Glienke C, Savi DC, Advances in Research on Biodiversity and Bioprospecting of Endophytes in Brazil. In: Deising HB; Fraaije B; Mehl A; Oerke EC; Sierotzki H; Stammler G (Eds), "Modern Fungicides and Antifungal Compounds", Vol. VIII, pp. 255-262. © 2017 Deutsche Phytomedizinische Gesellschaft, Braunschweig, ISBN: 978-3-941261-15-0

Advances in Research on Biodiversity and Bioprospecting of Endophytes in Brazil

Glienke C, Savi DC

Federal University of Paraná, PoBox 19071, 81531-990, Curitiba, Brazil

Email: ch.glienke@gmail.com

INTRODUCTION

In debates on future global practises of agriculture, compromises in food security are not tolerated. In conventional agriculture pesticide applications are primarily used to reduce disease severity. However, the excessive use - and misuse - of agrochemicals, has generated significant interest in developing approaches alternative to pesticise application. Among these alternatives are biological control (activities of living organisms) and biopesticide (use of the natural products extracted or fermented from several sources) strategies (Pal and Gardner 2006). These formulations may be very simple or complex mixtures of natural ingredients affceting the hosts and/or the target pathogens.

Plant diseases may be due to an imbalance between the microbiome and its host as well as to reduced microbial diversity. Endophytic microrganisms are increasingly recognized for their impact on host function, especially on host immunity (Schulz and Boyle 2005; Rodriguez et *al.* 2009; Christian et *al.* 2015). The plant microbiome has also been considered fundamental in protecting plants from pathogen either by synthesizing enzymes or metabilites negatively affecting pathogens (Mendes et *al.* 2013; Berg et *al.* 2016; Braga et *al.* 2016).

The bioprospecting aspect of endophytes has been extensively reviewed (Mousa and Raizada 2013; Brader et *al.* 2014; Strobel 2015, Jia et *al.* 2016). However, the role of microbial symbioses has been poorly understood, mainly because plant-microbe interactions are ubiquitous and diverse in nature (Genre and Russo 2016; Mitter et *al.* 2016). In 1997, the Brazilian Environment Ministry started a project to catalog the country's biological diversity. The first data were generated and analyzed in 1999 and it was estimated that from all microorganisms in the world, Brazil holds 20% of the diversity (MMA, 2002) distributed in six biomes: Amazon forest, Atlantic forest, Caatinga, Cerrado, Pampas and Pantanal.

Amazon and Atlantic forests, Cerrado and Pantanal are included in UNESCO List of World Heritage Sites, and harbor biomes with enormous biodiversity. Our group has studied endophytic microorganisms from Pantanal medicinal plants for more than ten years, demonsting the huge potential of these microbes. Due to the high diversity of plants present in Brazil, and considering that each plant harbors at least two endophytes with a high potential to produce secondary metabolites, we review here the survey on the biodiversity and bioprospecting of endophytes from different biomes found in Brazil.

ENDOPHYTES – GENERAL ASPECTS

Endophytes are living entities colonizing internal plant tissues, such as leaves, stems, bark, petioles and reproductive structures (Faeth and Fagan 2002; Hardoim et *al.* 2015), and play an important role in the natural environment. There is a great biological diversity of endophytic fungi particularly in tropical rainforests, wherein about 300,000 terrestrial plant species are distributed (Jia et *al.* 2016). The number of 1.5 million fungal species in nature is probably understimated (Hawksworth 1991) and Petrini (1991) suggested that there could be more than 1 million species of endophytic fungi remaining to be discovered (Sun and Guo 2012).

The definition of endophytes has changed in the past years. The term endophyte was introduced by de Bary (1866) who defined endophytes as a group of organisms occurring within plants tissues. Carroll (1986) defined endophytes as mutualists that colonize aerial parts of plant, excluding microorganism that cause disease symptoms and mycorrhizal fungi as formerly defined by de Bary. Petrini (1991) proposed an expansion of Carroll's definition to include all organisms inhabiting plant organs that, at some time in their life, can colonize internal plant tissues without causing apparent harm to the host. Therefore, latent pathogens known to live symptomless inside host tissues are also defined as endophytes. Recently, Hardoim et *al.* (2015) suggested that the term ¨endophyte¨ shoud refer to the habitat only, not the function, and should not be associated with a lifestyle, e.g. phytopathogen or non-phytopathogen, but rather refer to all microorganisms that colonize internal plant tissues.

ENDOPHYTES – STUDIES OF BIODIVERSITY IN BRAZIL

Endophytic fungi are important biotechnological tools because of their ability to produce a vast number of structurally diverse secondary metabolites (Glienke et *al.* 2012), and to access this important source of bioactive molecules the diversity of endophytes has been explored in different ecosystems (Hokama et *al.* 2016). The Brazilian government has encouraged research in biodiversity and community structuration, resulting in more than 30 papers on endophytes in different biomes in the PubMed database since 2015 (https://www.ncbi.nlm.nih.gov/pubmed/).

The different environmental conditions of the six Brazilian biomes significantly impact the distribution pattern of endophytic fungi (Suryanarayanan et *al.* 2005; Hardoim et *al.* 2015). Santos et *al.* (2015) analyzed the endophytic mycobiota of *Indigofera suffruticosa*, a plant commonly found in two different biomes in Brazil, the Atlantic Forest and Caatinga. Using the diversity indices, the authors suggested that the population divergence observed in the same plant species are related to seasonality rather than to geographical factors. However, Vaz et *al.* (2012) explored the biodiversity pattern of endophytes isolated from three plants found in the Brazilian Cerrado ecosystems (*Myrciaria floribunda*, *Alchornea castaneifolia* and *Eugenia* aff. *bimarginata*). This study indicated a rather low similarity among the fungal communities of the host plants, suggesting that not only the microbiome but also the hosts influence the endophyte distribution patterns. In addition, Almeida et *al.* (2015) studied two different species of *Eichhornia* (*E. azurea* and *E. crassipes*) native to the Upper Paraná River floodplain, and found high diversity in the endophytic community analyzed, with small differences between the endophytic species found in the two *Eichhornia* species analyzed.

Another aspect to be considered in biodiversity studies is the plant development stage. Miguel et *al.* (2016), employing culture-independent and culture dependent methods, explored the diversity of endophytic bacterial community at different stages of *Eucalyptus* growth and demonstrated that the distribution of the endophytic bacterial species in *Eucalyptus* was distinct and specific to the development stages.

Besides the efforts to catalog the richness of species, a common problem observed in studies about endophytes biodiversity is that the largest fraction of papers is associated with bioprospecting studies. Thus associative studies of biodiversity and bioprospecting in Brazil normally lead to an ineffective species richness description because only strains that showed bioactivities are identified at species level (Lopes et *al.* 2015; Nascimento et *al.* 2015; Conti et *al.* 2016; Orlandelli et *al.* 2016; Santos et *al.* 2016; Silva et *al.* 2016). Non-exploitation of the entire endophytic community and ineffective species descriptions led to underestimating the Brazilian endophytic richness.

In endophytes biodiversity studies, there are important points that should be considered: the correct identification of isolates at the species level, the number of samples analyzed, the method(s) used for endophyte isolation and the region where the research has been performed. The most common error observed in many papers is the species misidentification, due to improper interpretation of DNA sequence blasts in public databases (Almeida et *al.* 2015; Fernandes et *al.* 2015; Almeida-Lopes et *al.* 2016; Conti et *al.* 2016; Miguel et *al.* 2016; Silva et *al.* 2016). Furthermore there are huge numbers of misidentified sequences in some databanks, likewise leading to misidentifications. Nilsson et *al.* (2006), explored ITS sequences and noted that 27% of the sequences deposited even in renowned databases were incorrectly annotated at the species level, further supporting the inconsistence in species identification using the Blast tool (Clarridge 2004). In order to correctly identify species using a single DNA sequence, we recomend that the following premises be met: I) background phylogenetic analyses must have been performed for given species and barcoding should be available (Heinrichs et *al.* 2012); II) the comparison should be made with sequences from type or authentic strains (Crous et *al.* 2014); III) the new nomenclature rules (International Code of Nomenclature for Algae, Fungi, and Plants) must be followed (Hawksworth et *al.* 2011) for fungi, and prokaryotes (List of Prokaryotic Names; http://www.bacterio.net/). Therefore, the species identification should be performed by a primarily identification at the genus level, using the Blast tool in the database (like GenBank), and a robust analysis should be performed using the specific genus database, or by search of the sequence code of the type strains. As examples of useful websites we recommend: Mycobank (www.mycobank.org); The Genera of Fungi (www.generaoffungi.org/); *Fusarium*-ID (http://isolate.fusariumdb.org/), *Fusarium* MLST (www.cbs.knaw.nl/fusarium/), *Escherichia* MLST (http://mlst.warwick.ac.uk/mlst/dbs/Ecoli), *Streptomyces* MLST (http://pubmlst.org/streptomyces/).

ENDOPHYTES - STUDIES IN BIOPROSPECTING IN BRAZIL

Due to the large biodiversity observed in Brazil, a large number of studies have been published about biological activity of endophytes producing secondary metabolites (Conti et *al.* 2016; Hokama et *al.* 2016; Almeida-Lopes et *al.* 2016; Tonial et *al.* 2016; Silva et *al.* 2016), endophytes used in biological control (Chaverri et *al.* 2015; Dourado et *al.* 2015; Souza et *al.* 2016) or plant growth promotion (Almeida-Lopes et *al.* 2016; Soares et *al.* 2016), and in reduction of impacts of the environment (Costa et *al.* 2012; Mesquini et *al.* 2015).

A concern for the bioprospecting studies in Brazil is that, for a long time, many studies performed only a screening for biological activity by microbial confrontation tests or crude extract, without compounds elucidation or evaluation of plant-microbe interactions (Vaz et *al.* 2012; Bezerra et *al.* 2013; Banhos et *al.* 2014; Hokama et *al.* 2016; Silva et *al.* 2016). However, with the concept of multidisciplinarity in science, this context started to change, and microbiology and chemistry laboratories cooperate to purify and identify these metabolites, and to test their biological activities (Lima et *al.* 2005; Sebastianes et *al.* 2012; Chapla et *al.* 2014; Andrioli et *al.* 2014; Savi et *al.* 2015; Tonial et *al.* 2016).

In Brazil, the unique database available for compounds described from Brazilian biodiversity is the NuBBE (http://nubbe.iq.unesp.br/portal/index.html) and can serve as a useful platform for multidisciplinary research. The NuBBE contains data of more than 640 compounds, with only 6% representing microbial metabolites (Valli et *al.* 2013).

CONCLUSION

Brazil has the largest biodiversity in the world contained in a single political unit. Studies exploring the endophytes from different biomes of Brazil have been performed, using new strategies to catalog this diversity. One of the most exciting aspects is the discovery of microorganisms exhibiting biocontrol activity and to identify bioactive molecules, likewise to be used in plant disease control. A major future challenge will relate to the effectiveness of transforming the knowledge accumulated so far in the universities to commercial royalties in order to rationally use the Brazilian biodiversity in plant and possibly human and animal health.

REFERENCES

Almeida TT; Orlandelli RC; Azevedo JL; Pamphile JA (2015). Molecular characterization of the endophytic fungal community associated with *Eichhornia azurea* (Kunth) and *Eichhornia crassipes* (Mart) (*Ponderiaceae*) native to the Upper Paraná River floodplain, Brazil. *Genetic and Molecular Research* 14, 4920-4931.

Almeida-Lopes KB; Carpentieri-Pipolo V; Oro TH; Pagliosa SE; Degrassi G (2016). Culturable endophytic bacterial communities associated with field-grown soybean. *Journal of Applied Microbiology* 120, 740-755.

Andrioli WJ; Conti R; Araujo MJ; Zanasi R; Cavalcanti BC; Manfrim V; Toledo JS; Tedesco D; Moraes MO; Pessoa C; Cruz AK; Bertucci C; Sabino J; Nanayakkara DNP; Pupo M; Bastos JK (2014). Mycoleptones A-C and polyketides from the endophyte *Mycoleptodiscus indicus*. *Journal of Natural Products* 77, 70-78.

Banhos EF; Souza AQL; Andrade JC; Souza ADL; Koolen HHF; Albuquerque PM (2014). Endophytic fungi from Myrcia guianensis at the Brazilian Amazon: Distribution and bioactivity. *Brazilian Journal of Microbiology* 45, 153-161.

Berg G; Rybakova D; Grube M; Köber M (2016). The plant microbiome explored: implications for experimental botany. *Journal of Experimental Botany*, 67, 995–1002.

Bezerra JDP; Santos MGS; Barbosa RN; Svedese VM; Lima DMM; Fernandes MJS; Gomes BS; Paiva LM; Almeida-Cortez JS; Souza-Motta CM (2013). Fungal endophytes from cactus *Cereus jamacaru* in Brazilian tropical dry forest: a first study. *Symbiosis* 60, 53-63.

Brader G; Compant S; Mitter B; Trognitz F; Sessitsch A (2014). Metabolic potential of endophytic bacteria. *Current Opinion in Biotechnology* 27, 30–37.

Braga RM; Dourado MN; Araújo WL (2016). Microbial interactions: ecology in a molecular perspective. *Brazilian Journal of Microbiology* 47(Suppl 1), 86–98.

Carroll GE (1986). The biology of the endophytism in plants with particular reference to woody perennials. In: *The microbiology of the phyllosphere,* eds NJ Fokkema, I van den Heuvel, pp. 205-222. Cambridge University Press: Cambridge.

Chapla VM; Zeraik ML; Ximenes VF; Zanardi LM; Lopes MN; Cavalherio AJ; Silva DHS; Young MCM; Fonseca LM; Bolzani VS; Araújo AR (2014). Bioactive Secondary Metabolites from *Phomopsis* sp., an Endophytic Fungus from *Senna spectabilis. Molecules* 19, 6597-6608.

Chaverri P; Branco-Rocha F; Jaklitsch W; Gazis R; Degenkolb T; Samuels GJ (2015). Systematics of the *Trichoderma harzianum* species complex and the re-identification of commercial biocontrol strains. *Mycologia* 107, 558-590.

Christian N; Whitaker BK; Clay K (2015). Microbiomes: unifying animal and plant systems through the lens of community ecology theory. *Frontiers in Microbiology* 6:869. doi: 10.3389/fmicb.2015.00869.

Clarridge JE (2004). Impact of 16S rRNA Gene Sequence Analysis for Identification of Bacteria on Clinical Microbiology and Infectious Diseases. *Clinical Microbiological Reviews* 17, 840-862.

Conti R; Chagas FO; Carabalho-Rodriguez AM; Melo WG; do Nascimento AM; Cavalcanti BC; de Moraes MO; Pessoa C; Costa-Lotufo LV; Krogh R; Andricopulo AD; Lopes NP; Pupo MT (2016). Endophytic actinobacteria from the Brazilian medicinal plant *Lychnophora ericoides* Mart. And the biological potential of their secondary metabolites. *Chemical Biodiversity* 13, 727-736.

Costa W; Maia LC; Cavalcanti MA (2012). Diversity of leaf endophytic fungi in mangrove plants of northeast Brazil. *Brazilian Journal of Microbiology* 1, 1165-1173.

Crous PW; Giraldo A; Hawksworth DL; Robert V; Kirk PM; Guarro J; Robbertse B; Schoch CL, Damm U; Trakunyingcharoen T; and Groenewald JZ (2014). The Genera of Fungi: fixing the application of type species of generic names. *IMA Fungus* 5,141-160.

de Bary A (1866). *Morphologie and Physiologie der Pilze, Flechten and Myxomyceten. Holfmeister's Handbook of Physiological Botany*. v.2 Germany: Leipzig.

Dourado MN; Santos DS; Nunes LR; Costa RLO; de Oliveria MV; Araújo WL (2015). Differential gene expression in *Xylella fastidiosa* 9a5c during co-cultivation with the endophytic bacterium Methylobacterium mesophilicum SR1.6/6. *Journal of basic Microbiology* 55, 1357-1366.

Faeth SH; Fagan WF (2002). Fungal Endophytes: Common Host Plant Symbionts but Uncommon Mutualists. *Integrate and Comparative Biology* 42, 360-368.

Fernandes EG; Pereira OL; Silva CC; Bento CBP; Queiroz MV (2015). Diversity of endophytic fungi in *Glycine max*. *Microbiological Research* 181, 84-92.

Genre A; Russo G (2016). Does a common Pathway transduce Symbiotic Signals in Plant-Microbe Interactions? *Frontiers in Plant Science* 7, 96.

Glienke C; Tonial F; Gomes-Figueiredo J; Savi D; Vicente VA; Maia BHS; YM Possiede (2012). Antimicrobial Activity of Endophytes from Brazilian Medicinal Plants. In: *Antimicrobial Agents*, ed Dr. Varaprasad Bobbarala, InTech, DOI: 10.5772/32199. Available from: http://www.intechopen.com/books/antimicrobial-agents/antimicrobial-activity-of-endophytes-from-brazilian-medicinal-plants

Hardoim PR; Overbeek LSV; Berg G; Pirttila AM; Compant S; Campisano A; Doring M; Sessitsche A (2015). The Hidden World within Plants: Ecological and Evolutionary Considerations for Defining Function of Microbial Endophytes. *Microbiological Molecular Biology Reviews* 79, 293-320.

Hawksworth DL (1991). The fungal dimension of biodiversity: magnitude, significance, and conservation. *Mycological Research* 95, 641-655.

Hawksworth DL; Crous PW; Redhead SA; Reynolds DR; Samson RA; Seifert KA; Taylor JW; Wingfield MJ; Abaci O; Aime C; Asan A; Bai FY; de Beer ZW; Begerow D; Berikten D; Boekhout T; Buchanan PK; Burgess T; Buzina W; Cai L; Cannon PF; Crane JL; Damm U; Daniel HM; van Diepeningen AD; Druzhinina I; Dyer PS; Eberhardt U; Fell JW; Frisvad JC; Geiser DM; Geml J; Glienke C; Gräfenhan T; Groenewald JZ; Groenewald M; de Gruyter J; Guého-Kellermann E; Guo LD; Hibbett DS; Hong SB; de Hoog GS; Houbraken J; Huhndorf SM; Hyde KD; Ismail A; Johnston PR; Kadaifciler DG; Kirk PM; Kõljalg U; Kurtzman CP; Lagneau PE; Lévesque CA; Liu X; Lombard L; Meyer W; Miller A; Minter DW; Najafzadeh MJ; Norvell L; Ozerskaya SM; Oziç R; Pennycook SR; Peterson SW; Pettersson OV; Quaedvlieg W; Robert VA; Ruibal C; Schnürer J; Schroers HJ; Shivas R; Slippers B; Spierenburg H; Takashima M; Taşkın E; Thines M; Thrane U; Uztan AH; van Raak M; Varga J; Vasco A; Verkley G; Videira SI; de Vries RP; Weir BS; Yilmaz N; Yurkov A; Zhang N (2011). The Amsterdam Declaration on Fungal Nomenclature. *IMA Fungus* 2, 105-112.

Heinrichs G; Sybren de Hoog G; Haasea G (2012). Barcode Identifiers as a Practical Tool for Reliable Species Assignment of Medically Important Black Yeast Species. *Journal of Clinical Microbiology* 50, 3023-3030.

Hokama YM; Savi DC; Assad B; Aluizio R; Gomes-Figueiredo J; Adamoski DM; Possiede YM; Glienke C (2016). Endophytic Fungi Isolated from *Vochysia divergens* in the Pantanal, Mato Grosso do Sul: Diversity, Phylogeny, and Biocontrol of *Phyllosticta citricarpa*. In: *Endophytic Fungi: Diversity, Characterization and Biocontrol*. ed Hughes E. chap3 Hauppauge: Nova Publishers.

Jia M; Chen L; Xin HL; Zheng CJ; Rahman K; Han T; Qin LP (2016). A Friendly Relationship between endophytic Fungi and Medicinal Plants: A Systematic Review. *Frontiers in Microbiology* 7, 906, 1-14.

Lima AOS; Quenice MC; Fugaro MHP; Andreote FD; Maccheroni W; Araújo WL; Silva-Filho MC; Pizzirani-Kleiner AA; Azevelo JL (2005). Molecular characterization of a β-1,4-endoglucanase from an endophytic *Bacillus pumilus* strain. *Applied Microbiology and Biotechnology* 68, 57-65.

Lopes RB; Costa LE; Vanetii MC; de Araújo EF; de Queiroz MV (2015). Endophytic bacteria isolated from common bean (*Phaseolus vulgaris*) exhibiting high variability showed antimicrobial activity and quorum sensing inhibition. *Current Microbiology* 71, 509-516.

Mendes R; Garbeva P; Raaijmakers JM (2013). The rhizosphere microbiome: significance of plant beneficial, plant pathogenic, and human pathogenic microorganisms. *FEMS Microbiology Review* 37, 634–663.

Mesquini JA; Sawaya AC; López BG; Oliveira VM; Miyasaka NR (2015). Detoxification of atrazine by endophytic *Streptomyces* sp. isolated from Sugarcane and detection of nontoxic metabolite. *Bull Enviromental Contamination Toxicology* 95, 803-809.

Miguel PS; de Oliveira MN; Delvaux JC; de Jesus GL; Borges AC; Tótola MR; Neves JC; Costa MD (2016). Diversity and distribution of the endophytic bacterial community at different stages of *Eucalyptus* growth. *Antonie Van Leeuwnhoek* 109, 755-771.

Mitter B; Pfaffenbicher N; Sessitsch A (2016). Plant-microbe partnerships in 2020. *Microbial Biotechnology* 9, 635-640.

MMA (2002). *Project for the Conservation and Sustainable Use of Brazilian Biological Diversity: Activies Report 1996-2002.* Brasília: Ministry of Environment. 73pp. Available in: http://www.mma.gov.br/estruturas/chm/_arquivos/prb_eng.pdf

Mousa WK; Raizada MN (2013). The diversity of anti-microbial secondary metabolites produced by fungal endophytes: an interdisciplinary perspective. *Frontiers in Microbiology* 27, 4-65.

Nascimento AM; Soares MG; Silva FK; Araujo JA; Lage PS; Duarte MC; Andrade PH; Ribeiro TG; Coelho EA; Nascimento AM (2015). Antileishmanial activity of compounds produced by endophytic fungi derived from medicinal plant *Vernonia polyanthes* and their potential as source of bioactive substances. *World Journal of Microbiology and Biotechnology* 31, 1793-1800.

Nilsson RH; Ryber M; Kristiansson E; Abarenkov K; Larsson K; Koljalg U (2006). Taxonomic reliability of DNA sequences in public sequence databases: a fungal perspective. *PLoS One* 1, 59-62.

Orlandelli RC; Corradi ML; Vasconcelos AF; Almeida IV; Vicentini VE; Prieto A; Hernandez MD; Azevedo JL; Pamphile JA (2016). β-(1→3,1→6)-d-glucans produced by *Diaporthe* sp. endophytes: Purification, chemical characterization and antiproliferative activity against MCF-7 and HepG2-C3A cells. *International Journal of Biological Macromolecules* 94, 431-437.

Pal KK; Gardener BM (2006). Biological Control of Plant Pathogens *The Plant Health Instructor.* DOI: 10.1094/PHI-A-2006-1117-02

Petrini O. (1991). Fungal endophytes of tree leaves. In: *Microbial ecology of leaves*. eds J Andrews & S Hirano, pp 179-197. Springer-Verlag: New York.

Rodriguez RJ; White JFJr; Arnold AE; Redman RS (2009). Fungal endophytes: diversity and functional roles. *New Phytologist* 182, 314–330.

Santos IP; Bezerra JDP; Motta CMS; Cavalcanti MS; Lima VLM (2015). Endophytic mycobiota from leaves of *Indigofera suffruticosa* Miller (Fabaceae): The relationship between seasonal change in Atlantic Coastal Forest and tropical dry forest (Caatinga), Brazil. *African Journal of Microbiology* 9, 1227-1235.

Santos PJC; Savi DC; Gomes RR; Goulin EH; Senkiv CC; Tanaka FAO; Almeida AMR; Galli-Terasawa L; Kava V; Glienke C (2016). *Diaporthe endophytica* and *D. terebinthifolii* from medicinal plants for biological control of *Phyllosticta citricarpa*. *Microbiological Research* 186, 153–160.

Savi DC; Shaaban KA; Vargas N; Ponomareva LV; Possiede YM; Thorson JS; Glienke C; Rohr J (2015). Microbispora sp. LGMF259 endophytic actinomycete isolated from Vochysia divergens (Pantanal, Brazil) producing B-carbolines and indoles with biological activity. *Current Microbiology* 70, 345-354.

Schulz B; Boyle C (2005). The endophytic continuum. *Mycological Research* 109, 661–686.

Sebastianes FLS; Cabedo N; El Aouad N; Valente AMMP; Lacava PT; Azevedo JL; Pizzirani-Kleiner AA; Cortes D (2012). 3-Hydroxypropionic Acid as an Antibacterial Agent from Endophytic Fungi *Diaporthe phaseolorum. Current Microbiology* 65, 622-632.

Silva MCS; Polonio JC; Quecine MC; Almeida TT; Bogas AC; Pamphile JA; Pereira JO; Astolfi-Filho S; Azevedo JL (2016). Endophytic cultivable bacterial community obtained from the *Paullinia cupana* seed in Amazonas and Bahia regions and its antagonistic effects against *Colletotrichum gloeosporioides*. *Microbial Pathogenesis* 98, 16-22.

Soares MA; Li H-Y; Kowalski KP; Bergen M; Torres MS; White JF (2016). Functional role of bacteria from invasive *Phragmites australis* in promotion of host growth. *Microbiology and Ecology* 72, 407-417.

Souza JT; Trocoli RO; Monteiro FP (2016). Plants from the Caatinga biome harbor endophytic *Trichoderma* species active in the biocontrol of pineapple fusariosis. *Biological Control* 94, 25-32.

Strobel G (2015). Bioprospecting – fuels from fungi. *Biotechnological Letters* 37, 973-982.

Sun X & Guo LD (2012). Endophytic fungal diversity: review of traditional and molecular techniques. *Mycology* 3, 65-76.

Suryanarayanan TS; Thirunavukkarasu N; Hariharan GN; Balaji P (2005). Occurrence of non-obligate microfungi inside lichen thalli. *Sydowia* 57, 120–130.

Tonial F; Maia BH; Gomes-Figueiredo JA; Sobottka AM; Bertol CD; Nepel A; Savi DC; Vicente VA; Gomes RR; Glienke C (2016). Influence of culturing conditions on bioprospecting and the antimicrobial potential of endophytic fungi from *Schinus terebinthifolius*. *Current Microbiology* 72, 173-183.

Valli M; Santos RN; Figueira LD; Nakajima CH; Castro-Gamboa I; Andricopulo AD; Bolzani VS (2013). Development of Natural Products database from the Biodiversity of Brazil. *Journal of Natural Products* 76, 439-444.

Vaz ABM; Brandão LR; Vieira MLA; Pimenta RS; Morais PB; Sobral MEG; Rosa LH; Rosa CA (2012). Diversity and antimicrobial activity of fungal endophyte communities associated with plants of Brazilian savanna ecosystems. *Microbiology Research* 6, 3173-3185.