations have many advantages, are easy to handle, speed and application mode can be easily controlled, and they are applied in the furrow near the seeds to facilitate the interactions with the roots.

Ways of applying the formulated biofertilizers are: (a) seed inoculation with powder formulations; (b) dry biofuels mixed with the seeds in the seed tank; (c) method of suspension (the biofertilizer is suspended in water and the seeds are then treated); (d) incorporation into the soil; (e) immersion of the seedling root.

CONCLUSIONS

Biofertilizers increase crop productivity by increasing the availability or absorption of nutrients or stimulation of plant growth through hormone action or decomposition organic waste. Biofertilization can replace the use of chemical fertilizers or reduce their quantity thus preventing environmental pollution.

Biofertilizers can solve the problem of feeding an increased human population when agriculture is faced with different abiotic and biotic stress factors.

This work was carried out within the framework of PNCDI III, CCCDI - UEFISCDI, carried out with the support of the Ministry of Research and Innovation, project no. PN-IIIP1-1.2-FPRD-01.03.2017 / 28PCCDI / 2018

REFERENCES

AGGANI, S.L. (2013). Development of bio-fertilizers and its future perspective. *Scholars Academic Journal of Pharmacy*, 2, 327-332.

AKLADIOUS, S.A., ABBAS, S.M. (2012). Application of *Trichoderma harzianum* T22 as a biofertilizer supporting maize growth. *African Journal of Biotechnology*, 11, 35, 8672-8683.

ALTOMARE, C., NORVELL, W.A., BJORKMAN, T., HARMAN, G.A. (1999). Solubilization of phosphates and micronutrients by the plant-growth promoting and biocontrol fungus *Trichoderma harziamum* Rifai 1295-22. *Applied and Environmental Microbiology* 65, 2926–2933.

AZARMI R., HAJIEGHRARI B., GIGLOU A. (2011). Effect of *Trichoderma* isolates on tomato seedling growth response and nutrient uptake. *African Journal of Biotechnology*, 10, 31, 5850-5855.

BASHAN, Y, DE BASHAN L.E., PRABHU, S.R., HERNANDEZ, J.P. (2014). Advances in plant growth-promoting bacterial inoculant technology: formulations and practical perspectives (1998-2013). *Plant Soil*, 378, 1-33.

CHEN, J. (2006). The combined use of chemical and organic fertilizer or biofertilizer for crop growth and soil fertility. *International Workshop on Sustained Management of the Soil-Rhizosphere System for Efficient Crop Production and Fertilizer Use*. October, Thailand, 16-20.

COLLA, G., ROUPHAEL, Y., DI MATTIA, E., EL-NAKHEL, C., CARDARELLI, M. (2015). Co-inoculation of *Glomus* intraradices and *Trichoderma atroviride* acts as a biostimulant to promote growth, yield and nutrient uptake of vegetable crops. *Journal of the Science Food and Agriculture*, 95, 1706-1715.

DE SOUZA, J.T., BAILEY, B.A., POMELLA, A.W.V., ERBE E.F., MURPHY, C.A., BAE H. (2008). Colonization of cacao seedlings by *Trichoderma stromaticum* a mycoparasite of the witches' broom pathogen, and its influence on plant growth and resistance. *Biological Control*, 46, 36-45.

ENTESARI, M., SHARIFZADEH, F., AHMADZADEH, M., FARHANGFAR, M. (2013). Seed biopriming with *Trichoderma* species and *Pseudomonas* fluorescent on growth parameters, enzymes activity and nutritional status of soybean. *International Journal of Agronomy and Plant Production*, 4, 4, 610-619.

GHANY, T., ALAWLAQI, M.M., AL ABBOUD, M.A. (2013). Role of biofertilizers in agriculture: a brief review. *Mycopathologia*, 11, 95-101.

HAQUE, M.M., ILIAS, G.N.M., MOLLA, A.H. (2012). Impact of *Trichoderma*-enriched biofertilizer on the growth and yield of mustard (*Brassica rapa* L.) and tomato (*Solanum lycopersicon* Mill.). *Agriculturist*s, 10, 109-119.

HARMAN, G.E., HOWELL, C.R., VITERBO, A., CHET, I., LORITO, M. (2004). *Trichoderma* species-opportunistic, avirulent plant symbionts. *Nature Reviews Microbiology,* 2, 43-56.

HOYOS-CARVAJAL, L., ORDUZ, S., BISSETT, J. (2009). Growth stimulation in bean (*Phaseolus vulgaris* L.) by *Trichoderma*. *Biological Control*, 51, 3, 409-416.

KAPRI, A., TEWARI, L. (2010). Phosphate solubilization potential and phosphatase activity of rhizospheric *Trichoderma* spp. *Brazilian Journal of Microbiology,* 41, 3, 787-79.

KESWANI, C., BISEN, K., SINGH, V., SARMA, K.B., SINGH, H.B. (2016). Formulation technology of biocontrol agents: Present Status and Future Prospects, 35-53 pg in (Arora et al. ed) Bioformulation for sustainable agriculture, Springer Berlin Heidelberg, ISBN 978-81-322-2777-9.

LÓPEZ-BUCIO, J., PELAGIO-FLORES, R., HERRERA-ESTRELLA, A. (2015). *Trichoderma* as biostimulant: exploiting the multilevel properties of a plant beneficial fungus. *Scientia Horticulture*, 196, 109-123.

MALUSA, E.F., PINZARI, F., CANFORA, L. (2016). Efficacy of biofertilizers: challenges to improve crop production. In: Singh et al. (Eds.). *Microbial Inoculants in Sustainable Agricultural Productivity*, 17 - 40, Springer-Verlag, India.

MAHANTY, T., BHATTACHARJEE, S., GOSWAMI M., BHATTACHARYYA, P., DAS, B., GHOSH, A., TRIBEDI, P. (2017). Biofertilizers: a potential approach for sustainable agriculture development. *Environmental Science and Pollution Research*, 1-22.

MOHARAM, M.H., NEGIM, O.O. (2012) Biocontrol of *Fusarium* wilt disease in cucumber with improvement of growth and mineral uptake using some antagonistic formulations. *Communication in Agricultural and Applied Biological Sciences*, 77, 3, 53-63.

MOHAMMADI, K., SOHRABI, Y. (2012). Bacterial biofertilizers for sustainable crop production: a review. *Journal of Agricultural and Biological Science*, 7, 5, 307-316.

MOLLA, A.H., HAQUE, M., HAQUE, A., ILIAS, G.N.M. (2012). *Trichoderma*-enriched biofertilizer enhances production and nutritional quality of tomato (*Lycopersicon esculentum* Mill.) and minimizes NPK fertilizer use. *Agriculture Research*, 1, 3, 265-272.

OUSLEY, M.A., LYNCH, J.M., WHIPPS, J.M. (1994). Potential of *Trichoderm*a spp. as consistent plant growth stimulators. *Biology and Fertility of Soils*, 17, 85-90.

RAKSHIT, A., SUNITA, K., PAL, S., SINGH, A., SINGH, H.B. (2015). Bio-priming Mediated Nutrient Use Efficiency of Crop Species in Rakshit et al. (eds.), Nutrient Use Efficiency: from Basics to Advances, 182-191, Springer-Verlag, India.

REDDY, C.A., SARAVANAN, R.S. (2013). Polymicrobial multi-functional approach for enhancement of crop productivity. *Advance in Applied Microbiology*, 82, 53-113.

SAHU, P., BRAHMAPRAKASH, G.P. (2016). Formulations of biofertilizers approaches and advances. In *Microbial inoculants in sustainable agricultural productivity*, 179-198, Springer-Verlag, India.

SANTIAGO, A.D., GARCIA-LOPEZ, A.M., QUINTERO, J.M., AVILE´S, M., DELGADO, A. (2012). Effect of *Trichoderma asperellum* strain T34 and glucose addition on iron nutrition in cucumber grown on calcareous soils. *Soil Biology and Biochemistry*, 57, 598-605.

SARITHA, M., TOLLAMADUGU PRASAD, N.V.K.V. (2019). The status of research and application of biofertilizers and biopesticides: Global scenario recent developments in applied microbiology and biochemistry, 196-207 in Buddolla V. ed "Recent Developments in Applied Microbiology and Biochemisty", *Academic Press,* ISBN :9780128167007.

SIMARMATA, T., HERSANTI, A. TURMUKTINI, T., FITRIATIN B.N., SETIAWATI M.R., PURWANTO, C. (2016). Application of bioameliorant and biofertilizers to increase the soil health and rice productivity. *Journal of Biosciences*, 23, 181-184.

SIMARMATA, T., JOY, B., SOFYAN, E.T., CITRARESMINI, A., TURMUKTINI, T., SUDJANA, B. (2015). Innovation of biofertilisers-organic based nutrients management and water saving technology to secure rice productivity. In: *Proceeding of Tropentag* 2015. Berlin. Germany.

SINGH, N.K., JOSHI, K.D., GUPTA, R.K. (2013). Isolation of Phytase Producing Bacteria and Optimization of Phytase Production Parameter. *Journal of Microbiology*, 6, 5, 1-6.

STURZ, A.V., CHRISTIE, B.R. (2003). Beneficial microbial allelopathies in the root zone: the management of soil quality and plant disease with rhizobacteria. *Soil & Tillage Research*, 72, 107-123.

TUCCI, M., RUOCCO, M., DE MASI, L., DE PALMA, M., LORITO, M. (2011). The beneficial effect of *Trichoderma* spp. on tomato is modulated by the plant genotype. *Molecular Plant Pathology,* 12, 341-354.

YEDIDIA, I., SRIVASTVA, A.K., KAPULNIK, Y., CHET, I. (2001). Effect of *Trichoderma harzianum* on microelement concentrations and increased growth of cucumber plants. *Plant Soil* 235, 235-242.