# Plant-soil interactions determine ecosystem aboveground and belowground processes in primary dune ecosystems

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## Summary

Soil biodiversity is of great importance for the maintenance of multifunctionality in terrestrial ecosystems. A growing body of studies has indicated that interactions between plant and soil communities can have important consequences for both aboveground and belowground ecosystem functioning, such as community assembly, nutrient cycling and sensitivity to environmental stresses. However, due to the complexity of belowground biodiversity, novel insights about the combined influences of plant-soil interactions have been rarely empirically examined under realistic field conditions. To cope with this challenge, I used a soil inoculation approach in a field experiment to manipulate soil community composition. This thesis aims to shed light on the impacts of plant-soil interactions on the aboveground and belowground processes in primary dune ecosystems examined with the aid of such manipulation.

In natural ecosystems, arbuscular mycorrhizal (AM) fungi are exposed to an entire suite of soil microbial communities, where changes in abundance and diversity of one microbial guild alter the abundance and functioning of other microbes. Although there is increasing evidence that specific groups of soil organisms affect the symbiotic interactions between plants and AM fungi, the influence of entire soil communities on AM fungal colonization remains poorly understood and empirical field-based studies are lacking. In Chapter 2, the influence of altering entire soil communities on the composition of a community of AM fungi and the subsequent growth of the phytometer plant *P. lanceolata* was assessed in the first year after the soil inoculation treatment. The effects of shifts in the soil community on the composition of the root AM fungal community were detectable whereas the effect on soil AM fungi was not apparent. Additionally, the soil inoculation had no influence on root AM fungal colonization nor the growth of the host plant. These results suggest that the establishment of AM fungi was associated with the structure of the soil community despite the lack of responses in the colonization intensity of the root by AM fungi. Furthermore, in contrast to prior studies that demonstrated the beneficial role of AM fungi on plant performance, our study highlights that the performance of *P. lanceolata* in an early ecosystem is more related to small-scale differences in nutrient availability than to on the colonization of AM fungi.

Climate change predictions indicate that summer droughts will increase in severity and frequency in the coming years. Recent heat waves and drought events in Europe have significantly affected natural ecosystems. In Chapter 3, the influences of soil biota on the drought sensitivity of a plant community were tested during a summer drought event in 2020. In contrast to the prevailing view of positive impacts of highly developed soil communities, we show that soil biota originating from later-successional ecosystems did not improve the stability of plant communities subjected to drought. Added soil biota even reduced plant post-drought recovery. In addition, the distinct soil inocula had differential influences on the

drought sensitivity of individual plant functional groups and individual species. This study provides explicit evidence about the potential adverse role of soil biota in plant-soil interactions under climate change, suggesting that the impacts of the complexity of soil biota on the stability of plant communities are highly context-dependent.

Plant functional traits are increasingly recognized as being impacted by soil abiotic and biotic factors. Though soil conditions are known to control plant functional traits, the impacts of soil biota on between-trait links at the whole plant community level are unknown. In Chapter 4, the effects of alterations in soil biota and abiotic conditions on the suits of community-level plant functional traits relevant to the plant economic spectrum were assessed. In addition, the correlations between these suites of above-belowground traits were evaluated. We found that alteration in soil conditions imposes a strong decoupling in plant community-level leaf and root traits. Altered soil abiotic factors influenced both leaf and root traits at the community level, while altered soil biota only significantly influenced root traits. Herewith we conclude that the dynamics of plant aboveground traits are not necessarily informative of belowground dynamics and associated processes.

An increasing number of studies on plant-soil interactions have provided a foundation to our understanding of the coexistence of aboveground and belowground communities. However, we lack empirical evidence on the directional drivers of plant and soil communities under natural conditions. This poses the so-called “driver or passenger” dilemma: are soil microorganisms driving plant community functioning or do they adapt to the plant community? Based on our field experiment, where the assembly of plant and soil microbial communities was examined annually (Chapter 5), I found that changes in the soil community through soil inoculation induce divergence in soil fungal and bacterial composition. The plant community was also affected by soil inoculation, but there was no difference between the impacts of living vs. sterile inocula. Additionally, there was an increasing correlation between plant and soil microbial composition over time. Together these results suggest that soil microorganisms are “passengers”, and not “drivers” of the ecosystem functioning, i.e they are following the development of the plant community in early successional ecosystems. The results of Chapter 5 provide valuable insights into understanding the coexistence between plant and soil microbial communities which is vitally important for ecosystem management and restoration.

In conclusion, this thesis reveals that soil biota play an important role in determining the growth, stress tolerance and composition of plant communities. Importantly, the effects of plant-soil interactions on ecosystem functions are highly context-dependent and my work underlines the crucial role of biotic factors in determining aboveground and belowground ecosystem processes in primary dune ecosystems. In addition, my results demonstrate that the soil inoculation technique is a useful tool to empirically examine the short-term effects of the entire soil community on plant growth and composition. However, for a better

implementation of soil inoculation practices under natural conditions, the local soil abiotic factors should also be considered, especially under nutrient-limited conditions. Overall, our study provides valuable insights into understanding the impacts of plant-soil interactions on the aboveground and belowground processes at a primary successional stage.