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Invasive *Reynoutria* taxa as a contaminant of soil. Does it reduce abundance and diversity of microarthropods and damage soil habitat?

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Abstract: Little is known about the impact of exotic invasive plant species on soil invertebrate communities. The influence of highly productive invader *Reynoutria sachalinensis* on the soil microarthropods was studied. Three sites, with different coverage of the invader, have been selected in the mixed forest in the Jura Krakowsko-Częstochowska. The lowest abundance of microarthropods and the lowest oribatid species richness were noted in the monospecific *Reynoutria* infestation stand. The reduction of abundance of saprophagous mites (Oribatida, Acaridida) and springtails were observed at the totally invaded site, whereas gamasid and actinedid mites reacted positively to the presence of *Reynoutria*. Observed abundances and species richness of microarthropods at studied sites were in accordance with theories on biodiversity. Antifungal activity of phenolic compounds present in leaves of *R. sachalinensis* may negatively influence on saprophagous representatives of microarthropods. On the other hand, predacious mites profited from the simplified vegetation structure.

Keywords: Acari, Collembola, *Reynoutria*, invasion, soil

INTRODUCTION

Taxa from the genus *Reynoutria* are considered to be highly productive and aggressive invaders in Poland, which have spread both to ruderal habitats and to sites of natural character, e.g. broadleaf forests [1]. The exotic knotweed (*Reynoutria sachalinensis*) is the most rapidly spreading plant invader in Europe and North America. It reaches a height of 2-4.5 m and its biomass can exceed

200 t/ha, which is above any other herbaceous vegetation. The total cover of *Reynoutria* usually is in the range of 95-100% and all native plant species are displaced [2]. Although, invasions of exotic species are widely recognized as one of the major threats to biodiversity and ecosystem stability, little is known about their impact upon the soil invertebrates communities [3].

The goal of the project was to explore the effect of the exotic knotweed (*Reynoutria sachalinensis*) on soil communities of mites (*Acari*) and springtails (*Collembola*) in a mixed forest. More specifically we addressed the following hypotheses: (1) the invader supports a lower abundance of microarthropods, (2) *Reynoutria* invasion especially effects saprophagous microarthropods, e.g. Oribatida, (3) *Reynoutria* stands harbour a lower number of mite species, (4) fungivorous oribatid species are the most affected group of mites at *Reynoutria* infestation stands.

MATERIALS AND METHODS

Three sites have been selected in the mixed forest along a didactic path "Dolina Wodącej" in the Jura Krakowsko-Częstochowska (Silesian province, south Poland; 50°25'N, 19°40'E). The first site was totally invaded by knotweed, the second was characterized by medium coverage (30%) of the plant, and the third site was free of the invading *Reynoutria* species.

At sampling sites ten random soil samples of topsoil (0-10 cm) were taken using a corer of 4.8 cm diameter. The topsoil layer includes the litter layer. Samples were taken from a representative quadrat (10x10 m) at each site. Sampling was done seasonally (three times) in 2007-2008, making a total of 30 samples per date. The representatives of mesofauna were separated from the soil using the Tullgren metod. Mites and collembolans were sorted and oribatids were identified to species. We assessed abundance of four groups of mites and springtails. The oribatid communities were additionally characterized by species richness. One-way ANOVA was performed to identify statistically significant differences in abundance. Data were transformed to log (x+1) to minimize violations of parametric statistics. When a statistically significant difference ($p<0.05$) was noted differing pairs were identified with the Tukey *post-hoc* test. Levene's test was used to verify homogeneity of variance. The level of significance for all statistical tests was accepted at $\alpha=0.05$.

RESULTS AND DISCUSSION

Overall, 2862 specimens of Acari (2368) and Collembola (458) were collected in 90 samples and 70 oribatid species were identified in the material. The highest abundance of mites, springtails and total microarthropods was noted at the moderately invaded site (II), however, the difference between site II and site free of the invading *Reynoutria* (III) were not significant (Table 1). The abundance of microarthropods was 37% lower at an invaded site than at site without knotweed infestation. The abundance of Collembola was generally much lower than mites and the difference in abundance between sites were not significant ($p<0.05$, the Tukey test). The species richness of oribatid mites, the most numerous group of studied animals, was also noted. Similarly to the abundance, the highest number of species was recorded at site II (51) and much lower (38) at invaded site (I).

What might be the reason of lower abundance and species richness of microarthropods in the monospecific *Reynoutria* stand and the highest ones in the stand with low coverage of the invader? This phenomenon is in accordance with theories on biodiversity. They predict a higher number of animals and a higher diversity in species-rich vegetation [4, 5]. So, the replacement of most native plant species (site I) strongly influences on soil communities, whereas moderate presence of *Reynoutria* species temporally raises the total abundance and species richness of these soil animals.

Which groups of microarthropods do react negatively to the presence of *Reynoutria?* The highest reduction in abundance (comparison between site I and III) was noted for Acaridida (57%) and Oribatida (52%). Furthermore, the abundance of Collembola at site I was 22% lower than at site III. It was characteristic that saprophagy is the main way of feeding among these microarthropods. It is noteworthy to add, that both mite groups were the most numerous at site II, however, the difference was not significant. And the abundance of adult oribatids at site II was lower than at site III, whereas, the juvenile oribatids was significantly higher at site II than site III (Table 1).

Theoretically we can consider some positive and negative aspects of the *Reynoutria* presence for saprophagous microarthropods. *Reynoutria* provides a continuous detritus supply and is related to a decrease in soil pH [6, 7]. Especially oribatid mites are more abundant at lower pH [8]. On the other hand, *Reynoutria* invasion simplified the habitat structure [6] and the plant is known as producing high concentrations of biologically active substances [9]. Especially important to explain the shift of trophic groups among microarthropods might be the presence of phenolic compounds (e.g. stilbenes, catechins) with fungicidal effects, extracted from leaves of the giant knotweed [10]. Some of these extracts appeared to be harmless to parasitoids (used in biological control) in contrast to conventional fungicides [11]. As fungi are the main source of food for mite species, especially for oribatids [12], we concluded that the presence of these antimicrobial substances might be the main reason (besides simplified habitat) of low abundance of saprophagous microarthropods in the monospecific *Reynoutria* infestation stand.

Table 1. General characteristics of oribatid mite communities and mean abundances of other groups of mesofauna at three sites with different coverage of *Reynoutria sachalinensis* in the mixed forest at "Dolina Wodącej"

	Site I	Site II	Site III	ANOVA	
				F	p
Abundance of adults	4759.3 ± 667.3 ^{a}	8796.3 ± 1274.1 ^{b}	10240.7 ± 1408.9 ^{b}	**8.832**	**0.000**
Abundance of juveniles	611.1 ± 139.3 ^{a}	3166.7 ± 744.9 ^{b}	944.5 ± 204.9 ^{a}	**9.885**	**0.000**
Total abundance	5370.4 ± 745.5 ^{a}	11963.0 ± 1790.6 ^{b}	11185.2 ± 1478.5 ^{b}	**12.516**	**0.000**
Number of species	38	51	46		
Gamasida	3074.1 ± 452.6 ^{a}	7666.7 ± 793.0 ^{b}	3166.7 ± 624.7 ^{a}	**6.917**	**0.002**
Actinedida	314.8 ± 82.8	388.9 ± 110.3	111.1 ± 49.1	2.682	0.074
Acaridida	111.1 ± 49.1	240.7 ± 78.5	259.3 ± 95.0	0.827	0.441
Acari total	8870.4 ± 970.1 ^{a}	20259.3 ± 2408.3 ^{b}	14722.2 ± 1810.8 ^{b}	**11.041**	**0.000**
Collembola	2092.6 ± 521.1	3703.7 ± 597.0	2685.2 ± 799.1	0.352	0.704
Microarthropods	10962.9 ± 1285.2 ^{a}	23692.9 ± 2568.4 ^{b}	17407.4 ± 2263.2 ^{b}	**10.711**	**0.000**

Mean abundance of microarthropods (number of indiv./m^2 ± S.E.) is tested by one-way ANOVA. The results are compared by the Tukey *post-hoc* test for differences between sites. Bold typed values denote significant differences between abundances at the 0.05 and lower probability level. Different superscript letters denote significant differences among sites based on a Tukey *post hoc* test.

What was the reaction of fungivorous oribatid species on the presence of *Reynoutria*? The classification of feeding types in Oribatida was studied by Siepel and Ruiter-Dijkman [12]. Seven feeding guilds were defined based on the activity of three carbohydrates (cellulase, chitinase, trehalase). Fungivorous grazers and fungivorous browsers are specifically fungi feeders. It was characteristic that the abundance of these feeding groups was the lowest at the monospecific *Reynoutria* stand (2241 indiv./m^2) and two times higher at site free of the invading *Reynoutria* species (4481 indiv./m^2). At site II, the abundance of these oribatids was medium (3500 indiv./m^2). Similarly, species richness of fungivorous species was the lowest at site I (13 species) and higher at other sites (17 species). It might mean that fungi used by oribatids as a food are effected by antifungicidal activity of phenolic compounds from *Reynoutria*. We can concluded that, saprophagous microarthropods, especially oribatid mites, did not profit from the increased litter production in the *Reynoutria* stand (site I). Effects of high productivity of *Reynoutria* probably were counteracted by reduced differentiation of food sources and antifungal activity of extracts of *Reynoutria*. Different phenomenon was observed with regard to other detritivorous animals, e.g. detritivore beetles [7] and detritivorous diplopods and isopods [7]. Detritivores profited from the increased productivity and the resulting high-detritus supply in *Reynoutria* stands [6, 7].

Two other groups of microarthropods, Gamasida and Actinedida, reacted positively to the presence of *Reynoutria*. The abundance of gamasid mites was similar at site I and III and 2.5 higher at site II than at site I, whereas the abundance of actinedid mites was three times higher at site I than site III (Table 1). Predacious species dominate among soil representatives of both mite groups. The hunting efficiency hypothesis [13, 14] predicts that large predators are more efficient in sparse vegetation such as the *Reynoutria* stands. We can concluded that *Reynoutria* invasion primarily enhances predators that profit from the simplified vegetation structure. Similar phenomenon was observed by scientists from Germany with regard to litter-dwelling macrofauna [6].

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