Meeting reports

Mycorrhizal joy in the Amazon: a Meeting Report of the III International Symposium on Mycorrhizal Symbiosis in South America

Clara Peña-Venegas[1], Nahuel Policelli[2], María Isabel Mujica[3], Mónica A. Lugo[4], Patricia Silva-Flores[5, 6], C. Guillermo Bueno[7], Jéssica Duchicela[8], Fabiana Pezzani[9], Bethan F. Manley[10], Adriana Corrales[10], Maria Alice Neves[11], Aída M. Vasco-Palacios[12, 13], César Marín[14, 15]*

[1]Instituto Amazonico de Investigaciones Cientificas Sinchi, Leticia, Amazonas, Colombia. [2]Instituto Patagónico para el Estudio de los Ecosistemas Continentales IPEEC – CONICET, Argentina. [3]Instituto de Ciencias Ambientales y Evolutivas, Universidad Austral de Chile. [4]MICODIF-Micología, Universidad Nacional de San Luis, Argentina. [5]Centro de Investigación en Estudios Avanzados del Maule (CIEAM), Universidad Católica del Maule, Chile. [6]Centro del Secano, Universidad Católica del Maule, Chile. [7]Instituto Pirenaico de Ecología – CSIC, España. [8]Universidad de las Fuerzas Armadas – ESPE, Ecuador. [9]Departamento Sistemas Ambientales, Universidad de la República. Uruguay. [10]Society for the Protection of Underground Networks, SPUN, Dover, DE, United States. [11]Micolab, Universidade Federal de Santa Catarina, Brazil. [12]Grupo de Microbiología Ambiental y Grupo BioMicro, Universidad de Antioquia, Colombia. [13]Asociación Colombiana de Micología, Colombia. [14]Center for Research and Innovation for Climate Change, Santo Tomás University, Chile. [15]Amsterdam Institute for Life and Environment (A-LIFE), Section Systems Ecology, Vrije Universiteit Amsterdam, the Netherlands.

*E-mail: cmarind@santotomas.cl

The South American Mycorrhizal Research Network (Fig. 1; https://southmycorrhizas.org/) was created in Valdivia, Chile, in March 2017 and currently boasts 406 members from 50 countries. The South American Mycorrhizal Research Network is a horizontal scientific community directed towards the progress of mycorrhizal applications, research, and public outreach in South America. Since its creation, the Network has organized three international symposia (Valdivia, Chile in 2017; Bariloche, Argentina in 2019; and the one we are reporting here, Leticia, Colombia, 2023) (Bueno *et al.* 2017; Godoy et al. 2017; Mujica *et al.* 2019; Marín 2021), an online workshop, and three symposia within the Latin American Congress of Mycology (in Perú, Chile, and Panamá). In addition, it has published five scientific articles, two Springer books edited by Mónica A. Lugo and Marcela C. Pagano, and a special issue in the journal *Diversity* (https://southmycorrhizas.org/about/publications/). We have a dedicated team (South American Mycorrhizal Traits Database) leading the vast and important task of generating a database on mycorrhizal traits for South America (J. Duchicela, C.G. Bueno, P. Silva-Flores, and M.I.

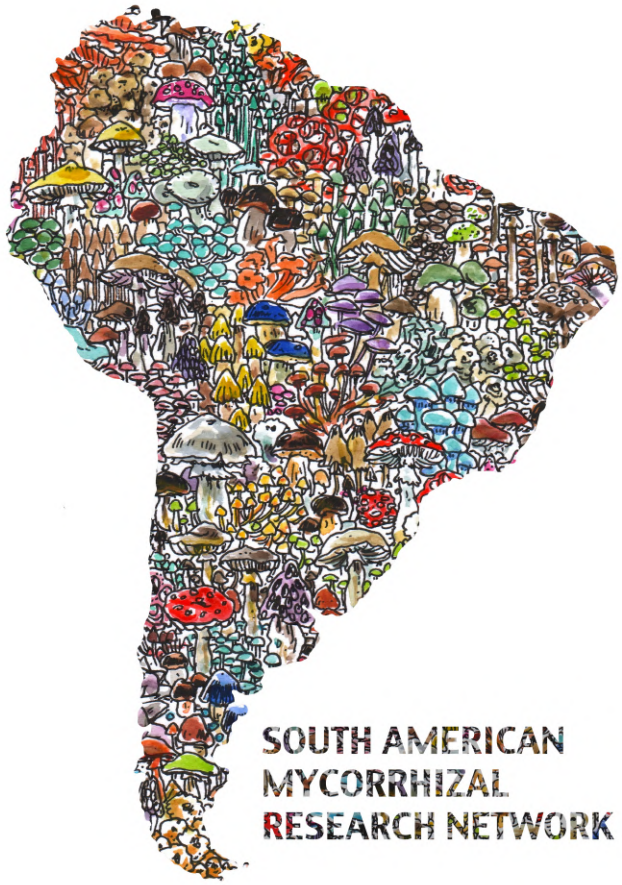

Figure 1. Logo of the South American Mycorrhizal Research Network. Designed by Heiko Sievers.

Mujica – all co-authors of this report). In addition, we regularly release interviews on YouTube featuring mycorrhizologists at all career stages (https://southmycorrhizas.org/reading/), provide outreach tools (Silva-Flores *et al.* 2021; https://southmycorrhizas.org/outreach/), and collaborate with various other networks and Latin American and global scientific societies (e.g. FAO, Soil-BON, Latin American Mycology Association, SPUN) and scientific journals. Notably, we collaborate strongly with the IMS Newsletter (https://southmycorrhizas.org/ims-newsletter/). Interested people can join our Network here: https://southmycorrhizas.org/join/

Since the creation of the Network, it became clear that despite South America's vast size, biodiversity, and an increasing number of mycologists and ecologists specializing in mycorrhizae, mycorrhizal research on the continent needs to be substantially expanded (Marín and Bueno 2019). We identified three main reasons for the regional shortfall in mycorrhizal research (Mujica *et al.* 2019): insufficient funding across South American nations with the absence of a unified mechanism for conducting continental-scale research (as seen in the European Union or the United States), a demand for more robust training in sampling, statistical, molecular, and bioinformatic methods, especially among young researchers and students, and a lack of comprehensive information on plant mycorrhizal traits across several biomes and countries. In turn, we have observed research biases about certain mycorrhizal types (with orchid and ericoid mycorrhizas generally overlooked compared to arbuscular or ectomycorrhizas), ecosystem functions (with a predominant focus on plant growth), and concentration of research in specific countries (with Brazil, Argentina, and Chile accounting for 80% of regional mycorrhizal research) (Marín *et al.* 2022). Our Network knows such biases and works directly and powerfully to combat them. Recently, Cazolla Gatti *et al.* (2022) estimated that more than 9,200 tree species worldwide are yet to be discovered, 40% of them in South America! This underscores the imperative for foundational, methodical research within our continent, beginning with the systematic collection of mycorrhizal-type information as a baseline.

In this context, we present our Meeting Report of the III International Symposium of the Mycorrhizal Symbiosis in South America (Fig. 2), held from August 24th to 31st, 2023, in the beautiful city of Leticia, Amazonas, Colombia. This symposium saw participation from approximately 75 attendees on-site and over 30

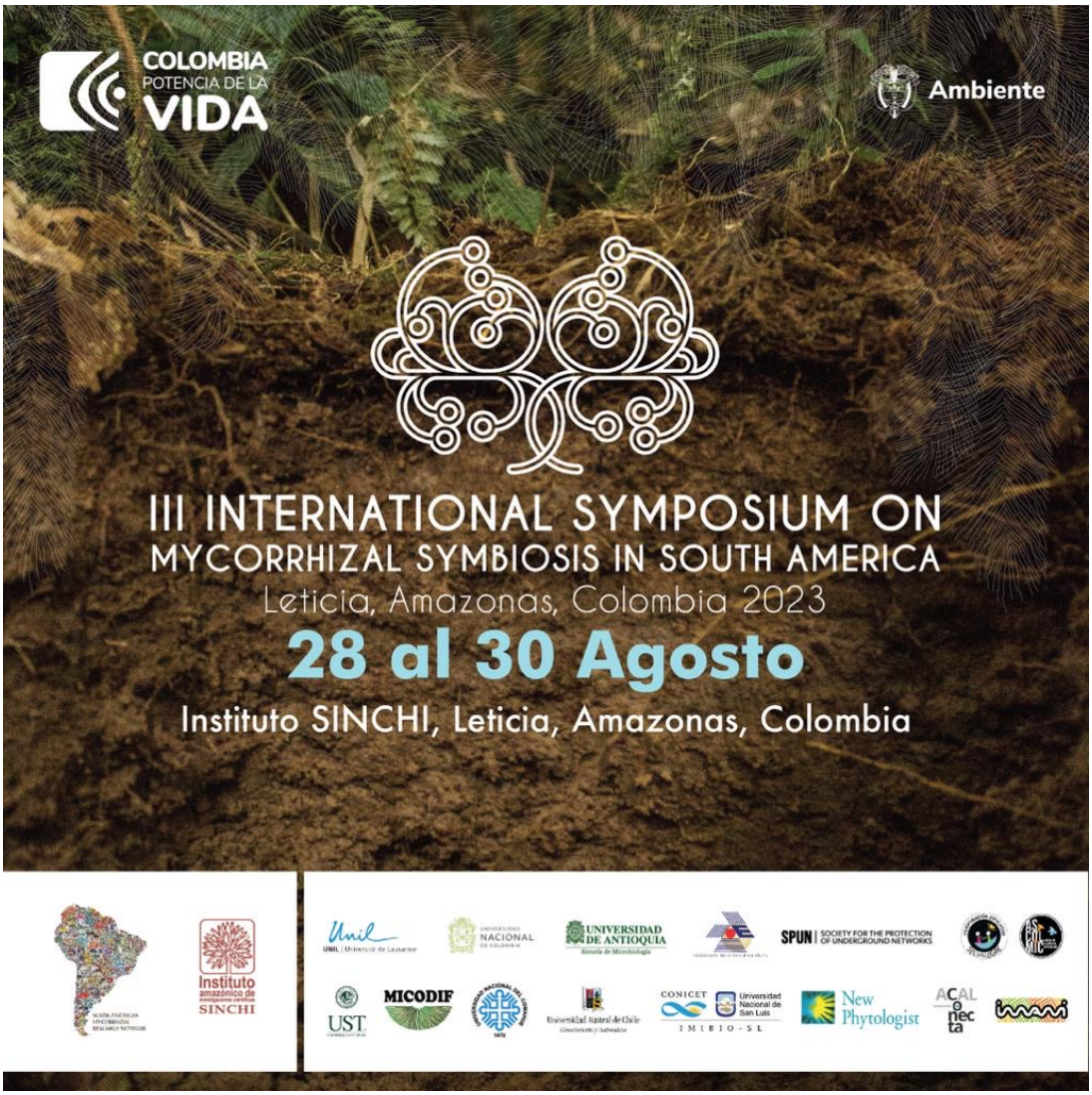

Figure 2. Logo of the event and sponsors.

individuals virtually (Fig. 3). The organization was headed by Clara Peña-Venegas and César Marín, with substantial contributions from all co-authors of this report. It was a great joy to have such a varied group discussing mycorrhizas in the Amazon! The event was supported and hosted by the Instituto Amazónico de Investigaciones Científicas – SINCHI and the Universidad Nacional de Colombia and also had financial support from the New Phytologist Foundation, the Society for the Protection of Underground Networks (SPUN), and MycoNativa ©. This event included two pre-symposium courses focused on Amazonian mycorrhizas (arbuscular mycorrhizas, AM, and ectomycorrhizas, ECM) and bioinformatics, as well as a post-symposium workshop to start building a South American mycorrhizal traits database. Here we summarize six significant themes discussed during the symposium and highlight selected presentations within each theme.

Mycorrhizas in Amazonia and other natural environments

Since the Amazon was the location of our symposium and given its status as such a diverse yet unexplored ecosystem in terms of mycorrhizal research, our initial focus was naturally on this region, where we had to start. Clara Peña-Venegas shared the latest research advances in

arbuscular mycorrhizal fungi (AMF) in the Colombian Amazon, showing fascinating evidence of a biogeographic gradient in the distribution of AMF in Colombia. Also, Aida M. Vasco-Palacios summarized about ten years of her career in the Colombian Amazon. Her work highlighted the discovery of new species of ECM fungi, specifically delving into the exploration of less studied underground environments like the Amazonian white sands and terra-firme forests, particularly emphasizing the association with the dipterocarp tree, *Pseudomonotes tropenbosii* (Vasco-Palacios *et al.* 2018, 2019; Vasco-Palacios and Boekhout 2022). Continuing with ectomycorrhizas, Maria Alice Neves introduced new Amazonian taxa of ectomycorrhizal fungi from the Atlantic Forest. Despite claims that they are only found in temperate and boreal ecosystems, these findings shed light on their morphology with detailed insights. Maria Alice Neves, Ariadne N.M. Furtado and their coauthors introduced a novel type of mycorrhiza (Furtado *et al.* 2023): guapiroid mycorrhizas. As the existence of guapirioid mycorrhizas may be unfamiliar to some, people can learn more about this topic in an interview with Ariadne, available online: https://youtu.be/npXtj05eX60?si=sOYIwYek-If1uFHk

At the same session, Tomas Figura showed how similar the seedling development is between orchids and the Pyrola genus (Ericaceae). Both plant groups have tiny seeds that require mycorrhizal fungi to germinate; this process is known as "symbiotic germination". Overall, this session spanned other countries such as Panamá, Colombia, and Brazil, as well as relationships with other soil organisms (like *Rhizobium*), among other topics. One open question that emerged during this session was whether the endemic ECM host tree *Pseudomonotes tropenbosii* (Dipterocarpaceae) forms dual relationships with AMF as well, an example of how much remains to be studied in the tropics with open minds.

Mycorrhizas and climate change

Understanding the environmental drivers of mycorrhizal fungal distribution is essential to predict their responses to global changes, including climate change. In addition, trait information might help to assess how different species will respond. Three contrasting talks tackled these issues. Through the study of the genus Tuber, Tine Grebenc presented compelling evidence that geographical distance is a determining factor in genome distribution. On her part, Bala Chaudhary captivated the audience, discussing the ecological traits of AMF and how these can provide insights into processes such as their dispersal, persistence, and relationships with plant carbon. Bala presented an AMF spore trait database, which includes information from 315 species and will be released soon. Through a large-scale phylogenetic study (using a comparative method), Marco Cosme detected correlated evolution between mycorrhizal types and plant drought adaptation. For example, plant taxa associated with ericoid mycorrhizas or ECM had higher transition rates between tolerance and intolerance to drought than those groups without mycorrhizal associations. Marco's work (Cosme 2023) was voted Top 1 in our last IMS Newsletter issue (Vol. 4, Issue 2). Other topics raised during this session included agronomic aspects (in tomatoes, grapevines, and legumes) and mycorrhizas in temperate and Mediterranean Chilean ecosystems.

Mycorrhizas in agriculture

This session boasted the highest number of talks and posters during our Symposium, reflecting the state of mycorrhizal research in our continent (Marín and Bueno 2019). Miroslav Vosátka showed significant advances in applying base knowledge of microorganisms (plant growth-

Figure 3. Upper part: group photo of the event. **Lower part:** countries of the participants.

promoting bacteria, AMF, among others), which helps improve sustainable agriculture. He and his team have experimented and put into practice mass inoculation techniques highlighting the importance of using native AMF in the field, which has increased agricultural yield in Middle-East deserts (by creating vertical gardens) and promoted a circular economy in Africa. In turn, Ian Sanders spoke about the immense potential of various AMF strains in improving Cassava production in Latin America and Africa. Cassava is a significant food source for millions of people in the world's poorest and most hungry countries. The increase in its production and sustainable production can contribute to the circular economy of different Global South countries. Nevertheless, the considerable intra and interspecific variation in AMF is still a stumbling block in predicting their application as inoculants (Terry *et al.* 2023), representing a challenge for mycorrhizal scientists. Also in Cassava systems, Diego Camilo Peña made visible the significant contribution of AMF in the retention of carbon (C), avoiding its incorporation into the atmosphere with its dire consequences on global climate change. This is relevant given the geographical range and agroeconomic importance of this crop. He also showed the differences in the productivity of

Cassava depending on the genetics of the inoculated AMF and soil aggregation, as well as the possible larger-scale effects being studied directly in the field in Colombian Cassava crops.

Fabiana Pezzani presented a platform for the efficient use and transfer of bio inputs in Latin America, whose mission is to disseminate basic knowledge and the broad benefits of bio inputs to agricultural and livestock producers in South America. Maria del Rocío Vega examined the above and belowground traits of chili peppers (*Capiscum annuum*). More than 60 varieties of *C. annuum* widely used in México, Bolivia, and Perú differ in the morphology and allometry of their leaves, stems, and roots, depending on their degree of domestication. One of the challenges in studying the allometric redistribution of resources in relation to associations with AMF and its relationship with domestication was to find wild forms of *C. annuum*. Eureka! Wild *C. annuum* only grows in very restricted pristine areas of the Mexican subdeciduous tropical forest. Comparative studies between wild, semi-wild, and domesticated plants inoculated with AMF show different morphological and functional leaves and root traits.

Erica McGale presented her research on using inoculants for different species of edible plants (corn, Cassava, and coffee), investigating different genetic variants of AMF and host allometry. AMF contributed to changing the 1:1 shoot: root tissue partition occurring in non-colonized plants, redistributing resources, and increasing the proportion of roots: aerial part of the host. This differential allometries produced by AMF could also be differentiated between structural and reproductive tissues and the competitive capacity of the host. Erica cautioned about the uninformative nature of evaluating host allometric traits only at the end of the inoculation trial, as allometry changes with plant phenology. María Margarita Ramírez presented an econometric analysis of AMF inoculants in cape gooseberry, "uchuva" (*Physalis peruviana*), in Colombia. The production of this native plant is carried out primarily by small local producers in high-altitude areas, which are dangerously ascending towards the Páramo, the great water reservoir of the country. After testing mixed inoculants with growth-promoting bacteria and AMF, she and her group tested them in field plots with promising results for their application. Although the estimated economic benefits were positive, they have once again encountered the unpredictability of applying inoculants in crops to mass produce cape gooseberry. It is necessary to continue investigating in order to apply this outstanding knowledge!

Distribution of mycorrhizal symbiosis, co-invasions, and restoration

Jéssica Duchicela showed that in the Ecuadorian jungle associated with *Inga* sp., mycorrhizal fungi were predominantly Ascomycota, while Glomeromycota were scarce, contradicting the paradigm of AMF associations being predominant in the Tropics. Furthermore, in the Galápagos, she studied not only native hosts but also invasive ones, finding little colonization in native plants and high colonization in invasive and naturalized ones. These results were also confirmed in field trials, where the invasive hosts were more successful than the native ones when grown in the islands' soils. Everything indicates that invasive plants and the expansion of the agricultural frontiers threaten the islands' endemic plants. It is imperative to apply conservation and management practices to avoid losing the rich endemic flora of the Galápagos!

The revelation that certain tropical tree species can host ECM fungi or even a new related

association called guapiriod, as showcased by Jessica Duchicela, Aida M. Vasco-Palacios, and Ariadne N.M. Furtado, in this conference, challenges the prevailing global assumptions regarding tropical forests. This underscores the imperative for a broader collection of empirical data on mycorrhizal associations and a more inclusive scientific stance toward diverse perspectives (as addressed in Albornoz *et al.* 2021, Bueno *et al.* 2021, among others). Part of the disparity between empirical evidence and expectations arises from unfounded assertions concerning the phylogenetic conservatism of mycorrhizal associations within plant orders, families, and genera. A significant stride in this direction was presented by C. Guillermo Bueno, where Tartu University researchers conducted pioneering measurements of the phylogenetic signal of various mycorrhizal associations. They also assessed the relative contributions of phylogeny and environment in elucidating the global distribution of mycorrhizal symbiosis (Meng *et al.* 2023). Utilizing the most recent plant mycorrhizal dataset, their study indicates that extrapolations of mycorrhizal types within plant taxa often neglect crucial environmental factors influencing these associations. Taxonomic extrapolations should be exercised cautiously, primarily when mycorrhizal information is limited, treating their outcomes as hypotheses. During this conference, Daniela León highlighted this cautious approach by presenting her research findings on the distribution of mycorrhizal symbiosis in the Colombian Páramo. Her study utilized genus extrapolations, emphasizing the need to consider outcomes as hypotheses (León *et al.* 2024).

Nahuel Policelli discussed the role of non-native invasive ectomycorrhizal fungi in partially explaining the invasiveness of their plant partners (Policelli *et al.* 2023). He highlighted the importance of critical non-native invasive fungi, such as suilloid fungi, which can act as global drivers of Pinaceae invasions. Policelli's research in temperate Patagonian forests demonstrated how the community of ECM fungi changes from non-native pine plantations to the pine invasion fronts, where suilloid fungi are dominant. In turn, the evidence presented demonstrates how native ECM *Nothofagus* trees and non-native pine trees can find suitable mycorrhizal partners in each other's dominated areas. While it is typically assumed that non-native invasive mammals, including wild boars and deer, play a significant role in the dispersal of invasive ECM fungi within Patagonia forests, Policelli's discovery of these non-native fungi on lake islands raises new questions regarding the potential for bird or human-mediated dispersal, as well as wind dispersal (Policelli *et al.* 2022). Finally, he introduced some new hypotheses on dryland systems in Patagonia dominated by willows (*Salix* spp.), where he is studying whether native trees can facilitate the invasion of non-native congeners mediated through ECM fungi.

Mycorrhizas: ecology, diversity, and evolution

This session commenced with a captivating presentation by Martin Bidartondo, revealing the extensive presence and multifaceted roles of Mucoromycotina fungi across various ecosystems, surpassing prior conceptions (Hoysted *et al.* 2023). Jason Hoeksema delivered an illuminating talk debunking misconceptions surrounding Common Mycorrhizal Networks (CMN) (Karst *et al.* 2023; with an interview on our YouTube channel: https://youtu.be/7IGhb36AyPM?si=gb6-GgkpSqikx9Wb). By a detailed analysis of cumulative misinterpretations of current evidence, Jason showed how we need much more evidence to understand and claim how widespread they are, the potential effects of CMN on plants' growth, and whether trees 'can talk' or not with each

other through a CMN. Adriana Corrales focused on characterizing the ECM fungal communities associated with the endangered and monodominant host tree *Trigonobalanus excelsa* (black oak) in the Colombian Andean region. She highlighted the high number of new species of ECM fungi and high beta diversity associated with different populations of this host plant. Adriana placed particular emphasis on conserving these forest systems to preserve tropical ECM fungi, highlighting the importance of continuous monitoring of permanent plots and developing strong collaborations with local communities.

Among several other topics, this session included discussions on the roles of plant mycorrhizal and seed dispersal interactions as drivers of ecosystem structure and function (Marta Correia), the mycorrhizal associations of the Eastern pasque flower (*Pulsatilla patens*) across its native range (Savannah Draud), and, when analyzing South American *Nothofagus* ECM associations, evidence suggesting that ECM fungi have a restricted habitat volume (Felipe Figueroa). From Czechia, Zuzana Kolaříková introduced the *GlobalAMFungi* database (Větrovský *et al.* 2023), and her understanding of community assembly in AMF, while Martina Janoušková showed compelling evidence of AMF from arable fields being equally efficient in providing P but more demanding for C and N compared to grassland AMF.

Mycorrhizal fungi and their interactions with other organisms

Peter Kennedy started this session by discussing how dead mycorrhizal fungal mycelium is linked to global carbon cycling, examining its decomposition's abiotic and biotic (other microorganisms) drivers. Fungal necromass constitutes a significant source of soil C and nitrogen, and its decomposition is highly dependent on both abiotic and biotic factors, including a diverse mix of bacteria and fungi with a consistent assemblage structure across ecosystems. Marcel G.A. van der Heijden, IMS President, talked about the past, present, and future of AMF-based agronomic practices, among other things, showing that a vast majority of AMF biofertilizers do not work (Salomon *et al.* 2022a), but also proposing a quality management framework for them (Salomon *et al.* 2022b). His approach was cautionary but optimistic, showing excellent results from trials across Switzerland and Spain.

Awards

We recognized the life and career of two eminent mycorrhizologists who have greatly impacted South American mycorrhizal research. First, Prof. Ewald Sieverding from Germany was recognized for his pioneer mycorrhizal contributions across several countries of the continent, such as Colombia and Chile. In a very emotive presentation, Prof. Gisela Cuenca from Venezuela was given the Second South American Eminent Mycorrhizologist Award for her outstanding contributions to AMF ecology and applications, new species descriptions, forming dozens of students across South America and building the first slides collections of AMF species in South America. In addition, we gave three awards for best oral presentations to (in order) Natalie Ferro Lozano (Wageningen University), João Paulo Ernzen (Universidade Federal de Santa Catarina), and Savannah Draud (University of Mississippi). The best poster award was given to Ezequiel A. Cruz-Campuzano (Universidad Nacional Autónoma de México), with Sofía Crescio (Universidad de Buenos Aires) in the second place. The best online poster award was given to Pablo García Parisi (Universidad de Buenos Aires), while a special mention award – poster with social impact, was given to Yessica Lorena Perdomo (Fundación Universitaria del Área

Andina). More details on the awards here: https://southmycorrhizas.org/events/awards/

Concluding remarks and acknowledgments

Over the past 6.5 years, more than 100 individuals have contributed voluntarily to our Network in various capacities, excluding the authors of our published works. This includes but is not limited to organizing events, conducting interviews on our YouTube channel, writing blog posts, arranging online workshops and working groups, and providing financial and outreach support. The organization of this Symposium involved many individuals, as noted below. In today's climate, it is essential to reject helicopter science (Haelewaters *et al.* 2021) and acknowledge the prevalence of discrimination, particularly racial discrimination, in academia (Hofstra *et al.* 2020). Additionally, incorporating non-English scientific literature can enhance global understanding of ecological matters (Zenni *et al.* 2023). Therefore, our Network and scientific methodology appear well-suited for this current landscape. It is impressive that despite being from the Global South and lacking a legal constitution and a traditional scientific society structure with formality and annual fees, we have achieved so much in such a short time. The attention received from numerous individuals, organizations, and journals is impressive, reinforcing our personalized and horizontally collaborative approach to science and scientific engagement.

Our III Symposium would have been impossible without the support of the Instituto Amazónico de Investigaciones Científicas – SINCHI. We thank its General Director Luz Marina Mantilla, Clara Peña-Venegas, Sandra Mora, Daniela León, Ana Paola Aponte, Andrés Barona, and Diana Mora. This Symposium also took place and was supported by the Universidad Nacional de Colombia sede Amazonas, with the crucial help of its Director and co-organizer Eliana Jiménez, and also from Angela Hooz Chaparro, Patricia Marín, Laura Vargas, Camila Orca, and Mónica Andrea Ríos. Thanks for the support of the Colombian Mycology Association, ASCOLMIC. From New Phytologist, we thank its Editor-in-Chief Alistair M. Hetherington, Maarja Öpik, and Sarah Lennon. From the Society for the Protection of Underground Networks (SPUN), we thank its Executive Director, Toby Kiers, Adriana Corrales, and Bethan F. Manley for organizing a fantastic bioinformatics course! Similarly, many thanks to Clara Peña-Venegas, Aída M. Vasco-Palacios, Maria Alice Neves, and several other co-authors in this piece and people above-mentioned in this paragraph, for organizing an excellent course on Amazonian mycorrhizas which involved an intense, well-deserved, and even better-planned fieldwork. On that note, special thanks to Angel Pijachi and Miguel Angel Arcangel of the Bora and Uitoto-N+pode indigenous communities, whose guidance and expertise were crucial for an unforgettable and successful fieldwork. Thanks to the South American Mycorrhizal Traits Database leading team and all the post-symposium workshop attendees for starting to build our database. C.G.B was supported by the Spanish Ministry of Science and Innovation through a Ramón y Cajal fellowship (RYC2021-032533-I).

References

- Albornoz FE, Dixon KW, Lambers H. 2021. Revisiting mycorrhizal dogmas: Are mycorrhizas really functioning as they are widely believed to do? *Soil Ecol Lett* 3:73-82. https://doi.org/10.1007/s42832-020-0070-2
- Bueno CG, Davison J, Leon D, *et al.* 2021. Towards a consistent benchmark for plant mycorrhizal association databases. *New Phytol* 231:913-916. https://doi.org/10.1111/nph.17417
- Bueno CG, Marín C, Silva-Flores P, et al. 2017. Think globally, research locally: emerging opportunities for mycorrhizal research in South America. *New Phytol* 215:1306-1309. https://doi.org/10.1111/nph.14709
- Cazzolla Gatti R, Reich PB, Gamarra JG, *et al.* 2022. The number of tree species on Earth. *Proc Natl Acad Sci USA*, 119:e2115329119. https://doi.org/10.1073/pnas.2115329119
- Cosme M. 2023. Mycorrhizas drive the evolution of plant adaptation to drought. *Commun Biol*, 6:346.

https://doi.org/10.1038/s42003-023-04722-4

- Furtado AN, Leonardi M, Comandini O, et al. 2023. Guapirioid ectomycorrhiza: a novel fungus-plant subtype is described associated to *Guapira opposita* (Nyctaginaceae) in the Brazilian restinga. *For Syst* 32:e009-e009. https://doi.org/10.5424/fs/2023322-19998
- Godoy R, Silva-Flores P, Aguilera P, Marín C. 2017. Microbial Interactions in the plant-soil continuum: Research results presented at the Workshop "Mycorrhizal Symbiosis in the Southern Cone of South America". *J Soil Sci Plant Nutr* 17:1-3.
- Haelewaters D, Hofmann T.A, Romero-Olivares AL. 2021. Ten simple rules for Global North researchers to stop perpetuating helicopter research in the Global South. *PLoS Comput Biol* 17:e1009277. https://doi.org/10.1371/journal.pcbi.1009277
- Hofstra B, Kulkarni VV, Munoz-Najar Galvez S, *et al*. 2020. The diversity–innovation paradox in science. *Proc Natl Acad Sci USA* 117:9284-9291. https://doi.org/10.1073/pnas.1915378117
- Hoysted GA, Field KJ, Sinanaj B, *et al*. 2023. Direct nitrogen, phosphorus and carbon exchanges between Mucoromycotina 'fine root endophyte' fungi and a flowering plant in novel monoxenic cultures. *New Phytol* 238:70-79. https://doi.org/10.1111/nph.18630
- Karst J, Jones MD, Hoeksema JD. 2023. Positive citation bias and overinterpreted results lead to misinformation on common mycorrhizal networks in forests. *Nat Ecol Evol* 7:501-511. https://doi.org/10.1038/s41559-023-01986-1
- León D, Peyre G, Zobel M, *et al*. 2024. Mycorrhizal symbioses in the Andean páramo. *Mycorrhiza*. In press.
- Marín C. 2021. Knowledge of biodiversity and ecosystem services of South American mycorrhiza through research networking. In: FAO (Ed.), Keep soil alive, protect soil biodiversity – Global Symposium on Soil Biodiversity, 19–22 April 2021, Proceedings (pp. 68-74). Rome, Italy: FAO. https://doi.org/10.4060/cb7374en
- Marín C, Bueno CG. 2019. A systematic review on South American and European mycorrhizal research: is there a need for scientific symbiosis? In: Pagano M, Lugo M (eds) *Mycorrhizal Fungi in South America*. Springer, Cham, Fungal Biology Series. Pp. 97-110. https://doi.org/10.1007/978-3-030-15228-4_5
- Marín C, Godoy R, Rubio J. 2022. Gaps in South American Mycorrhizal Biodiversity and Ecosystem Function Research. In: Lugo MA, Pagano MC (eds) *Mycorrhizal Fungi in South America*. Springer, Cham, Fungal Biology Series. Pp. 445-461. https://doi.org/10.1007/978-3-031-12994-0_22
- Meng Y, Davison J, Clarke JT, et al. 2023. Environmental modulation of plant mycorrhizal traits in the global flora. *Ecol Lett* 26:1862-1876. https://doi.org/10.1111/ele.14309
- Policelli N, Hoeksema JD, Moyano J, *et al*. 2023. Global pine tree invasions are linked to invasive root symbionts. *New Phytol* 237:16-21. https://doi.org/10.1111/nph.18527
- Policelli N, Horton TR, Kitzberger T, Nuñez MA. 2022. Invasive ectomycorrhizal fungi can disperse in the absence of their known vectors. *Fungal Ecol* 55:101124. https://doi.org/10.1016/j.funeco.2021.101124
- Salomon MJ, Demarmels R, Watts-Williams SJ, *et al*. 2022a. Global evaluation of commercial arbuscular mycorrhizal inoculants under greenhouse and field conditions. *Appl Soil Ecol* 169:104225. https://doi.org/10.1016/j.apsoil.2021.104225
- Salomon MJ, Watts-Williams SJ, McLaughlin MJ, *et al*. 2022b. Establishing a quality management framework for commercial inoculants containing arbuscular mycorrhizal fungi. IScience, 25:104636. https://doi.org/10.1016/j.isci.2022.104636
- Silva-Flores P, Argüelles-Moyao A, Aguilar A, *et al*. 2021. Mycorrhizal science outreach: scope of action and available resources in the face of global change. *Plants People Planet* 3:506-522. https://doi.org/10.1002/ppp3.10213
- Vasco-Palacios AM, Boekhout T. 2022. *Pseudomonotes tropenbosii*, an endemic dipterocarp tree from a neotropical terra-firme forest in Colombian Amazonia that hosts ectomycorrhizal fungi. In: Pagano M, Lugo M (eds) *Mycorrhizal Fungi in South America*. Springer, Cham, Fungal Biology Series. Pp. 47-78. https://doi.org/10.1007/978-3-031-12994-0_3
- Vasco-Palacios AM, Bahram M, Boekhout T, Tedersoo L. 2019. Carbon content and pH as important drivers of fungal community structure in three Amazon forests. *Plant Soil* 450:111-131. https://doi.org/10.1007/s11104-019-04218-3
- Vasco-Palacios AM, Hernandez J, Peñuela-Mora MC, *et al*. 2018. Ectomycorrhizal fungi diversity in a white sand forest in western Amazonia. *Fungal Ecol* 31:9-18. https://doi.org/10.1016/j.funeco.2017.10.003
- Větrovský T, Kolařík ová Z, Lepinay C, *et al*. 2023. GlobalAMFungi: a global database of arbuscular mycorrhizal fungal occurrences from high-throughput sequencing metabarcoding studies. *New Phytol* 240:2151-2163. https://doi.org/10.1111/nph.19283
- Zenni RD, Barlow J, Pettorelli N, *et al*. 2023. Multi-lingual literature searches are needed to unveil global knowledge. *J Appl Ecol* 60:380-383. https://doi.org/10.1111/1365-2664.14370