Biology and Fertility of Soils (2023) 59:707–708
https://doi.org/10.1007/s00374-023-01732-6

POSITION AND OPINION PAPERS

A rebuttal to "Response to "Feremycorrhizal fungi: A confusing and erroneous term": Feremycorrhiza means 'nearly mycorrhiza'; hence, it is a clear and correct term because the fungal partner has mycorrhizal traits and lineage"

Christopher P. Chanway[1] · Akshit Puri[2,3] · Kiran Preet Padda[1] · Che-Wei Chang[1]

Received: 27 February 2023 / Revised: 16 April 2023 / Accepted: 9 May 2023 / Published online: 16 May 2023

Abstract
Kariman et al. (2023) claim that *Austroboletus occidentalis*, a rhizosphere inhabiting plant growth promoting fungus, should be part of a new group of fungi called "feremycorrhizal fungi", meaning "nearly" mycorrhizal fungi. This fungus does not infect plant roots or require true mycorrhizal fungi to be present while stimulating plant growth through mechanisms identical to several documented plant growth promoting rhizosphere-dwelling fungi. We argue that calling *A. occidentalis* a "feremycorrhizal" fungus makes no sense and is an incorrect and confusing term that should not be used in the scientific literature.

Keywords Feremycorrhizal fungus · Incorrect · Unnecessary · Confusing term

Recently, Kariman et al. (2018) introduced a new term in the scientific literature, "feremycorrhizal" fungus, which refers to a particular rhizosphere-colonizing fungus, *Austroboletus occidentalis,* that stimulates plant growth. We found this term to be unnecessary and confusing due to the myriad rhizosphere-colonizing fungi that also are capable of plant growth promotion and are referred to simply as plant growth promoting rhizosphere fungi (Chanway et al. 2023). In response to our argument, Kariman et al. (2023) suggest that the term "feremycorrhiza" is a clear and correct term because the fungal partner has mycorrhizal traits and lineage. Specifically, they argue that this term is well suited for this symbiosis because: (1) the Australian native fungus *A. occidentalis* phylogenetically belongs to an ectomycorrhizal (ECM) lineage, (2) *A. occidentalis* possesses several established hallmarks of the ECM symbiosis, and (3) *A. occidentalis* does not enter roots and hence does not form any interface structures in the root. Therefore, it is not a fully developed mycorrhiza structurally; it is a 'nearly' mycorrhiza (with mycorrhiza-like effects on plant growth and nutrition).

While we focused on the old English definition of the term "fere", meaning "companion" in our initial argument (Chanway et al., 2023), Kariman et al. (2023) justify their position by focusing on the Latin root of the term "fere", meaning "nearly". Regardless of whether the Latin or the old English definition of "fere" is used, neither definition makes sense to use when describing the fungus in question, *A. occidentalis* (Kariman et al. 2014). We have previously presented arguments why the old English definition "companion" is inappropriate (Chanway et al. 2023), and we argue that using the Latin root is equally meaningless rendering the rationale used by Kariman et al. (2023) invalid. To illustrate this point, consider the re-classification of *Agrobacterium tumefaciens* and *Agrobacterium rhizogenes* (Young et al. 2001). Both species have now been assigned to the genus *Rhizobium*: *R. radiobacter* for *A. tumefaciens* and *R. rhizogenes* for *A. rhizogenes* (Young et al. 2001). Both of these species infect plants as does *Rhizobium* and are phylogenetically related to root nodulating *Rhizobium* species, but they are plant pathogens (Young et al. 2001). Karimam et al. (2023) argue that feremycorrhiza, meaning

✉ Christopher P. Chanway
chris.chanway@ubc.ca

[1] Department of Forest and Conservation Sciences, Faculty of Forestry, University of British Columbia, Vancouver, BC V6T 1Z4, Canada

[2] School of Agriculture and Food Science, University College Dublin, Belfield, Dublin 4, Ireland

[3] UCD Earth Institute, University College Dublin, Belfield, Dublin 4, Ireland

"nearly mycorrhiza", is an appropriate term in part due to the phylogenetic relationship between *A. occidentalis* and an ectomycorrhizal lineage. Using this logic, *Rhizobium radiobacter* should be called a fere root nodule forming bacterium which, of course, it isn't. Phylogenetic relationships are useful to discern evolutionary relationships, but such relationships are clearly not useful from the perspective of microbial function at the species level.

Kariman et al. (2023) also indicate that the purported feremycorrhizal fungus, *A. occidentalis*, possesses several established hallmarks of the ECM symbiosis, though there are no reports of this fungus being capable of entering into a true mycorrhizal relationship with any plant. Similarly, *R. radiobacter* and *R. rhizogenes* possess several established hallmarks of the genus *Rhizobium* that are involved in the root nodule symbiosis. Does this mean that these plant pathogens are fere = nearly root nodule bacteria? Absolutely not.

Finally, Kariman et al. (2023) argue that the purported feremycorrhizal fungus, *A. occidentalis*, is not a fully developed mycorrhiza structurally; it is a 'nearly' mycorrhiza (with mycorrhiza-like effects on plant growth and nutrition) (Kariman et al. 2018). This argument is also spurious, as we have previously argued (Chanway et al. 2023), because many common soil fungi, for example members of the genera *Aspergillus*, *Penicillium* and *Trichoderma* (references in Chanway et al. 2023) as well as *Piriformospora* (Gill et al. 2016), stimulate plant growth through mechanisms similar to those described for *A. occidentalis*. Does this mean that all rhizosphere inhabiting fungi that stimulate plant growth are feremycorrhizal fungi as well? We think not and continue to call for the elimination of the confusing and erroneous term "fere" when describing plant growth promoting fungi and other plant beneficial microorganisms that inhabit the rhizosphere, rhizoplane or root interior.

Declarations

Conflict of Interest The authors declare that they have no conflict of interest

References

Chanway CP, Puri A, Padda KP (2023) Feremycorrhizal fungi: A confusing and erroneous term. Soil Biol Biochem 176:108867. https://doi.org/10.1016/j.soilbio.2022.108867

Gill SS, Ritu Gill DK, Trivedi NA, Anjum KK, Sharma MW, Ansari AA, Ansari AK, Johri RP, Eduarda P, Ajit V, Narendra T (2016) *Piriformospora indica*: potential and significance in plant stress tolerance. Front Microbiol 7: Article 332:1–20. https://doi.org/10.3389/fmicb.2016.00332

Kariman K, Barker SJ, Finnegan PM, Tibbett M (2014) Ecto- and arbuscular mycorrhizal symbiosis can induce tolerance to toxic pulses of phosphorus in jarrah (Eucalyptus marginata) seedlings. Mycorrhiza 24:501–509. https://doi.org/10.1007/s00572-014-0567-6

Kariman K, Barker SJ, Tibbett M (2018) Structural plasticity in root-fungal symbioses: diverse interactions lead to improved plant fitness. PeerJ 6:e6030. https://doi.org/10.7717/peerj.6030

Kariman K, Rengel Z, Rodica P, Rahimlou S, Tibbett M (2023) Response to "Feremycorrhizal fungi: A confusing and erroneous term": Feremycorrhiza means 'nearly mycorrhiza'; hence, it is a clear and correct term because the fungal partner has mycorrhizal traits and lineage. Soil Biol Biochem 177:108934. https://doi.org/10.1016/j.soilbio.2022.108934

Young JM, Kuykendall LD, Martínez-Romero E, Kerr A, Sawada H (2001) A revision of *Rhizobium* Frank 1889, with an emended description of the genus, and the inclusion of all species of *Agrobacterium* Conn 1942 and *Allorhizobium undicola* de Lajudie et al. 1998 as new combinations: *Rhizobium radiobacter*, R. rhizogenes, *R. rubi*, *R. undicola* and *R. vitis*. Int J Syst Evol Microbiol 51:89–103. https://doi.org/10.1099/00207713-51-1-89