ISSN 2563-1497

VOL. 2 ISSUE 3, OCTOBER 2021

International Mycorrhiza Society
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IMS Newsletter

The International Mycorrhiza Society quarterly e-newsletter

Talk talk
By: Heiko Sievers, 2010
@SieversHeiko

CONTENT:

Editorial Vol 2, Issue 3 (2021)

César Marín[1]* and Marcel G.A. van der Heijden[2, 3]
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We are very delighted to release our sixth Newsletter (Vol. 2, Issue 3) of the International Mycorrhiza Society (IMS). After six issues, we are happy with the result, as it has encouraged many researchers in all stages to share their mycorrhizal research, as well as it has expanded the communication within and outside the IMS, being an important source of mycorrhizal research outreach. We would like to thank all the mycorrhizal researchers who have contributed with votes, short articles, YouTube interviews, and events/jobs advertising to our Newsletter. Also, many thanks to our Executive, Board of Directors, to the South American Mycorrhizal Research Network, and to the Topic Editors. We encourage our readers to please continue giving feedback, suggestions, and/or advice in order to improve our content.

Call for Topic Editor: dear all, in addition to the current topics our Newsletter touches (Ecology, Evolution, Molecular biology), we are looking for a mycorrhizal Applications Editor. If you have interest and experience in the applications of mycorrhizal research (agriculture, forestry, remediation, etc), please contact César Marín (cesar.marin@postgrado.uach.cl). Your duties will be to coordinate articles in this research area (approach researchers to write a short article and/or approach them for being interviewed about their recent mycorrhizal work), promote the IMS Newsletter, and you can vote for the top 10 mycorrhiza papers.

Top Ten Mycorrhizal articles

In this issue, we present our list of the Top 10 mycorrhizal articles for the last four months (May to August, 2021). Many congratulations to Ylva Lekberg and colleagues for the first rank with their paper entitled "Nitrogen and phosphorus fertilization consistently favor pathogenic over mutualistic fungi in grassland soils" (*Nat Commun*). They demonstrate that N and P addition to 25 grasslands around the globe promotes the relative abundance of fungal pathogens, suppresses mycorrhiza, but does not affect saprotrophic fungi. Further highlights on this list include work by Clemmensen *et al.* (2021) in *Ecol Lett* (rank 2) demonstrating that there are tipping points in carbon storage when forests expand into tundra, and that this is related to ectomycorrhizal fungi contributing to decomposition when mining N from organic matter. The No. 3 article by Rich *et al.* (2021) in *Science* postulated how AMF helped recently evolved terrestrial plants with their adaptation to increased ultraviolet light exposure, desiccation, and less accessible nutrients.

Short Research articles on mycorrhizas, tree survival, and a changing world

This issue also contains two short research articles/commentaries about different issues. The topics include the mutualism to parasitism continuum under different soil nutrient conditions (by Ylva Lekberg and Lauren Waller; No. 1 in our Top 10 vote), and the effects of mycorrhizal fungi and networks on large trees survival and their resistance to native pests and pathogens (by Sara J Germain and James A Lutz). This issue also includes three YouTube interviews, one with Mathu Malar on the genome of Geosiphon pyriformis and the emergence of the AM symbiosis, other with Aidee Guzman on how crop diversity enriches AMF communities in California (article No. 9 in our Top 10 vote), and the last one with Laura Martinez-Suz on ectomycorrhizas, forest recovery, and tipping points. The Tools section provides short commentaries to methods on molecular community ecology of AMF, modeling tools, and pharmaceuticals removal using AMF. In the events section we highlight conferences and meetings linked to mycorrhizal research. We also highlight a recent special issue in *Plants, People, Planet* regarding mycorrhizas in a changing world. Please do contact us if you have useful information that you wish to be mentioned in the "Tools" or "Events" sections, or other special annoucements about mycorrhiza.

Registration for ICOM11 in Beijing

Please do register and schedule for the next meeting of the International Mycorrhiza Society (ICOM11), which is scheduled next year (31 July – 5 August, 2022) in Beijing, China. It is not fully clear yet whether this will be an on-site meeting or a mix of on-line and on-site. This will be announced until the end of the year. Also, the scientific program for ICOM11 is being finalised and will be announced the coming month.

Top 10 papers on mycorrhizal research*

1. Lekberg Y, Arnillas CA, Borer ET, *et al.* 2021. Nitrogen and phosphorus fertilization consistently favor pathogenic over mutualistic fungi in grassland soils. *Nat Commun* 12: 3484. https://doi.org/10.1038/s41467-021-23605-y

2. Clemmensen KE, Durling MB, Michelsen A, *et al.* 2021. A tipping point in carbon storage when forest expands into tundra is related to mycorrhizal recycling of nitrogen. *Ecol Lett* 24: 1193-1204. https://doi.org/10.1111/ele.13735

3. Rich MK, Vigneron N, Libourel C, *et al.* 2021. Lipid exchanges drove the evolution of mutualism during plant terrestrialization. *Science* 372: 864-868. https://doi.org/10.1126/science.abg0929

4. Averill C, Werbin ZR, Atherton KF, *et al.* 2021. Soil microbiome predictability increases with spatial and taxonomic scale. *Nat Ecol Evol* 5: 747-756. https://doi.org/10.1038/s41559-021-01445-9

5. Karst J, Franklin J, Simeon A, *et al.* 2021. Assessing the dual-mycorrhizal status of a widespread tree species as a model for studies on stand biogeochemistry. *Mycorrhiza* 31: 313-324. https://doi.org/10.1007/s00572-021-01029-2

6. Moyano J, Rodriguez-Cabal MA, Nuñez MA. 2021. Invasive trees rely more on mycorrhizas, countering the ideal-weed hypothesis. *Ecology* 102: e03330. https://doi.org/10.1002/ecy.3330

7. Meeds JA, Kranabetter JM, Zigg I, *et al.* 2021. Phosphorus deficiencies invoke optimal allocation of exoenzymes by ectomycorrhizas. *ISME J* 15: 1478-1489. https://doi.org/10.1038/s41396-020-00864-z

8. Yin L, Dijkstra FA, Phillips RP, *et al.* 2021. Arbuscular mycorrhizal trees cause a higher carbon to nitrogen ratio of soil organic matter decomposition via rhizosphere priming than ectomycorrhizal trees. *Soil Biol Biochem* 157: 108246. https://doi.org/10.1016/j.soilbio.2021.108246

9. Guzman A, Montes M, Hutchins L, *et al.* 2021. Crop diversity enriches arbuscular mycorrhizal fungal communities in an intensive agricultural landscape. *New Phytol* 231: 447-459. https://doi.org/10.1111/nph.17306

10. Lindahl BD, Kyaschenko J, Varenius K, *et al.* 2021. A group of ectomycorrhizal fungi restricts organic matter accumulation in boreal forest. *Ecol Lett* 24: 1341-1351. https://doi.org/10.1111/ele.13746

*Selected from 139 Web of Science articles published between May – August, 2021 by: Justine Karst, Jonathan Plett, Melanie Jones, Marcel van der Heijden, Francis Martin, Jan Jansa, John Klironomos, Liang-Dong Guo, Miranda Hart, Jason Hoeksema, Judith Lundberg-Felten, Bala Chaudhary, Annegret Kohler, Joseph Cooper, Junling Zhang, and César Marín.

Research commentaries

Switch in function with resource additions – are AM fungi misbehaving or are they simply misunderstood?

Ylva Lekberg[1]* and Lauren Waller[2]
[1]MPG Ranch and University of Montana, United States. [2]Lincoln University, New Zealand. *E-mail: ylekberg@mpgranch.com

The mutualism to parasitism continuum paper by Johnson *et al.* (1997) is one of the foundational papers in mycorrhizal ecology and has shaped how we view the arbuscular mycorrhizal (AM) symbiosis. Without question, AM fungi can be parasitic when costs outweigh benefits for plants, and this may happen when light levels are low and nutrient—especially phosphorus (P) —availabilities are high. But given that AM fungi can provide multiple benefits, is it possible that we fail to consider the environmental context, and therefore do not focus on the most relevant function sometimes? In this brief commentary, we argue that communities of AM fungi may shift their function from nutrient acquisition (especially P) to protection against pathogens as nutrients become more available. If that is the case, AM fungi might not be parasitic in nutrient-rich soils but could provide a benefit we seldom test for in the greenhouse.

There are indications from several independent lines of research that this is a possibility. First, high nutrient soils often contain greater pathogen abundance and richness (Walters and Bingham 2007; Semchenko *et al.* 2018). Second, AM fungi are known to protect plants against fungal pathogens (Borowicz 2001), but this ability appears largely restricted to some Glomeromycota families, which may be related to differences in growth patterns. Acknowledging that there are exceptions, taxa in the Gigasporaceae tend to grow a more extensive extraradical mycelium and excel at acquiring P (recently termed edaphophilic AM fungi; Weber *et al.* 2019), whereas taxa in the Glomeraceae appear to occupy roots more than soil (rhizophilic) and may offer superior protection against soil pathogens (Maherali and Klironomos 2007; Sikes *et al.* 2009). Third, several studies report a loss of some Gigasporaceae fungi and an increasing dominance of Glomeraceae fungi with nutrient additions (Johnson 1993; Egerton-Warburton and Allen 2000). This is also what we found at the Konza prairie (Waller and Lekberg, *unpublished*), where nutrient addition promoted putative fungal pathogens and suppressed most AM fungal taxa, except for one Glomeraceae taxon that significantly increased (Fig. 1). Had we isolated that taxon and tested it for pathogen protection ability, would it have been a parasite or mutualist?

One of our recent articles (Lekberg *et al.* 2021) supported the Konza results, and found that pathogens were stimulated by single and combined N and P additions in 25 grasslands globally within the Nutrient Network (NutNet; Borer *et al.* 2014). Adding N and P together also decreased the relative

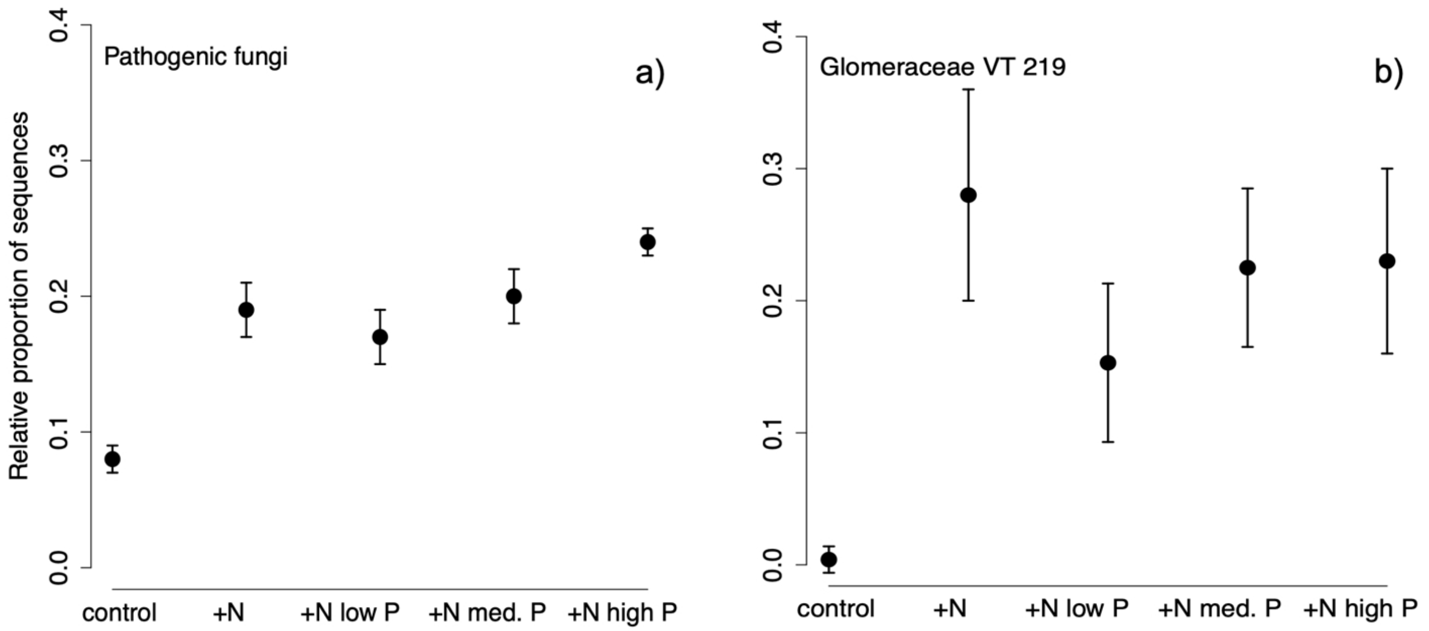

Figure 1. Shifts in relative proportion of potential pathogenic fungi (**a**) and one AM fungal taxon (**b**) in response to nitrogen (N; 10 g m-2) and low (2.5 g m-2), medium (5 g m-2) and high (10 g m-2) phosphorus (P) additions sampled from *Andropogon gerardii* rhizosphere soil in a grassland at Konza Prairie Research Natural Area in Kansas, USA (Waller and Lekberg, *unpublished data*; means ± se, n=6).

abundance of AM fungi in soils. These responses were observed across grasslands despite drastic differences in plant and fungal community composition, climatic conditions, and edaphic properties (Fig. 2), suggesting that this is a strong and predictable response. AM fungal colonization of roots, however, was not suppressed by N and P and even trended higher with N. This combination of results indicates that nutrient additions may alter the distribution of AM fungal biomass from soil to roots, which is a pattern previously observed by Weber *et al.* (2019). Thus, resource additions seem to promote pathogen abundances and prompt a shift in AM fungal community composition toward taxa that occupy roots more than soil and are known to be good at protecting plants from certain pathogens.

A presentation by Kasanke *et al.* (2021) at the 2021 Ecological Society of America conference highlighted that climate may be an additional driver of the distribution of rhizophilic vs. edaphophilic AM fungi. Sampling from a subset of the NutNet sites, they found that rhizophilic fungi dominated in arid sites whereas mesic sites harbored more edaphophilic fungi, irrespective of nutrient additions. A similar shift toward rhizophilic fungi with drought was also observed by Weber *et al.* (2019). This raises the question whether there are some advantages of associating with rhizophilic fungi in arid habitats, perhaps involving drought tolerance, or, alternatively, if an extensive extraradical mycelium may be difficult to maintain at low soil moisture. Regardless, it suggests that there are multiple drivers of AM fungal communities to consider, which could affect the distribution of edaphophilic and rhizophilic fungi, and possibly also AM function.

The only way to assess the support for the idea of a switch in function from resource acquisition to protection against pathogens is to use Koch's postulates, and isolate AM fungi from

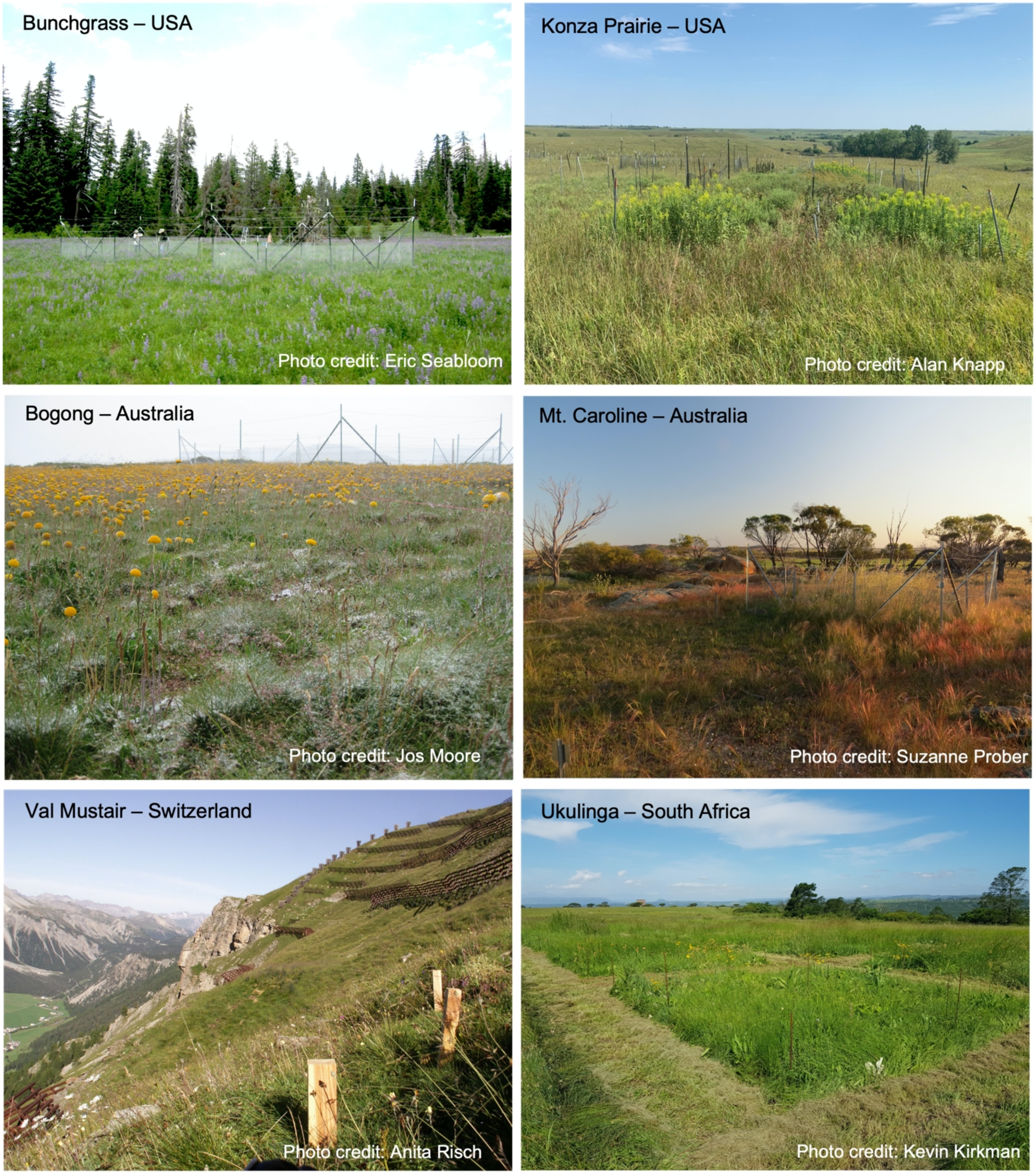

Figure 2. Pictures of a subset of the 25 grasslands that were included in the study by Lekberg *et al*. (2021), which showed consistent promotion of pathogens and suppression of AM fungi despite drastic differences in plant community composition and climate across sites. Data also indicated a concomitant shift in allocation from soil to root occupancy by AM fungi. Does that correspond to a potential shift in function from resource acquisition to pathogen protection?

fertilized and non-fertilized areas and see if they differ in pathogen protection ability. Thus, a useful addition to the model first presented by Johnson (1993) may be pathogen load, which would capture an additional function of AM fungi. This proposed experiment has never been done as far as we are aware, but it offers a suite of new research lines centered around whether AM fungi that co-occur with pathogens in the field can protect plants against pathogens, what traits are important for this function, and, whether information about AM fungal communities can be informative of function. In addition, choice experiments, where plants are given the option of rhizo- or edaphophilic fungi when pressured with pathogens, can tell us whether plants can identify and selectively reward AM fungal taxa that protect them under those conditions. We also need to assess the generality of AM fungal traits and function, because the few empirical studies linking pathogen protection with specific AM fungal taxa have all used AM fungal cultures isolated from a small geographic range (Hart and Reader 2002; Maherali and Klironomos 2007; Sikes *et al*. 2009). These taxa may or may not be representative of taxa from elsewhere, including the many unculturable AM fungi. More experimental work in additional locations is clearly needed.

We have come a long way and have learned so much about this fascinating symbiosis, but there are clearly many things that are yet unknown. As many ecosystems around the world receive elevated inputs of N and P from agriculture and atmospheric deposition, these questions may become increasingly important.

Acknowledgements

This article was prompted by an initial request by Jason Hoeksema for Ylva Lekberg to write a summary of the recent publication by Lekberg *et al*. (2021). We are grateful to him for being open to broadening this and allowing us to discuss this idea that we have had for some time. We also thank Roger Koide and Lorinda Bullington for comments that improved an earlier draft.

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Shared friends counterbalance shared enemies in old forests

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Large trees are hubs of vast mycorrhizal networks connecting plants in the forest and improving tree seedling establishment (Beiler *et al.* 2010). We investigated whether this was more than a unidirectional relationship by asking: do large, old trees connected to a diversity of smaller trees by mycorrhizal networks also have improved survival? Because large trees rarely die from competition alone, we compiled over a decade of spatially and temporally explicit tree mortality causes to determine how mycorrhizae may influence large trees' resistance to native pests and pathogens. We were excited to find that more diverse forest communities provided more mycorrhizal benefits that helped large trees to survive. Forest managers can incorporate this knowledge into silvicultural treatments and management to promote facilitative interactions and build forest resilience.

We used Bayesian hierarchical modeling to examine mycorrhizal type- and mortality cause-specific tree survival at three Smithsonian ForestGEO sites spanning an elevational gradient (of 2,700 m) in western North America (Lutz 2015, Davies *et al.* 2021). All woody stems ≥ 1 cm diameter at breast height (DBH; 1.37 m) were identified to the species level, mapped, and measured at DBH to calculate neighborhood crowding metrics. The large spatial extent of tree mapping at each site allowed us to parse the relative effects of mycorrhizal networks and neighboring forest plants on the large trees (those ≥90th percentile DBH per species). We revisited each stem annually to assess survival, and conducted pathology exams on newly dead stems to determine multiple causes of mortality, identified to the species level when biotic agents were present. Tree mycorrhizal associations were classified by each mycorrhizal type (AM, EM, ErM, or both AM/EM).

Across all three forest sites, conspecific crowding-dependent mortality (CNDD) prevailed for small trees, while heterospecific crowding-dependent mortality (HNDD) prevailed for large trees. Informed by our pathology exams, this HNDD primarily reflected the activity of bark beetles and fungal pathogens. However, large trees shifted from negative to positive HDD given sufficiently high mycorrhizal type-sharing neighbor diversity. Specifically, we found net facilitation in dense, species-rich woody plant communities that were connected via mycorrhizal networks: here, large trees were better able to survive enemy attacks compared to trees in less dense networked communities and trees in equally dense but un-networked communities. This finding suggests that lower large-diameter tree mortality susceptibility resulted from greater access to shared mycorrhizal networks afforded by a denser, more species-rich woody plant community.

Examples of beetle galleries identified during pathology exams. *Scolytus ventralis* on *Abies concolor* in the Yosemite Forest Dynamics Plot (YFDP), California, USA (**A**); *Dendroctonus pseudotsugae* on *Pseudotsuga menziesii* ssp. *menziesii* in the Wind River Forest Dynamics Plot, Washington, USA (**B**); *Ips paraconfusus* on *Pinus lambertiana* in YFDP (**C**); *Dryocoetes confusus* on *Abies bifolia* in the Utah Forest Dynamics Plot, Utah, USA (UFDP) (**D**); *Pityokteines minutus* on *Abies bifolia* in UFDP (often forming a disease complex with *Armillaria ostoyae*; **E**). Windows of bark were removed near 1.4 m height (B) to uncover galleries and/or live beetles. Calipers were used to distinguish between galleries of similar shapes but distinct sizes (D, E). Photo credits: Sara Germain (A, C–E), Tucker Furniss (B).

Findings from these western forests join the growing body of evidence demonstrating the interconnected importance of aboveground and belowground biodiversity to tree survival (Schuldt *et al.* 2018). When generalizing these findings to other mature forests, we highlight the importance of delineating the most limiting factor for large trees in that forest (e.g., fire, drought, beetles). Although these factors often co-occur (Franklin *et al.* 1987), identifying the most foundational and threatening factor can help put our findings into context. For instance, reducing tree density and removing ladder fuels is critically important in fire-suppressed

Examples of fungal mortality agents identified during pathology exams. *Encoelia pruinosa* on a exterior stem of *Populus tremuloides* in the Utah Forest Dynamics Plot, Utah, USA (**A**); *Armillaria ostoyae* on root collar under bark of *Abies concolor* in Yosemite Forest Dynamics Plot, California, USA (**B**); *Phellinus pini* on exposed sapwood and heartwood of fallen *Pseudotsuga menziesii* ssp. *menziesii* in the Wind River Forest Dynamics Plot, Washington, USA (**C**). Photo credits: Sara Germain (A–C).

Ponderosa pine forests that are otherwise susceptible to uncharacteristic crown fires (D'Amato *et al*. 2013). In pinyon woodlands, where drought is increasingly limiting (greater incidents of embolism and hydraulic failure; Allen *et al*. 2010), thinning can reduce competition for water to increase forest health (D'Amato *et al*. 2013).

For mature forests that do not reside at these ends of the fire- and drought-severity spectrums, such as those analyzed here, the next most limiting factors for large trees are biotic enemies (Bentz *et al*. 2010). Our results advise some prudence before reducing tree densities in these forests, as losing friends may unwittingly correspond with deleterious side effects. We show that forest composition, not just density, is essential to consider in order to maintain positive counterbalances for the large trees: if woody plant species richness was low, density also needed to be low for large trees to survive. Yet, the greatest survival effects for large trees were in denser, networked communities with high species richness. If the management objective is to increase forest resilience to bark beetles and pathogens, many of which are becoming more virulent with climate changes, then we must first ask: are neighboring trees acting primarily as enemies themselves, needing to be removed, or are they friendly purveyors of mycorrhizal networking critical to retaining resilience?

Our study demonstrates a promising—and actionable—mechanism by which fungal mutualisms may act as a key counterbalance to increasing threats in western forests. Trees across western North America have been dying at higher rates due to bark beetles, pathogens, fire, and drought, all of which are being exacerbated by climate change (Allen *et al*. 2010; Rodriguez-Ramos *et al*. 2020). This is particularly alarming with regard to large-diameter trees (Lindenmayer *et al*. 2012), which capture immense amounts of carbon, help filter air and water, and provide habitat for many wildlife species (Lutz *et al*. 2018).

The author remeasuring a large Douglas-fir in the Wind River Forest Dynamics Plot, Washington, USA.

We show that large trees of 17 common western coniferous species converged on similar facilitation dynamics across the decadal sampling period —despite residing in distinct topographic positions, forest types, and climatological contexts. The significance of these facilitation mechanisms deserves continued study to offer pathways for adaptive management and conservation.

Going forward, future research would benefit management the most by developing a process-based approach for addressing these complex issues in different forest types. To begin, we propose a greater effort to adapt the silvicultural paradigm to include not just how to remove negative dynamics, but also how to retain and even bolster positive dynamics in forests. There is a growing need for research and management action that considers existing facilitation mechanisms as tools to conserve forests amidst rapid environmental change. Continued discovery of big trees' fungal friends will help managers to protect old-growth forests and maintain the many ecosystem services provided by these trees and their symbionts. ForestGEO sites are vital conservation resources uniquely poised to serve this need, providing longitudinal datasets capable of disentangling multitrophic facilitation dynamics in forests across the globe.

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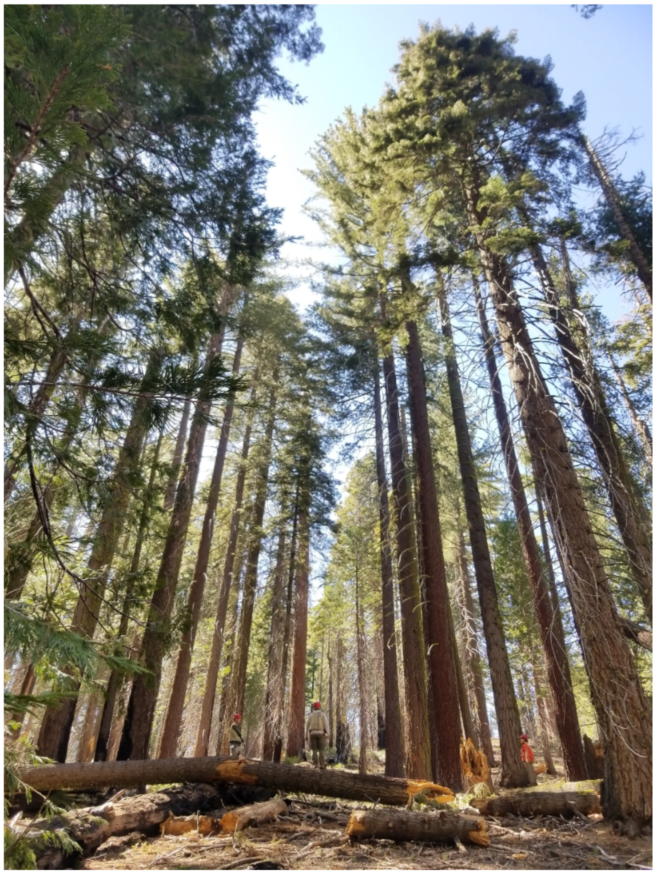

Large sugar pine in the Yosemite Forest Dynamics Plot, California, USA.

One of our favorite ectomycorrhizal fungi, *Morchella* spp.

An old aspen clone with large stems in the Utah Forest Dynamics Plot, Utah, USA.

YouTube interviews*

- Mathu Malar on the genome of Geosiphon pyriformis and the emergence of the AM symbiosis

César Marín interviews Mathu Malar, postdoc at the University of Ottawa, about the genome of a very interesting AMF species, Geosiphon pyriformis, its relationship with Nostoc, and the emergence of the AM symbiosis.

Interview: https://southmycorrhizas.org/reading/june-2021/
Study: Malar C M, Krüger M, Krüger C, *et al*. 2021. The genome of *Geosiphon pyriformis* reveals ancestral traits linked to the emergence of the arbuscular mycorrhizal symbiosis. *Curr Biol* 31: 1570-1577.
https://doi.org/10.1016/j.cub.2021.01.058

- Aidee Guzman on how crop diversity enriches AMF communities

César Marín interviews Aidee Guzman, recent graduate from University of California – Berkeley, on how polyculture systems in California significantly enriches AMF communities in a landscape with very strong agriculutral intensification.

Interview: https://southmycorrhizas.org/reading/september-2021/
Study: Guzman A, Montes M, Hutchins L, *et al*. 2021. Crop diversity enriches arbuscular mycorrhizal fungal communities in an intensive agricultural landscape. *New Phytol* 231: 447-459. https://doi.org/10.1111/nph.17306

- Laura Martinez-Suz on forest recovery and tipping points

Camille Truong interviews Laura Martinez-Suz, Research Leader at the Royal Botanic Gardens Kew, about using a large-scale dataset across Europe to assess the status of ECM forests affected by anthropogenic nitrogen deposition. Have we reached a tipping point yet?

Interview: https://southmycorrhizas.org/reading/september-ii-2021/
Study: Suz LM, Bidartondo MI, van der Linde S, Kuyper TW. 2021. Ectomycorrhizas and tipping points in forest ecosystems. *New Phytol* 231: 1700-1707.
https://doi.org/10.1111/nph.17547

***Section by:**
South American Mycorrhizal Research Network
Contact/Join us: https://southmycorrhizas.org/join/

Tools

→ *PacBio* for sequencing AMF rDNA

Given the lack of consensus on a barcoding region to determine AMF taxa, Kolaříková *et al.* (2021) present an approach based on the PacBio platform utilizing Single Molecule Real Time (SMRT) sequencing a 2.5 kb part of the rDNA that included spanning the majority of the SSU gene, the complete ITS region, and a part of the LSU gene. The authors were able to successfully describe and phylogenetically assign complex AMF communities, which included AMF lineages without known sequences from pure cultures. This integrative approach seems quite promising for AMF molecular community ecology.

Study: Kolaříková Z, Slavíková R, Krüger C, *et al.* 2021. *PacBio* sequencing of Glomeromycota rDNA: a novel amplicon covering all widely used ribosomal barcoding regions and its applicability in taxonomy and ecology of arbuscular mycorrhizal fungi. *New Phytol* 231: 490-499. https://doi.org/10.1111/nph.17372

→ Functional-structural plant modelling for light/nutrients competition by plants with or without AMF

De Vries *et al.* (2021) present a functional-structural plant (FSP) modelling approach that simulates plants competing for light and nutrients in the presence or absence of AMF. This with the aim to quantify how interactions with AMF affect the impact of root traits on plant performance. With their simulations, the authors found that in the absence of AMF, plants rely on thin, highly branched roots for their nutrient uptake, as it was their expectation. They also found that the presence of AMF promotes thick, unbranched roots as an alternative strategy for uptake of immobile phosphorus, but not for mobile nitrogen.

Study: De Vries J, Evers JB, Kuyper TW, *et al.* 2021. Mycorrhizal associations change root functionality: a 3D modelling study on competitive interactions between plants for light and nutrients. *New Phytol* 231: 1171-1182. https://doi.org/10.1111/nph.17435

→ AMF to remove pharmaceuticals from wetlands

Hu *et al.* (2021) investigated the effects of AMF colonization on the growth of the wetland plant Glyceria maxima, and their capacity to remove ibuprofen and diclofenac in constructed wetlands. AMF lead to the accumulation of ibuprofen and diclofenac in the rhizosphere, therefore reducing their concentration and metabolites in AMF+ effluents. AMF also increased antioxidant enzymes of host plants to decrease oxidative damages.

Study: Hu B, Hu S, Chen Z, Vymazal J. 2021. Employ of arbuscular mycorrhizal fungi for pharmaceuticals ibuprofen and diclofenac removal in mesocosm-scale constructed wetlands. *J Hazard Mater* 409: 124524. https://doi.org/10.1016/j.jhazmat.2020.124524

For previous Tools click: here for Issue 1 (p. 11), here for Issue 2 (p. 15), here for issue 3 (p. 16) (Vol. 1), here for Vol. 2, Issue 1 (p. 19), and here for Vol. 2, Issue 2 (p. 15).

Events

MYCORRHIZAL EVENTS: (see also p. 18)

ICOM11
Website
China National Convention Center, Beijing, China
31 July – 5 August, 2022

Organizers: Chinese Society of Mycology and IMS

III International Symposium on Mycorrhizal Symbiosis in South America
Website
Instituto SINCHI, Leticia, Colombia
24 August – 2 September, 2023

Organizers: South American Mycorrhizal Research Network and Instituto SINCHI

EVENTS POSTPONED DUE TO COVID-19:

- Soil Ecology Society Meeting
Website
Richland, Washington, United States
16 – 20 May 2022

Organizers: Soil Ecology Society

- 18th International Symposium on Microbial Ecology
Website
Lausanne, Switzerland
13 – 19 August 2022

Organizers: International Society for Microbial Ecology

- 45th *New Phytologist* Symposium: Ecological and evolutionary consequences of plant–fungal invasions
Website
Campinas, Brazil
Date not yet announced

Organizers: New Phytologist Trust and symposium organizers.

- 10th International Symposium on Forest Soils - ISFS 2022

Website

Zhijiang Hotel, Hangzhou, China
17 – 21 October, 2022

Organizers: Zhejiang A&F University and others

- 3rd Global Soil Biodiversity Conference

Website

Clayton Hotel, Dublin, Ireland
13 – 15 March 2023

Organizers: Global Soil Biodiversity Initiative

EVENTS AS SCHEDULED:

26th UN Climate Change Conference of the Parties (COP26)

Website

Scottish Event Campus, Glasgow, UK
1 – 12 November, 2021

Organizers: UN & UK

Microbiome Centers Consortium

Website

Scottish Event Campus, Glasgow, UK
23 – 25 March, 2022

Organizers: University of Chicago

22nd World Congress of Soil Science 2022

Website

Scottish Event Campus, Glasgow, UK
31 July – 5 August, 2022

Organizers: British Society of Soil Science

Workshop: "Building a database of mycorrhizal traits for South America", 8-12 November, 2021 (online).

Speakers:
- Dr. Bala Chaudhary, Dartmouth College.
- Dr. Jason Hoeksema, University of Missisipi.
- Dr. Jim Bever, University of Kansas.

Register here: https://forms.gle/YBovKH5geozVionQ6
Contact information: jiduchicela@espe.edu.ec

Special issue of *Plants, People, Planet*: Mycorrhizas for a changing world

Inspired by the themes that ran across ICOM10 in Mérida (México, 2019), Katie Field (University of Sheffield), Dave Johnson (University of Manchester), Tim Daniell (University of Sheffield), and Thorunn Helgason (University of York) joined forces to put together an special issue of The New Phytologist Foundation journal, *Plants, People, Planet*.

The special issue, itself put together during a time of unprecedented global change, features a unique collection of papers from across the mycorrhizal research community and aims to explore the current and potential significance of mycorrhizal fungi in the human world. Following a wonderful response from the community to our call for papers, the editorial team have put together an exciting selection that spans the significance and potential of mycorrhizal fungi to contribute towards our achievement of global change goals. These encompass the broad themes of improved sustainability, food security, and conservation, as well as how we, as a community, might best implement mycorrhizal knowledge and technologies to achieve these outcomes in modern societies.

The special issue is completely open access, and you can explore the exciting collection of papers here:
https://nph.onlinelibrary.wiley.com/toc/25722611/2021/3/5

IMS Newsletter

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ICOM11 is scheduled for next year (31 July – 5 August, 2022) in Beijing, China. It is not fully clear yet whether this will be an on-site meeting or a mix of on-line and on-site. The scientific program will be announced soon.

ICOM12 will be organised in the summer of 2024 in Manchester, United Kingdom, by Prof. Dr. David Johnson (University of Manchester) and colleagues.