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# What role do plant–soil interactions play in the habitat suitability and potential range expansion of the alpine dwarf shrub *Salix herbacea*?

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## Abstract

Mountain plants may respond to warming climates by migrating along altitudinal gradients or, because climatic conditions on mountain slopes can be locally very heterogeneous, by migrating to different microhabitats at the same altitude. However, in new environments, plants may also encounter novel soil microbial communities, which might affect their establishment success. Thus, biotic interactions could be a key factor in plant responses to climate change. Here, we investigated the role of plant–soil feedback for the establishment success of the alpine dwarf shrub *Salix herbacea* L. across altitudes and late- and early snowmelt microhabitats. We collected *S. herbacea* seeds and soil from nine plots on three mountain-slope transects near Davos, Switzerland, and we transplanted seeds and seedlings to substrate inoculated with soil from the same plot or with soils from different microhabitats, altitudes and mountains under greenhouse conditions. We found that, on average, seeds from higher altitudes (2400–2700 m) and late-exposed snowbeds germinated better than seeds from lower altitudes (2200–2300 m) and early-exposed ridges. However, despite these differences in germination, growth was generally higher for plants from low altitudes, and there were no indications for a an home-soil advantage within the current range of *S. herbacea*. Interestingly, seedlings growing on soil from above the current altitudinal distribution of *S. herbacea* grew on average less well than on their own soil. Thus, although the lack of a home-soil advantage in the current habitat might be beneficial for *S. herbacea* in a changing environment, migration to habitats beyond the current altitudinal range might be limited, probably due to missing positive soil-feedback.

## Zusammenfassung

Pflanzen in Gebirgen können sich an ein wämeres Klima anpassen, indem sie entweder in andere Höhenlagen, oder, da die klimatischen Bedingungen an Gebirgshängen lokal sehr heterogen sein können, in unterschiedliche Mikrohabitate auf gleicher Höhe wandern. An neuen Standorten treffen Pflanzen auch neuartige Gesellschaften von Bodenorganismen an, welche deren

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Etablierung beeinflussen können. Biotische Interaktionen stellen deshalb einen möglicher Schlüsselfaktor bei der Anpassung von Pflanzen an den Klimawandeld dar. In unsererem Experiment untersuchen wir, welche Rolle das Pflanze-Boden-Feedback für die Etablierung des Alpinen Zwergstrauchs *Salix herbacea* L. entlang eines Höhengradienten und zwischen Mikrohabitaten mit früher und später Schneeschmelze spielt. Wir haben Samen von *S. herbacea* und Bodenmaterial an neun Standorten gesammelt, die auf Transekte an drei Bergen in der Nähe von Davos, Schweiz, verteilt waren. Unter Gewächshausbedingungen haben wir die Samen und Keimlinge in Substrat verpflanzt, das mit dem Boden desselben Standorts oder mit dem Boden von unterschiedlichen Mikrohabitaten, Höhenstufen und Bergen inokuliert wurde. Unsere Ergebnisse zeigen, dass Samen von hohen Standorten (2400-2700 m) und von spät ausapernden Schneetälchen durchschnittlich besser keimten als Samen von niedrigen Standorten (2200-2300 m) und früh ausapernden Kämmen. Trotz dieser Unterschiede in der Keimung, war das Wachstum von Pflanzen von niedrigen Standorten im Allgemeinen stärker. Innerhalb des heutigen Verbreitungsgebiets von *S. herbacea* konnten wir keine Hinweise darauf finden, dass Pflanzen einen Vorteil hatten, wenn sie auf Substrat vom eigenen Standort wuchsen. Interessanterweise wuchsen Keimlinge auf Substrat von überhalb des heutigen Verbreitungsgebietes, schlechter als auf Substrat vom eigenen Standort. Obwohl das Fehlen eines Heim-Boden-Vorteils für *S. herbacea* unter sich ändernden Umweltbedingungen möglicherweise von Vorteil ist, könnte die Migration zu Standorten überhalb des heutigen Verbreitungsgebietes, aufgrund von fehlendem positivem Pflanze-Boden-Feedback, eingeschränkt sein.


***Keywords:*** Biotic interaction; Range limit; Elevation; Genetic differentiation; Microhabitat; Microtopography; Migration; Snowmelt gradient; Soil feedback

## Introduction

Over the last 100 years, the global surface temperature has increased by 0.7 °C (Stocker, Qin, Platner, Tignor, & Allen, 2013) with the most pronounced temperature increases in the arctic and alpine regions by 2 °C (EEA, 2009). For these regions, climate models predict further increases in temperatures and precipitation, in the form of rain rather than snow, resulting in fewer days with snow cover, particularly in spring (Beniston, Keller, Koffi, & Goyette, 2003). As a result, 36–55% of European alpine plant species have been predicted to lose more than 80% of their suitable habitat by 2070–2100 (Engler, Randin, Thuiller, Dullinger, & Zimmermann, 2011). However there are many uncertainties surrounding these projections, since most of them are based on observed correlations between abiotic environmental factors and species occurrences, and ignore potentially important mechanisms of plant response to climate change (Thuiller, Albert, Araújo, Berry, & Cabeza, 2008).

There are many studies showing clear evidence that species are already migrating along altitudinal and/or latitudinal gradients as a consequence of climate change (reviewed in Chen, Hill, Ohlemüller, Roy, & Thomas, 2011). For example, a recent study by Pauli, Gottfried, and Dullinger (2012) showed that, because of upward migration, species richness of European mountain summits has increased by 3.9 species on average between 2001 and 2008. Climatic and other environmental conditions, however, do not only change across latitude and altitude, but also across microhabitats. This is especially true in mountain ecosystems, where microtopography is extremely heterogenous, even over distances of a few metres, resulting in small-scale variation in temperatures and snowmelt timing (Körner, 2003; Scherrer & Körner, 2011). This small-scale variation could explain why observed elevational shifts in contrast to latitudinal shifts lag behind the expected shifts of plant species (Chen et al., 2011). Therefore, not only altitudinal but also microhabitat shifts could provide opportunities for alpine plant species to escape warming climates (Scherrer & Körner, 2011).

The ability of a plant to successfully establish in a new habitat depends on how it deals with both climatic conditions and biotic factors. A home-site advantage of plants has been reported for various abiotic factors, e.g. along altitudinal gradients with different climatic conditions (Byars, Papst, & Hoffmann, 2007; Gonzalo-Turpin & Hazard, 2009) or habitats with different soil conditions (Sambatti & Rice, 2006). However, home-site advantages with respect to biotic interactions have rarely been studied (but see: Macel, Lawson, Mortimer, Smilauerova, Bischoff, et al., 2007; Grassein, Lavorel, & Till-Bottraud, 2014). Biotic factors that influence colonization success in new habitats include interactions with pollinators, herbivores, inter- and intraspecific competitors, pathogens and soil microbes (Tylianakis, Didham, Bascompte, & Wardle, 2008; Van der Putten, Macel, & Visser, 2010). Specifically, many soil microbes have negative effects on plant performance and act as pathogens, but others have positive effects on plants, e.g. by improving nutrient accessibility and uptake for the plant. A home-site advantage could emerge either because plants adapt to the local microbes or because plants select the most beneficial microbes. A home-site advantage may be disrupted when plant species shift their altitudinal range, migrate to other microhabitats or when soil microbial communities are altered due to climate change (Van Grunsven, van Der Putten, Bezemer, Tamis, & Berendse, 2007; Van der Putten, Bardgett, Bever, Bezemer, & Casper, 2013). Therefore, in order to be able to predict