SOIL MICROBIOLOGY AND SUSTAINABLE AGRICULTURAL SYSTEMS: APPLICATION OF BENEFICIAL MICROORGANISMS IN AGROECOSYSTEMS IN THE CANARY ISLANDS

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Introduction

Soil microbiology can be defined as the study of organisms inhabiting in soil, their metabolic activity and their functions within energy flows and nutrient cycling [1]. The biological fraction of soils is now considered to play a fundamental role in soils fertility, i.e. biology fertility, which involves organic reserve, as well as abundance and activity of soil biomass. Plant-associated microbiota has demonstrated their crucial role in maintaining soil ecological balance and therefore the sustainability of either natural ecosystems or agroecosystems [2]. Among others, soil microorganisms are involved in nitrogen fixing or humus synthesis. They can also promote vegetal development through the production of phytohormones, protect plants against root pathogens or ease soil pollution by degrading toxic substances [2]. Therefore, the knowledge of the soil microbiology is essential to understand agronomy.

In the same way, soil microorganisms can influence agroecosystems activity; they can be affected by environment. Environmental conditions (temperature, humidity, solar radiation…) and crop management (crop type and variety, fertilisation, pesticides…) may drastically affect soil microbial populations. Therefore, crops sustainable management should include practises that contribute to preserve soil microbial activity and health, which in turn, assures soil health and fertility.

Microbial activity is mainly concentrated around the roots, within the zone of soil directly surrounding and influenced by them, which is called the rhizosphere, as a result of the organic compounds constantly released by roots. This process known as the rhizodeposition involves a large portion of the matter photosynthesized by the plant and provides a substantial amount of nutrients to soil microbes [3]. Plant-microbe interactions that take place within the rhizosphere area are among the major factor to regulate plant health and growth [2]. Two main groups of microorganisms can be distinguished: saprophytes and symbionts. Both of them comprise detrimental, neutral and beneficial bacteria and fungi. Among these beneficial rhizosphere microbes, arbuscular mycorrhizal fungi (AMF) and plant growth-promoting rhizobacteria (PGPR) can be considered.

Arbuscular mycorrhizal fungi are obligate symbionts that colonise the roots of most cultivated plant species. Mycorrhizal symbiosis can be found in nearly all types of ecological situations and most plant species are able to form this symbiosis naturally. Mycorrhiza establishment involves benefits for both partners, plant and fungus. These associations occur naturally when plantlets are transplanted into the field, favouring plant development by increasing nutrient uptake, growth rates and hormonal activities [2].

Mycorrhizae may also increase plant tolerance to stress conditions such as salinity, drought, heavy metals, root soilborne pathogens and the improvement of soil structure [2]. An increasingly interest in their application as biofertiliser to ease plant stress situations, as well as the significant presence of high quality commercial products based on mycorrhizal inoculants is favouring the integration of these symbionts within vegetal production systems.

Plant growth-promoting rhizobacteria are able to colonise the root surface, survive and multiply in microhabitats associated with the root surface, in competition with native microbiota; at least to express their plant promotion activities. Certain strains of *Pseudomonas*, *Bacillus*, *Azospirillum*, *Azotobacter, Enterobacter* or *Serratia*, have been frequently described as PGPR. Their positive effect on plant development has been described for different crops; both herbaceous such as potato and soybean or woody ones such as apple and citrus [4]. Several mechanisms, which involve phytohormone production, mineral solubilisation and availability or biological control of soilborne pathogens, have been proposed to explain bacterial activity. Certain crucial environmental processes such as nutrient cycling or seed establishment are also attributed to rhizobacteria [5, 6].

Isolation and multiplication of rhizosphere microorganisms

Both mycorrhizal fungi and rhizobacteria can be isolated from their natural environment (soil and/or roots) and later multiplied in the laboratory or in the greenhouse. This feature has contributed to the establishment of mycorrhiza and rhizobacteria isolates collections for further studies. The study process involves multiplication and selection through specific bioassays where isolates are evaluated on different plant species, having different propagation systems and different management conditions. These bioassays allow determining the biofertiliser and biocontrol ability of the isolates. The optimisation of large-scale multiplication techniques by certain enterprises has contributed to develop high quality commercial inoculants for agricultural proposes.

Application of rhizosphere microoganisms on some crops with agronomic importance in the Canary Islands

In the recent years, numerous studies have been conducted in order to determine, the effect of these microorganisms as biofertilisers and biocontrol agents against certain root pathogens. Those studies have been conducted on different plant species of agronomic interest and under closer commercial conditions. Summarized results from some of these works are presented herein.

AMF-fodder crops

Several tedera or psoralea species (*Bituminaria bituminosa* L. var. albomarginata), are well distributed in the Canary Islands. This autochthon leguminous specie traditionally used as fodder has been also considered for reforestation of degraded soils. A previous work conducted under nursery conditions confirmed the positive effect of several mycorrhizal isolates on different ecotypes of this plant specie [7]. Benefits of *Glomus mosseae* inoculation on Famara ecotype (one of the most difficult agronomic management) are shown on Figure 1 [8]. Aerial biomass of mycorrhizal plants was two folds higher while root biomass was five folds higher as compared to non-inoculated plants.

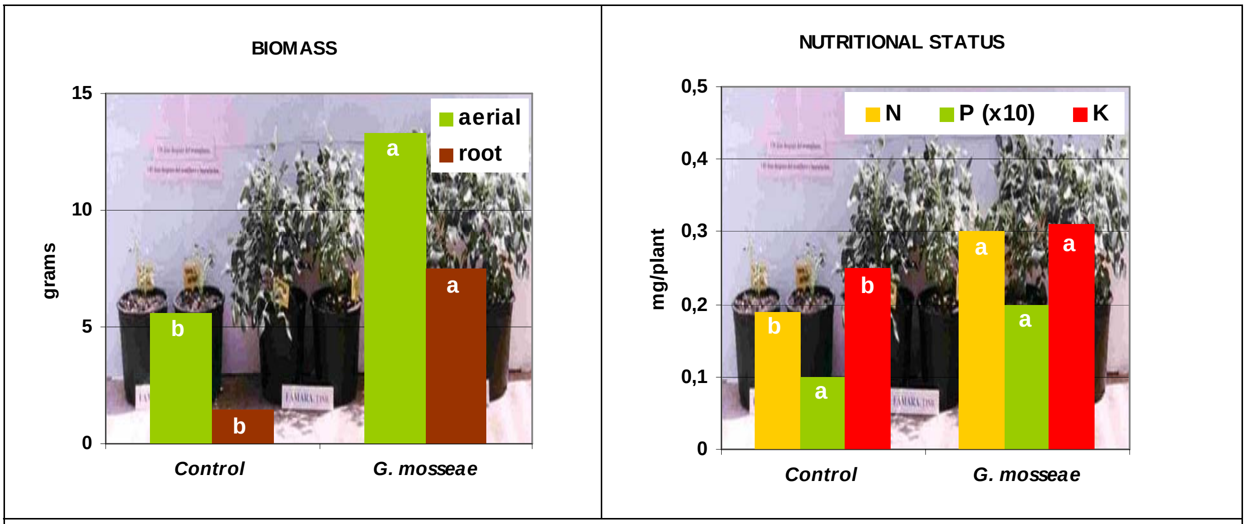

Figure 1.- Effect of the AMF inoculation (*Glomus mosseae*) on tedera (*B. bituminosa* L. var. albomarginata, Famara ecotype) 6 months after inoculation

AMF-tomato

Tomato culture (*Solanum lycopersicum* L.) is one the most important crop in our region both economically and socially. Despite it is described to be able to establish mycorrhizal symbiosis; practical application is not always easy, due to the high degree of sophistication of recent commercial seeds. Thus, several works have been conducted to determine under organic management whether commercial varieties can be benefited of mycorrhization on harvest [9, 10] (Figure 2).

Figure 2.- Effect of AMF on tomato harvest (*Solanum lycopersicon* L. cv. Daniela)

AMF-rhizobacteria-tropical crops

Rhizosphere microorganisms' inoculation (AMF), during the early phases, can contribute to improve plant development and nutritional status as well as tolerance to stress conditions. In order to gather up more data, in the last decade, several works on the combined effect of both types of microorganisms on plant development or against root pathogens have been performed [11, 12]. Results have confirmed beneficial effects of rhizobacteria on banana plants: plants inoculated with any of both microorganisms had a significant higher development as compared to non-inoculated plants (Figure 3). In addition, combined effect of both types of rhizosphere microbes was higher to individual effect of any of them.

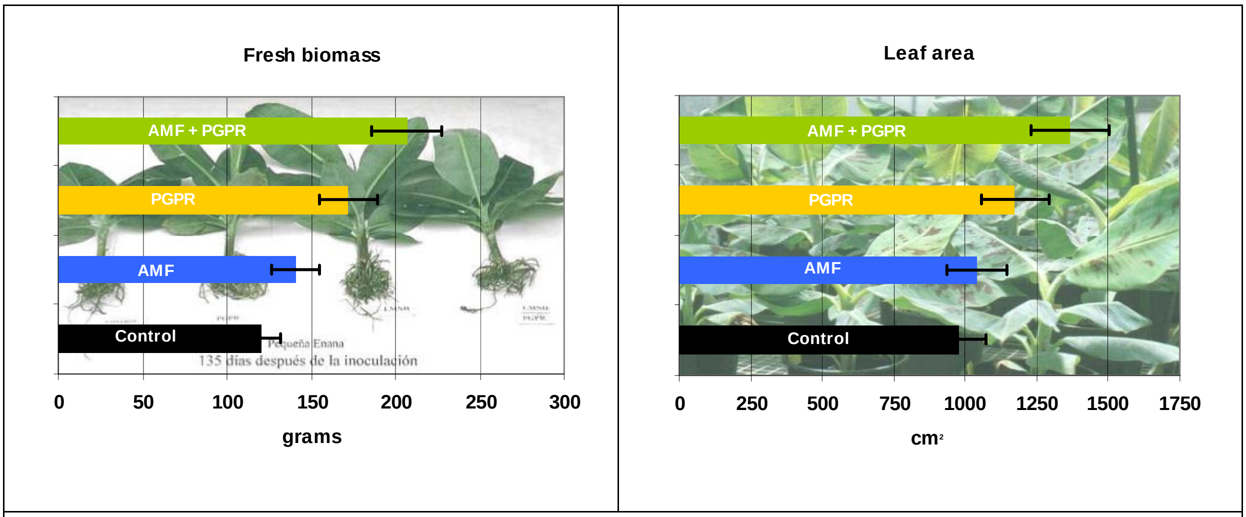

Figure 3.- Effect of the inoculation of AMF and rhizobacteria strains on micropropagated banana development (*Musa acuminata* Colla AAA, cv. 'Petite Naine')

Concerning to papaya, another tropical crop economically important in our region, our results showed protection provided by mycorrhization against nematodes from *Meloidogyne* genus, while no effective protection was detected due to rhizobacteria presence (Figure 4).

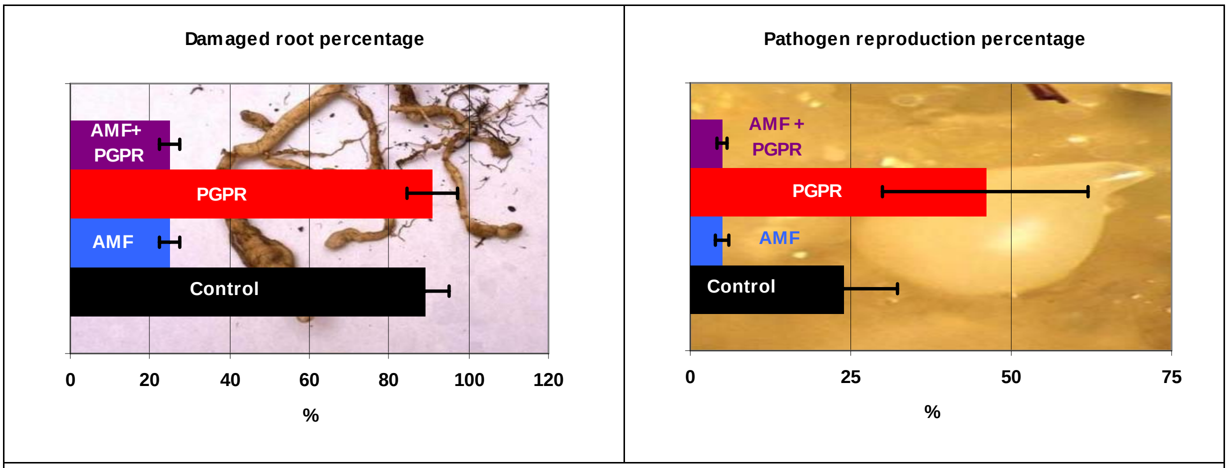

Figure 4.- Effect of the inoculation of AMF and PGPR on root damage and the pathogen reproduction on papaya (*Carica papaya* Mill, cv. Bauxino) infected with the root-knot nematode *Meloidogyne* sp.

Conclusions

According to our results as well as results from other authors, the inoculation of these rhizosphere microbes during early phases have demonstrated consistent improvements in plant development and nutritional status and may contribute to reduce plant stress.

Research advances in the recent years have worked out some basic biology aspects from those microorganisms which led to a more complete outlook of these plant-microbe interactions. Consequently, increasing high quality production inocula, either *in vivo* or *in vitro*, may facilitate their application under certain circumstances. AM fungi and rhizobacteria early inoculation may be included in intensive production systems or in poor soil systems which have a minimal microbial population level unable to assure soil fertility. Otherwise, organic agrosystems should contain their own microbial population richness from selected native strains as a consequence of their adaptation to the environment. In this case, cultural practises should be conducted to preserve and enhance natural sustainability of the systems.

References

[1] Atlas, R.M.; Bartha, R. (1993) Microbial ecology: Fundamentals and applications. 3ª ed. Redwood City, CA: Benjamin/Cummin.

[2] Barea, J.M.; Pozo, M.J.; Azcón, R.; Azcón-Aguilar, C. (2005) Microbial co-operation in the rhizosphere. *J. Exp. Bot* 56, pp. 1761–1778.

[3] Gobat, J.M., Aragno, M., Matthey, W., 2003. The Living Soil. Fundamental of Soil Science and Soil Biology. Science Publishers, Inc. Enfield (NH), USA., 602 p.

[4] Rodríguez-Romero, A.S. (2003) Alternativas biotecnológicas en cultivares de *Musa* frente a los principales patógeno de suelo en Canarias. Tesis Doctoral. Universidad de La Laguna, 299 p.

[5] Kloepper, J.W. (1994) Plant growth-promoting rhizobacteria (other systems). *In: Azospirillum* / plant associations. (Ed.). Y Okon. CRC Press. Boca Ratón, pp111-118.

[6] Lemanceau, P.; Alabouvette, C. (1993) Suppression of *Fusarium*-wilts by fluorescent Pseudomonads: mechanisms and applications. *Biocontrol Sci. Technol* 3, pp. 219-234.

[7] Flores González, H. (1999) Efecto de los hongos formadores de micorrizas arbusculares (MA) sobre la tedera (*Bituminaria bituminosa* (L.) Stirton) durante las primeras fases de cultivo. Trabajo Fin de Carrera. Centro Superior de Ciencias Agrarias, Universidad de La Laguna.

[8] Jaizme-Vega, M.C.; Mendez, P.; Flores, H. (1999) Efecto de la micorrización sobre la tedera (Bituminaria bituminosa) en las primeras fases del cultivo. “Biodiversidad en pastos”: Ponencias y Comunicaciones de la XLI Reunión Científica de la SEEP. I Foro Iberoamericano de Pastos. Alicante, pp. 181-187.

[9] Jaizme-Vega, M.C.; Carnero, A. (1990) Estudio preliminar del uso de los hongos micorrícicos en el cultivo del tomate bajo invernadero en las Islas Canarias. *Act. Horticultura* 4, pp. 186-190.

[10] Puerta González, M.; Jaizme-Vega, M.C. (1997) Application of arbuscular mycorrhizal fungi (AM) in tomato protected crops with high soil phosphorus level. Working group on integrated control in protected crops in Mediterranean climate. 3-6 Noviembre 1997. Tenerife. Islas Canarias.

[11] Rodríguez-Romero, A.S.; Piñero Guerra, M.S.; Jaizme-Vega, M.C. (2005) Effect of arbuscular mycorrhizal fungi and rhizobacteria on banana growth and nutrition. *Agron. Sustain. Dev* 25, pp. 395-399.

[12] Jaizme-Vega, M.C.; Rodríguez-Romero, A.S.; Barroso Núñez, L.A. (2006) Effect of the combined inoculation of two arbuscular mycorrhizal fungi and plant growth-promoting rhizobacteria on papaya (*Carica papaya* L.) infected with the root-knot nematode *Meloidogyne incognita*. *Fruits* 61, pp. 151-162.