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Experimental evidence for a delayed response of the above-ground vegetation and the seed bank to the invasion of an annual exotic plant in deciduous forests

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Abstract

Invasions by alien plants significantly affect native biodiversity and ecosystem functioning. We conducted a 5-year field experiment to investigate potential effects of the annual invasive plant *Impatiens glandulifera* on both the native above-ground vegetation and the soil seed bank in a deciduous forest in Switzerland. Eight years after the establishment of *I. glandulifera*, we set up plots in patches invaded by the alien plant, in plots from which the invasive plant had been manually removed and in plots which were not yet colonized by the invasive plant. We examined plant species richness, diversity and plant species composition in the above-ground vegetation and soil seed bank in all plots one year and five years after the initiation of the experiment. The 36 plots (3 plot types × 6 replicates × 2 sites) were equally distributed over two forest sites. Neither the native above-ground vegetation nor the soil seed bank was influenced by the presence of *I. glandulifera* one year after the start of the field experiment. After five years, however, plant species richness of both the above-ground vegetation and the soil seed bank was reduced by 25% and 30%, respectively, in plots invaded by the alien plant compared to plots from which *I. glandulifera* had been removed or uninvaded plots. Furthermore, plots invaded by the alien plant had a lower total seedling density (reduction by 60%) and an altered plant species composition in the soil seed bank compared to control plots. Our field experiment indicates that negative effects of the annual invasive plant on the native above-ground vegetation and soil seed bank of deciduous forests become visible with a delay of several years.

Zusammenfassung

Die schnelle Ausbreitung invasiver Pflanzenarten kann die einheimische Biodiversität und die Ökosystemfunktionen negativ beeinflussen. Wir führten ein fünf Jahre dauerndes Feldexperiment durch, in welchem der potenzielle Einfluss der einjährigen invasiven Pflanze *Impatiens glandulifera* (Drüsiges Springkraut) auf die einheimische Vegetation und die vorhandene Samenbank in einem Laubmischwald in der Schweiz untersucht wurde. Acht Jahre nachdem die invasive Pflanze den Wald besiedelt hatte, installierten wir Untersuchungsflächen in Beständen von *I. glandulifera*, in Flächen in denen die invasive Art regelmässig von Hand entfernt wurde und in Flächen, welche noch nicht von der invasiven Art besiedelt waren. Die 36 Untersuchungsflächen (3 Typen × 6 Wiederholungen × 2 Standorte) waren gleichmässig über 2 Waldgebiete verteilt. Ein Jahr sowie 5 Jahre nach Beginn des Feldexperimentes erfassten wir die Anzahl Pflanzenarten, die Vielfalt und Zusammensetzung der Arten sowohl in der Bodenvegetation als auch in der Samenbank. Nach einem Jahr konnte kein Einfluss von *I. glandulifera* auf die Bodenvegetation und die Samenbank nachgewiesen werden. Nach einer Experimentdauer von 5 Jahren war hingegen die Anzahl Arten in der

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Bodenvegetation in den Untersuchungsflächen mit der invasiven Art um 25% und diejenige in der Samenbank um 30% reduziert im Vergleich zu den Untersuchungsflächen aus welchen die invasive Art entfernt wurde und den Untersuchungsflächen, welche noch nicht von invasiven Pflanzen besiedelt waren. Zudem wiesen Untersuchungsflächen mit *I. glandulifera* eine reduzierte Keimlingsdichte von einheimischen Arten (60%) und veränderte Artenzusammensetzung in der Samenbank im Vergleich zu den Kontrollflächen auf. Unser Feldexperiment zeigt, dass negative Effekte des einjährigen invasiven Springkrautes auf die Vegetation und auf die Samenbank erst mit einer Verzögerung von mehreren Jahren sichtbar wurden.

Keywords: Annual invasive plant species; Disturbance; *Impatiens glandulifera*; Temperate deciduous forest; Time-dependent

Introduction

The invasion of non-native plant species is considered as major threat to native biodiversity (Pimentel, Zuniga, & Morrison 2005; Pejchar & Mooney 2009). There is ample evidence for negative effects of invasive plants on the diversity and species composition of native plant communities, the reproductive output of plants and dispersal of propagules (e.g., Miller & Gorchov 2004; Vila et al. 2011; Stoll, Gatzsch, Rusterholz, & Baur 2012; Jauni & Ramula 2015). The potential impact of invasive plant species on the soil seed bank, however, has received less attention (Gioria, Pysek, & Moravcova 2012; Gioria, Jarosik, & Pysek 2014).

Soil seed banks are reservoirs of biodiversity (Leck, Parker, & Simpson 1989), representing important sources for the recovery of native vegetation following natural and/or human-caused disturbances (Bossuyt & Honnay 2008). The resilience of plant communities to environmental changes depends on both species richness and abundance of seeds in the soil seed bank (Tererai, Gaertner, Jacobs, & Richardson 2015). Furthermore, the soil seed bank is a source of genetic diversity for the plant species in a given habitat (Hanin, Quaye, Westberg, & Barazani 2013).

The impact of an invasive plant on the soil seed bank may differ from that on the above-ground vegetation due to different interactions between biotic and abiotic factors (Gioria et al. 2014; Ferreras, Giorgis, Tecco, Cabido, & Funes 2015). Dense stands of invasive plants may negatively affect the survival and/or flowering probability of co-occurring native plants and thus reduce their reproductive output (e.g., D'Antonio, Hughes, Mack, Hitchcock, & Vitousek 1998; Jauni & Ramula 2015). Furthermore, invasive plants have the potential to outcompete pollinators of native plants, which may reduce their seed set (Morales & Traveset 2009). Dense stands of invasive plants can also inhibit seed dispersal of native plants (Gioria, Dieterich, & Osborne 2011). Furthermore, invasive plants may indirectly modify abiotic habitat characteristics such as physical and chemical soil properties (e.g., soil moisture and/or soil nutrients), important factors determining the survival of seeds in the soil seed bank (Bewley & Black 1994). The exudation of allelochemical compounds released from invasive plants into the soil can also reduce the germination of native seeds (Greer, Wilson, Hickman, & Wilson 2014; Ruckli, Hesse, Glauser, Rusterholz, & Baur 2014).

The soil seed bank may react with a delay to the invasion of alien plants (Wearne & Morgan 2006). However, the majority of studies investigating the impact of invasive plants considered only short-term effects on the species richness and species composition of native plants at a particular invasion stage. A repeated assessment of the potential impact of invasive plants over a longer period provides additional knowledge on time-dependent processes of invasions. This can be best done in experimental field studies with adequate controls that rule out potential differences in plant performance as well as in historical and initial conditions between invaded and uninvaded sites (Hulme & Bremner 2006; Nienhuis, Dietzsch, & Stout 2009).

The aim of this study was to examine the potential impact of the invasive plant *Impatiens glandulifera* (Himalayan balsam) on both the native above-ground vegetation and the soil seed bank in a controlled 5-year experiment in a deciduous forest. *I. glandulifera* is a herbaceous annual plant native to the western Himalaya. It was introduced to Europe and North America as a garden ornamental in the middle of the 19th century (Beerling & Perrins 1993). After some decades, it became naturalized and invasive in riparian habitats (Hejda & Pysek 2006). In the last decades, *I. glandulifera* has increasingly invaded deciduous and coniferous forests disturbed by wind throws and/or intensive forest management (Nobis 2008), becoming the dominant species in many places. *I. glandulifera* reduces species richness of native plants, causes shifts in plant species composition in riparian habitats (Hejda & Pysek 2006), and competes successfully with native plants for pollinators which may reduce the fitness of native plants (Brown, Mitchell, & Graham 2002; Lopezaraiza-Mikel, Hayes, Whalley, & Memmott 2007). In mixed deciduous forests, *I. glandulifera* reduces the colonization rate of both arbuscular and ectomycorrhizal fungi on roots of native tree species (Ruckli, Rusterholz, & Baur 2014, 2016) and alters the species composition of litter-dwelling invertebrates (Ruckli, Rusterholz, & Baur 2013; Rusterholz, Salamon, Ruckli, & Baur 2014).

In the present study, we established plots in dense stands of *I. glandulifera*, plots in which the invasive plant had been removed and plots which were not yet colonized by the