Title: Understanding Taxonomic, Environmental, and Mycorrhizal Influences on Fine-Root Trait Variation Using the Global Fine-Root Ecology Database (FRED)

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Project Abstract: Fine roots (< 2 mm in diameter) perform essential plant functions such as nutrient and water acquisition. Linking plants and the soil, they also play a central role in belowground carbon cycling and storage. However, unlike the leaf economic spectrum, empirical patterns of fine-root trait variation and their relationship to plant strategies remain unclear. The complex pattern of trait covariation in fine roots likely arise due to the multi-dimensional nature of root trait expression, trait relationships with environmental conditions, and the influence of mycorrhizal associations. This study aims to understand the major influences on fine-root trait variation: taxonomy, mycorrhizal association, environmental conditions, and root-branching order. We conducted a hierarchical Bayesian analysis to assess how these factors influence morphological (root diameter, specific root length [SRL], and root tissue density [RTD]) and chemical (nitrogen, phosphorous, and calcium contents) root traits using the from the global Fine-Root Ecology Database (FRED v2.3).
After accounting for inherent variation in root traits among root orders within the root-branch hierarchy, we found that fine-root traits showed clear taxonomic and environmental signals, as well as tradeoffs among traits. Traits such as phosphorous content, RTD, and SRL varied less within species than across species. For example, the medians of standard deviation for standardized phosphorous content values (unitless) were 0.07 (intra-specific) and 0.11-0.48 (inter-specific, depending on mycorrhizal types). Intra-specific variation in many traits, especially morphological traits, was explained by significant association with environmental covariates (mean annual temperature and precipitation). However, the strength of environmental influence on intra-specific variation was small (e.g. taxonomy explained 88% of the variation in root phosphorous content, whereas environmental conditions only explained an additional 0.5%), although this could be related to insufficient within-species trait sampling across the representative range of environmental conditions. Moreover, different mycorrhizal associations modify the strength of the multivariate trait trade-offs across species, which may reflect different strategies for growth and competition belowground. These findings suggest that the major taxonomic-constrained trait groups and trade-off relationships provide a starting point for representing fine-root form and function in ecosystem models, and further investigation on how environmental conditions influence intra-specific variation is needed.