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IMS Newsletter

The International Mycorrhiza Society quarterly e-newsletter

Chondrogaster cf. *packysporus*, southern Brazil
Photo: Marcelo A. Sulzbacher

CONTENT:

Launching the Newsletter

Dr. César Marín, University of O'Higgins, Chile
Newsletter Editor

This Newsletter is an effort of the International Mycorrhiza Society to communicate recent developments on mycorrhizal research. If you are interested on highlighting (short articles, interviews, photos) your research on this symbiosis, contact us (cesar.marin@uoh.cl).

Editorial

Reflections on the career of Professor Sally E. Smith

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Professor Sally Smith FAA, one of the most eminent researchers in the mycorrhizal research field passed away on 13th September, 2019. Sally leaves behind a big gap and many mycorrhizal researchers and plant physiologists, young and old, remember her as a vibrant personality who contributed substantially to the development of the mycorrhizal research field, always with a lot of enthusiasm and knowledge. In writing this article I was aim to identify some of the research' highlights of the career of Professor Sally Smith FAA. Of Sally's hundreds of papers I have selected just a few, for no reason other than they spoke to me. If others had written this, they undoubtedly would have included a different set of publications (Gianinazzi-Pearson 2020), but the conclusion would be the same: Sally was a pioneer and leader in the field. But more than that, she was a mentor and friend to so very many of us in the 'Mycorrhizal community'.

Sally held degrees including: B.A./M.A., Natural Sciences Tripos (Cambridge, U.K., 1962), PhD (Cambridge, U.K. 1965), and D.Sc. (Adelaide, Australia, 1991). She was elected a Fellow of the Australian Academy of Sciences (2001), was awarded a Personal Chair (University of Adelaide, 1995), was an Honorary Professor (Research Centre for Eco-Environmental Sciences, Chinese Academy of Sciences, 2001), and Honorary Research Professor (China Agricultural University, 2002). She won many awards, including The J.K. Taylor, OBE, Gold Medal in Soil Science (2006), The Clarke Medal of the Royal Society of New South Wales (2001), and most recently, the Eminent Mycorrhiza Researcher Award (awarded by the International Mycorrhiza Society in 2019). Sally taught generations of undergraduate students Soil Science and Botany at the University of Adelaide, and supervised (by our count) 30+ PhD students, not to mention many postdocs, staff and visitors.

In her own words, Sally took a physiologists approach to her research; that is, she wanted to know "how things work". And when things did not work, she would advise that "it was all part of life's rich tapestry". Sally used many tools and techniques in her research, including whole plant physiology, molecular biology, morphological studies, mycorrhiza defective mutants, and isotope tracing.

Sally's first publication, which arose from her PhD studies on orchid mycorrhizas, appeared in *New Phytologist* in 1966 (Smith 1966). In this study she used P and C radioisotopes to study the uptake and translocation of P and C by the fungal symbiont. I highlight this paper, not only because it was her first, but also because her use of isotopes continued over the span of her career. This led to many fruitful collaborations, for example, with Iver Jokobsen, F. Andrew Smith and many of their staff, students and collaborators (Drew, Poulsen, Gao, Stonor, Li, Jansa, Cavagnaro, to name but a few). Of particular note was the work in which she demonstrated that mycorrhizal fungi can dominate phosphate supply to plants irrespective of growth responses (Smith *et al*. 2003). This work highlighted the importance of the mycorrhizal pathway of nutrient uptake, and has since been extended to other plants species (wheat, rice, buckwheat, barley, and tomato) and nutrients (P and Zn).

Sally undertook pioneering work on the functioning of mycorrhizas, including studies of the location and expression of transporters at the interface between plant and fungus. This started with enzymatic studies on the metabolism of arbuscular mycorrhizas (AM) (or as then known vesicular-arbuscular mycorrhizas -VAM), which involved the localisation of H+-ATPases at the plant-fungus interface (Gianinazzi-Pearson *et al*. 1991). With the advent of molecular biology she also undertook work focused on the expression of transporters at the plant-fungal interface, again with many students and collaborators, e.g. Glassop *et al*. (2005). A comment frequently made by Sally was that "it is important to not only measure the expression of the transporter, but also the flux of the ion across the membrane" –this still holds true today!

Sally was also part of the team that identified the mycorrhiza defective tomato mutant (*rmc*) (Barker *et al*. 1998). In addition to providing a powerful tool for the study on controls on the formation and functioning of AM (Larkan *et al*. 2013), it has also been used extensively in the study of AM under field conditions.

In collaboration with F. Andrew Smith, Sally co-authored a *New Phytologist* Tansley review on structural diversity on VAM (Smith and Smith 1997). This major review explored the link between the morphology of AM and plant identity. This review has led to much ongoing work not only on AM morphology, but also on the physiology of AM *Arum*- and *Paris*-types.

Undoubtedly, one of Sally's greatest contributions was her authorship of the three editions of *Mycorrhizal Symbiosis* (Harley and Smith 1983; Smith and Read 1997, 2008). My first encounter with "The Book" as Sally called it, was in my first meeting as a PhD student in Sal's lab. I asked if she could recommend a good text book on the topic. She quietly handed me the second edition and simply said "this might be useful". Of "The Book", Sally was sometimes heard to say "did we really say that?" when it was cited (perhaps incorrectly), or "I wish people would cite the original reference, not The Book".

As is to be expected of any such article, this one is incomplete and does not do full justice to the immense impact that Sally had on the field of mycorrhizal research, and even more so, the careers of so many. But I tried my best, and that is all that Sally would expect!

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Top 10 papers on mycorrhizal research*

1. Averill C, Bhatnagar JM, Dietze MC, Pearse WD, Kivlin SN. 2019. Global imprint of mycorrhizal fungi on whole-plant nutrient economics. *Proc Natl Acad Sci USA* 116: 23163-23168. https://doi.org/10.1073/pnas.1906655116

2. Soudzilovskaia NA, van Bodegom PM, Terrer C, *et al.* 2019. Global mycorrhizal plant distribution linked to terrestrial carbon stocks. *Nature Commun* 10: 5077. https://doi.org/10.1038/s41467-019-13019-2

3. Zhou Y, Ge S, Jin L, *et al.* 2019. A novel CO 2-responsive systemic signaling pathway controlling plant mycorrhizal symbiosis. *New Phytol* 224: 106-116. https://doi.org/10.1111/nph.15917

4. Wagg C, Schlaeppi K, Banerjee S, Kuramae EE, van der Heijden MG. 2019. Fungal-bacterial diversity and microbiome complexity predict ecosystem functioning. *Nature Commun* 10: 4841. https://doi.org/10.1038/s41467-019-12798-y

5. Mueller RC, Scudder CM, Whitham TG, Gehring CA. 2019. Legacy effects of tree mortality mediated by ectomycorrhizal fungal communities. *New Phytol* 224: 155-165. https://doi.org/10.1111/nph.15993

6. Müller LM, Flokova K, Schnabel E, *et al.* 2019. A CLE–SUNN module regulates strigolactone content and fungal colonization in arbuscular mycorrhiza. *Nat Plants* 5: 933-939. https://doi.org/10.1038/s41477-019-0501-1

7. Rimington WR, Pressel S, Duckett JG, Field KJ, Bidartondo MI. 2019. Evolution and networks in ancient and widespread symbioses between Mucoromycotina and liverworts. *Mycorrhiza* 29: 551-565. https://doi.org/10.1007/s00572-019-00918-x

8. Cope KR, Bascaules A, Irving TB, *et al.* 2019. The ectomycorrhizal fungus *Laccaria bicolor* produces lipochitooligosaccharides and uses the common symbiosis pathway to colonize *Populus* roots. *Plant Cell* 31: 2386-2410. https://doi.org/10.1105/tpc.18.00676

9. Robin A, Pradier C, Sanguin H, *et al.* 2019. How deep can ectomycorrhizas go? A case study on *Pisolithus* down to 4 meters in a Brazilian eucalypt plantation. *Mycorrhiza* 29: 637-648. https://doi.org/10.1007/s00572-019-00917-y

10. Pyšek P, Guo WY, Štajerová K, *et al.* 2019. Facultative mycorrhizal associations promote plant naturalization worldwide. *Ecosphere* 10: e02937. https://doi.org/10.1002/ecs2.2937

*Web of Science articles *published* between September – December 2019, selected by: Miranda Hart, Melanie Jones, Marcel van der Heijden, Liang-Dong Guo, Justine Karst, John Klinoromos, Jonathan Plett, Jan Jansa, Francis Martin, and César Marín.

Research commentary

Biological functions in agriculture: cover crops and soil microorganisms increase the availability of organic P

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In the following commentary, I want to discuss the results of a recent meta-analysis about the potential use of biological functions for a more sustainable agriculture, with examples of cover crops for improving phosphorus management (Hallama *et al.* 2019).

Phosphorus as a macronutrient has a special role due to its strong physicochemical interactions with soil, and its resulting limited availability for plants, being the microbial community the principal driver of soil P dynamics (Bünemann *et al.* 2011). Agricultural management can be used to manage the microbial community (Oberson *et al.* 2006). One promising, multifunctional tool is cover cropping between main crops during the off-season, as the field is maintained with plants -in opposition to a bare fallow, with many associated benefits, as erosion control, enhancement of soil biodiversity and fertility, increase of soil organic matter, etc. We propose different main pathways of P benefit for the main crops, depending on the cover crop species and management. Firstly, the cover crops take up nutrients from the soil into their biomass. Later, when the plant residues are decomposed, the stored P is made available for the main crop.

Another important mechanism is the enhancement of the soil microbial community by the cover crop (mixtures) that provides a legacy of increased mycorrhizal abundance, microbial biomass P, and phosphatase activity. In the meta-analysis, we found strong increases (of around 50%) on the abundance of arbuscular mycorrhizal fungi (AMF) after mycorrhizal cover crops. Mycorrhizal plant species tended to increase main crop yield and P uptake more than non-mycorrhizal cover crops did, and AMF abundance was positively related to the main crop yield and P uptake. A mycorrhizal cover crop can transfer its ability to access P in the soil to the main crop in the form of mycorrhizal inoculum as hyphae or spores in the soil.

Crop rotation is important, as the build-up of AMF inoculation potentially benefits only AMF-competent main crops, and the ability of the main crop to take advantage of earlier increased mycorrhization by previous cover crops determines the P benefit. The carbon input from roots through mycorrhizal hyphae extends our concept of a modified rhizosphere (mycorrhizosphere) to a much greater soil volume, and the microflora of this mycorrhizosphere may play a critical role in P acquisition (Bending *et al.* 2006). However, non-mycorrhizal cover crops as Lupinus sp. and members of the Brassicaceae family also can have interesting effects on P dynamics. Many issues are still unknown, and current agricultural practices lead to complex situations. A question worth to investigate is, e.g., to which degree pesticide use affects negatively the microbial community enhanced by cover crops.

Hidden miners – the roles of cover crops and soil microorganisms in phosphorus cycling through agroecosystems. However, in view of the multiple ecosystem functions of soil microbes, a holistic approach of increasing biodiversity through agronomic management as opposed to a reductionist approach focusing on single species may be more appropriate (Fester and Sawers 2011). Mycorrhiza can be considered "umbrella" species for agroecosystems, as several management techniques that enhance mycorrhiza have other beneficial effects on other species and in the agroecosystem. Therefore, I advocate for a broader approach by embracing agroecology, where farmer–scientist alliances co-create and exchange knowledge, transforming the research system (Levidow et al. 2014), while producing relevant results for a more sustainable agriculture.

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Fungal biodiversity in tropical rainforests of Colombian Amazonia

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While Colombia is a megadiverse country, data on fungal biodiversity and its ecosystem roles are still scarce. Studies in fungal biodiversity and ecology have been complex and limited due to the morphological approaches traditionally used, were ascomata and basidiomata were necessary for macrofungi, and cultures for microfungi. Significant advances have been made in the ecology of fungal communities in the region over the past decade with the implementation of next generation molecular techniques. In 2014, a global study on soil fungi that included 365 samples from around the globe - including the Colombian Amazonia- using next generation techniques, revealed numerous unknown taxa (Tedersoo *et al*. 2014). This study demonstrated that climatic, edaphic, and spatial factors are the main predictors of soil fungal richness and community composition, and that plant diversity does not have a direct effect at a global scale, as previously thought. Tedersoo *et al*. (2014) also found that the diversity of soil fungi peaked in tropical forests with the highest diversity observed in the Colombian Amazonia.

In Colombia we have developed several studies documenting the fungal biodiversity of Amazonian ecosystems (Peña-Venegas and Vasco-Palacios 2019; Sanjuan *et al*. 2015; Vasco-Palacios *et al*. 2014, 2018, 2019; Yilmaz *et al*. 2016). The Amazonia comprises a soil complex


Sarcodon rufobrunneus , Amazonas, Colombia
Photo: Aída M. Vasco-Palacios

that results in many types of forest niches that harbor high fungal diversity; although studies on Amazonian fungal diversity are limited, recent studies suggest that soil fungi have strong effects in the plant biodiversity and composition of these ecosystems (Vasco-Palacios *et al.* 2019). Aboveground characterization of macrofungi in Colombia has revealed a high fungal diversity and different guild composition in different forest types (López-Quintero *et al*. 2012; Vasco-Palacios *et al*. 2018, 2019). We have described 29 new species from Amazonian material including ectomycorrhizal and saprophytic fungi. In a recent study using molecular approaches (Vasco-Palacios *et al*. 2019), we characterized the soil fungal communities (by *454 pyrosequencing* of the ITS2 rDNA) and its relation with soil chemistry in three lowland rainforest types of Colombian Amazonia: a *terra-firme* mixed forest dominated by arbuscular mycorrhizal (AM) host plants, a *terra-firme* forest with the ectomycorrhizal (ECM) tree host *Pseudomonotes tropenbosii* (Dipterocarpaceae), and a white-sand forest dominated by members of the ectomycorrhizal family Fabaceae. We detected a high diversity of soil fungi, identifying 2,507 OTUs belonging to 64 orders, 147 families, and 292 genera. A 22.4% of OTUs were not identified at lower taxonomic levels, possibly reflecting a lack of a full understanding of fungal biodiversity in the tropics.

The saprotroph guild was the most diverse fungal group (59% of all OTUs), followed by plant-pathogens (9%), and ECM fungi (6%). ECM fungi comprised 144 OTUs belonging to 21 families, where Telephoraceae (25%), Russulaceae (16%), Cantharellaceae (13%), Boletaceae (6.9%), and Cortinariaceae (5.6%) were the most diverse. We expect that the number of ECM species may increase in future studies. Fungal community composition from the white-sand forest presented a particular composition that differed with AM and ECM-dominated *terra-firme* plots -the composition was similar within terra-firme plots. Forest type, soil pH, and C/N ratio were the main drivers structuring these highly diverse fungal communities. Although ECM host trees are rare and scattered in *terra-firme* forests, they associate with a large number of ECM fungal taxa. We suggest that scattered ECM hosts as *Coccoloba* (Polygonaceae), *Guapira* and *Neea* (Nyctaginaceae) in tropical lowland rainforests may connect ECM fungi between *P. tropenbosii* patches, thus facilitating the distribution of ECM fungi in various types of *terra-firme* forests, and probably also in white-sand forests. Also, the data suggests that other ECM hosts in Amazonian forests have not been identified, as studies looking for ECM fungi are based on previously reported ECM hosts.

Further studies about the main factors that shape fungal communities, and their role in structuring plant communities and nutrient cycling in Amazonian ecosystems, are needed. Also, more mycologists in Colombia and South American countries are required to fill knowledge gaps. Recently we founded the Colombian Association of Mycology with the aims to promote the development of mycology in Colombia through research, non-formal education, technology, and innovation.

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YouTube interviews*

- Adriana Romero on soil metatranscriptomes under climate change

Camille Truong interviews Adriana L. Romero-Olivares from the University of New Hampshire on how climate change is affecting the metabolism of soil fungi using long-term warming experiments and metatranscriptome data.

Interview: https://southmycorrhizas.org/reading/september-2019/
Study: Romero-Olivares AL, Meléndrez-Carballo G, Lago-Lestón A, Treseder KK. 2019. Soil metatranscriptomes under long-term experimental warming and drying: Fungi allocate resources to cell metabolic maintenance rather than decay. *Front Microbiol* 10: 1914. https://doi.org/10.3389/fmicb.2019.01914

- Camille Delavaux on island biogeography of mycorrhizal associations

C. Guillermo Bueno interviews Camille Delavaux from the University of Kansas, about the importance of mycorrhizal fungi in shaping global plant biogeography using mainland versus island floras as a model.

Interview: https://southmycorrhizas.org/reading/october-2019/
Study: Delavaux CS, Weigelt P, Dawson W, *et al.* 2019. Mycorrhizal fungi influence global plant biogeography. *Nat Ecol Evol* 3: 424-429.
https://doi.org/10.1038/s41559-019-0823-4

- Mary Luz Vanegas-León on Neotropical ectomycorrhizae

Camila Monroy Gúzman interviews Mary Luz Vanegas-León from the Federal University of Santa Catarina in Brazil about her master project on the diversity and trophic modes in Trechisporales (Basidiomycota).

Interview: https://southmycorrhizas.org/reading/november-2019/
Study: Vanegas-León ML, Sulzbacher MA, Rinaldi AC, Roy M, Selosse MA, Neves MA. 2019. Are Trechisporales ectomycorrhizal or non-mycorrhizal root endophytes? *Mycol Prog* 18: 1231-1240. https://doi.org/10.1007/s11557-019-01519-w

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South American Mycorrhizal Research Network

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Tools

→ Observed fungal richness depends strongly on the bioinformatic approach

Pauvert *et al.* (2019) sequenced an artificial fungal community of 189 strains, and compared 360 software and parameter combinations, founding that USEARCH and VSEARCH clustering algorithms detected almost all fungal strains but greatly overestimated abundance. In contrast, DADA2 algorithms worked well for recovering fungal richness and composition.

Study: Pauvert C, Buée M, Laval V, *et al.* 2019. Bioinformatics matters: the accuracy of plant and soil fungal community data is highly dependent on the metabarcoding pipeline. *Fungal Ecol* 41: 23-33. https://doi.org/10.1016/j.funeco.2019.03.005

→ *Ramf*, an R package to quantify and analyze arbuscular mycorrhizal colonization

Chiapello *et al.* (2019) have created *Ramf*, an R package that allows to analyze, quantify, and run several statistical analyses on data of root colonization by arbuscular mycorrhizal fungi. Furthermore, this package allows to distinguish between the Gridline-intersect or the Trouvelot methods to quantify mycorrhizal colonization.

Study: Chiapello M, Das D, Gutjahr C. 2019. *Ramf*: An open-source R package for statistical analysis and display of quantitative root colonization by arbuscular mycorrhiza fungi. *Front Plant Sci* 10: 1184. https://doi.org/10.3389/fpls.2019.01184

→ *PacBio* metabarcoding of eukaryotes using full-length ITS sequences

Tedersoo and Aslan (2019) showed that *PacBio* metabarcoding of the ITS region, allows to cover the diversity of almost all groups of eukaryotes, given sufficient sequencing depth. Furthermore, they recommend to use the degenerate primers ITS9munngs + ITS4ngsUni for eukaryotes.

Study: Tedersoo L, Anslan S. 2019. Towards *PacBio*-based pan-eukaryote metabarcoding using full-length ITS sequences. *Environ Microbiol Rep* 11: 659-668. https://doi.org/10.1111/1758-2229.12776

IMS News

The IMS has a Diversity and Inclusivity Statement

The International Mycorrhiza Society (IMS) is committed to promoting the international study of mycorrhizas, to raising public awareness of the importance of this symbiosis, and to facilitating and expanding communication between IMS members, policy-makers, granting councils and other stakeholders. Our Society embraces diversity and inclusivity and believes that all members, visitors, and event participants deserve to be treated with respect, dignity and kindness and will treat others in the same manner. The IMS will not tolerate discrimination against members of any form, including discrimination based on age, cultural background, ethnicity, gender identity or expression, national origin, physical or mental difference, political affiliation, pregnancy or parental role, race, religion, sexual orientation, or socio-economic circumstance. IMS recognizes that all of our members have roles to play in promoting diversity and encouraging inclusivity in Society activities, including member meetings to help ensure that voices of underrepresented communities are heard within our society. IMS is committed to proactively promoting a culture of equity, diversity, and inclusivity through implementation of our standing rules, committee work, and by identifying and tackling barriers to participation of its members.

The IMS has put together a Code of Conduct that will be posted in full before the next International Conference on Mycorrhiza (ICOM). The Code will apply to all activities, meetings, and events that are organized by IMS. The IMS is committed to maintaining a safe, inclusive, and respectful environment, and to promoting lively and open discussion among participants at meetings for the International Conference on Mycorrhiza (ICOM). A commitment from all participants to uphold the code of conduct will allow for a safe, open, and productive exchange of scientific ideas, to the benefit of all attendees. This code will be reviewed with each ICOM to reflect ongoing discussions on diversity and inclusivity.

International Mycorrhiza Society Board of Directors

International Mycorrhiza Society

http://mycorrhizas.org/

Dear IMS members,
We are conducting a research study to research motivations for usage of mycorrhizal inoculum by consumers, and if you have ever **used mycorrhizal inoculum outside of a research setting**, we would really appreciate your participation! Responses will be kept anonymous and the survey should take approximately 15 minutes.
Follow this link for the survey:
https://depaul.qualtrics.com/jfe/form/SV_dmVAYM2N747mNuZ
Thank you! For any questions or concerns please contact the Primary Investigator Dr. Bala Chaudhary at
bala.chaudhary@depaul.com
The deadline for submission of surveys is March 13, 2020

Events

Global Symposium on Soil Biodiversity
Rome, Italy
10-12 March 2020

Organizers: UN Food and Agriculture Organization (FAO), Global Soil Partnership (GSP), Intergovernmental Technical Panel on Soils (ITPS), UN Convention on Biological Diversity (UNCBD), Global Soil Biodiversity Initiative (GSBI).

Website: http://www.fao.org/about/meetings/soil-biodiversity-symposium/en/

45th New Phytologist Symposium: Ecological and evolutionary consequences of plant–fungal invasions
Campinas, Brazil
20-23 June 2020

Organizers: New Phytologist Trust and symposium organizers.

Website: https://www.newphytologist.org/symposia/45

18th International Symposium on Microbial Ecology
Cape Town, South Africa
9-14 August 2020

Organizers: International Society for Microbial Ecology

Website: https://isme18.isme-microbes.org/

ISME18 Cape Town

X Latin American Mycology Congress
University of Chile, Santiago, Chile,
12-14 December 2020

Organizers: University of Chile and local organizers.

Website: https://almic.science/

X Congreso Latinoamericano de Micología
Chile 2020

10th International Symbiosis Society Congress
Lyon, France
18-23 July 2021

Organizers: International Symbiosis Society
Website: http://iss-symbiosis.org/

3rd Global Soil Biodiversity Conference
Clayton Hotel, Dublin, Ireland
1-3 November 2021

Organizers: Global Soil Biodiversity Initiative
Website: https://gsb2021.ie/

The **5th International Molecular Mycorrhiza Meeting** that was planned for Shanghai (July 2020) has been postponed to 2021 and specific details will be announced later.

Future ICOMs

The IMS Board of Directors is pleased to announce

ICOM11 will be held in **2021 in Beijing, China,** and organized by the Chinese Society of Mycology (Prof GUO Liang-Dong)

and

ICOM12 will be held in **2023 in Manchester, UK,** and organized by Prof David Johnson (University of Manchester), Dr Katie Field (University of Leeds), Prof Tim Daniell (University of Sheffield), Dr Thorunn Helgason (University of York) and Dr. Uta Paszkowski (University of Cambridge)

More information at: http://mycorrhizas.org/

International Mycorrhiza Society