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Orchid mycorrhizal interactions: evolutionary trajectories and ecological variations

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References

A

- Abadie JC, Püttsepp Ü, Gebauer G, et al. 2006.** *Cephalanthera longifolia* (Neottieae, Orchidaceae) is mixotrophic: a comparative study between green and nonphotosynthetic individuals. *Canadian Journal of Botany* 84:1462–1477.
- Abarenkov K, Henrik NR, Larsson KH, et al. 2010.** The UNITE database for molecular identification of fungi – recent updates and future perspectives. *New Phytologist* 186: 281–285.
- Aime MC, Urbina H, Liber JA, et al. 2018.** Two new endophytic Atractiellomycetes, *Atractidochium hillariae* and *Proceropycnis hameedii*. *Mycologia* 110:136–146.
- Alberdi A, Aizpurua O, Gilbert MTP, et al. 2018.** Scrutinizing key steps for reliable metabarcoding of environmental samples. *Methods in Ecology and Evolution* 9: 134–147.
- Alcock J. 2006.** *An Enthusiasm for Orchids*. Oxford University Press.
- Allen M. 2022.** *Mycorrhizal Dynamics in Ecological Systems*. Cambridge: Cambridge University Press.
- Amend AS, Seifert KA, Bruns TD. 2010.** Quantifying microbial communities with 454 pyrosequencing: does read abundance count? *Molecular Ecology* 19: 5555–5565.
- Anderson MJ. 2001.** A new method for non-parametric multivariate analysis of variance. *Austral Ecology* 26: 32–46.
- Anderson MJ, Ellingsen KE, McArdle BH. 2006.** Multivariate dispersion as a measure of beta diversity. *Ecology Letters* 9: 683–693.
- Aung, YL, Mu, AT, Aung, MH, et al. 2020.** An annotated checklist of Myanmar orchid flora. *PhytoKeys* 138, 49–112.

B

- Barrett CF, Freudenstein JV, Lee TD, et al. 2010.** Rangewide analysis of fungal associations in the fully mycoheterotrophic *Corallorhiza striata* complex (Orchidaceae) reveals extreme specificity on ectomycorrhizal *Tomentella* (Thelephoraceae) across North America. *American Journal of Botany* 97: 628–643.
- Bates D, Mächler M, Bolker B, et al. 2015.** Fitting Linear Mixed-Effects Models Using lme4. *Journal of Statistical Software* 67: 1–48.
- Batty AL, Brundrett MC, Dixon KW, et al. 2006.** New methods to improve symbiotic propagation of temperate terrestrial orchid seedlings from axenic culture to soil. *Australian Journal of Botany* 54: 367.
- Batjes, NH. 2009.** Harmonized soil profile data for applications at global and continental scales: updates to the WISE database. *Soil Use and Management* 25: 124–127.
- Batstone RT, Carscadden KA, Afkhami ME, et al. 2018.** Using niche breadth theory to explain generalization in mutualisms. *Ecology* 99: 1039–1050.
- Bauer R, Begerow D, Sampaio JP, et al. 2006.** The simple-septate basidiomycetes: A synopsis. *Mycological Progress* 5: 41–66.

- Bayman P, Otero JT. 2007.** Microbial endophytes of orchid roots. In: *Microbial Root Endophytes*. Springer Berlin Heidelberg, Berlin, Heidelberg, pp 153–177
- Begerow D, Stoll M, Bauer R. 2006.** A phylogenetic hypothesis of Ustilaginomycotina based on multiple gene analyses and morphological data. *Mycologia* 98: 906–916.
- Begum N, Qin C, Ahanger MA, et al. 2019.** Role of Arbuscular Mycorrhizal Fungi in Plant Growth Regulation: Implications in Abiotic Stress Tolerance. *Frontiers in Plant Science* 10: 1068.
- Bell J, Yokoya K, Kendon JP, et al. 2020.** Diversity of root-associated culturable fungi of *Cephalanthera rubra* (Orchidaceae) in relation to soil characteristics. *PeerJ* 8: e8695.
- Bever JD. 2015.** Preferential allocation, physio-evolutionary feedbacks, and the stability and environmental patterns of mutualism between plants and their root symbionts. *New Phytologist* 205: 1503–1514.
- Bever JD, Richardson SC, Lawrence BM, et al. 2009.** Preferential allocation to beneficial symbiont with spatial structure maintains mycorrhizal mutualism. *Ecology Letters* 12: 13–21.
- Bhunjun CS, Niskanen T, Suwannarach N, et al. 2022.** The numbers of fungi: are the most speciose genera truly diverse? *Fungal Diversity*: 1-76.
- Bidartondo MI, Bruns TD, Weiß M, et al. 2003.** Specialized cheating of the ectomycorrhizal symbiosis by an epiparasitic liverwort. *Proceedings of the Royal Society of London. Series B: Biological Sciences* 270: 835–842.
- Bidartondo MI, Burghardt B, Gebauer G, et al. 2004.** Changing partners in the dark: isotopic and molecular evidence of ectomycorrhizal liaisons between forest orchids and trees. *Proceedings of the Royal Society of London. Series B: Biological Sciences* 271: 1799–806.
- Bidartondo MI & Read DJ. 2008.** Fungal specificity bottlenecks during orchid germination and development. *Molecular Ecology* 17: 3707–3716.
- Bidartondo MI, Read DJ, Trappe JM, et al. 2011.** The dawn of symbiosis between plants and fungi. *Biology Letters* 7: 574–577.
- Binder M & Hibbett DS. 2006.** Molecular systematics and biological diversification of Boletales. *Mycologia* 98:971–981.
- Binder M, Justo A, Riley R, et al. 2013.** Phylogenetic and phylogenomic overview of the Polyporales. *Mycologia* 105:1350–1373.
- Binder M, Larsson KH, Matheny PB, Hibbett DS. 2010.** Amylocorticiales ord. nov. and Jaapiales ord. nov.: early diverging clades of Agaricomycetidae dominated by corticioid forms. *Mycologia* 102:865–880.
- Blaxter M, Mann J, Chapman T, et al. 2005.** Defining operational taxonomic units using DNA barcode data. *Philosophical Transactions of the Royal Society B: Biological Sciences* 360: 1935-1943.
- Bogar L, Peay K, Kornfeld A, et al. 2019.** Plant-mediated partner discrimination in ectomycorrhizal mutualisms. *Mycorrhiza* 29: 97–111.
- Bonito G, Hameed K, Toome-Heller M, et al. 2017.** *Atractiella rhizophila*, sp. nov., an endorhizal fungus isolated from the *Populus* root microbiome. *Mycologia* 109:18–26.
- Bollback JP. 2006.** SIMMAP: Stochastic character mapping of discrete traits on phylogenies. *BMC Bioinformatics* 7: 88–94.
- Bouckaert R, Vaughan TG, Barido-Sottani J, et al. 2019.** BEAST 2.5: an advanced software platform for Bayesian evolutionary analysis. *PLoS Computational Biology* 15: e1006650.
- Bougoure JJ, Brundrett MC, Grierson PF. 2010.** Carbon and nitrogen supply to the underground orchid,

Rhizanthella gardneri. New Phytologist 186: 947–956.

Bray JR, Curtis JT. 1957. An Ordination of the Upland Forest Communities of Southern Wisconsin. Ecological Monographs 27: 325–349.

Brundrett MC. 2002. Coevolution of roots and mycorrhizas of land plants. New Phytologist 154: 275–304.

Brundrett MC, Scade A, Batty AL, et al. 2003. Development of *in situ* and *ex situ* seed baiting techniques to detect mycorrhizal fungi from terrestrial orchid habitats. Mycological Research 107: 1210–1220.

Brundrett MC. 2009. Mycorrhizal associations and other means of nutrition of vascular plants: understanding the global diversity of host plants by resolving conflicting information and developing reliable means of diagnosis. Plant and Soil 320: 37–77.

Brundrett MC & Tedersoo L. 2018. Evolutionary history of mycorrhizal symbioses and global host plant diversity. New Phytologist 220: 1108–1115.

Bruns TD, Szaro TM, Gardes M, et al. 1998. A sequence database for the identification of ectomycorrhizal basidiomycetes by phylogenetic analysis. Molecular Ecology 7:257–272.

Bunch WD, Cowden CC, Wurzburger N, et al. 2013. Geography and soil chemistry drive the distribution of fungal associations in lady’s slipper orchid, *Cypripedium acaule*. Botany 91: 850–856.

C

Cai J, Liu X, Vanneste K, et al. 2015. The genome sequence of the orchid *Phalaenopsis equestris*. Nature genetics 47: 65–72.

Cameron DD, Johnson I, Read DJ, et al. 2008. Giving and receiving: measuring the carbon cost of mycorrhizas in the green orchid, *Goodyera repens*. New phytologist 180: 176–184.

Cameron DD, Leake JR, Read DJ. 2006. Mutualistic mycorrhiza in orchids: Evidence from plant-fungus carbon and nitrogen transfers in the green-leaved terrestrial orchid *Goodyera repens*. New Phytologist 171: 405–416.

Campomenosi P, Gini E, Noonan DM, et al. 2016. A comparison between quantitative PCR and droplet digital PCR technologies for circulating microRNA quantification in human lung cancer. BMC Biotechnology 16: 1–10.

Cao B, Haelewaters D, Schoutteten N, et al. 2021. Delimiting species in Basidiomycota : a review. Fungal Diversity 109: 181–237.

Capo E, Spong G, Koizumi S, et al. 2021. Droplet digital PCR applied to environmental DNA, a promising method to estimate fish population abundance from humic-rich aquatic ecosystems. Environmental DNA 3: 343–352.

Cernusak LA, Pate JS, Farquhar GD. 2004. Oxygen and carbon isotope composition of parasitic plants and their hosts in southwestern Australia. Oecologia 139: 199–213.

Cevallos S, Declerck S, Suárez JP. 2018a. *In situ* orchid seedling-trap experiment shows few keystone and many randomly associated mycorrhizal fungal species during early plant colonization. Frontiers in Plant Science 9: 1664.

Cevallos S, Herrera P, Sánchez-Rodríguez A, et al. 2018b. Untangling factors that drive community composition of root associated fungal endophytes of Neotropical epiphytic orchids. Fungal Ecology 34: 67–75.

Cevallos S, Sánchez-Rodríguez A, Decock C, et al. 2017. Are there keystone mycorrhizal fungi associated to tropical epiphytic orchids? Mycorrhiza 27: 225–232.

Chamberlain S. (2019) Package “rgbif” - Interface to the Global “Biodiversity” Information Facility API. *CRAN Repository*.

- Chase MW, Cameron KM, Freudenstein JV, et al. 2015.** An updated classification of Orchidaceae. *Botanical Journal of the Linnean Society* 177: 151–174.
- Chen XM, Dong HL, Hu KX, et al. 2010.** Diversity and antimicrobial and plant-growth-promoting activities of endophytic fungi in *Dendrobium loddigesii* Rolfe. *Journal of Plant Growth Regulation* 29: 328–337.
- Collyer ML & Adams DC. 2018.** RRPP: An R package for fitting linear models to high-dimensional data using residual randomization. *Methods in Ecology and Evolution* 9: 1772–1779.
- Conran JG, Bannister JM, Lee DE. 2009.** Earliest orchid macrofossils: Early Miocene *Dendrobium* and *Earina* (Orchidaceae: Epidendroideae) from New Zealand. *American Journal of Botany* 96: 466–474.
- Cox CB. 2001.** The biogeographic regions reconsidered. *Journal of Biogeography* 28: 511–523.
- Chomicki G, Bidel LPR, Ming F, et al. 2015.** The velamen protects photosynthetic orchid roots against UV-B damage, and a large dated phylogeny implies multiple gains and losses of this function during the Cenozoic. *New phytologist* 205: 1330–1341.
- Clements MA, Muir H, Cribb PJ. 1986.** A Preliminary Report on the Symbiotic Germination of European Terrestrial Orchids. *Kew Bulletin* 41: 437.
- Comandini O, Rinaldi AC, Kuyper TW. 2012.** Measuring and Estimating E Ctomycorrhizal. In: Marcela Pagano (ed) *Mycorrhiza: Occurrence in Natural and Restored Environments*. Nova Science Publishers, pp 165–200
- Cowden CC & Shefferson RP. 2013.** Diversity of root-associated fungi of mature *Habenaria radiata* and *Epipactis thunbergii* colonizing manmade wetlands in Hiroshima Prefecture, Japan. *Mycoscience* 54: 327–334.
- Cruz-Higareda JB, Luna-Rosales BS, et al. 2015.** A novel seed baiting technique for the epiphytic orchid *Rhynchosstele cervantesii*, a means to acquire mycorrhizal fungi from protocorms. *Lankesteriana* 15: 67–76.
- Currah RS & Sherburne R. 1992.** Septal ultrastructure of some fungal endophytes from boreal orchid mycorrhizas. *Mycological Research* 96: 583–587.
- Currah RS, Smreciu EA, Hambleton S. 1990.** Mycorrhizae and mycorrhizal fungi of boreal species of *Platanthera* and *Coeloglossum* (Orchidaceae). *Canadian Journal of Botany* 68: 1171–1181.

D

- Darriba D, Posada D, Kozlov AM, et al. 2020.** ModelTest-NG: a new and scalable tool for the selection of DNA and protein evolutionary models. *Molecular Biology and Evolution* 37: 291–294.
- Darwin C. 1862.** *On the various Contrivances by which British and foreign orchids are fertilized by insects, and on the good effects of intercrossing* (J Murray, Ed.). London.
- Davis BJ, Phillips RD, Wright M, et al. 2015.** Continent-wide distribution in mycorrhizal fungi: implications for the biogeography of specialized orchids. *Annals of Botany* 116: 413–421.
- Deagle BE, Thomas AC, McInnes JC, et al. 2019.** Counting with DNA in metabarcoding studies: How should we convert sequence reads to dietary data? *Molecular Ecology* 28: 391–406.
- Dearnaley JDW. 2006a.** The fungal endophytes of *Erythrorchis cassythoides* – is this orchid saprophytic or parasitic? *Australas Mycol* 25:51–57
- Dearnaley JDW. 2006b.** Molecular identification of fungal endophytes in australian myco-heterotrophic orchids. In: 8th International Mycological Congress (IMC8)
- Dearnaley JDW. 2007.** Further advances in orchid mycorrhizal research. *Mycorrhiza* 17: 475–486.
- Dearnaley JDW, Le Brocq AF. 2006.** Molecular identification of the primary root fungal endophytes of *Dipodium hamiltonianum* (Orchidaceae). *Australian Journal of Botany* 54: 487.

- Dearnaley JDW, Martos F, Selosse MA. 2012.** Orchid mycorrhizas: Molecular ecology, physiology, evolution and conservation aspects. In: Esser K, ed. *Fungal Associations*. Berlin, Germany: Springer, pp 207–230.
- Dearnaley JDW & Cameron DD. 2017.** Nitrogen transport in the orchid mycorrhizal symbiosis – further evidence for a mutualistic association. *New Phytologist* 213:10–12.
- Delaux PM, Radhakrishnan GV, Jayaraman D, et al. 2015.** Algal ancestor of land plants was preadapted for symbiosis. *Proceedings of the National Academy of Sciences of the United States of America* 112: 13390–13395.
- Delaux PM, Séjalon-Delmas N, Bécard G, et al. 2013.** Evolution of the plant-microbe symbiotic ‘toolkit’. *Trends in Plant Science* 18: 298–304.
- Dickson S. 2004.** The Arum-Paris continuum of mycorrhizal symbioses. *New Phytologist* 163: 187–200.
- Didaskalou EA, Trimbos KB, Stewart KA. 2022.** Environmental DNA. *Current Biology* 32: R1250–R1252.
- Doyle JJ. 1987.** Arapid isolation procedure for small quantities of fresh leaf tissue. *Phytochemical Bulletin* 19: 11–15.
- Dray S & Dufour AB. 2007.** The ade4 Package: Implementing the Duality Diagram for Ecologists. *Journal of Statistical Software* 22: 1–20.
- Drummond AJ, Ho SYW, Phillips MJ, et al. 2006.** Relaxed phylogenetics and dating with confidence. *PLoS Biology* 4: e88.
- Dressler RL & Rasmussen HN. 1996.** Terrestrial orchids: from seed to mycotrophic plant. *Systematic Botany*, 21, 625.
- Dressler RL. 2005.** How many orchid species? *Selbyana* 96: 1997–2009.
- Dufrêne M, Legendre P. 1997.** Species assemblages and indicator species: the need for a flexible asymmetrical approach. *Ecological monographs* 67: 345–66.
- Duffy KJ, Waud M, Schatz B, et al. 2019.** Latitudinal variation in mycorrhizal diversity associated with a European orchid. *Journal of Biogeography* 46: 968–980.
- Duong T. 2007.** ks: Kernel density estimation and kernel discriminant analysis for multivariate data in R. *Journal of Statistical Software* 21: 1–16.

E

- Edgar RC. 2004.** MUSCLE: multiple sequence alignment with high accuracy and high throughput. *Nucleic Acids Research* 32: 1792–1797.
- Edgar RC. 2010.** Search and clustering orders of magnitude faster than BLAST. *Bioinformatics* 26: 2460–2461.
- Edgar RC, Haas BJ, Clemente JC, et al. 2011.** UCHIME improves sensitivity and speed of chimera detection. *Bioinformatics* 27: 2194–2200.
- Ekanayaka AH, Hyde KD, Jones EBG, et al. 2018.** Taxonomy and phylogeny of operculate discomycetes: Pezizomycetes. *Fungal Diversity* 90: 161–243.
- Ercole E, Adamo M, Rodda M, et al. 2015.** Temporal variation in mycorrhizal diversity and carbon and nitrogen stable isotope abundance in the wintergreen meadow orchid *Anacamptis morio*. *New Phytologist* 205: 1308–1319.
- Esposito F, Jacquemyn H, Waud M, et al. 2016.** Mycorrhizal fungal diversity and community composition in two closely related *Platanthera* (Orchidaceae) species. *PLoS One* 11: e0164108.

F

- Fan L, Guo S, Cao W, *et al.* 1996.** Isolation, culture, identification and biological activity of *Mycena orchidicola* sp. nov. in *Cymbidium sinense* (Orchidaceae). *Acta Mycologica* 15: 251–255
- Faith DP. 1992.** Conservation evaluation and phylogenetic diversity. *Biological Conservation* 61: 1–10.
- Feijen FAA, Vos RA, Nuytinck J, *et al.* 2018.** Evolutionary dynamics of mycorrhizal symbiosis in land plant diversification. *Scientific Reports* 8: 10698.
- Feng YL, Wicke S, Li JW, Han Y, *et al.* 2016.** Lineage-Specific Reductions of Plastid Genomes in an Orchid Tribe with Partially and Fully Mycoheterotrophic Species. *Genome Biology and Evolution* 8: 2164–2175.
- Field KJ, Pressel S, Duckett JG, *et al.* 2015.** Symbiotic options for the conquest of land. *Trends in Ecology & Evolution* 30: 477–486.
- Fisher KJ & Lang GI. 2016.** Experimental evolution in fungi: An untapped resource. *Fungal Genetics and Biology* 94: 88–94.
- Fochi V, Chitarra W, Kohler A, *et al.* 2017.** Fungal and plant gene expression in the *Tulasnella calospora*–*Serapias vomeracea* symbiosis provides clues about nitrogen pathways in orchid mycorrhizas. *New Phytologist* 213: 365–379.
- Frank B. 2005.** On the nutritional dependence of certain trees on root symbiosis with belowground fungi (an English translation of A.B. Frank's classic paper of 1885). *Mycorrhiza* 15: 267–275.

G

- Gardes M & Bruns TD. 1993.** ITS primers with enhanced specificity for basidiomycetes – application to the identification of mycorrhizae and rusts. *Molecular Ecology* 2: 113–118.
- GBIF.org (26 August 2020)** GBIF Occurrence Download <https://doi.org/10.15468/dl.fx5myv>.
- Gebauer G, Meyer M. 2003.** ¹⁵N and ¹³C natural abundance of autotrophic and myco-heterotrophic orchids provides insight into nitrogen and carbon gain from fungal association. *New Phytologist* 160: 209–223.
- Gebauer G, Preiss K, Gebauer AC. 2016.** Partial mycoheterotrophy is more widespread among orchids than previously assumed. *New Phytologist* 211: 11–15.
- Gebauer G, Schweiger JMI. 2021.** The use of multi-element stable isotope natural abundance (C, N, H) to elucidate orchid mycorrhizal nutrition. In: *Proceedings of the 2021 Virtual World Orchid Conference*. Taiwan Orchid Growers Association (TOGA).
- Geml J. 2018.** Landscape-level DNA metabarcoding study in the Pannonian forests reveals differential effects of slope aspect on taxonomic and functional groups of fungi. *bioRxiv*.
- Giesemann P, Rasmussen HN, Gebauer G. 2021.** Partial mycoheterotrophy is common among chlorophyllous plants with Paris-type arbuscular mycorrhiza. *Annals of Botany* 127: 645–653.
- Giesemann P, Rasmussen HN, Liebel HT, *et al.* 2020.** Discreet heterotrophs: green plants that receive fungal carbon through Paris-type arbuscular mycorrhiza. *New Phytologist* 226: 960–966.
- Girlanda M, Selosse MA, Cafasso D, *et al.* 2005.** Inefficient photosynthesis in the Mediterranean orchid *Limodorum abortivum* is mirrored by specific association to ectomycorrhizal Russulaceae. *Molecular Ecology* 15: 491–504.
- Givnish TJ, Spalink D, Ames M, *et al.* 2015.** Orchid phylogenomics and multiple drivers of their extraordinary diversification. *Proceedings of the Royal Society of London. Series B: Biological Sciences* 282: 20151553.

- Givnish TJ, Spalink D, Ames M, et al. 2016.** Orchid historical biogeography, diversification, Antarctica and the paradox of orchid dispersal. *Journal of Biogeography* 43: 1905–1916.
- Gomes SIF, Aguirre-Gutiérrez J, Bidartondo MI, et al. 2017.** Arbuscular mycorrhizal interactions of mycoheterotrophic *Thismia* are more specialized than in autotrophic plants. *New Phytologist* 213: 1418–1427.
- Gomes SIF, Fortuna MA, Bascompte J, et al. 2022.** Mycoheterotrophic plants preferentially target arbuscular mycorrhizal fungi that are highly connected to autotrophic plants. *New Phytologist* 235: 2034–2045.
- Gomes SIF, Merckx VSFT, Kehl J, et al. 2020.** Mycoheterotrophic plants living on arbuscular mycorrhizal fungi are generally enriched in ^{13}C , ^{15}N and ^2H isotopes. *Journal of Ecology* 108: 1250–1261.
- Gomes SIF, Bodegom PM Van, Soudzilovskaia NA. 2019a.** Environmental drivers for cheaters of arbuscular mycorrhizal symbiosis in tropical rainforests. *New Phytologist* 223: 1575–1583.
- Gomes SIF, van Bodegom PM, Merckx VSFT, et al. 2019b.** Global distribution patterns of mycoheterotrophy. *Global Ecology and Biogeography* 28: 1133–1145.
- Gonneau C, Jersáková J, de Tredern E, et al. 2014.** Photosynthesis in perennial mixotrophic *Epipactis* spp. (Orchidaceae) contributes more to shoot and fruit biomass than to hypogeous survival. *Journal of Ecology* 102: 1183–1194.
- González-Chávez M, del Carmen A, Torres-Cruz TJ, et al. 2018.** Microscopic characterization of orchid mycorrhizal fungi: *Scleroderma* as a putative novel orchid mycorrhizal fungus of *Vanilla* in different crop systems. *Mycorrhiza* 28: 147–157.
- Guo SX, Fan L, Cao WQ, et al. 1997.** *Mycena anoetochila* sp. nov. isolated from mycorrhizal roots of *Anoetochilus roxburghii* from Xishuangbanna, China. *Mycologia* 89: 952.
- Guo S & Xu J. 1992.** The relation between the seed germination and seedling development of *Bletilla striata* and *Mycena osmundicola* etc. fungi. *Zhongguo Yi Xue Ke Xue Yuan Xue Bao* 14: 51–4
- Guo T, Wang HC, Xue WQ, et al. 2016.** Phylogenetic analyses of *Armillaria* reveal at least 15 phylogenetic lineages in China, seven of which are associated with cultivated *Gastrodia elata*. *PLoS One* 11: e0154794.
- Gould SJ. 1989.** *Wonderful life*. Norton, New York, USA. Graham.
- Graham SW, Lam VK, Merckx VS. 2017.** Plastomes on the edge: the evolutionary breakdown of mycoheterotroph plastid genomes. *New Phytologist* 214: 48–55.
- Green PJ. 1995.** Reversible jump Markov chain Monte Carlo computation and Bayesian model determination. *Biometrika* 82: 711–732.
- Grigoriev IV, Nikitin R, Haridas S, et al. 2014.** MycoCosm portal: Gearing up for 1000 fungal genomes. *Nucleic Acids Research* 42: 699–704.
- Gryndler M, Černá L, Bukovská P, et al. 2014.** *Tuber aestivum* association with non-host roots. *Mycorrhiza* 24: 603–610.

H

- Hansen K & Pfister DH. 2006.** Systematics of the Pezizomycetes – the operculate discomycetes. *Mycologia* 98: 1029–1040.
- Hadley G. 1984.** Uptake of [^{14}C] glucose by asymbiotic and mycorrhizal orchid protocorms. *New Phytologist* 96: 263–274.
- He MQ, Zhao RL, Hyde KD, et al. 2019.** Notes, outline and divergence times of Basidiomycota. *Fungal Diversity* 99: 105–367.

- Heled J, Drummond AJ. 2015.** Calibrated birth-death phylogenetic time-tree priors for Bayesian inference. *Systematic Biology* 64: 369–383.
- Helmus MR, Bland TJ, Williams CK, et al. 2007.** Phylogenetic measures of biodiversity. *The American Naturalist*, 169: E68–E83.
- Hendrix E & Vos R. 2019.** Differentiation between wild and domesticated Ungulates based on ecological niches. *bioRxiv*.
- Hess J, Skrede I, Chaib De Mares M, et al. 2018.** Rapid divergence of genome architectures following the origin of an ectomycorrhizal symbiosis in the genus *Amanita*. *Molecular Biology and Evolution* 35: 2786–2804.
- Herrera H, Valadares R, Contreras D, et al. 2017.** Mycorrhizal compatibility and symbiotic seed germination of orchids from the Coastal Range and Andes in south central Chile. *Mycorrhiza* 27: 175–188.
- Herrera P, Suárez JP, Kottke I. 2010.** Orchids keep the ascomycetes outside: a highly diverse group of ascomycetes colonizing the velamen of epiphytic orchids from a tropical mountain rainforest in Southern Ecuador. *Mycology* 1: 262–268.
- Hibbett DS, Binder M, Bischoff JF, et al. 2007.** A higher-level phylogenetic classification of the Fungi. *Mycological Research* 111: 509–547.
- Hijner JA, Arditti J. 1973.** Orchid Mycorrhiza: Vitamin production and requirements by the symbionts. *American Journal of Botany* 60: 829.
- Hillel D. 2004.** *Encyclopedia of soils in the environment*. Amsterdam: Elsevier, 2005.
- Hindson BJ, Ness KD, Masquelier DA, et al. 2011.** High-throughput droplet digital PCR system for absolute quantitation of DNA copy number. *Analytical Chemistry* 83: 8604–8610.
- Hoeksema JD, Chaudhary VB, Gehring CA, et al. 2010.** A meta-analysis of context-dependency in plant response to inoculation with mycorrhizal fungi. *Ecology Letters* 13: 394–407.
- Holland T, Bowen P, Kokkoris V, et al. 2019.** Does inoculation with arbuscular mycorrhizal fungi reduce trunk disease in grapevine rootstocks? *Horticulturae* 5: 1–12.
- Hong JW, Suh H, Kim OH, et al. 2015.** Molecular identification of mycorrhizae of *Cymbidium kanran* (Orchidaceae) on Jeju Island, Korea. *Mycobiology* 43: 475–480.
- Hongsanan S, Maharachchikumbura SSN, Hyde KD, et al. 2017.** An updated phylogeny of Sordariomycetes based on phylogenetic and molecular clock evidence. *Fungal Diversity* 84: 25–41.
- Horton TR & Bruns TD. 2001.** The molecular revolution in ectomycorrhizal ecology: peeking into the black-box. *Molecular Ecology* 10: 1855–1871.
- Hou XQ & Guo SX. 2009.** Interaction between a dark septate endophytic isolate from *Dendrobium* sp. and roots of *D. nobile* seedlings. *Journal of Integrative Plant Biology* 51: 374–381.
- Hoysted GA, Jacob AS, Kowal J, et al. 2019.** Mucoromycotina Fine Root Endophyte Fungi Form Nutritional Mutualisms with Vascular Plants. *Plant Physiology* 181: 565–577.
- Hoysted GA, Kowal J, Jacob A, et al. 2018.** A mycorrhizal revolution. *Current Opinion in Plant Biology* 44: 1–6.
- Huang WE, Stoecker K, Griffiths R, et al. 2007.** Raman-FISH: combining stable-isotope Raman spectroscopy and fluorescence in situ hybridization for the single cell analysis of identity and function. *Environmental Microbiology* 9: 1878–1889.
- Huang F, Zhang C. 2015.** Diversity, host- and habitat- preferences on the fungi communities from the roots of *Cymbidium* spp. at two sites in China. *Journal of Animal and Plant Sciences* 25: 270–277
- Hynson NA, Preiss K, Gebauer G, et al. 2009.** Isotopic evidence of full and partial myco-heterotrophy in the plant

tribe Pyroleae (Ericaceae). *New Phytologist* 182: 719–726.

Hynson NA, Madsen TP, Selosse M, et al. 2013. The Physiological Ecology of Mycoheterotrophy. In: Merckx VSFT, ed. *Mycoheterotrophy: The Biology of Plants Living on Fungi*. Springer, New York, 297–342.

I

Ihrmark K, Bodeker ITM, Cruz-Martinez K, et al. 2012. New primers to amplify the fungal ITS2 region – evaluation by 454-sequencing of artificial and natural communities. *FEMS Microbiology Ecology* 82: 666–677.

Illyés Z, Halász K, Rudnóy S, et al. 2009. Changes in the diversity of the mycorrhizal fungi of orchids as a function of the water supply of the habitat. *Journal of Applied Botany and Food Quality* 83:28–36

Iles WJD, Smith SY, Gandolfo MA, et al. 2015. Monocot fossils suitable for molecular dating analyses. *Botanical Journal of the Linnean Society* 178: 346–374.

J

Jacquemyn H, Honnay O, Cammue BPA, et al. 2010. Low specificity and nested subset structure characterize mycorrhizal associations in five closely related species of the genus *Orchis*. *Molecular Ecology* 19:4086–4095.

Jacquemyn H, Brys R, Cammue BPA, et al. 2011a. Mycorrhizal associations and reproductive isolation in three closely related *Orchis* species. *Annals of Botany* 107: 347–356.

Jacquemyn H, Merckx V, Brys R, et al. 2011b. Analysis of network architecture reveals phylogenetic constraints on mycorrhizal specificity in the genus *Orchis* (Orchidaceae). *New Phytologist* 192: 518–528.

Jacquemyn H, Brys R, Merckx VSFT, et al. 2014. Coexisting orchid species have distinct mycorrhizal communities and display strong spatial segregation. *New Phytologist* 202:616–627.

Jacquemyn H, Waud M, Merckx VSFT, et al. 2015. Mycorrhizal diversity, seed germination and long-term changes in population size across nine populations of the terrestrial orchid *Neottia ovata*. *Molecular Ecology* 24: 3269–3280.

Jacquemyn H, Waud M, Lievens B, et al. 2016. Differences in mycorrhizal communities between *Epipactis palustris*, *E. helleborine* and its presumed sister species *E. neerlandica*. *Annals of Botany* 118: 105–114.

Jacquemyn H, Duffy KJ, Selosse MA. 2017a. Biogeography of orchid mycorrhizas. In: Tedersoo L, ed. *Biogeography of mycorrhizal symbiosis*. Tartu, Estonia: Springer, 159–177.

Jacquemyn H, Waud M, Brys R, et al. 2017b. Mycorrhizal Associations and Trophic Modes in Coexisting Orchids: An Ecological Continuum between Auto- and Mixotrophy. *Frontiers in plant science* 8: 1497.

Jacquemyn H & Merckx VSFT. 2019. Mycorrhizal symbioses and the evolution of trophic modes in plants. *Journal of Ecology* 107: 1567–1581.

Jacquemyn H, Brys R, Waud M, et al. 2021. Mycorrhizal Communities and Isotope Signatures in Two Partially Mycoheterotrophic Orchids. *Frontiers in Plant Science* 12: 1–9.

Jersáková J, Minasiewicz J, Selosse MA. 2022. Biological flora of Britain and Ireland: *Neottia nidus-avis*. *Journal of Ecology* 110: 2246–63.

Ji B & Bever JD. 2012. Mycorrhizal Ecology. In: *Ecology*. Oxford University Press.

Jiang J, Zhang K, Cheng S, et al. 2019. *Fusarium oxysporum* KB-3 from *Bletilla striata*: an orchid mycorrhizal fungus. *Mycorrhiza* 29:531–540.

Jiang Y, Hu X, Yuan Y, Guo X, et al. 2022. The *Gastrodia menghaiensis* (Orchidaceae) genome provides new

insights of orchid mycorrhizal interactions. *BMC Plant Biology* 22: 1–14.

Johnson NC, Graham JH, Smith FA. 1997. Functioning of mycorrhizal associations along the mutualism-parasitism continuum. *New Phytologist* 135: 575–585.

Johnson TR, Stewart SL, Dutra D, et al. 2007. Asymbiotic and symbiotic seed germination of *Eulophia alta* (Orchidaceae) – preliminary evidence for the symbiotic culture advantage. *Plant Cell, Tissue and Organ Culture* 90:313–323.

Julou T, Burghardt B, Gebauer G, et al. 2005. Mixotrophy in orchids: insights from a comparative study of green individuals and nonphotosynthetic individuals of *Cephalanthera damasonium*. *New Phytologist* 166: 639–653.

Jumpponen A & Trappe JM. 1998. Dark septate endophytes: A review of facultative biotrophic root-colonizing fungi. *New Phytologist* 140: 295–310.

K

Kaiser C, Kilburn MR, Clode PL, et al. 2015. Exploring the transfer of recent plant photosynthates to soil microbes: mycorrhizal pathway vs direct root exudation. *New Phytologist* 205: 1537–1551.

Karst J, Jones MD, Hoeksema JD. 2023. Positive citation bias and overinterpreted results lead to misinformation on common mycorrhizal networks in forests. *Nature Ecology & Evolution*: 1–11.

Kaur J, Phillips C, Sharma J. 2021. Host population size is linked to orchid mycorrhizal fungal communities in roots and soil, which are shaped by microenvironment. *Mycorrhiza* 31: 17–30.

Kawecki TJ, Lenski RE, Ebert D, et al. 2012. Experimental evolution. *Trends in Ecology and Evolution* 27: 547–560.

Kembel SW, Cowan PD, Helmus MR, et al. 2010. Picante: R tools for integrating phylogenies and ecology. *Bioinformatics* 26: 1463–1464.

Kennedy AH, Taylor DL, Watson LE. 2011. Mycorrhizal specificity in the fully mycoheterotrophic *Hexalectris* Raf. (Orchidaceae: Epidendroideae). *Molecular Ecology* 20: 1303–1316.

Khamchatra N, Dixon KW, Tantiwiwat S, et al. 2016. Symbiotic seed germination of an endangered epiphytic slipper orchid, *Paphiopedilum villosum* (Lindl.) Stein. from Thailand. *South African Journal of Botany* 104: 76–81.

Kiers ET, Duhamel M, Beesetty Y, et al. 2011. Reciprocal rewards stabilize cooperation in the mycorrhizal symbiosis. *Science* 333: 880–882.

Kiss L. 2012. Limits of nuclear ribosomal DNA internal transcribed spacer (ITS) sequences as species barcodes for Fungi. *Proceedings of the National Academy of Sciences of the United States of America* 109: 2012.

Klawonn I, Van den Wyngaert S, Parada AE, et al. 2021. Characterizing the “fungal shunt”: Parasitic fungi on diatoms affect carbon flow and bacterial communities in aquatic microbial food webs. *Proceedings of the National Academy of Sciences* 118: e2102225118.

Klironomos JN. 2003. Variation in Plant Response To Native and Exotic. *Ecology* 84: 2292–2301.

Klunder L, van Bleijswijk JDL, Kleine Schaars L, et al. 2022. Quantification of marine benthic communities with metabarcoding. *Molecular Ecology Resources* 22: 1043–1054.

Kohler A, Kuo A, Nagy LG, et al. 2015. Convergent losses of decay mechanisms and rapid turnover of symbiosis genes in mycorrhizal mutualists. *Nature Genetics* 47: 410–415.

Kohler A & Martin F. 2016. The evolution of the mycorrhizal lifestyles – a genomic perspective. *Molecular Mycorrhizal Symbiosis*: 87–106.

- Kohout P. 2017.** Biogeography of ericoid mycorrhiza. In: *Biogeography of Mycorrhizal Symbiosis*. pp 179–193
- Kohout P, Těšitelová T, Roy M, et al. 2013.** A diverse fungal community associated with *Pseudorchis albida* (Orchidaceae) roots. *Fungal Ecology* 6: 50–64.
- Kokkoris V, Li Y, Hamel C, et al. 2019.** Site specificity in establishment of a commercial arbuscular mycorrhizal fungal inoculant. *Science of the Total Environment* 660: 1135–1143.
- Kokkoris V, Stefani F, Dalpé Y, et al. 2020.** Nuclear Dynamics in the Arbuscular Mycorrhizal Fungi. *Trends in Plant Science* 25: 765–778.
- Kolařík M, Spakowicz DJ, Gazis R, et al. 2017.** *Biatriospora* (Ascomycota: Pleosporales) is an ecologically diverse genus including facultative marine fungi and endophytes with biotechnological potential. *Plant Systematics and Evolution* 303: 35–50.
- Koricheva J & Gurevitch J. 2014.** Uses and misuses of meta-analysis in plant ecology. *Journal of Ecology* 102: 828–844.
- Kotlínek M, Těšitelová T, Jersáková J. 2015.** Biological Flora of the British Isles: *Neottia ovata*. *Journal of Ecology* 103: 1354–1366.
- Kottke I & Nebel M. 2005.** The evolution of mycorrhiza-like associations in liverworts: An update. *New Phytologist* 167: 330–334.
- Kottke I, Suárez JP, Herrera P, et al. 2010.** Atractiellomycetes belonging to the ‘rust’ lineage (Pucciniomycotina) form mycorrhizae with terrestrial and epiphytic neotropical orchids. *Proceedings of the Royal Society B: Biological Sciences* 277: 1289–1298.
- Kristiansen KA, Taylor DL, Kjeller R, et al. 2001.** Identification of mycorrhizal fungi from single pelotons of *Dactylorhiza majalis* (Orchidaceae) using single-strand conformation polymorphism and mitochondrial ribosomal large subunit DNA sequences. *Molecular Ecology* 10: 2089–2093.
- Kuga Y, Sakamoto N, Yurimoto H. 2014.** Stable isotope cellular imaging reveals that both live and degenerating fungal pelotons transfer carbon and nitrogen to orchid protocorms. *New Phytologist* 202: 594–605.
- Kühndorf K, Münzenberger B, Begerow D, et al. 2015.** *Leotia cf. lubrica* forms arbutoid mycorrhiza with *Comarostaphylis arbutoides* (Ericaceae). *Mycorrhiza* 25:109–120.
- Kurtzman CP & Boekhout T. 2017.** Yeasts as distinct life forms of fungi. In: *Yeasts in Natural Ecosystems: Ecology*. Springer International Publishing, Cham, pp 1–37
- Kuske CR, Hesse CN, Challacombe JF, et al. 2015.** Prospects and challenges for fungal metatranscriptomics of complex communities. *Fungal Ecology* 14: 133–137.

L

- Lai YJ, Han Y, Schuiteman A, et al. 2021.** Diversification in Qinghai-Tibet Plateau: Orchidinae (Orchidaceae) clades exhibiting pre-adaptations play critical role. *Molecular Phylogenetics and Evolution* 157: 107062.
- Lajtha K, Driscoll CT, Jarrell WM, et al. 1999.** Soil phosphorus: characterization and total element analysis. *Standard Soil Methods for Long Term Ecological Research*.
- Lallemand F, Logacheva M, Le Clainche I, et al. 2019.** Thirteen New Plastid Genomes from Mixotrophic and Autotrophic Species Provide Insights into Heterotrophy Evolution in Neottieae Orchids. *Genome Biology and Evolution* 11: 2457–2467.
- Lallemand F, Robioneck A, Courty PE, et al. 2018.** The ¹³C content of the orchid *Epipactis palustris* (L.) Crantz responds to light as in autotrophic plants. *Botany Letters* 165: 265–273.

- Lamb PD, Hunter E, Pinnegar JK, et al. 2019.** How quantitative is metabarcoding: A meta-analytical approach. *Molecular Ecology* 28: 420–430.
- Larsson KH, Parmasto E, Fischer M, et al. 2006.** Hymenochaetales: a molecular phylogeny for the hymenochaetoid clade. *Mycologia* 98:926–936.
- Law SR, Serrano AR, Daguerre Y, et al. 2022.** Metatranscriptomics captures dynamic shifts in mycorrhizal coordination in boreal forests. *Proceedings of the National Academy of Sciences* 119: 1–11.
- Leake JR. 1994.** The biology of myco-heterotrophic ('saprophytic') plants. *New Phytologist* 127: 171–216.
- Leake JR, Cameron DD, Beerling DJ. 2008.** Fungal fidelity in the myco-heterotroph-to-autotroph life cycle of Lycopodiaceae: a case of parental nurture? *New Phytologist* 177: 572–576.
- Lee KS, Pereira FC, Palatinszky M, et al. 2021.** Optofluidic Raman-activated cell sorting for targeted genome retrieval or cultivation of microbial cells with specific functions. *Nature Protocols* 16: 634–676.
- Lee YI, Yang CK, Gebauer G. 2015.** The importance of associations with saprotrophic non-Rhizoctonia fungi among fully mycoheterotrophic orchids is currently under-estimated: Novel evidence from sub-tropical Asia. *Annals of Botany* 116: 423–435.
- Lee Y & Yeung ECT. 2017.** *Orchid Propagation : From Laboratories to Greenhouses — Methods and Protocols* Edited by Edward Chee-Tak Yeung (Y Lee and Edward Chee-Tak Yeung, Eds.). Springer New York.
- Li Y-Y, Boeraeve M, Cho Y-H, et al. 2022.** Mycorrhizal Switching and the Role of Fungal Abundance in Seed Germination in a Fully Mycoheterotrophic Orchid, *Gastrodia confusoides*. *Frontiers in Plant Science* 12: 1–12.
- Li YY, Guo SX, Lee YI. 2020.** Ultrastructural changes during the symbiotic seed germination of *Gastrodia elata* with fungi, with emphasis on the fungal colonization region. *Botanical Studies* 61: 4.
- Li YX, Li ZH, Schuiteman A, et al. 2019.** Phylogenomics of Orchidaceae based on plastid and mitochondrial genomes. *Molecular phylogenetics and evolution* 139: 106540.
- Li T, Yang W, Wu S, et al. 2021.** Progress and Prospects of Mycorrhizal Fungal Diversity in Orchids. *Frontiers in Plant Science* 12: 646325.
- Li MH, Liu KW, Li Z, et al. 2022.** Genomes of leafy and leafless *Platanthera* orchids illuminate the evolution of mycoheterotrophy. *Nature Plants* 8: 373–388.
- Liebel HT, Bidartondo MI, Gebauer G. 2015.** Are carbon and nitrogen exchange between fungi and the orchid *Goodyera repens* affected by irradiance? *Annals of Botany* 115: 251–261.
- Lindahl BD, Nilsson RH, Tedersoo L, et al. 2013.** Fungal community analysis by high-throughput sequencing of amplified markers – a user's guide. *New Phytologist* 199: 288–299.
- Liu N, Jacquemyn H, Liu Q, et al. 2022.** Effects of a Dark Septate Fungal Endophyte on the Growth and Physiological Response of Seedlings to Drought in an Epiphytic Orchid. *Frontiers in Microbiology* 13: 2590.
- Liu XZ, Wang QM, Göker M, et al. 2015.** Towards an integrated phylogenetic classification of the Tremellomycetes. *Stud Mycol* 81: 85–147.
- Luo Z-B, Janz D, Jiang X, et al. 2009.** Upgrading Root Physiology for Stress Tolerance by Ectomycorrhizas: Insights from Metabolite and Transcriptional Profiling into Reprogramming for Stress Anticipation. *Plant Physiology* 151: 1902–1917.
- Lozupone C, Knight R. 2005.** UniFrac: a New Phylogenetic Method for Comparing Microbial Communities. *Applied and Environmental Microbiology* 71: 8228–8235.

M

- Ma X, Kang J, Nontachaiyapoom S, et al. 2015.** Non-mycorrhizal endophytic fungi from orchids. *Current Science* 109:72–87.
- Malacrino A. 2022.** Host species identity shapes the diversity and structure of insect microbiota. *Molecular Ecology* 31: 723–735.
- Masuhara G & Katsuya K. 1994.** In situ and in vitro specificity between *Rhizoctonia* spp. and *Spiranthes sinensis* (Persoon) Ames, var. *amoena* (M. Bieberstein) Hara (Orchidaceae). *New Phytologist* 127: 711–8.
- Mao H & Wang H. 2019.** Resolution of deep divergence of club fungi (phylum Basidiomycota). *Synthetic and Systems Biotechnology* 4: 225–231.
- Mauvisseau Q, Davy-Bowker J, Bulling M, et al. 2019.** Combining ddPCR and environmental DNA to improve detection capabilities of a critically endangered freshwater invertebrate. *Scientific Reports* 9: 1–9.
- Margulis L & Fester R. 1991.** *Symbiosis as a source of evolutionary innovation: Speciation and morphogenesis*. Massachusetts, US: MIT Press.
- Margulis L. 1991.** Symbiogenesis and symbiogenesis. In: Margulis L, Fester R, eds. *Symbiosis as a source of evolutionary innovation: Speciation and morphogenesis*. Massachusetts, US: MIT Press.
- Martin M. 2011.** Cutadapt removes adapter sequences from high-throughput sequencing reads. *EMBnet.journal* 17: 10–12.
- Martin F, Cullen D, Hibbett D, et al. 2011.** Sequencing the fungal tree of life. *New Phytologist* 190: 818–821.
- Martin R, Gazis R, Skaltsas D, et al. 2015.** Unexpected diversity of basidiomycetous endophytes in sapwood and leaves of *Hevea*. *Mycologia* 107:284–297.
- Martin F & Selosse MA. 2008.** The *Laccaria* genome: A symbiont blueprint decoded. *New Phytologist* 180: 296–310.
- Martin FM, Uroz S, Barker DG. 2017.** Ancestral alliances: Plant mutualistic symbioses with fungi and bacteria. *Science* 356: eaad4501.
- Martos F, Dulormne M, Pailler T, et al. 2009.** Independent recruitment of saprotrophic fungi as mycorrhizal partners by tropical achlorophyllous orchids. *New Phytologist* 184: 668–681.
- Martos F, Munoz F, Pailler T, et al. 2012.** The role of epiphytism in architecture and evolutionary constraint within mycorrhizal networks of tropical orchids. *Molecular ecology* 21: 5098–109.
- Matheny PB, Curtis JM, Hofstetter V, et al. 2006.** Major clades of Agaricales: a multilocus phylogenetic overview. *Mycologia* 98:982–995.
- May M, Jąkowski M, Novotná A, et al. 2020.** Three-year pot culture of *Epipactis helleborine* reveals autotrophic survival, without mycorrhizal networks, in a mixotrophic species. *Mycorrhiza* 30: 51–61.
- McCormick MK, Whigham DF, O'Neill J. 2004.** Mycorrhizal diversity in photosynthetic terrestrial orchids. *New Phytologist* 163: 425–438.
- McCormick MK, Whigham DF, O'Neill JP, et al. 2009.** Abundance and distribution of *Corallorhiza odontorhiza* reflect variations in climate and ectomycorrhizae. *Ecological Monographs* 79: 619–635.
- McCormick MK, Lee TD, Juhaszova K, et al. 2012.** Limitations on orchid recruitment: Not a simple picture. *Molecular ecology* 21: 1511–23.
- McCormick MK & Jacquemyn H. 2014.** What constrains the distribution of orchid populations? *New Phytologist* 202: 392–400.

- McCormick MK, Whigham DE, Canchani-Viruet A. 2018.** Mycorrhizal fungi affect orchid distribution and population dynamics. *New phytologist* 219: 1207–1215.
- McKendrick SL, Leake JR, Read DJ. 2000a.** Symbiotic germination and development of myco-heterotrophic plants in nature: transfer of carbon from ectomycorrhizal *Salix repens* and *Betula pendula* to the orchid *Corallorhiza trifida* through shared hyphal connections. *New Phytologist* 145: 539–548.
- McKendrick SL, Leake JR, Taylor DL, et al. 2000b.** Symbiotic germination and development of myco-heterotrophic plants in nature: ontogeny of *Corallorhiza trifida* and characterization of its mycorrhizal fungi. *New Phytologist* 145: 523–537.
- McKendrick SL, Leake JR, Taylor DL, et al. 2002c.** Symbiotic germination and development of the myco-heterotrophic orchid *Neottia nidus-avis* in nature and its requirement for locally distributed *Sebacina* spp. *New Phytologist* 154: 233–247.
- McLaughlin DJ, Spatafora JW. 2014.** *Systematics and evolution: Part A: Second edition*. Springer Berlin Heidelberg.
- Merckx VSFT. 2013.** Mycoheterotrophy: an introduction. In: Merckx VSFT, ed. *Mycoheterotrophy: the biology of plants living on fungi*. New York, US: Springer, 1–17.
- Merckx V & Freudenstein JV. 2010.** Evolution of mycoheterotrophy in plants: a phylogenetic perspective. *New Phytologist* 185: 605–609.
- Merckx VSFT, Freudenstein J V, Kissling J, et al. 2013.** Taxonomy and Classification. In: V.S.F.T. Merckx, ed. *Mycoheterotrophy: The Biology of Plants Living on Fungi*. Springer Science & Business Media: pp 19–101.
- Merckx V, Stockel M, Fleischmann A, et al. 2010.** ¹⁵N and ¹³C natural abundance of two mycoheterotrophic and a putative partially mycoheterotrophic species associated with arbuscular mycorrhizal fungi. *New Phytol* 188: 590–596.
- Millanes AM, Diederich P, Ekman S, et al. 2011.** Phylogeny and character evolution in the jelly fungi (Tremellomycetes, Basidiomycota, Fungi). *Molecular Phylogenetics and Evolution* 61: 12–28.
- Miller MA, Pfeiffer W, Schwartz T. 2010.** Creating the CIPRES Science Gateway for inference of large phylogenetic trees. In: *2010 Gateway Computing Environments Workshop*, GCE 2010.
- Miotke L, Lau BT, Rumma RT, et al. 2015.** High sensitivity detection and quantitation of DNA copy number and single nucleotide variants with single color droplet digital PCR. *Analytical Chemistry* 86: 2618–2624.
- Miyauchi S, Kiss E, Kuo A, et al. 2020.** Large-scale genome sequencing of mycorrhizal fungi provides insights into the early evolution of symbiotic traits. *Nature Communications* 11: 1–17.
- Motomura H, Selosse MA, Martos F, et al. 2010.** Mycoheterotrophy evolved from mixotrophic ancestors: Evidence in *Cymbidium* (Orchidaceae). *Annals of Botany* 106: 573–581.
- Mujica MI, Saez N, Cisternas M, et al. 2016.** Relationship between soil nutrients and mycorrhizal associations of two *Bipinnula* species (Orchidaceae) from central Chile. *Annals of botany* 118: 149–58.
- Mujica I, Fernanda P, Jakalski M, et al. 2020.** Soil P reduces mycorrhizal colonization while favors fungal pathogens: observational and experimental evidence in *Bipinnula* (Orchidaceae). *FEMS Microbiology Ecology* 96: faaa178.

N

- Nathan LM, Simmons M, Wegleitner BJ, et al. 2014.** Quantifying environmental DNA signals for aquatic invasive species across multiple detection platforms. *Environmental Science and Technology* 48: 12800–12806.
- Metusala D & Supriatna J. 2017.** *Gastrodia bambu* (Orchidaceae: Epidendroideae), a new species from Java,

Indonesia. *Phytotaxa*, 317, 211.

Nehls U & Plassard C. 2018. Nitrogen and phosphate metabolism in ectomycorrhizas. *New Phytologist* 220: 1047–1058.

Nurfadilah S, Swarts ND, Dixon KW, *et al.* 2013. Variation in nutrient-acquisition patterns by mycorrhizal fungi of rare and common orchids explains diversification in a global biodiversity hotspot. *Annals of Botany* 111: 1233–1241.

Neufeld JD, Dumont MG, Vohra J, *et al.* 2007a. Methodological Considerations for the Use of Stable Isotope Probing in Microbial Ecology. *Microbial Ecology* 53: 435–442.

Neufeld JD, Vohra J, Dumont MG, *et al.* 2007b. DNA stable-isotope probing. *Nature Protocols* 2: 860–866.

Nguyen NH, Song Z, Bates ST, *et al.* 2016. FUNGuild: an open annotation tool for parsing fungal community datasets by ecological guild. *Fungal Ecology* 20: 241–248.

Nilsson RH, Anslan S, Bahram M, *et al.* 2019. Mycobiome diversity: high-throughput sequencing and identification of fungi. *Nature Reviews Microbiology* 17: 95–109.

O

Oberwinkler F, Kirschner R, Arenal F, *et al.* 2006. Two new pycnidial members of the Atractiellales: *Basidiopycnis hyalina* and *Proceropycnis pinicola*. *Mycologia* 98:637–649.

Oberwinkler F, Riess K, Bauer R, *et al.* 2013. Enigmatic Sebaciniales. *Mycological Progress* 12: 1–27.

Ogura-Tsujita Y & Yukawa T. 2008. High mycorrhizal specificity in a widespread mycoheterotrophic plant, *Eulophia zollingeri* (Orchidaceae). *American Journal of Botany* 95: 93–97.

Ogura-Tsujita Y, Gebauer G, Hashimoto T, *et al.* 2009. Evidence for novel and specialized mycorrhizal parasitism: the orchid *Gastrodia confusa* gains carbon from saprotrophic *Mycena*. *Proceedings of the Royal Society B: Biological Sciences* 276: 761–767.

Ogura-Tsujita Y, Gebauer G, Xu H, *et al.* 2018. The giant mycoheterotrophic orchid *Erythrorchis altissima* is associated mainly with a divergent set of wood-decaying fungi. *Molecular Ecology* 27: 1324–1337.

Ogura-Tsujita Y, Yokoyama J, Miyoshi K, *et al.* 2012. Shifts in mycorrhizal fungi during the evolution of autotrophy to mycoheterotrophy in *Cymbidium* (Orchidaceae). *American Journal of Botany* 99: 1158–1176.

Ogura-Tsujita Y, Yukawa T, Kinoshita A. 2021. Evolutionary histories and mycorrhizal associations of mycoheterotrophic plants dependent on saprotrophic fungi. *Journal of Plant Research* 134: 19–41.

Oja J, Kohout P, Tedersoo L, *et al.* 2015. Temporal patterns of orchid mycorrhizal fungi in meadows and forests as revealed by 454 pyrosequencing. *New Phytologist* 205: 1608–1618.

Oja J, Vahtra J, Bahram M, *et al.* 2017. Local-scale spatial structure and community composition of orchid mycorrhizal fungi in semi-natural grasslands. *Mycorrhiza* 27: 355–367.

Oksanen J, Blanchet FG, Friendly M, *et al.* 2019. vegan: Community Ecology Package. R package version 2.5-5. <https://CRAN.R-project.org/package=vegan>. *Community ecology package*.

Okayama M, Yamato M, Yagame T, *et al.* 2012. Mycorrhizal diversity and specificity in *Lecanorchis* (Orchidaceae). *Mycorrhiza* 22: 545–553.

Oldroyd GED. 2013. Speak, friend, and enter: Signalling systems that promote beneficial symbiotic associations in plants. *Nature Reviews Microbiology* 11: 252–263.

Oliveira SF, Bocayuva MF, Veloso TGR, *et al.* 2014. Endophytic and mycorrhizal fungi associated with roots of endangered native orchids from the Atlantic Forest, Brazil. *Mycorrhiza* 24: 55–64.

- Onipchenko VG, Cornelissen JH, Vakhrameeva MG, et al. 2023.** Light and 13C: are orchids different from other vascular plants in their response to shade?. *Biology Bulletin Reviews* 13: 55–62.
- Öpik M, Vanatoa A, Vanatoa E, et al. 2010.** The online database MaarjAM reveals global and ecosystemic distribution patterns in arbuscular mycorrhizal fungi (Glomeromycota). *New Phytologist* 188: 223–241.
- Orchard S, Hilton S, Bending GD, et al. 2017a.** Fine endophytes (*Glomus tenue*) are related to Mucoromycotina, not Glomeromycota. *New Phytologist* 213: 481–486.
- Orchard S, Standish RJ, Dickie IA, et al. 2017b.** Fine root endophytes under scrutiny : a review of the literature on arbuscule-producing fungi recently suggested to belong to the Mucoromycotina. *Mycorrhiza* 27: 619–638.

P

- Padje A Van, Galvez LO, Klein M, et al. 2021.** Temporal tracking of quantum-dot apatite across in vitro mycorrhizal networks shows how host demand can influence fungal nutrient transfer strategies. *The ISME Journal*: 435–449.
- Pagel M. 1999.** Inferring the historical patterns of biological evolution. *Nature* 401: 877–884.
- Pagel M & Meade A. 2006.** Bayesian analysis of correlated evolution of discrete characters by reversible-jump Markov chain Monte Carlo. *The American Naturalist* 167: 808–825.
- Paradis E & Schliep K. 2019.** ape 5.0: an environment for modern phylogenetics and evolutionary analyses in R. *Bioinformatics* 35: 526–528.
- Park EJ & Lee WY. 2013.** In vitro symbiotic germination of myco-heterotrophic *Gastrodia elata* by *Mycena* species. *Plant Biotechnol Rep* 7: 185–191.
- Pecoraro L, Caruso T, Cai L, et al. 2018.** Fungal networks and orchid distribution: new insights from above- and below-ground analyses of fungal communities. *IMA Fungus* 9: 1–11.
- Pecoraro L, Girlanda M, Kull T, et al. 2013.** Fungi from the roots of the terrestrial photosynthetic orchid *Himantoglossum adriaticum*. *Plant Ecology and Evolution* 146: 145–152.
- Pecoraro L, Wang X, Venturella G, et al. 2020.** Molecular evidence supports simultaneous association of the achlorophyllous orchid *Chamaegastrodia inverta* with ectomycorrhizal Ceratobasidiaceae and Russulaceae. *BMC Microbiology* 20: 236.
- Pennell MW, Eastman JM, Slater GJ, et al. 2014.** geiger v2.0: an expanded suite of methods for fitting macroevolutionary models to phylogenetic trees. *Bioinformatics* 30: 2216–2218.
- Pérez-Escobar OA, Chomicki G, Condamine FL, et al. 2017.** Recent origin and rapid speciation of Neotropical orchids in the world's richest plant biodiversity hotspot. *New Phytologist* 215: 891–905.
- Perez-Lamarque B, Selosse M, Öpik M, et al. 2020.** Cheating in arbuscular mycorrhizal mutualism: a network and phylogenetic analysis of mycoheterotrophy. *New Phytologist* 226: 1822–1835.
- Phillips RD, Barrett MD, Dixon KW, et al. 2011.** Do mycorrhizal symbioses cause rarity in orchids? *Journal of Ecology* 99: 858–869.
- Phillips RD, Barrett MD, Dalziel EL, et al. 2016.** Geographical range and host breadth of *Sebacina* orchid mycorrhizal fungi associating with *Caladenia* in south-western Australia. *Botanical Journal of the Linnean Society* 182: 140–151.
- Pirozynski KA & Malloch DW. 1975.** The origin of land plants: a matter of mycotrophism. *Biosystems* 6: 153–164.
- Plett JM & Martin F. 2011.** Blurred boundaries: Lifestyle lessons from ectomycorrhizal fungal genomes. *Trends*

in *Genetics* 27: 14–22.

Pölme S, Abarenkov K, Henrik NR, et al. 2020. FungalTraits: a user-friendly traits database of fungi and fungus-like stramenopiles. *Fungal Diversity* 105: 1–16.

Powell JR & Rillig MC. 2018. Biodiversity of arbuscular mycorrhizal fungi and ecosystem function. *New Phytologist* 220: 1059–1075.

Preiss K, Adam IKU, Gebauer G. 2010. Irradiance governs exploitation of fungi: Fine-tuning of carbon gain by two partially myco-heterotrophic orchids. *Proceedings of the Royal Society B: Biological Sciences* 277: 1333–1336.

Preiss K & Gebauer G. 2008. A methodological approach to improve estimates of nutrient gains by partially myco-heterotrophic plants. *Isotopes in environmental and health studies* 44: 393–401.

Prescott CE, Grayston SJ, Helmisaari HS, et al. 2020. Surplus carbon drives allocation and plant–soil interactions. *Trends in Ecology & Evolution* 35: 1110–1118.

Pridgeon MA, Cribb PJ, Chase MW. 2009. *Genera Orchidacearum*. Oxford University Press.

Prieto M, Wedin M. 2013. Dating the Diversification of the Major Lineages of Ascomycota (Fungi). *PLoS One* 8: e65576.

Q

Qin J, Zhang W, Ge ZW, et al. 2019. Molecular identifications uncover diverse fungal symbionts of *Pleione* (Orchidaceae). *Fungal Ecology* 37: 19–29.

R

Raes N & Aguirre-Gutiérrez J. 2018. A modeling framework to estimate and project species distributions in space and time. *Mountains, Climate and Biodiversity* 309.

Ramirez SR, Gravendeel B, Singer RB, et al. 2007. Dating the origin of the Orchidaceae from a fossil orchid with its pollinator. *Nature* 448: 1042–1045.

Rammitsu K, Yagame T, Yamashita Y, et al. 2019. A leafless epiphytic orchid, *Taeniophyllum glandulosum* Blume (Orchidaceae), is specifically associated with the Ceratobasidiaceae family of basidiomycetous fungi. *Mycorrhiza* 29: 159–166.

Rasmussen HN & Whigham DF. 1993. Seed ecology of dust seeds in situ: a new study technique and its application in terrestrial orchids. *American Journal of Botany* 80: 1374–1378.

Rasmussen HN. 1995. *Terrestrial orchids: from seed to mycotrophic plant*. Cambridge, UK: Cambridge University Press.

Rasmussen HN. 2002. Recent developments in the study of orchid mycorrhiza. *Plant and Soil* 244: 149–163.

Rasmussen HN & Rasmussen FN. 2014. Seedling mycorrhiza: a discussion of origin and evolution in Orchidaceae. *Botanical Journal of the Linnean Society* 175: 313–327.

Rasmussen HN, Dixon KW, Jersáková J, et al. 2015. Germination and seedling establishment in orchids: a complex of requirements. *Annals of Botany* 116: 391–402.

Read DJ. 1991. Mycorrhizas in ecosystems. *Experientia* 47: 376–391.

Read DJ, Leake JR, Perez-Moreno J. 2004. Mycorrhizal fungi as drivers of ecosystem processes in heathland and boreal forest biomes. *Canadian Journal of Botany* 82: 1243–1263.

- Redecker D, Kodner R, Graham LE. 2000.** Glomalean fungi from the Ordovician. *Science* 289: 1920–1921.
- Reiter N, Phillips RD, Swarts ND, et al. 2020.** Specific mycorrhizal associations involving the same fungal taxa in common and threatened *Caladenia* (Orchidaceae): Implications for conservation. *Annals of Botany* 126: 943–955.
- Remy W, Taylor TN, Hass H, et al. 1994.** Four hundred-million-year-old vesicular arbuscular mycorrhizae. *Proceedings of the National Academy of Sciences of the United States of America* 91: 11841–11843.
- Revell LJ. 2012.** phytools: an R package for phylogenetic comparative biology (and other things). *Methods in Ecology and Evolution* 3: 217–223.
- Rillig MC & Mummey DL. 2006.** Mycorrhizas and soil structure. *New Phytologist* 171: 41–53.
- Rinaldi AC, Comandini O, Kuyper TW. 2008.** Ectomycorrhizal fungal diversity: Separating the wheat from the chaff. *Fungal Diversity* 33:1–45
- Roberts P. 1999.** *Rhizoctonia-forming fungi: a taxonomic guid*. Royal Botanic Gardens, Kew, London.
- Roberts DW. 2019.** labdsv: ordination and multivariate analysis for ecology. *R package version 2.0-1*.
- Robertson GP, Coleman DC, et al. 1999.** *Standard soil methods for long-term ecological research*. Oxford University Press on Demand.
- Rognes T, Flouri T, Nichols B, et al. 2016.** VSEARCH: a versatile open source tool for metagenomics. *PeerJ* 4: e2584.
- Roy M, Watthana S, Stier A, et al. 2009.** Two mycoheterotrophic orchids from Thailand tropical dipterocarpacean forests associate with a broad diversity of ectomycorrhizal fungi. *BMC Biology* 7: 51.

S

- Salazar JM, Pomavilla M, Pollard AT, et al. 2020.** Endophytic fungi associated with roots of epiphytic orchids in two Andean forests in Southern Ecuador and their role in germination. *Lankesteriana*: 37–47.
- Sánchez-García M, Matheny PB. 2017.** Is the switch to an ectomycorrhizal state an evolutionary key innovation in mushroom-forming fungi? A case study in the Tricholomatineae (Agaricales). *Evolution* 71: 51–65.
- Sayers EW, O’Sullivan C, Karsch-Mizrachi I. 2022.** Using GenBank and SRA. In *Plant Bioinformatics*, pp 1–25. Humana, New York, NY.
- Schenkel D, Lemfack MC, Piechulla B, et al. 2015.** A meta-analysis approach for assessing the diversity and specificity of belowground root and microbial volatiles. *Frontiers in Plant Science* 6: 1–11.
- Schiebold JMI, Bidartondo MI, Karasch P, et al. 2017.** You are what you get from your fungi: nitrogen stable isotope patterns in *Epipactis* species. *Annals of Botany* 119: 1085–1095.
- Schiebold JMI, Bidartondo MI, Lenhard F, et al. 2018.** Exploiting mycorrhizas in broad daylight: Partial mycoheterotrophy is a common nutritional strategy in meadow orchids. *Journal of Ecology* 106: 168–178.
- Schoch CL, Seifert KA, Huhndorf S, et al. 2012.** Nuclear ribosomal internal transcribed spacer (ITS) region as a universal DNA barcode marker for Fungi. *Proceedings of the National Academy of Sciences of the United States of America* 109: 6241–6246.
- Schweiger JMI, Kemnade C, Bidartondo MI, et al. 2019.** Light limitation and partial mycoheterotrophy in rhizoctonia-associated orchids. *Oecologia* 189: 375–383.
- Schweiger JM-I, Bidartondo MI, Gebauer G. 2018.** Stable isotope signatures of underground seedlings reveal the organic matter gained by adult orchids from mycorrhizal fungi. *Functional Ecology* 32: 870–881.

- Selosse MA & Le Tacon F. 1998.** The land flora: A phototroph-fungus partnership? *Trends in Ecology & Evolution* 13: 15–20.
- Selosse MA, Weiss M, Jany JL, et al. 2002.** Communities and populations of sebacinoïd basidiomycetes associated with the achlorophyllous orchid *Neottia nidus-avis* (L.) L.C.M. Rich. and neighbouring tree ectomycorrhizae. *Molecular Ecology* 11: 1831–1844.
- Selosse MA, Faccio A, Scappaticci G, et al. 2004.** Chlorophyllous and achlorophyllous specimens of *Epipactis microphylla* (Neottieae, Orchidaceae) are associated with ectomycorrhizal septomycetes, including truffles. *Microbial ecology* 47: 416–26.
- Selosse MA, Richard F, He X, et al. 2006.** Mycorrhizal networks: des liaisons dangereuses? *Trends in Ecology & Evolution* 21: 621–628.
- Selosse MA, Setaro S, Glatard F, et al. 2007.** Sebacinales are common mycorrhizal associates of Ericaceae. *New Phytologist* 174: 864–878.
- Selosse MA & Roy M. 2009.** Green plants that feed on fungi: facts and questions about mixotrophy. *Trends in Plant Science* 14: 64–70.
- Selosse MA, Dubois MP, Alvarez N. 2009.** Do Sebacinales commonly associate with plant roots as endophytes? *Mycological Research* 113: 1062–1069.
- Selosse MA, Martos F, Perry B, et al. 2010.** Saprotrophic fungal symbionts in tropical achlorophyllous orchids. *Plant Signaling & Behavior* 5: 349–353.
- Selosse MA, Rousset F. 2011.** The Plant-Fungal Marketplace. *Science* 333: 828–829.
- Selosse MA, Martos F. 2014.** Do chlorophyllous orchids heterotrophically use mycorrhizal fungal carbon? *Trends in Plant Science* 19: 683–685.
- Selosse MA, Schneider-Maunoury L, Martos F. 2018.** Time to re-think fungal ecology? Fungal ecological niches are often prejudged. *New Phytologist* 217: 968–972.
- Selosse M-A, Petrolli R, Mujica MI, et al. 2022.** The Waiting Room Hypothesis revisited by orchids: were orchid mycorrhizal fungi recruited among root endophytes? *Annals of Botany* 129: 259–270.
- Shah S, Shrestha R, Maharjan S, et al. 2018.** Isolation and characterization of plant growth-promoting endophytic fungi from the roots of *Dendrobium moniliforme*. *Plants* 8: 5.
- Shao SC, Luo Y, Jacquemyn H. 2020.** Co-Cultures of Mycorrhizal Fungi Do Not Increase Germination and Seedling Development in the Epiphytic Orchid *Dendrobium nobile*. *Frontiers in Plant Science* 11: 571426.
- Shefferson RP, Cowden CC, McCormick MK, et al. 2010.** Evolution of host breadth in broad interactions: mycorrhizal specificity in East Asian and North American rattlesnake plantains (*Goodyera* spp.) and their fungal hosts. *Molecular Ecology* 19: 3008–3017.
- Shefferson RP, Taylor DL, Weiß B, et al. 2007.** The Evolutionary History of Mycorrhizal Specificity among Lady's Slipper Orchids. *Evolution* 61: 1380–1390.
- Shefferson RP, Weiss M, Kull T, et al. 2005.** High specificity generally characterizes mycorrhizal association in rare lady's slipper orchids, genus *Cypripedium*. *Molecular Ecology* 14: 613–26.
- Shefferson RP, Bunch W, Cowden CC, et al. 2019.** Does evolutionary history determine specificity in broad ecological interactions? *Journal of Ecology*, 107, 1582–1593.
- Shimaoka C, Fukunaga H, Inagaki S, et al. 2017.** Artificial Cultivation System for *Gastrodia* spp. and Identification of Associated Mycorrhizal Fungi. *International Journal of Biology* 9: 27.
- Shubin N, Tabin C, Carroll S. 2009.** Deep homology and the origins of evolutionary novelty. *Nature* 457: 818–

- Simard SW, Beiler KJ, Bingham MA, et al. 2012.** Mycorrhizal networks: Mechanisms, ecology and modelling. *Fungal Biology Reviews* 26: 39–60.
- Simard SW, Perry DA, Jones MD, et al. 1997.** Net transfer of carbon between ectomycorrhizal tree species in the field. *Nature* 388: 579–582.
- Silveira Lobo Sternberg LD. 1989.** Oxygen and Hydrogen Isotope Ratios in Plant Cellulose: Mechanisms and Applications. In: *Stable isotopes in ecological research*. Berlin: Springer, pp 124–141.
- Sisti LS, Flores-Borges DNA, Andrade SALD, et al. 2019.** The role of non-mycorrhizal fungi in germination of the mycoheterotrophic orchid *Pogoniopsis schenckii* Cogn. *Frontiers in Plant Science* 10: 1589.
- Smith SE & Read DJ. 2008.** *Mycorrhizal symbiosis*. Cambridge, UK: Academic Press.
- Smith SA & O'Meara BC. 2012.** TreePL: Divergence time estimation using penalized likelihood for large phylogenies. *Bioinformatics* 28: 2689–2690.
- Stamatakis A. 2014.** RAxML version 8: a tool for phylogenetic analysis and post-analysis of large phylogenies. *Bioinformatics* 30: 1312–1313.
- Stark C, Babik W, Durka W. 2009.** Fungi from the roots of the common terrestrial orchid *Gymnadenia conopsea*. *Mycological Research* 113: 952–959.
- Steidinger BS, Crowther TW, Liang J, et al. 2019.** Climatic controls of decomposition drive the global biogeography of forest-tree symbioses. *Nature* 569: 404–408.
- Stockel M, Meyer C, Gebauer G. 2011.** The degree of mycoheterotrophic carbon gain in green, variegated and vegetative albino individuals of *Cephalanthera damasonium* is related to leaf chlorophyll concentrations. *New Phytologist* 189: 790–796.
- Stöckel M, Těšitelová T, Jersáková J, et al. 2014.** Carbon and nitrogen gain during the growth of orchid seedlings in nature. *New Phytologist* 202: 606–615.
- Strullu-Derrien C, Selosse MA, Kenrick P, et al. 2018.** The origin and evolution of mycorrhizal symbioses: from palaeomycology to phylogenomics. *New Phytologist* 220: 1012–1030.
- Suetsugu K, Yamato M, Miura C, et al. 2017.** Comparison of green and albino individuals of the partially mycoheterotrophic orchid *Epipactis helleborine* on molecular identities of mycorrhizal fungi, nutritional modes and gene expression in mycorrhizal roots. *Molecular Ecology* 26: 1652–1669.
- Suetsugu K, Suleiman M, Anthony F, et al. 2018.** *Aphyllorchis maliauensis* (Orchidaceae), a new species from the Maliau Basin, Sabah, Borneo. *Phytotaxa* 367: 85.
- Suetsugu K & Matsubayashi J. 2021.** Evidence for mycorrhizal cheating in *Apostasia nipponica*, an early-diverging member of the Orchidaceae. *New Phytologist* 229: 2302–2310.
- Suetsugu K, Haraguchi TF, Okada H, et al. 2021a.** *Stigmatodactylus sikokianus* (Orchidaceae) mainly acquires carbon from decaying litter through association with a specific clade of Serendipitaceae. *New Phytologist* 231: 1670–1675.
- Suetsugu K, Haraguchi TF, Tayasu I. 2021b.** Novel mycorrhizal cheating in a green orchid: *Cremastra appendiculata* depends on carbon from deadwood through fungal associations. *New Phytologist* 235: 333–343.
- Summerell BA, Leslie JF, Liew ECY, et al. 2011.** *Fusarium* species associated with plants in Australia. *Fungal Diversity* 46: 1–27.
- Swarts ND, Sinclair EA, Francis A, et al. 2010.** Ecological specialization in mycorrhizal symbiosis leads to rarity in an endangered orchid. *Molecular ecology* 19: 3226–42.

Szathmáry E & Smith JM. 1995. The major evolutionary transitions. *Nature* 374: 227–232.

T

Tao G, Liu ZY, Hyde KD, *et al.* 2008. Whole rDNA analysis reveals novel and endophytic fungi in *Bletilla ochracea* (Orchidaceae). *Fungal Diversity* 33: 101–112

Taylor DL, Bruns TD. 1997. Independent, specialized invasions of ectomycorrhizal mutualism by two nonphotosynthetic orchids. *Proceedings of the National Academy of Sciences of the United States of America* 94: 4510–4515.

Taylor DL, Bruns TD. 1999. Population, habitat and genetic correlates of mycorrhizal specialization in the “cheating” orchids *Corallorhiza maculata* and *C. mertensiana*. *Molecular Ecology* 8:1719–1732.

Taylor DL, Bruns TD, Leake JR, *et al.* 2002. Mycorrhizal Specificity and Function in Myco-heterotrophic Plants. In: *Mycorrhizal ecology*. Springer-Verlag, 375–413.

Taylor DL, Bruns TD, Szaro TM, *et al.* 2003. Divergence in mycorrhizal specialization within *Hexalectris spicata* (Orchidaceae), a nonphotosynthetic desert orchid. *American Journal of Botany* 90: 1168–1179.

Taylor DL, Bruns TD, Hodges SA. 2004. Evidence for mycorrhizal races in a cheating orchid. *Proceedings of the Royal Society B: Biological Sciences* 271: 35–43.

Taylor DL & McCormick MK. 2008. Internal transcribed spacer primers and sequences for improved characterization of basidiomycetous orchid mycorrhizas. *New Phytologist* 177: 1020–1033.

Taylor TN, Remy W, Hass H, *et al.* 1995. Fossil Arbuscular Mycorrhizae from the Early Devonian. *Mycologia* 87: 560.

Taylor DL, Walters WA, Lennon NJ, *et al.* 2016. Accurate estimation of fungal diversity and abundance through improved lineage-specific primers optimized for Illumina amplicon sequencing. *Applied and environmental microbiology* 82: 7217–7226.

Tedersoo L, Suvi T, Beaver K, *et al.* 2007. Ectomycorrhizas of *Coltricia* and *Coltriciella* (Hymenochaetales, Basidiomycota) on Caesalpiniaceae, Dipterocarpaceae and Myrtaceae in Seychelles. *Mycological Progress* 6: 101–107.

Tedersoo L, Pellet P, Koljalg U, *et al.* 2007. Parallel evolutionary paths to mycoheterotrophy in understorey Ericaceae and Orchidaceae: Ecological evidence for mixotrophy in Pyroleae. *Oecologia* 151: 206–217.

Tedersoo L, Pärtel K, Jairus T, *et al.* 2009. Ascomycetes associated with ectomycorrhizas: Molecular diversity and ecology with particular reference to the Helotiales. *Environmental Microbiology* 11: 3166–3178.

Tedersoo L, May TW, Smith ME. 2010. Ectomycorrhizal lifestyle in fungi: global diversity, distribution, and evolution of phylogenetic lineages. *Mycorrhiza* 20:217–263.

Tedersoo L & Smith ME. 2013. Lineages of ectomycorrhizal fungi revisited: Foraging strategies and novel lineages revealed by sequences from belowground. *Fungal Biology Reviews* 27: 83–99.

Tedersoo L & Brundrett MC. 2017. Evolution of ectomycorrhizal symbiosis in plants. In: Tedersoo L, ed. *Biogeography of mycorrhizal symbiosis*. New York, US: Springer, 407–467.

Tedersoo L, Sánchez-Ramírez S, Kõljalg U, *et al.* 2018. High-level classification of the Fungi and a tool for evolutionary ecological analyses. *Fungal Diversity* 90: 135–159.

Tedersoo L & Smith ME. 2017. Ectomycorrhizal fungal lineages: detection of four new groups and notes on consistent recognition of ectomycorrhizal taxa in high-throughput sequencing studies. In: *Biogeography of Mycorrhizal Symbiosis*. pp 125–142.

- Tedersoo L, Sánchez-Ramírez S, Kõljalg U, et al. 2018.** High-level classification of the Fungi and a tool for evolutionary ecological analyses. *Fungal Diversity* 90:135–159.
- Tedersoo L & Bahram M. 2019.** Mycorrhizal types differ in ecophysiology and alter plant nutrition and soil processes. *Biological Reviews* 94: 1857–1880.
- Tedersoo L, Bahram M, Zobel M. 2020.** How mycorrhizal associations drive plant population and community biology. *Science* 367: eaba1223.
- Tedersoo L, Bahram M, Zinger L, et al. 2022.** Best practices in metabarcoding of fungi: From experimental design to results. *Molecular Ecology* 31: 2769–2795.
- Těšitel J, Těšitelová T, Minasiewicz J, et al. 2018.** Mixotrophy in Land Plants: Why To Stay Green? *Trends in Plant Science* 23: 656–659.
- Těšitelová T, Jersáková J, Roy M, et al. 2013.** Ploidy-specific symbiotic interactions: divergence of mycorrhizal fungi between cytotypes of the *Gymnadenia conopsea* group (Orchidaceae). *New Phytologist* 199: 1022–1033
- Těšitelová T, Kotlínek M, Jersáková J, et al. 2015.** Two widespread green *Neottia* species (Orchidaceae) show mycorrhizal preference for Sebaciniales in various habitats and ontogenetic stages. *Molecular Ecology* 24: 1122–1134.
- Těšitelová T, Těšitel J, Jersakova J, et al. 2012.** Symbiotic germination capability of four *Epipactis* species (Orchidaceae) is broader than expected from adult ecology. *American Journal of Botany* 99: 1020–1032.
- Thompson JN. 1999.** The evolution of species interactions. *Science* 284: 2116–2118.
- Thompson J. 2005.** *The geographic mosaic of coevolution*. Illinois, US: University of Chicago Press.
- Tkacz A, Hortal M, Poole PS. 2018.** Absolute quantitation of microbiota abundance in environmental samples. *Microbiome* 6: 1–13.
- Tondello A, Vendramin E, Villani M, et al. 2012.** Fungi associated with the southern Eurasian orchid *Spiranthes spiralis* (L.) Chevall. *Fungal Biology* 116: 543–549.
- Toju H, Tanabe AS, Ishii HS. 2016.** Ericaceous plant – fungus network in a harsh alpine – subalpine environment. *Molecular Ecology* 25: 3242–3257.
- Trudell SA, Rygiewicz PT, Edmonds RL. 2003.** Nitrogen and carbon stable isotope abundances support the myco-heterotrophic nature and host-specificity of certain achlorophyllous plants. *New Phytologist* 160: 391–401.
- Turenne CY, Sanche SE, Hoban DJ, et al. 1999.** Rapid identification of fungi by using the ITS2 genetic region and an automated fluorescent capillary electrophoresis system. *Journal of Clinical Microbiology* 37: 1846–1851

U

- Umata H. 1995.** Seed germination of *Galeola altissima*, an achlorophyllous orchid, with aphyllophorales fungi. *Mycoscience* 36: 369–372.
- Umata H. 1999.** Germination and growth of *Erythrorchis ochobiensis* (Orchidaceae) accelerated by monokaryons and dikaryons of *Lenzites betulinus* and *Trametes hirsuta*. *Mycoscience* 40: 367–371.
- Umata H. 1997.** Formation of endomycorrhizas by an achlorophyllous orchid, *Erythrorchis ochobiensis*, and *Auricularia polytricha*. *Mycoscience* 38: 335–339.
- Umata H, Ota Y, Yamada M, et al. 2013.** Germination of the fully myco-heterotrophic orchid *Cyrtosia septentrionalis* is characterized by low fungal specificity and does not require direct seed-mycobiont contact. *Mycoscience* 54: 343–352.

V

- van der Heijden MGA, Boller T, Wiemken A, et al. 1998.** Different arbuscular mycorrhizal fungal species are potential determinants of plant community structure. *Ecology* 79: 2082–2091.
- van der Heijden MGA, Horton TR. 2009.** Socialism in soil? the importance of mycorrhizal fungal networks for facilitation in natural ecosystems. *Journal of Ecology* 97: 1139–1150.
- van der Heijden MGA, Martin FM, Selosse MA, et al. 2015.** Mycorrhizal ecology and evolution: The past, the present, and the future. *New Phytologist* 205: 1406–1423.
- Vanegas-León ML, Sulzbacher MA, Rinaldi AC, et al. 2019.** Are Trechisporales ectomycorrhizal or non-mycorrhizal root endophytes? *Mycological Progress* 18: 1231–1240.
- Vági P, Knapp DG, Kósa A, et al. 2014.** Simultaneous specific in planta visualization of root-colonizing fungi using fluorescence *in situ* hybridization (FISH). *Mycorrhiza* 24: 259–266.
- Varga T, Krizsán K, Földi C, et al. 2019.** Megaphylogeny resolves global patterns of mushroom evolution. *Nature Ecology & Evolution* 3: 668–678.
- Varma A, Prasad R, Tuteja N. 2017.** *Mycorrhiza - Eco-Physiology, Secondary Metabolites, Nanomaterials* (A Varma, R Prasad, and N Tuteja, Eds.). Cham: Springer International Publishing.
- Veldre V, Abarenkov K, Bahram M, et al. 2013.** Evolution of nutritional modes of Ceratobasidiaceae (Cantharellales, Basidiomycota) as revealed from publicly available ITS sequences. *Fungal Ecology* 6: 256–268.
- Ventre Lespiaucq A, Jacquemyn H, Rasmussen HN, et al. 2021.** Temporal turnover in mycorrhizal interactions: a proof of concept with orchids. *New Phytologist* 230: 1690–1699.
- Vogt-Schilb H, Těšitelová T, Kotlínek M, et al. 2020.** Altered rhizoctonia assemblages in grasslands on ex-arable land support germination of mycorrhizal generalist, not specialist orchids. *New Phytologist* 227: 1200–1212.
- Vujanovic V. 2000.** Viability Testing of Orchid Seed and the Promotion of Colouration and Germination. *Annals of Botany* 86: 79–86.

W

- Walker JF, Aldrich-Wolfe L, Riffel A, et al. 2011.** Diverse Helotiales associated with the roots of three species of Arctic Ericaceae provide no evidence for host specificity. *New Phytologist* 191: 515–27.
- Wallander H, Ekblad A, Godbold DL, et al. 2013.** Evaluation of methods to estimate production, biomass and turnover of ectomycorrhizal mycelium in forests soils—A review. *Soil Biology and Biochemistry* 57: 1034–47.
- Wang B & Qiu YL. 2006.** Phylogenetic distribution and evolution of mycorrhizas in land plants. *Mycorrhiza* 16: 299–363.
- Wang B, Yeun LH, Xue JY, et al. 2010.** Presence of three mycorrhizal genes in the common ancestor of land plants suggests a key role of mycorrhizas in the colonization of land by plants. *New Phytologist* 186: 514–525.
- Wang D, Jacquemyn H, Gomes SIF, et al. 2021.** Symbiont switching and trophic mode shifts in Orchidaceae. *New Phytologist* 231: 791–800.
- Wang D, Lerou J, Nuytinck J, et al. 2022.** Root-associated Fungi in Orchidaceae : Diversity , Phylogeny , Ecology , and Outstanding Questions. *bioRxiv*. <https://biorxiv.org/cgi/content/short/2022.12.16.519622v1>
- Wang Q & Guo LD. 2010.** Ectomycorrhizal community composition of *Pinus tabulaeformis* assessed by ITS-RFLP

and ITS sequences. *Botany* 88: 590–595.

- Wang X, Li Y, Song X, et al. 2017.** Influence of host tree species on isolation and communities of mycorrhizal and endophytic fungi from roots of a tropical epiphytic orchid, *Dendrobium sinense* (Orchidaceae). *Mycorrhiza* 27: 709–718.
- Warcup JH. 1971.** Specificity of mycorrhizal association in some australian terrestrial orchids. *New Phytol* 70: 41–46.
- Warcup JH. 1981.** The Mycorrhizal Relationships of Australian Orchids. *New Phytologist* 87: 371–381.
- Warcup JH, Talbot PHB. 1967.** Perfect States of Rhizoctonias Associated With Orchids. *New Phytologist* 66: 631–641.
- Waterman RJ, Bidartondo MI, Stoffberg J, et al. 2011.** The effects of above- and belowground mutualisms on orchid speciation and coexistence. *The American Naturalist* 177: E54–E68.
- Watkinson SC. 2016.** Mutualistic symbiosis between fungi and autotrophs. In: *The Fungi*. Elsevier, pp 205–243
- Wand M & Ripley B. 2015.** KernSmooth. Functions for Kernel Smoothing Supporting Wand & Jones (1995). *R package version*.
- Waud M, Brys R, Van Landuyt W, et al. 2017.** Mycorrhizal specificity does not limit the distribution of an endangered orchid species. *Molecular Ecology* 26: 1687–1701.
- Waud M, Busschaert P, Lievens B, et al. 2016.** Specificity and localised distribution of mycorrhizal fungi in the soil may contribute to co-existence of orchid species. *Fungal Ecology* 20: 155–165.
- Waud M, Busschaert P, Ruyters S, et al. 2014.** Impact of primer choice on characterization of orchid mycorrhizal communities using 454 pyrosequencing. *Molecular Ecology Resources* 14: 679–699.
- Webb CO. 2000.** Exploring the phylogenetic structure of ecological communities: An example for rain forest trees. *The American Naturalist* 156: 145.
- Webb CO, Ackerly DD, McPeck MA, et al. 2002.** Phylogenies and community ecology. *Annual Review of Ecology and Systematics* 33: 475–505.
- Wei T. 2013.** corrplot: Visualization of a correlation matrix. R package version 0.73. URL <https://github.com/taiyun/corrplot>.
- Weiß M, Waller F, Zuccaro A, et al. 2016.** Sebaciniales – one thousand and one interactions with land plants. *New Phytologist* 211: 20–40.
- Weiß M & Oberwinkler F. 2001.** Phylogenetic relationships in Auriculariales and related groups – hypotheses derived from nuclear ribosomal DNA sequences. *Mycological Research* 105: 403–415.
- Weiß M, Selosse M-A, Rexer K-H, et al. 2004.** Sebaciniales: a hitherto overlooked cosm of heterobasidiomycetes with a broad mycorrhizal potential. *Mycological Research* 108: 1003–10.
- Werner GDA, Cornelissen JHC, Cornwell WK, et al. 2018.** Symbiont switching and alternative resource acquisition strategies drive mutualism breakdown. *Proceedings of the National Academy of Sciences* 115: 5229–5234.
- White TJ, Bruns T, Lee S, et al. 1990.** Amplification and direct sequencing of fungal ribosomal RNA genes for phylogenetics. In: *PCR protocols: a guide to methods and applications*. pp 315–322.
- Whitridge H, Southworth D. 2005.** Mycorrhizal symbionts of the terrestrial orchid *Cypripedium fasciculatum*. *Selbyana*: 328–334
- Wijayawardene NN, Hyde KD, Rajeshkumar KC, et al. 2017.** Notes for genera: Ascomycota. *Fungal Diversity* 86: 1–594.

Wu G, Zhao H, Li C, *et al.* 2015. Genus-wide comparative genomics of malassezia delineates its phylogeny, physiology, and niche adaptation on human skin. PLOS Genetics 11: e1005614.

X

Xing S & Fayle TM. 2021. The rise of ecological network meta-analyses: Problems and prospects. Global Ecology and Conservation 30: e01805.

Xing X, Gao Y, Zhao Z, *et al.* 2020. Similarity in mycorrhizal communities associating with two widespread terrestrial orchids decays with distance. Journal of Biogeography 47: 421–433.

Xing X, Jacquemyn H, Gai X, *et al.* 2019. The impact of life form on the architecture of orchid mycorrhizal networks in tropical forest. Oikos 128: 1254–1264.

Xing YM, Chen J, Cui JL, *et al.* 2011. Antimicrobial Activity and Biodiversity of Endophytic Fungi in *Dendrobium devonianum* and *Dendrobium thyrsiflorum* from Vietman. Current Microbiology 62: 1218–1224.

Xu JT & Guo SX. 1989. Fungus associated with nutrition of seed germination of *Gastrodia elata* – *Mycena osmundicola* Lange. Acta Mycologica Sinica 8: 221–226.

Xu J & Guo S. 2000. Retrospect on the research of the cultivation of *Gastrodia elata* Bl, a rare traditional Chinese medicine. Chinese medical journal 113: 686–92.

Xu JT & Mu C. 1990. The Relation between Growth of *Gastrodia elata* Protocorms and Fungi. Acta Botanica Sinica 32: 26–31.

Y

Yagame T, Ogura-Tsujita Y, Kinoshita A, *et al.* 2016. Fungal partner shifts during the evolution of mycoheterotrophy in *Neottia*. American Journal of Botany 103: 1630–1641.

Yagame T & Yamato M. 2013. Mycoheterotrophic growth of *Cephalanthera falcata* (Orchidaceae) in tripartite symbioses with Thelephoraceae fungi and *Quercus serrata* (Fagaceae) in pot culture condition. Journal of Plant Research 126: 215–222.

Yagame T, Yamato M, Mii M, *et al.* 2007. Developmental processes of achlorophyllous orchid, *Epipogium roseum*: from seed germination to flowering under symbiotic cultivation with mycorrhizal fungus. Journal of Plant Research 120: 229–236.

Yamato M, Iwase K, Yagame T, *et al.* 2005. Isolation and identification of mycorrhizal fungi associating with an achlorophyllous plant, *Epipogium roseum* (Orchidaceae). Mycoscience 46: 73–77.

Yamashita Y, Kinoshita A, Yagame T, *et al.* 2020. *Physisporinus* is an important mycorrhizal partner for mycoheterotrophic plants: Identification of mycorrhizal fungi of three *Yuania* species. Mycoscience 61: 219–225.

Yang JX, Peng S, Wang JJ, *et al.* 2021. Morphological and genomic evidence for a new species of *Corallorhiza* (Orchidaceae: Epidendroideae) from SW China. Plant Diversity 43: 409–419.

Yang WK, Li TQ, Wu SM, *et al.* 2020. Ex situ seed baiting to isolate germination-enhancing fungi for assisted colonization in *Paphiopedilum spicerianum*, a critically endangered orchid in China. Global Ecology and Conservation 23: e01147.

Yeates D. 1992. Why remove autapomorphies? Cladistics 8: 387–389.

Yeh CM, Chung KM, Liang CK, *et al.* 2019. New insights into the symbiotic relationship between orchids and fungi. Applied sciences 9:1–14.

Yeung EC, Li YY, Lee YI. 2019. An overview of the life of an orchid protocorm – a developmental perspective.

- Yuan Z, Chen Y, Yang Y. 2009.** Diverse non-mycorrhizal fungal endophytes inhabiting an epiphytic, medicinal orchid (*Dendrobium nobile*): estimation and characterization. *World Journal of Microbiology and Biotechnology* 25: 295–303.
- Yu G. 2020.** Using ggtree to visualize data on tree-like structures. *Current Protocols in Bioinformatics* 69: e96.
- Yuan Y, Jin X, Liu J, et al. 2018.** The *Gastrodia elata* genome provides insights into plant adaptation to heterotrophy. *Nature Communications* 9: 1615.
- Yukawa T, Ogura-Tsujita Y, Shefferson RP, et al. 2009.** Mycorrhizal diversity in *Apostasia* (Orchidaceae) indicates the origin and evolution of orchid mycorrhiza. *American Journal of Botany* 96: 1997–2009.

Z

- Zelmer CD & Currah RS. 1995.** *Ceratorhiza pernacatena* and *Epulorhiza calendulina* spp.nov.: mycorrhizal fungi of terrestrial orchids. *Canadian Journal of Botany* 73: 1981–1985.
- Zhang GQ, Liu KW, Li Z, et al. 2017.** The *Apostasia* genome and the evolution of orchids. *Nature* 549: 379–383.
- Zhang GQ, Xu Q, Bian C, et al. 2016.** The *Dendrobium catenatum* Lindl. genome sequence provides insights into polysaccharide synthase, floral development and adaptive evolution. *Scientific reports* 6: 19029.
- Zhang L, Chen J, Lv Y, et al. 2012.** *Mycena* sp., a mycorrhizal fungus of the orchid *Dendrobium officinale*. *Mycological Progress* 11:395–401.
- Zhang W, Zhang X, Li K, et al. 2018.** Introgression and gene family contraction drive the evolution of lifestyle and host shifts of hypocrealean fungi. *Mycology* 9: 176–188.
- Zhao XL, Yang JZ, Liu S, et al. 2014.** The colonization patterns of different fungi on roots of *Cymbidium hybridum* plantlets and their respective inoculation effects on growth and nutrient uptake of orchid plantlets. *World Journal of Microbiology and Biotechnology* 30: 1993–2003.
- Zhao B, van Bodegom PM, Trimbos K. 2021.** The particle size distribution of environmental DNA varies with species and degradation. *Science of the Total Environment* 797: 149175.
- Zhao Z, Li X, Liu MF, et al. 2021.** Specificity of assemblage, not fungal partner species, explains mycorrhizal partnerships of mycoheterotrophic *Burmannia* plants. *The ISME Journal* 15: 1614–1627.
- Zhao RL, Li GJ, Sánchez-Ramírez S, et al. 2017.** A six-gene phylogenetic overview of Basidiomycota and allied phyla with estimated divergence times of higher taxa and a phyloproteomics perspective. *Fungal Diversity* 84: 43–74.
- Zhou T & Jin X. 2018.** Molecular systematics and the evolution of mycoheterotrophy of tribe Neottieae (Orchidaceae, Epidendroideae). *PhytoKeys* 94: 39–49.
- Zhu GS, Yu ZN, Gui Y, et al. 2008.** A novel technique for isolating orchid mycorrhizal fungi. *Fungal Diversity* 33: 123–137.
- Zi X-M, Sheng C-L, Goodale UM, et al. 2014.** In situ seed baiting to isolate germination-enhancing fungi for an epiphytic orchid, *Dendrobium aphyllum* (Orchidaceae). *Mycorrhiza* 24: 487–499.
- Ziegler. 1989.** Hydrogen Isotope Fractionation in Plant Tissues. In: Rundel PW, Ehleringer JR, Nagy K, eds. *Stable Isotopes in Ecological Research*. New York, NY: Springer New York, pp 105–123.
- Zimmer K, Hynson NA, Gebauer G, et al. 2007.** Wide geographical and ecological distribution of nitrogen and carbon gains from fungi in pyroloids and monotropoids (Ericaceae) and in orchids. *New Phytologist* 175: 166–175.
- Zizka A, Silvestro D, Andermann T, et al. 2019.** CoordinateCleaner: Standardized cleaning of occurrence records from biological collection databases. *Methods in Ecology and Evolution* 10: 744–751.