Research commentaries

Trait-based approaches in arbuscular mycorrhizal fungi need to distinguish between response and effect traits

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Mycologists usually borrow models or theoretical frameworks from other ecological disciplines to test them in fungal ecology. For example, using models from plant and animal ecology, some attempts intended to classify fungi according to life-history strategies, or functional groups and guilds (Pugh 1980; Urcelay and Robledo 2004; Zanne *et al*. 2019). In this way, species composition in a community is simplified to a few groups or guilds of species sharing similar traits from which we can make some predictions about nature functioning. Importantly, these classifications could be based on "response" traits to environmental changes or "effect" traits on ecosystem processes, and classifications based on response traits could differ from those based on effect traits (Díaz and Cabido 2001; Lavorel and Garnier 2001).

Although there is a large number of studies on the effects of arbuscular mycorrhizal fungi (AMF) on plant nutrition and growth, and even on the composition and productivity of plant communities, we still do not have a clear understanding of the differences in the symbiotic efficiency between species or groups of species in different contexts. Some studies have proposed that developmental traits (as the production of intra- and extraradical hyphae), regenerative traits (as spore size and abundance), and phenology, are phylogenetically conserved (Hart and Reader 2002; Chagnon *et al*. 2013). Therefore,

AMF taxonomic groups in a phylogeny-based classification would roughly correspond to functional groups or guilds based on those traits. Thus, if we know the taxonomic composition of the AMF communities, we can predict their response to the biotic and abiotic environmental changes and their effects on plant communities and ecosystem processes (Van der Heijden and Scheublin 2002; Chagnon *et al*. 2013; Weber *et al*. 2019; Davison *et al*. 2020). In addition, it has been recently proposed a trait-based framework that expands this perspective by considering other traits and distinguishing between plant, fungal, and symbiotic mycorrhizal traits (Chaudhary *et al*. 2022). A common feature of most trait-based frameworks and functional classifications of AMF is that they frequently do not distinguish between response and effect traits. Instead, they indistinctly referred to "traits" and therefore, the proposed groupings do not distinguish between response and effect groups or guilds.

The results of the literature instead show that the traits that might be useful to postulate AMF functional response groups to environmental changes are not useful to postulate AMF functional effect groups on the performance of plants and/or soil processes. For instance, it has been observed that Gigasporales are more sensitive to disturbances such as land use while Glomerales are more resistant or even
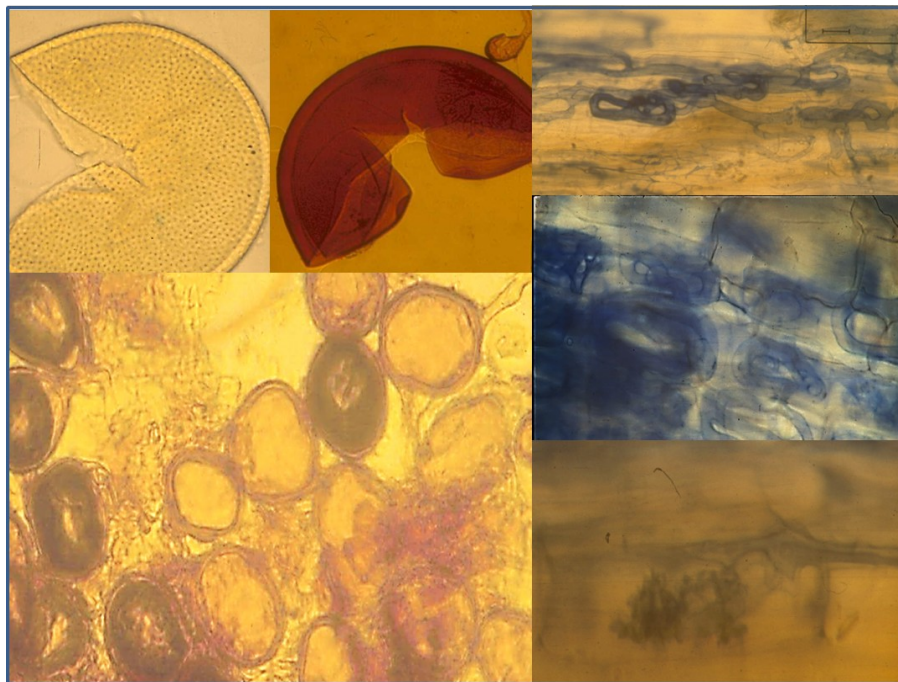
Structures from different Glomeromycota species. By: Nicolás Marro.

favoured (e.g. Jansa *et al*. 2003; Longo *et al*. 2016; Cofré *et al*. 2017). In turn, the Diversisporales, specifically Acaulosporaceae, showed to be more resistant to some stressful conditions such as low pH and low temperatures (Jansa *et al*. 2014; Davison *et al*. 2021). These findings are roughly in line with the above mentioned models. In contrast, a recent meta-analysis showed that the effects of those taxonomic groups on plant performance were not aligned with the predictions derived by the functional classifications based on taxonomic groups (Marro *et al*. 2022). For example, while Gigasporales are predicted to have greater efficiency in plant nutrition (Chagnon *et al*. 2013; Weber *et al*. 2019), the meta-analysis showed that they are more efficient in reducing the adverse effects of biotic stress such as defense against herbivores and pathogens. In turn, Diversisporales (including Acaulosporaceae) have the greatest benefits on plant nutrition and growth under regular conditions (i.e. without stress). A remarkable result that arises from that study is that only a few species of most groups have been studied, which indicates that the knowledge

we have built on this subject could be biased toward those few species (Marro *et al*. 2022).

In our opinion, we might be facing similar challenges that plant ecologists faced a couple of decades ago: the need to recognize traits useful to construct response groups (or guilds) and traits useful for effect groups (Díaz and Cabido 2001; Lavorel and Garnier 2001). In AMF ecology, the evidence thus far, suggests that traits that respond to environmental changes seem not to be the same as those that explain the effects on plant performance and/or ecosystem processes. For instance, the greater extraradical mycelial production and lower spore production that could be related to a higher susceptibility of Gigasporales to soil disturbances do not seem to provide greater access to soil P (and thus higher plant nutrition), as has been suggested based on some evidence (e.g. Chagnon *et al*. 2013). In turn, these traits could be related to soil aggregation (Van der Heijden and Scheublin 2007; Rillig *et al*. 2015), but this remains to be tested. On the other hand, the higher intraradical colonization and spore

production in Glomerales would make this group more resistant to disturbances but not provide greater root protection from plant pathogens or herbivores as has been previously proposed (e.g. Chagnon *et al*. 2013). Apparently, we are still far from knowing which are the traits through which AMF provide different benefits to plants. But what we know is that they are probably not the same as those related to their response to environmental changes.

As has been recently asserted in a previous article in this Newsletter, the ecology of AMF based on functional traits is still in its infancy (Chagnon 2022). There are many AMF species or groups of species that have been little studied or have not been studied at all (Van der Heijden and Scheublin 2007; Chagnon 2022; Marro *et al*. 2022). Therefore, the number of studied species must increase, particularly in those phylogenetic groups that have been poorly studied. This will allow testing for the generality of trait phylogenetic conservatism in AMF and provide more solid bases for assimilating taxonomic groups with functional groups or guilds (Chagnon 2022). In addition, trait-based frameworks should be more inclusive, considering a greater number of traits (Chaudhary *et al*. 2022). Last but not least, trait-based frameworks and functional classifications need to distinguish between "response" and "effect" traits, and within the latter, those that are related to the effects on plant performance and those that affect soil processes. Only after that, the challenges will lie in trying to link functional response groups with functional effects (Lavorel and Garnier 2001) in order to understand the functional diversity maintaining ecosystems functioning.

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