



# Misallocation of mycorrhizal traits leads to misleading results

Leho Tedersoo<sup>a,b,1</sup>, Saleh Rahimlou<sup>a</sup>, and Mark Brundrett<sup>c</sup>

Based on a long-term field experiment involving 35 tree species, Sun et al. (1) suggest that mycorrhizal types of plants differ in decomposition rates of leaf litter, but not root litter. Although the authors refer to several publications regarding mycorrhizal status of plants and claim to have performed their own observations, we contest that they have misallocated the mycorrhizal type in many of the woody plants, a fundamental mistake that may invalidate their findings. In particular, we are concerned that 4 species of *Acer*, 2 species of *Ulmus*, *Lonicera praeflorens*, *Aralia elata*, and *Acanthopanax senticosus* were assigned as only or mostly ectomycorrhizal, whereas *Alnus sibirica*, *Corylus mandshurica*, *Salix raddeana*, and 2 species of *Tilia* are misinterpreted as entirely or predominately arbuscular mycorrhizal. Thus, 40% of plants are misallocated in this study, which is an exceptionally high rate even in the context of reported issues in the recent mycorrhizal literature (2, 3). Such errors typically have a small effect on the results when the overall status of natural communities is determined (3, 4). However, in phylogenetic studies and experimental studies such as this, incorrect trait allocations have greater weight and may completely distort the resultant conclusions (5, 6).

To test the influence of mycorrhizal type misallocations in Sun et al.'s (1) paper, we recoded the mycorrhizal types according to recent literature (4, 7–9) and used the mean values from figure 2 of ref. 1. We were only able to test Sun et al.'s principal hypothesis that mycorrhizal types differ in leaf and root decomposition rates, since other data for each species were

not available for reanalysis. Our one-way ANOVA with corrected species allocations revealed that ectomycorrhizal and arbuscular mycorrhizal plants display only slight differences in the rate of leaf litter composition ( $F_{1,33} = 4.919$ ,  $R^2_{\text{adj}} = 0.103$ ,  $P = 0.034$ ) and no differences when accounting for phylogeny ( $F_{1,31} = 2.35$ ,  $R^2_{\text{adj}} = 0.040$ ,  $P = 0.135$ ). This contrasts with the original analysis ( $R^2_{\text{adj}} = 0.225$ ), which appears to be substantially inflated by these errors.

Mistaken mycorrhiza type assignments may come from poor analysis of literature, misidentification of roots during sample collection, or both. Misallocation of 40% of species, most of which have mycorrhizal types well documented in literature, suggests that errors in the examination and diagnosis of roots are the main culprit here. This can easily happen, because beaded first-order roots of some arbuscular mycorrhizal trees can be mistaken for ectomycorrhizal root tips upon superficial observation and roots of trees are heavily intermingled in old forests (10). If this is the case, root samples used for the experiments (1) may also belong to nontarget species, potentially resulting in invalid analyses and interpretation.

Taken together, we argue that authors should pay more attention to mycorrhiza type assignments, because even a few mistakes can affect the results of ecological, physiological, or evolutionary studies, and the inclusion of many errors is certain to severely impact on the validity of conclusions. Prior knowledge of root architecture and morphology and use of a microscope are required to overcome these issues (2, 10).

- 1 T. Sun et al., Contrasting dynamics and trait controls in first-order root compared with leaf litter decomposition. *Proc. Natl. Acad. Sci. U.S.A.* **115**, 10392–10397 (2018).
- 2 M. C. Brundrett, Mycorrhizal associations and other means of nutrition of vascular plants: Understanding global diversity of host plants by resolving conflicting information and developing reliable means of diagnosis. *Plant Soil* **320**, 37–77 (2009).
- 3 M. Brundrett, L. Tedersoo, Misdiagnosis of mycorrhizas and inappropriate recycling of data can lead to false conclusions. *New Phytol.* **221**, 18–24 (2019).
- 4 C. G. Bueno et al., Plant mycorrhizal status, but not type, shifts with latitude and elevation in Europe. *Glob. Ecol. Biogeogr.* **26**, 690–699 (2017).

<sup>a</sup>Natural History Museum, University of Tartu, Tartu 50411, Estonia; <sup>b</sup>Institute of Ecology and Earth Sciences, University of Tartu, Tartu 50411, Estonia; and <sup>c</sup>School of Biological Sciences, University of Western Australia, Crawley, WA 6009, Australia

Author contributions: L.T. designed research; L.T. and M.B. performed research; L.T. contributed new reagents/analytic tools; L.T., S.R., and M.B. analyzed data; and L.T. and M.B. wrote the paper.

The authors declare no conflict of interest.

Published under the [PNAS license](#).

<sup>1</sup>To whom correspondence should be addressed. Email: leho.tedersoo@ut.ee.

Published online June 6, 2019.

- 5 H. Maherali, B. Oberle, P. F. Stevens, W. K. Cornwell, D. J. McGlenn, Mutualism persistence and abandonment during the evolution of the mycorrhizal symbiosis. *Am. Nat.* **188**, E113–E125 (2016).
- 6 J. D. Hoeksema et al., Evolutionary history of plant hosts and fungal symbionts predicts the strength of mycorrhizal mutualism. *Commun. Biol.* **1**, 116 (2018).
- 7 L. Tedersoo, M. Brundrett, Evolution of ectomycorrhizal symbiosis in plants. *Ecol. Stud.* **230**, 407–467 (2017).
- 8 M. C. Brundrett, L. Tedersoo, Evolutionary history of mycorrhizal symbioses and global host plant diversity. *New Phytol.* **220**, 1108–1115 (2018).
- 9 A. A. Akhmetzhanova et al., A rediscovered treasure: Mycorrhizal intensity database for 3000 vascular plant species across the former Soviet Union. *Ecology* **93**, 689–690 (2012).
- 10 M. Brundrett, G. Murase, B. Kendrick, Comparative anatomy of roots and mycorrhizae of common Ontario trees. *Can. J. Bot.* **68**, 551–578 (1990).