Abstract

Extraradical mycorrhizal hyphae (EMH) are a major driver of the plant – soil C flux in temperate and boreal forests. Numerous studies at more than 140 sites have, hence, quantified EMH production dynamics in these forests. However, field studies on EMH production have mainly been conducted in cold-temperate and boreal forests and only in forests of ectomycorrhizal (ECM) tree species. The **first objective of this dissertation** was to reveal the EMH production dynamics in wide-spread warm-temperate forests of arbuscular mycorrhizal (AM) tree species, specifically in plantation forests of the AM conifer *Chamaecyparis obtusa* (hinoki cypress) in Central Japan.

In **Chapter 2**, I focused on the seasonal variation in EMH production in *C. obtusa* forest plots and compared it to the seasonal variation in EMH production in *Quercus serrata* forest plots (ECM, deciduous broad-leaf). EMH productions of six consecutive two-month periods were estimated from hyphal lengths (HLs) and hyphal carbon masses (HCs) in 360 in-growth bags. Seasonal variations in HL and HC productions of EMH were significant in both forest types but less pronounced in the evergreen *C. obtusa* forest. HL and HC productions of EMH in both forest types were significantly related to air temperature which drives plant C assimilation. The less pronounced seasonal variation in EMH production in the evergreen compared to the deciduous forest and the significant relationship to air temperature, both provide evidence for a coupling of EMH production to plant C assimilation, regardless of the forest or dominating mycorrhizal type.

In **Chapter 3**, I assessed the variation of EMH production by soil depth in two *C. obtusa* stands and its relation to fine root biomass and soil nutrient availabilities. For this, HL productions of EMH were measured in sixteen 30 cm-long in-growth cores and tested for their relationship with fine root biomass and nitrogen (N) and phosphorus (P) availabilities among soil depths with mixed effect modeling. 54 – 57% of the total HL production of EMH was observed in 10 – 30 cm soil depth. HL production of EMH among soil depths was significantly positively and negatively affected by fine root biomass and soil available P content, respectively. Results highlight the significance of EMH production in greater soil depths of warm-temperate forests of AM tree species and provide evidence for an increased C-investment of AM plants to EMH where available P is scarce.

Understanding how EMH affect the cycling and retention of plant-assimilated C in forest soils requires field observations of the mortality and decomposition of produced EMH. A few recent studies have parallelly estimated EMH production, mortality, and decomposition. To do this, mass-balance models in combination with in-growth bags were used. However, poor knowledge on the decomposition of field-grown EMH, derived mainly from short-term studies with laboratory-grown EMH prevents confirmation of assumed EMH decomposition dynamics and how they may affect estimates of EMH production and decomposition. The **second objective of this dissertation** was to reveal the decomposition dynamics of EMH in a *C. obtusa* plantation forest.

In **Chapter 4**, I observed the decrease in hyphal length of field-grown EMH over 2 – 8 month periods in 88 in-growth bags inserted in a warm-temperate *C. obtusa* forest. Decomposition models were used to assess the variation in the decomposition rate of EMH over the time following in-growth bag insertion, between EMH diameter classes, and between seasons of in-growth bag insertion. A rapid decrease of the decomposition rate of EMH within months was estimated from 2.5 to 0.1 $month^{-1}$. Furthermore, significant variation of the initial maximum decomposition rate was estimated between fine (1.6 $month^{-1}$) and coarse EMH (3.1 $month^{-1}$) and between in-growth bag insertions in October and February (2.7 $month^{-1}$) and April and August (1.1 $month^{-1}$). Results indicate a large variability of the decomposition dynamics of field-grown EMH which needs to be observed in the field and accounted for in mass-balance models to estimate EMH production, mortality, and decomposition in forest soils.

In **Chapter 5**, I estimated EMH production, mortality, and decomposition over three two-month intervals with two mass-balance models, one that assumed that all dead EMH (*N*) in in-growth bags decomposed with the same constant decomposition rate and one that assumed *N*-cohorts that had different decomposition rates depending on the interval of EMH death. In the former model, 32 – 74% of produced EMH were estimated to decompose within two months. In the latter model, 9 – 51% of produced EMH were estimated to decompose within two months. Different assumptions on EMH decomposition, hence, led to a considerable, though statistically insignificant, difference in the estimated EMH decomposition. Regardless of which mass-balance model was used, large fractions of produced EMH died and decomposed rapidly, suggesting EMH production and decomposition as important drivers for the cycling of plant-assimilated C through the forest soil.

Overall, this dissertation provides, for the first time, a comprehensive overview of production and decomposition dynamics of EMH in warm-temperate forests of AM tree species. Assuming an EMH production of 2.4 g C m^{-2} $year^{-1}$ in 0 – 10 cm soil depth and an evenly large EMH production in 10 – 30 cm soil depth, EMH production accounted for ca. 3 – 5% of the below-ground net primary production (NPP) in *C. obtusa* plots of Ryukoku Forest. This contribution is at a similar level as the one estimated for the EMH production in boreal and cold-temperate forests of ECM tree species of 9%. At the same time, the C cycling by EMH was highly variable and rapid: EMH production showed large seasonal variation in response to plant C assimilation, produced EMH, in turn, died within weeks or months and decomposed within days or weeks. EMH production and decomposition, hence, may hardly be ignored as driving processes of the cycling of plant-assimilated C into and through the soil of forests of AM tree species and must be further studied for understanding and predicting the C cycling dynamics in respective forests.