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Response of oribatid mites to reforestation of degraded tropical montane pastureland

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ABSTRACT

Tropical montane forests are being turned into pastures for cattle at an unprecedented rate. However, efforts are being made to reforest pastures in particular if invaded by weeds of low nutritional value, but until today little is known on the response of the decomposer system to reforestation. We focused on the response of soil fauna, specifically oribatid mites, which play an important role in the breakdown of organic matter. In the south Ecuadorian Andes we chose two sites with distinct vegetation: one pasture site invaded by *Setaria sphacelata* (grass pasture) and another invaded by *Pteridium arachnoideum* (bracken pasture). At both sites plots reforested with native (*Alnus accuminata*) and exotic tree species (*Pinus patula* and *Eucalyptus saligna*) were established. We hypothesized that oribatid mite abundance, species richness and community structure differ between reforestation treatments. To identify driving factors for oribatid mite community structure, we measured environmental variables, e.g. C-to-N ratio, water content, and microbial biomass. Overall, 65 species of oribatid mites were found with small species such as Suctobelbidae and *Rostrozetes ovulum* dominating. In contrast to our hypotheses, the abundance and species richness of oribatid mites differed more between pasture types than between reforestation treatments. This resembled the response of soil microbial biomass. Presumably, the duration of the experiment of seven years was too short to allow establishment of forest specific oribatid mite and microbial communities, suggesting that oribatid mites and microorganisms respond slowly to reforestation and changes in plant cover, reflecting long lasting legacy effects of previous land use.

1. Introduction

The Andean region of Ecuador harbours a vast biodiversity but also faces the highest deforestation rate of South America [1], mainly due to the expansion of pastureland for cattle grazing [2]. Tropical montane forests in the south of Ecuador are characterized by an exceptionally high diversity of plants and animals. Large regions of the native rainforest are converted into pastureland or meadows; however, recently efforts are being made to turn pastureland back into rainforests [3–5]. Unfortunately, regrowth of trees and afforestation of pastures is hampered by frequent burning and also by invasion by *Setaria sphacelata* (South African pigeon grass) and *Pteridium arachnoideum* (bracken fern), both aggressive weeds, resulting in further degradation of pastures. Due to variable and robust rhizomes and fast propagation, these degraded pastures resist mechanical, herbicidal and biological control [6,7].

Reforestation of degraded pastures in the south of Ecuador started in the 1970′s. Most of the forest plantations consisted of introduced tree species, mainly *Eucalyptus* spp. and *Pinus* spp. From a conservation perspective, these species are problematic as their plantations result in the homogenization of the landscape, and their effect on the diversity of native plants and animals remains unknown, but being exotic species, the effect may be detrimental rather than beneficial. Indeed, the plantations are prone to fires and attack by pathogens [1].

Soils perform several functions that support ecosystem services, such as provision of nutrients and water for plant growth. In terrestrial ecosystems up to 90% of the net primary production enters the decomposer system as detritus [8] and forms the source of energy and nutrients for soil microorganisms and decomposer soil fauna. Decomposition processes and mineralization of nutrients rely on the combined

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action of decomposer invertebrates and microorganisms, the belowground communities. These communities comprise a vast diversity of fungi, bacteria, meso- and macrofauna, which depend on plant resources, such as leaf litter and root exudates, which are abundant in forests and tree plantations. Generally, the diversity of soil meso- and macrofauna in forests and tree plantations exceeds that of grasslands [8,9], presumably due to pronounced organic layers in forests. However, the effect of reforestation of degraded and abandoned pastures on soil animal communities has received little attention until today and this applies in particular to the tropics. Among the decomposer mesofauna, oribatid mites are one of the dominant groups reaching densities of > 100,000 individuals per square meter in humus rich temperate and boreal forests [10,11]. Oribatid mites contribute to the breakdown of organic matter and affect microbial activity [12–16].

Here, we investigated the effects of reforestation of abandoned pastures in the southern Ecuadorian Andes on oribatid mite abundance, species richness and community structure. The tree species used for reforestation included one native species (alder - *Alnus acuminata*) and two exotic species (pine - *Pinus patula* and eucalypt - *Eucalyptus saligna*). One of the study sites was dominated by pigeon grass and the other infested by bracken fern. We also studied if reforestation of abandoned pastures affects microbial activity and environmental factors (C-to-N ratio, water content) in litter and soil.

We hypothesized that oribatid mite community structure is affected primarily by the tree species used for reforestation, independent of pasture type (pigeon grass *vs*. bracken pasture), as forests typically harbour higher abundances of soil mesofauna than pastures [17,18]. Further, we hypothesized that the effects of reforestation with native alder on oribatid mite communities will exceed those of reforestation with exotic pine and eucalypt due to high litter quality (C-to-N ratio) of alder as compared to pine and eucalypt being rich in plant secondary compounds and having thicker leaves/needles.

2. Materials and methods

2.1. Study sites and biophysical conditions

We used two abandoned pasture sites near the Reserva Biológica San Francisco (RBSF) located in the southeast of the Ecuadorian Andes between the city of Loja and Zamora (3° 58′ 27″ S, 79° 4′ 70″ W) close to the Podocarpus National Park. The sites are located at south facing slopes at 1800–2100 m a.s.l. (Fig. 1). The climate in this Andean region is tropical humid with eleven humid months per year. Mean annual rainfall is 2176 mm with humid months between April and July and more dry months between September and December. Mean annual temperature is 15.5 °C [19].

In 2003 a reforestation experiment was started at two sites: (1) pasture sites dominated by the South African pigeon grass (*S. sphacelata*) and other grass species, in particular *Melinis minutiflora* and *Axonopus compressus*, and (2) pastures invaded by bracken fern *P. arachnoideum* and other plant species like *Ageratina dendroides* and *Baccharis latifolia*. Both sites were reforested with one native (*A. acuminata*) and two exotic tree species (*P. patula* and *E. saligna*) both widely used for reforestation in Ecuador. Soils at the study sites are characterized as cambisols, podzols and gleysols, typically affected by landslides [1].

2.2. Experimental design

The experiment was set up as randomized complete block design, with pasture types as blocks. Both blocks were at similar altitude, climatic conditions and soil types, with the distances between each being less than 3 km. In each block, four treatments were established: (1) control without reforestation, and reforestation with (2) alder, (3) pine and (4) eucalypt. Four replicates were set up per treatment resulting in a total of 32 plots. The pasture sites were about 600 m apart from each other. Samples for analyzing oribatid mites and microbial parameters were taken in October 2010. Samples were taken at least 50 m apart from each other.

2.3. Environmental factors

C and N content of litter and soil was measured from samples taken with a soil corer (5 cm diameter), with each core being divided into O horizon (litter) and Ah horizon (5 cm of mineral soil underneath the litter layer); the samples were analyzed using a C/N elemental analyzer (Vario EL III, elementar, Hanau, Germany). From the soil cores also the thickness of the O horizon was measured. Water content (%) in litter and soil was measured from aliquots dried at 60° for two days.

2.4. Microbial activity

Using the same soil corer, three additional soil samples were taken for microbial analyses. Samples were divided in litter and soil as described above, placed in plastic bags and stored at 4 °C until further processing. Prior to measurement, an aliquot of litter was cut into pieces < 0.5 mm^2 and the soil was sieved through 2 mm mesh and mixed thoroughly. After homogenization, the samples were left to equilibrate at room temperature for three days. Then, subsamples equivalent to ca. 0.5 and 5 g dry weight of litter and soil, respectively, were placed into glass vessels to measure microbial O_2 consumption at 22 °C (basal respiration, BR; μg O_2 g^{-1} dw h^{-1}) using an O_2 microcompensation apparatus [20]; readings were taken every hour during a 24 h period. Microbial biomass was measured by substrate-induced respiration (SIR) after the addition of glucose to saturate the catabolic activity of microorganisms [21,22]. Microbial biomass was calculated from the maximum initial respiratory response (MIRR; μl O_2 g^{-1} dw h^{-1}) as $C_{mic} = 38 \times$ MIRR (μg C_{mic} g^{-1} dw [23,24]).

2.5. Oribatid mites

For the analysis of soil oribatid mites, one soil core of 5 cm diameter was taken in each plot, and divided into litter and soil as described above. Soil animals were extracted by heat for ten days. During extraction the temperature was increased gradually from 30 to 40 °C [25]. Oribatid mites were identified to species level whenever possible using the keys of Balogh and Balogh (1988) [26]; species names follow Subias (2004) [27]). Reproductive mode of oribatid mites was ascribed to the species according to Norton et al. (1993) [28], Cianciolo and Norton 2006 [29] and Domes-Wehner 2009 [30]. If the reproductive mode was not known we inferred it from closely related species of the same genus.

2.6. Statistical analysis

Soil characteristics (C-to-N ratio, water content), microbial activity (BR and C_{mic}) and oribatid mite abundance, species richness and reproductive mode were analyzed using randomized complete block analysis of variance (ANOVA) with pasture type as block and reforestation treatments as independent factor; in case of significant treatment effects post-hoc tests were performed (Tukey's honestly significant difference test; HSD). To compare oribatid mite community composition we used non-metric multidimensional scaling (NMDS). Using the four axes from the NMDS as dependent variables, multivariate analysis of variance (MANOVA) was used to test if pasture type or reforestation sites influenced oribatid mite community structure. Interrelationships between environmental factors and oribatid mite community structure were inspected using canonical correspondence analysis (CCA) with pasture type and reforestation treatments included as passive variables not affecting the ordination; we considered species present in at least three independent samples and environmental variables (log-transformed) which significantly differed among treatments or pasture type (as indicated by ANOVA; $p < 0.05$). For CCA we used CANOCO 5.02,