

## Editorial

## Plant trait effects on soil organisms and functions



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## ABSTRACT

Global change alters the composition and functioning of ecosystems by creating novel environmental conditions and thereby selecting for specific traits of organisms. Thus, trait-based approaches are promising tools to more mechanistically understand compositional and functional shifts in ecological communities as well as the dependency of response and effect traits upon global change. Such approaches have been particularly successful for the study of plant communities in terrestrial ecosystems. However, given the intimate linkages between aboveground and belowground compartments as well as the significance of plants as integrating organisms across those compartments, the role of plant traits in affecting soils communities has been understudied. This special issue contains empirical studies and reviews of plant trait effects on soil organisms and functions. Based on those contributions, we discuss plasticity in trait expression, the context-dependency of plant trait effects, time lags in soil biotic responses to trait expression, and limitations of measured plant traits. We conclude that plant trait-based approaches are an important tool to advance soil ecological research, but also identify critical limitations and next steps.

The quest for overarching principles in ecology has advanced trait-based approaches and unprecedented collaborative efforts (e.g., [Kattge et al., 2011](#); [Pey et al., 2014](#); [Iversen et al., 2017](#)) due to their predictive capacity across ecological scales ([Shipley et al., 2016](#)). Plant traits have been successfully utilized to predict the distribution of biodiversity ([Díaz et al., 2016](#)) as well as the functioning of ecosystems ([Kunstler et al., 2016](#)). Thus, plant trait-based approaches have been proposed to also develop a better mechanistic understanding of the composition and functioning of soil communities ([Laliberté, 2016](#); [Eisenhauer et al., 2017](#)), as well as means to translate effects on soil communities to the ecosystem scale ([Powell et al., 2013](#)). In fact, such an improved understanding of aboveground-belowground linkages may allow soil ecologists to derive predictions from plant community characteristics ([Eisenhauer et al., 2017](#)). For instance, [Liu et al. \(2017\)](#) show in this issue that traits related to tree growth explain tree identity and diversity effects on soil respiration in young tree stands. Despite such promising applications, few studies have been conducted to link plant traits to soil communities and functions ([Steinauer et al., 2017](#)).

In a recent review paper, [Laliberté \(2016\)](#) identified six main belowground frontiers in plant trait ecology that are also reflected by contributions to this special issue:

- (1) redefining fine roots as trait data typically is collected on different root orders, which complicates across-study comparisons, syntheses, and thus generalizations ([Steinauer et al., 2017](#));
- (2) quantifying trait dimensionality as it is unclear whether aboveground and belowground traits are coordinated ([Ferlian et al., 2017](#); [Liu et al., 2017](#); [Powell et al., 2017](#));
- (3) integrating mycorrhizal fungi due to their ubiquity and functional importance ([Powell et al., 2017](#); [Donn et al., 2017](#));
- (4) broadening the suite of traits because few belowground traits are typically measured ([Tsunoda and van Dam, 2017](#));
- (5) determining trait-environment linkages due to the limited knowledge regarding trait variation across environmental contexts ([Patoine et al., 2017](#); [Wang et al., 2017](#)); and
- (6) understanding ecosystem-level consequences due to the likely significant effect of root ([Steinauer et al., 2017](#); [Wang et al., 2017](#)) and mycorrhizal traits ([Powell et al., 2017](#)) for determining ecosystem functions like microbial respiration and carbon storage.

In this special issue, we present recent soil ecological case studies using plant traits and their diversity to predict soil functions as well as studies that introduce heretofore rarely considered plant traits in certain contexts, such as plant secondary metabolites in association with rhizosphere ecology ([Tsunoda and van Dam, 2017](#)) and mycorrhizal associations in relation to leaf flammability ([Powell et al., 2017](#)). Taken together, these studies support the notion that plant traits can advance the development of overarching theories in soil ecology ([Bardgett and van der Putten, 2014](#)). Furthermore, there is the increasing awareness that a stronger emphasis on belowground plant traits is required ([Bardgett et al., 2014](#); [Laliberté, 2016](#); [Eisenhauer et al., 2017](#)). However, several studies also exemplify the limitations of traditional trait-based approaches by showing the context-dependency of plant trait effects as well as the plasticity of traits in response to their abiotic and biotic environment. Future research should consider

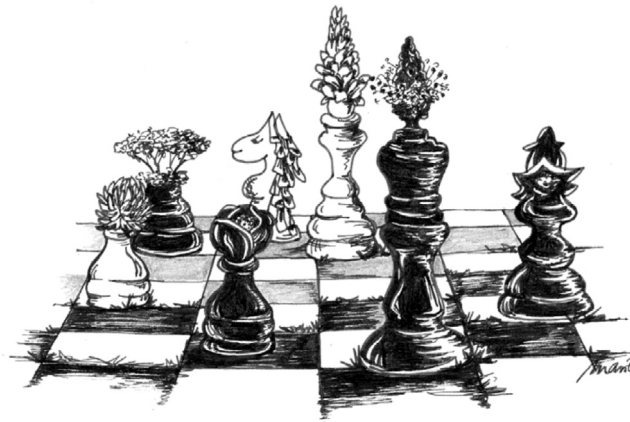


Fig. 1. Schematic illustration of trait plasticity in plants. Plants express traits in plastic ways (alter their strategy) depending on the abiotic and biotic environment, calling for detailed trait measurements in different contexts. Pawns in the game being placed at the wrong positions (colors) indicate that plant traits might shift in unexpected ways, i.e., they may not play according to predicted rules. Drawing by Marit Bodenstern.

and embrace this plasticity and explore the role of soil organisms in co-determining the expression of plant traits.

### 1. Plasticity in trait expression

Plant traits are assumed to predict how plants compete and capture resources (e.g., [Kunstler et al., 2016](#); [Laliberté, 2016](#)), with subsequent consequences for many ecosystem functions. This has resulted in analytical approaches and experiments to predict how ecosystems function (e.g., [Ebeling et al., 2014](#)). However, the extensive use of traits in ecological studies over the last few decades to predict community functions has revealed that morphological plant traits are plastic and respond to various environmental factors ([Laliberté, 2016](#)). As a consequence, some researchers called traits *moving targets* as plants may adjust their resource use strategies depending on the strategies of their competition partners ([Fig. 1](#)). Indeed, studies in the Jena Experiment ([Roscher et al., 2004](#)) have shown that plant species growing in plant communities of differing diversity vary in the expression of functional traits (e.g., [Roscher et al., 2011](#); [Gubsch et al., 2011](#); [Lipowsky et al., 2015](#)).

In the present issue, [Steinauer et al. \(2017\)](#) used a grassland field experiment that manipulated the functional dissimilarity of plant communities based on six traits related to aboveground and belowground resource use as well as plant phenology ([Ebeling et al., 2014](#)) to study soil microbial respiration and biomass. They found that plant species richness and trait diversity effects on soil microbial properties were non-significant over the course of the five-year experiment. However, soil basal respiration and biomass were higher in plant communities with smaller leaves and both denser and shallower root systems than in plant communities with taller plants and sparse root systems four to five years after experimental set-up ([Steinauer et al., 2017](#)). Structural equation modeling revealed many correlations among plant traits and that rooting depth was the most important driver of soil microbial functions, stressing the significance of root traits ([Bardgett et al., 2014](#); [Laliberté, 2016](#)). Despite the targeted experimental design, the explanatory power of the statistical models was low, indicating that slow soil responses to plant community treatments may take several years to materialize and/or that plant traits are plastic and measurements in plant monocultures have limited capacity to predict trait expression in polyculture. Thus, future studies on drivers of belowground communities and functions should consider root traits as well as their plasticity in different biotic and abiotic contexts ([Steinauer et al., 2017](#)).

### 2. Context-dependency of plant trait effects

Trait-based ecology strives to identify general principles (e.g., [Díaz et al., 2016](#); [Kunstler et al., 2016](#)); however, as explained above, traits can be plastic, and trait effects on soil communities can depend on the environmental context. Contributions to this special issue support this context-dependency. Previous studies reported correlations between the stoichiometry of soil microorganisms and stoichiometry of different plant tissues (e.g., [Fanin et al., 2013](#)), although the generality of those relationships is unclear. Here, [Ferlian et al. \(2017\)](#) investigated associations of C and N concentrations between leaf, root, and soil as well as their ratios and soil microbial biomass C and activity (microbial basal respiration and specific respiratory quotient) across 32 young native angiosperm tree species at two locations in central Germany. At both sites, soil C concentrations rather than N concentrations determined significant effects of soil C:N ratio on soil microbial properties, indicating soil stoichiometry to represent a consistent determinant of soil microbial biomass and activity. However, soil microbial properties were not affected by the stoichiometry of plant tissues in the investigated young trees ([Ferlian et al., 2017](#)), which could be due to the relatively young age of the investigated trees or the dominance of soil abiotic effects in certain environments.

Plant trait effects on soil functions can also depend on the biotic context, such as exemplified by the studies by [Patoine et al. \(2017\)](#) and [Wang et al. \(2017\)](#). [Patoine et al. \(2017\)](#) performed a microcosm study to investigate the influence of litter functional traits and diversity as well as two major groups of soil macro-detrivores (earthworms and isopods) on the litter mass loss of tree leaf mixtures. The effect of functional diversity of the litter material was highest in the presence of both macro-detrivore groups ([Patoine et al., 2017](#)), supporting the notion that litter diversity effects are most pronounced in the presence of different detritivore species ([Hättenschwiler and Gasser, 2005](#); [Vos et al., 2011](#)). Notably, these complex interactions among litter traits, diversity, and the macro-detrivore community changed over the course of the experiment. This suggests that the temporal dynamics of litter trait diversity effects and their interaction with detritivore diversity are key to advancing our understanding of litter mass loss in nature.

Moreover, plant trait expression can be significantly affected by soil organisms; for instance, several studies have shown that detritivores can alter nutrient concentrations in plant tissue (e.g., [Partsch et al., 2006](#); [Eisenhauer and Scheu, 2008](#)) as well as plant secondary metabolites (e.g., [Endlweber et al., 2011](#)). [Wang et al. \(2017\)](#) examined decomposition of roots and litter collected from two plant species, *Eriophorum vaginatum*

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