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Plant succession and rhizosphere microbial communities in a recently deglaciated alpine terrain

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Summary

This study describes how early and late successional plant species affect soil microorganisms in alpine ecosystems. We quantify the relative importance of plant species and soil properties as determinants of belowground microbial communities. Sixteen plant species were selected from six successional stages (4–14–20–43–75–135 years) within the foreland of the Rotmoosferner glacier, Austria, and at one (reference) site outside the foreland. The size, composition and function of the communities of microorganism in the bulk soil and the rhizosphere were characterized by ninhydrin-reactive nitrogen, phospholipid fatty acids and enzyme activities (β-glucosidase, β-xylosidase, *N*-acetyl-β-glucosaminidase, leucine aminopeptidase, acid phosphatase, sulphatase). The results show that the microbial data could be grouped according to early (up to 43 years) and late-colonizing plant species (75 or more years). In early succession, no plant species or soil age effect was detected on the microbial biomass, phospholipid fatty acids, or enzyme activity. The rhizosphere microbial community was similar to that in the bulk soil, which in turn was determined by the abiotic environmental conditions. In late succession, improved soil conditions probably mediated plant species effects on the belowground microbial community. The most pronounced rhizosphere effects were attributed to plant species of the 75- and 135-year-old sites. The microbial colonization (size, composition, activity) of the bulk soil predominantly followed changes in vegetation cover, plant life forms and soil

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organic matter. In summary, the observed successional pattern of the above- and belowground communities provides an example of the facilitation models of primary succession.

Zusammenfassung

Ziel dieser Arbeit ist die Charakterisierung der Rhizosphärenmikroorganismen von Pionier- und Folgearten entlang des Rotmoosferner Gletschervorfeldes im Ötztal, Österreich. Sechs Standorte innerhalb (Alter: 4–14–20–43–75–135 Jahre) und ein Standort ausserhalb des Gletschervorfeldes (Referenz) und 16 Pflanzenarten wurden unter dem Aspekt der fortschreitenden Sukzession ausgewählt, und Rhizosphärenboden der für das jeweilige Sukzessionsstadium representativen Pflanzenarten, sowie der Gesamtboden beprobt. Die mikrobielle Gemeinschaftsstruktur wurde anhand von Phospholipidfettsäuremustern, mikrobielle Umsetzungsraten anhand von Enzymmessungen (β-Glucosidase, β-Xylosidase, *N*-Acetyl-β-Glucosaminidase, Leucin-Aminopeptidase, saure Phosphatase, Sulfatase) mittels fluorogener Substrate charakterisiert. Innerhalb der ersten 43 Sukzessionsjahre konnte kein artspezifischer Effekt auf die mikrobielle Rhizosphärengemeinschaft nachgewiesen werden. Die Aktivität und Zusammensetzung wurde überwiegend von den extremen abiotischen Standortsbedingungen geprägt. Ab 75 Sukzessionsjahren konnte aufgrund verbesserter Boden- und Nährstoffbedingungen ein pflanzenspezifischer Einfluss auf die mikrobielle Gemeinschaft nachgewiesen werden. Der stärkste Rhizosphäreneffekt wurde auf den 75- und 135 Jahre alten Standorten beobachtet. Die mikrobielle Kolonisierung des Bodens wurde durch die Vegetationsbedeckung, die Lebensformen und vom Humusgehalt bestimmt.

Introduction

In the Alps, primary succession on glacier forelands has been frequently studied since the 19th century, and vegetation development along the chronosequences has been described. The processes of primary succession; however, remain incompletely understood. Grime (2001) identified three primary plant strategies: competitors (C), stress-tolerators (S) and ruderals (R) and suggested according to his CSR model that shifting equilibria between competition, mineral nutrient stress, and disturbance are determinants of vegetation composition in primary succession. On a more plant-specific level, Callaway, Brooker, Choler, Kikvidze, Lortie, et al. (2002) proposed a model in which facilitative interactions among alpine plant communities predominate when abiotic conditions are harsh, but that competitive interactions predominate when abiotic conditions are less stressful. Both concepts provide an example of the facilitation model of vegetation succession (Connell & Slatyer, 1977). How this shift in plant species composition and interaction in primary succession affects the plant–microbial interface has received little attention, although soil colonization and the establishment of plants may depend on this process (Allen, Allen, Zink, Harney, Yoshida, et al., 1999). The species of plant is known to affect the composition of the rhizosphere microbial community (Fang, Radosevich, & Fuhrmann, 2001; Marschner, Yang, Lieberei, & Crowley, 2001; Kuske, Ticknor, Miller, Dunbar, Davis, et al., 2002; Knauff, Schulz, & Scherer, 2003). The composition and activity of the soil microbiota along primary successional gradients of glacier forelands have also been characterized (Ohtonen, Fritze, Pennanen, Jumpponen, & Trappe, 1999; Schipper, Degens, Sparling, & Duncan, 2001; Sigler, Crivii, & Zeyer, 2002; Tscherko, Rustemeier, Richter, Wanek, & Kandeler, 2003). Much less is known about the microbial colonization of rhizospheres in primary succession. Only two studies have investigated the impact of colonizing plants on microbial community growth and composition on recently deglaciated terrain (Bardgett & Walker, 2004; Tscherko, Hammesfahr, Marx, & Kandeler, 2004). To date, however, no attempt has been made to study microbial populations in the rhizosphere of plants exposed to environmental gradients such as increasing species richness and soil productivity in alpine landscapes.

The aim of this study is therefore to compare the rhizosphere microorganisms of successional plant species along a vegetational gradient of recently deglaciated terrain. Based on the models proposed by Grime (2001) and Callaway et al. (2002), we specifically investigated (i) the impact of successional plant species on the soil microbial