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Communities of mites (Acari) in litter and soil under the invasive red oak (*Quercus rubra* L.) and native pedunculate oak (*Q. robur* L.)

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Abstract: Because of thoughtless decisions or unintentional introduction, alien species disturb native ecosystems. Red oak (*Quercus rubra*), among other alien woody plants, is still used to rehabilitate degraded land because of its better resistance to pollution and faster growth, as compared to native tree species. Soil mites, especially Oribatida, are good bioindicators of ecosystem disturbance, so the main goal of this study was to explore the influence of invasive and native oaks on mite communities. Forest stands dominated by 40-year-old *Q. rubra* or 35-year-old *Q. robur* were compared. Over 2300 soil mites were extracted from 20 soil and 20 litter samples. Mite densities in the communities were higher in red oak litter, which is probably a result of the thicker layer of shed leaves. Changes in species composition of oribatid communities were observed in litter, in contrast to a lack of differences in soil. These observations are consistent with other researches on invasive woody plants. We expect that over time these changes will also be noticeable in the soil and will increase in litter.

Keywords: invasive species, woody plant, *Quercus rubra*, *Quercus robur,* soil mites, Oribatida

INTRODUCTION

Some alien introduced plant species expand their range very quickly, threatening biodiversity, so they are classified as invasive plants. The problem of invasive species is alarming, as the process of invasion is irrevocable and can lead to catastrophic results (Gniazdowska 2005). Invasive alien species are regarded today as the greatest threat to the biodiversity and stability of ecosystems (Solarz 2007).

Red oak (*Quercus rubra*) was introduced to Poland in the 19th century from North America. It still is and was used in the past for afforestation of areas destroyed by human activity, for planting as an ornamental tree in parks, in forests as an admixture, and for establishing shelterbelts. The choice of red oak is usually justified by its rapid growth and good quality of wood in comparison to the native oaks (Gazda 2003). Other relevant economic characteristics of red oak include its modest environmental requirements, resistance to pollution (Katzur & Haubold-Rosara 1996), and aesthetic value (beautiful red leaves in autumn). Current observations show that red oak seedlings are able to eliminate other plants by creating dense patches in the undergrowth.

Nowadays, surveys on plant invasiveness are focused on disturbances in circulation of water and nutrients (Crooks 2002; Ehrenfeld 2003; Ashton et al. 2005), reaction of microorganisms (level of soil enzymes) (Kourtev et al. 2002; Lankau 2010), production of allelopathic compounds (Gniazdowska 2008; Ens et al. 2009; Cantor et al. 2011), rate of expansion and impact on plant communities (Chmura & Sierka 2006; Tokarska-Guzik et al. 2006), and even mathematical modelling aiming to predict invasiveness (Křivánek & Pyšek 2006). Nevertheless, the impact of invasive species on the abundance and composition of invertebrates is rarely studied (Gerber et al. 2008).

Mites inhabiting the soil are an important part of the ecosystem, playing a crucial role in organic matter decomposition and nutrient cycling. Participation of Oribatida in the total number of soil mites ranges from 60% to 90%. They are a pivotal element in the detritus food chain (Lebrun 1979) and can be used as indicators of changes in the environment (e.g. Niedbała 1983). Using them as bioindicators provides an opportunity to replenish information about the state of the soil based on plant and chemical indicators. It is still unclear what causes the alien plants to become invasive, so monitoring of organisms performing a vital role in maintaining ecosystem balance is required.

Until now, in Poland, only Skubała & Mierny (2009) have tested the condition of soil mites under *Fallopia sachalinensis* (*Reynoutria sachalinensis*), one of the most dangerous invasive alien species. The results have confirmed the assumption that the way it occupies a terrain, i.e. virtually complete displacement of the existent flora, coincides with a decline in biodiversity of soil mite communities, especially of the groups that feed on diverse substrates: the saprophagous Oribatida and Astigmata. Simplification of the environment results in a greater proportion of predatory mites (Mesostigmata, Prostigmata) within the mite communities. Stopping the spread of plant invaders is a serious problem, particularly in environments modified by humans (e.g. Maurel et al. 2010). A major threat posed by red oak is its competition with the native species, i.e. an effect similar to that of *Fallopia* spp.

In this study we investigated the problem of invasive woody plants at the stage of young trees (35–40 years old), which would be helpful in planning a second part of the experiment on development of invasiveness by including older age classes of forest stands. We tested whether red oak – an invasive plant in Poland – affects the biodiversity of native soil mesofauna in less fertile soils. Our goal was to answer the following questions:

1. Is the density of various soil mite groups lower in the soil and litter under the invasive red oak, compared with the native pedunculate oak (*Quercus robur* L.)?
2. Is the soil and litter under red oak dominated by different oribatid species than the soil and litter under the native oak?
3. Is the species richness and species diversity of oribatid communities in soil and litter under red oak lower than in under the native oak?

MATERIAL AND METHODS

A 40-year-old stand with predominance of *Quercus rubra* (90%) and a 35-year-old stand with predominance of *Q. robur* (70%) were compared, both located south-east of Rybnik (southern Poland, Upper Silesia). Geographical coordinates of the selected areas are 50°03'58"N, 18°34'09"E and 50°03'55"N, 18°34'24"E, respectively. To eliminate the influence of some other factors, resulting from geographical differences (likely to affect the analysis), we selected forest stands that are only 295 m apart, both on poor acid brown soil according to data from the Bureau of Forest Management and Geodesy in Cracow (BULiGL). Such a choice was dictated by different reactions of soil mites to soil parameters (e.g. Nielsen et al. 2008) and the observation made by Nicolini & Topp (2005), who discovered that nutrient uptake by red oak on highly fertile soil had a less significant negative impact on the pool of nutrients for soil microorganisms and mites than in a soil deficient in nutrients.

On 24 April 2010, we took randomly 10 soil and 10 litter samples from each forest stand within a randomly selected square plot (10 m × 10 m). The samples were collected using a steel cylinder of 137 cm^3 in volume and 7.5 cm in height. The fallen leaves and humus were regarded as the litter layer. It should be noted that this layer was 1–3 cm thick. On average, litter under red oak was thicker than under pedunculate oak. The samples of soil and litter were separated in the field, then transported to the laboratory, and placed in the Tullgren apparatus. Extracted material was divided into 4 mite orders: Oribatida, Prostigmata, Astigmata, and Mesostigmata. Only adult Oribatida were determined to the species level. In total, 2307 specimens of Acari were collected, including 1024 oribatid mites of 52 species. The list of oribatid species recorded at the forest stands is given in Appendix I. Taxonomic nomenclature follows Subías (2004).

Analyses of mite communities were based on density of mites of each order (mean number of individuals per 1 m^2), separately for the soil and litter. To assess the significance of differences in mite density between the forest stands, the Kruskal-Wallis test was used. To assess the significance of differences in mite density between all pairs of sites, the multiple comparison test was done. The use of nonparametric tests was dictated by the heavily skewed mite density distributions in the examined sites and the fact that attempts to transform the data to normal distribution did not give the expected results. To recognize the potential influence of oak stands on oribatid species communities, the species richness, evenness, and diversity indices were calculated. The expected total species richness in the studied stands was estimated using non-parametric, incidence-based estimators: 1st order jackknife and 2nd order Jackknife . Estimators were computed using Species Diversity and Richness IV software. In order to compare the species composition of communities found in different habitats, cluster analysis was conducted (based on Euclidean distances). Correspondence analysis was performed to evaluate relationships between species density and habitat. Statistical analyses were carried out using STATISTICA 10.0 software.

Table 1. Mean density of mites (individuals/m^2 ± standard error) in soil and litter under *Quercus rubra* and *Q. robur*, and significance of differences between the habitats (Kruskal-Wallis test, $N = 40$)

Group of mites	*Quercus rubra*		*Quercus robur*		*H*	*p*
	soil	litter	soil	litter		
Oribatida adults	11333 ± 7837.6^{a}	19500 ± 3786.5^{b}	15055 ± 3462.0^{ab}	11000 ± 1662.1^{a}	**10.562**	**0.014**
Oribatida juveniles	1666 ± 1123.4^{a}	4444 ± 1250.5^{b}	1555 ± 528.9^{a}	1888 ± 469.9^{ab}	**11.795**	**0.008**
Oribatida total	13000 ± 4807.3^{a}	23944 ± 156.8^{b}	16611 ± 1931.3^{ab}	12888 ± 3335.8^{a}	**11.546**	**0.009**
Mesostigmata	1111 ± 414.1	6277 ± 2281.7	1722 ± 520.2	1722 ± 441.7	5.483	0.139
Prostigmata	1388 ± 937.8^{a}	8000 ± 1500.3^{b}	444 ± 231.3^{a}	2166 ± 425.9^{ab}	**23.474**	**<0.001**
Astigmata	166 ± 84.9^{a}	19333 ± 13941.3^{b}	1333 ± 683.93^{a}	3166 ± 1203.1^{ab}	**17.080**	**0.001**

Bold values denote significant differences in density ($P < 0.05$). Different letters denote significant differences between habitats, based on a multiple comparison test.

RESULTS

Statistically significant differences were observed in mean density of mites (individuals/m^2) in the soil and litter under *Quercus rubra* and *Q. robur* with regard to most mite groups. As regards oribatid mites, their density in red oak litter was significantly higher than in litter under the native oak. The density of Oribatida in the soil in both forest stands was much lower. No statistically significant differences in this parameter between forest stands were observed, but the numbers of oribatids in the soil under *Q. rubra* were generally lower than in the soil under *Q. robur.* Numbers of prostigmatid and astigmatid mites in *Q. rubra* litter were also higher than in litter of the native oak and in both cases much higher than in soil layers. Although differences in densities of Mesostigmata were not significant, the pattern was similar as for the above groups of mites. Higher numbers of mesostigmatid mites were noted in the litter under red oak than under the native species, and numbers of these mites in the soil under *Q. rubra* were lower than in the soil under *Q. robur* (Table 1).

Species richness, diversity, and evenness indices of communities were similar within the habitats (litter or soil) but differences between tree species were observed. Numbers of oribatid species in the litter were generally higher than in the soil. Furthermore, species diversity and evenness indices were higher in the litter under both oaks than in the soil (Table 2). The estimated theoretical number of species in studied sites was slightly higher (e.g. in litter under *Q. rubra*) or significantly higher (e.g. soil under *Q. rubra*) than the number of observed species. The estimates were higher when 2nd order jackknife was used (instead of 1st order jackknife) and ranged then from 37.6 (litter under *Q. rubra*) to 56.0 (litter under *Q. robur*) (Table 2). The in-

Table 2. Observed and estimated species richness and diversity of oribatid mite communities in the soil and litter under *Quercus rubra* and *Q. robur*

Parameter	*Quercus rubra*		*Quercus robur*	
	soil	litter	soil	litter
Average number of species	7.36	13.75	7.81	12.63
Total number of species	18	36	20	30
Shannon index (*H*’)	1.613	2.725	1.844	2.548
Evenness index (*J*)	0.558	0.760	0.616	0.749
Jackknife 1st order	28.8±5.6[1]	45.9±5.1	30.8±2.6	45.3±6.1
	(60.0)	(27.5)	(54.0)	(51.0)
Jackknife 2nd order	37.6	46.8	40.4	56.0
	(108.8)	(30.0)	(122.0)	(86.6)

[1] Values are mean estimates (± standard deviation)

[2] Percentage increase in relation to the observed species numbers is given in parentheses

crease in relation to the number of collected species varied between 30% (litter under *Q. rubra*) to over 100% (soil under *Q. robur* and *Q. rubra*) (Table 2).

Cluster analysis of oribatid communities shows similarities within the analysed soil or litter layer and differences between them (Fig. 1). The species composition of oribatid communities in soil is much more similar than the species composition of oribatid fauna in litter under oaks.

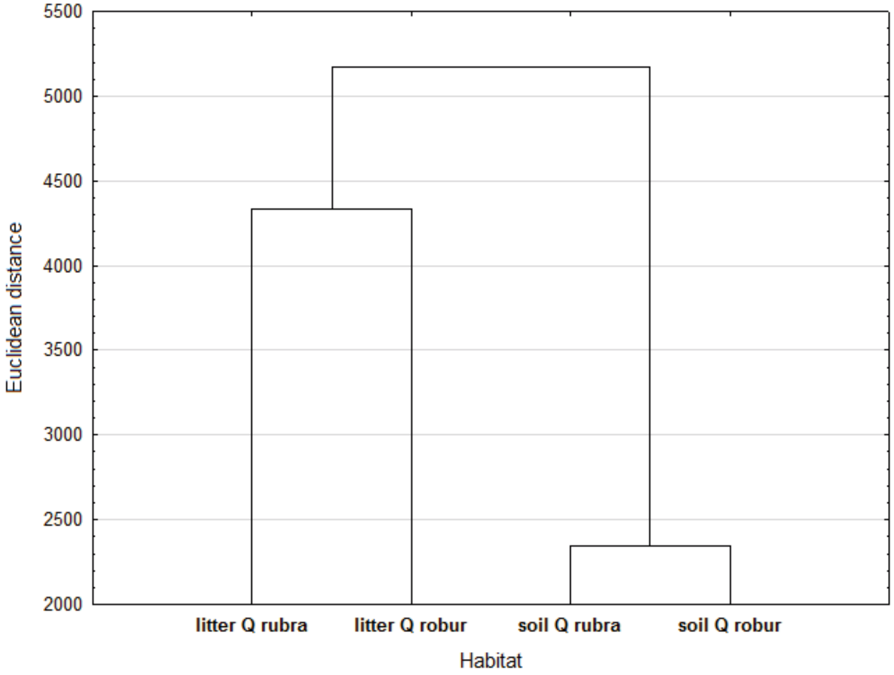

Fig. 1. Dendrogram for 4 compared habitats, based on Unweighted Pair Group Method with Arithmetic Mean (UPGMA) and Euclidean distance coefficients

In correspondence analysis, evaluating relationships between species density and habitat (Fig. 2), eigenvalues were high for axis 1 ($\lambda_1 = 0.28$) and axis 2 ($\lambda_2 = 0.27$). Over 92% of the variance was explained by the first 2 axes. Results of the analysis confirm the lack of valid differences in soil mite communities between the forest stands. The dominant species in the soil in both forest stands was *Microppia minus minus* (Paoli, 1908). It is a eurytopic (Weigmann 2006) and cosmopolitan (Subías 2004) fungivorous grazer (Zaitsev et al. 2002), considered as parthenogenetic (Cianciolo & Norton 2006).

By contrast, oribatid communities of litter layers of the 2 compared forest stands differ significantly. The habitat of *Q. rubra* litter and the associated species are lo-

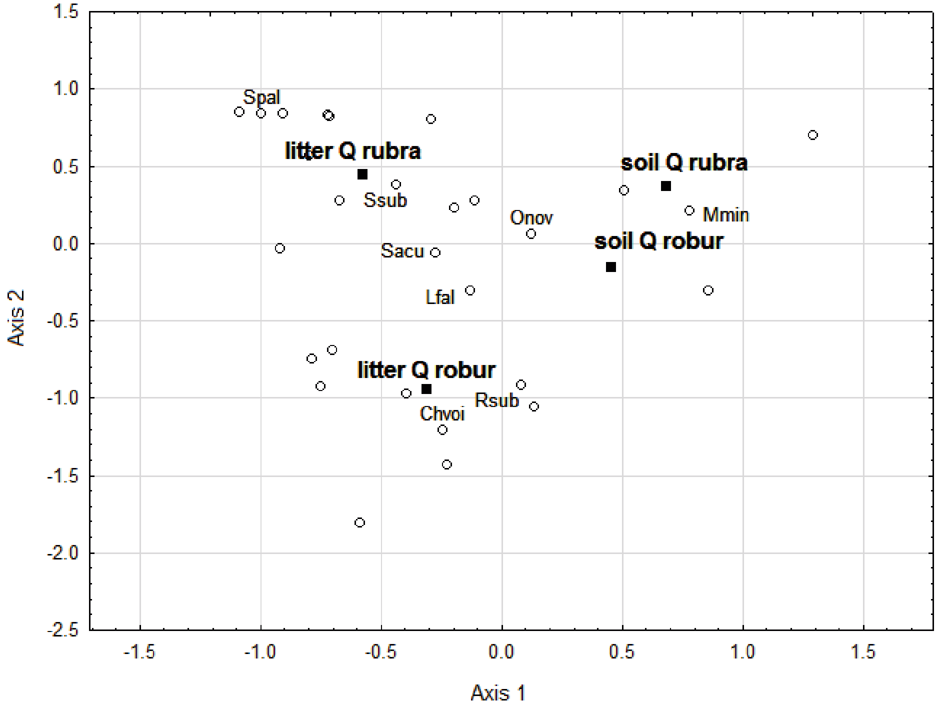

Fig. 2. Correspondence analysis biplot showing positions of 52 oribatid species and 4 compared habitats. Dominant species: Chvoi = *Chamobates* (*Xiphobates*) *voigtsi*, Lfal = *Lauroppia falcata falcata*, Mmin = *Microppia minus minus*, Onov = *Oppiella* (*O.*) *nova nova*, Rsub = *Rhinoppia subpectinata*, Sacu = *Suctobelbella* (*S.*) *acutidens acutidens*, Spal = *Scheloribates* (*S.*) *pallidulus pallidulus*, Ssub = *Suctobelbella* (*S.*) *subcornigera subcornigera*

cated along the positive values of axis 2, whereas the index of the *Q. robur* litter and associated species are situated along the negative part of axis 2 (Fig. 2).

Two dominant species were typical for red oak litter. *Scheloribates* (*S.*) *pallidulus pallidulus* (Koch, 1841) is known as a forest species (Weigmann 2006) of broad cosmopolitan distribution, excluding Antarctica (Subías 2004). Because of its feeding preferences it has been recently specified as a herbo-fungivorous grazer (Maślak 2010), which confirms an earlier opinion on the species as secondary decomposer feeding mainly on fungi (Schneider et al. 2004). The second dominant species, *Suctobelbella* (*S.*) *subcornigera subcornigera* (Forsslund, 1941), is known from different forest soils, but is also recorded at ruderal sites (Weigmann 2006). It is an eurytopic species (Weigmann 2006) of Holarctic distribution extending to the Orient and New Zealand (Subías 2004). The species is a fungivorous browser (Zaitsev et al. 2002), reproducing parthenogenetically (Cianciolo & Norton 2006).

Chamobates (*Xiphobates*) *voigtsi* (Oudemans, 1902) and *Rhinoppia subpec-*

tinata (Oudemans, 1900) were characteristic for the litter layer under the native *Q. robur*. The former species, connected with acid forest soils (Weigmann 2006), is Palaearctic (Subías 2004), regarded as a herbo-fungivorous grazer (Maślak 2010). The latter species, *R. subpectinata*, is eurytopic (Weigmann 2006), with a Holarctic range excluding the eastern part of Orient (Subías 2004). It is also included in the feeding guild of fungivorous grazers (Zaitsev et al. 2002).

Several dominant species were not associated with any of the studied habitats. *Oppiella* (*O.*) *nova nova* (Oudemans, 1902) is one of the most widely distributed oribatids in the world, occurring in various habitats (Subías 2004; Weigmann 2006). It is known as a fungivorous grazer (Zaitsev et al. 2002) and characterized by parthenogenetic mode of reproduction (Cianciolo & Norton 2006). *Suctobelbella* (*S.*) *acutidens acutidens* (Forsslund, 1941) is mainly known from acid soil forests (Weigmann 2006). It is a fungivorous browser (Zaitsev et al. 2002), reproducing parthenogenetically (Cianciolo & Norton 2006). *Lauroppia falcata falcata* (Paoli, 1908) is observed in deciduous European forests (Weigmann 2006). It belongs to the feeding guild of omnivores (Schneider et al. 2004).

DISCUSSION

In Poland, Article 120, point 1 of the Nature Protection Act of 16 April 2004 (Journal of Laws [Dz. U.] No. 92, item 880) prohibits introduction of alien species of plants into the natural environment. However, the National Forest Holding "State Forests" (PGL LP) allows the introduction of red oak and its use as an additional species in establishing of shelterbelts, based on the "Principles of silviculture". Red oak soil requirements are lower than those of native oaks. This tree species is resistant to frost and industrial pollution, thus recommended for post-industrial land restoration. It is still recommended also for urban planting because of its decorative value, also used as roadside trees (Bodył 2011). Among foresters there is a conviction that additional alien species in unprotected forest are not harmful and should remain in place. Some foresters believe that to increase biodiversity it may sometimes be desirable to supplement reforestation and afforestation with alien species (Bogatko 2010), which has no support from environmentalists.

Considering the problem of invasive woody plant species, Gazda (2003) suggested we should ask the question: what predisposes a species to become invasive? Kowarik (1995) emphasizes the specificity of invasive woody plants, paying attention to a longer period of their development. In Brandenburg, the average time from introduction of a species to its transition into an invasive species was 131 years for shrubs and 170 for trees, of which for the black cherry (*Prunus serotina* Ehrh.) a minimum duration of 29 years was reported, and for walnut (*Juglans regia* L.), a maximum time of 374 years (Kowarik 1995).

Red oak was brought into Poland in the 19th century, which means that the period from the first introduction is about 100–200 years. How its invasiveness has developed? It should be noted that Reich et al. (2005) observed widespread and rapid (within three decades) changes in soils under different tree species in an experiment conducted in Poland. Those authors studied 14 species, including *Quercus robur* and *Q. rubra*, and observed that tree species affected soils both directly, through the chemistry of their litter, and indirectly, through the effect of their litter on detritivores (e.g. earthworms).

Results of this study suggest that the changes in soil mite communities in 35-40-year-old forest stands of invasive and native oak are not remarkable. The observed influence of the invasive red oak on mite communities was weaker than that observed by Skubała & Mierny (2009) with regard to the aggressive plant invader *Reynoutria sachalinensis*. Within stands investigated by us, significantly higher densities of oribatid, prostigmatid, and astigmatid mites were associated with red oak litter. This is probably a result of its thicker layer, which creates more microhabitats to be occupied. Reich et al. (2005) found that the litter production of red oak is over twice as high as that of native oaks. By contrast, no significant differences in density of these mites were observed in the soil, but mean numbers of oribatid and astigmatid mites in the soil under the invasive oak were lower than under the native oak. For Mesostigmata, no significant differences between the investigated habitats were observed, although the same pattern of relationships was found.

As regards the species composition of oribatid communities under the invasive and native oak, a lack of important differences was noticed. Some remarkable differences in species composition were found only in the litter layer. However, despite differences in composition of oribatid communities in the litter under invasive and native oak, the ecological function of dominant species did not differ. In the litter under *Q. rubra*, one of the dominant species was *Scheloribates pallidulus*. *Chamobates voigtsi* reached high numbers in the litter under *Q. robur*. Both species are known as occurring in forests and belong to the same feeding guild: herbo-fungivorous grazers. *Suctobelbella subcornigera* was another dominant species in the red oak litter, whereas *Rhinoppia subpectinata* dominates in the litter under the native oak. Both mite species occur in a broad range of habitats (eurytopic) and feed on similar substrates. *S. subcornigera* is a fungivorous browser, whereas *R. subpectinata* is a fungivorous grazer.

It should be emphasized that despite higher densities of oribatid mites in the litter under red oak, no remarkable differences in mite species richness and diversity were observed between litter of both oaks. Species richness of oribatid mites in the soil was much lower than in the litter under both oaks. However, it was more underestimated in comparison with species richness in the litter layer. It can be concluded that changes in species composition of oribatid communities under invasive and native oaks proceed slowly. The changes in oribatid communities start from the litter layer, because of its specificity. Oribatid mites feed on hyphae and spores of fungi, decaying organic matter, and plant debris overgrown (predecomposed) by mycelium (Maraun et al. 2003). The main source of this feeding material is found in the litter layer. All dominant oribatid species in the litter layer were fungivores, which proves that fungi developed quite well in litter under native as well as invasive oak. Thus, one of the most popular hypotheses of fungicidal effect of invaders (Gniazdowska 2008) is not credible at this stage of oak stand development.

Our results suggest different conclusions than those obtained in an experiment conducted by Nicolini & Topp (2005), concerning the use of red oak in restoration of lignite opencast mines. They compared forest stands of red and native oak (*Q.*

petraea) at the same age (18 years), planted on soils of different fertility. Those authors found that red oak, because of its proprieties associated with environmental requirements, has a negative effect on the density of soil mesofauna in the poor soil (Oribatida and Collembola). They suggested an explanation that when a fast-growing tree, like red oak, is planted on a poor soil, nutrient depletion in soil is much quicker, as compared to slow-growing tree species. The depletion is due to increasing immobilization of nutrients in woody biomass of fast-growing trees and also increasing recalcitrance of its organic matter. All this has a significant impact on reducing the pool of nutrients for soil microorganisms and mites. The mechanism would not have such consequences in fertile soils. This means that those authors observed negative effects much quicker than we did because of initial impoverishment of the soil, which would be greater in a lignite opencast mine in Rhineland. The managed forest stands studied by us were situated in the vicinity of a coal mine and urban area of Rybnik, but the soil was not mixed or deposited from other places as it was in the case of restored land of the lignite mine.

We considered above the age aspect of woody plant invasiveness. A second important question posed by Gazda (2003) is: what makes the environment vulnerable to the invasion? Vauramo & Setälä (2010) paid attention to the choice of plants used in urban areas. Those authors showed the great potential of plant species that they divided into some functional types. All the distinguished types are likely to alter the soil organism communities and, consequently, the dynamics of nutrients in disturbed soil (e.g. in the city). Thus some other question arise. Are the disturbances in circulation of nutrients a direct consequence of the invasion of alien plants or they result from disturbance of the functioning of the soil animal communities, their biology and ecology, or they depend on a variety of coexisting factors? An interesting paper was presented by Simberloff & Von Holle (1999) who worked on the problem of enhanced susceptibility to further invasions of the areas already invaded (by another invasive alien species). Those authors give many examples showing the complexity of the phenomenon, from the standpoint of the invader and of endemic land with its flora and fauna. They emphasize that the characteristics of alien organisms cannot be defined in general but in relation to a particular situation. Consequently, Reich et al. (2005) highlight the fact that vegetation, soil organisms, and soil chemistry should be viewed as co-developing components of terrestrial ecosystems, even on decadal scales. This also leads to a conclusion about the necessity to incorporate detailed soil analyses in our research and continue observations in older forest stands, which is planned.

As postulated by Crooks (2002), there is a need for research in which the sites colonized by invasive plants are compared with natural, undisturbed sites, to examine comprehensively the impact of specific invaders in the given conditions on the native environment. Our study area is situated within managed forests but still we can observe differences between the forest stands, starting from the litter level. There is a need to continue these surveys in the context of collecting knowledge on mechanisms of the impact of red oak as an invasive woody plant in Polish conditions. Our data will help to plan other experiments that would help to develop methods for controlling the expansion of particular invasive alien species in certain conditions. The results presented are part of a larger research project taking into account forest stands in the same area (Silesia) but with longer impact on the ecosystem.

CONCLUSIONS

The density of all groups of mites and (to a smaller extent) their species richness were higher in the forest stand dominated by the invasive oak than in the native oak forest. Two facts may explain the observed relationship. In general, the litter layer is occupied by higher numbers of oribatid mites than the soil layer, while litter production of red oak is higher than that of native oak.

More specimens and species of Oribatida were observed in the litter of the invasive oak than in that of the native oak. An opposite situation was observed with regard to the soil layer, but the differences were not remarkable. The probable reason for this phenomenon is a short time of the impact of the invader. Three to four decades appear to have no significant impact on the soil layer.

The species composition of oribatid communities in the soil layer under both species of oaks is similar, whereas the oribatid fauna in the litter under invasive and native oaks differs significantly. However, the ecological role of dominant mite species found in litter of both oaks was similar. We expect that over time changes will be more noticeable between the stands and between both analysed levels.

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Appendix I. Species list of oribatid mites and numbers of major mite groups recorded in the soil and litter under *Quercus rubra* and *Q. robur*. Numbers indicate the absolute number of individuals found at each habitat

Taxon	*Q. rubra*		*Q. robur*	
	soil	litter	soil	litter
Acrotritia duplicata (Grandjean, 1953)	2	14	1	4
Belba (*B.*) *patelloides* (Michael, 1888)	-	-	-	1
Carabodes (*C.*) *femoralis* (Nicolet, 1855)	1	2	-	-
Carabodes (*C.*) *ornatus* Štorkán, 1925	-	-	1	1
Cepheus cepheiformis (Nicolet, 1855)	-	1	-	-
Ceratozetes (*C.*) *gracilis* (Michael, 1884)	-	-	1	1
Chamobates (*Xiphobates*) *voigtsi* (Oudemans, 1902) [Chvoi]	-	4	14	35
Damaeus (*D.*) *auritus* Koch, 1835	-	-	-	1
Eupelops subuliger (Berlese, 1916)	-	-	-	2
Eupelops torulosus torulosus (Koch, 1839)	-	-	1	3
Euphthiracarus (*E.*) *cribrarius cribrarius* (Berlese, 1904)	-	-	-	1
Galumna (*G.*) *lanceata* (Oudemans, 1900)	-	7	1	10
Hafenrefferia gilvipes (Koch, 1839)	-	2	-	3
Heminothrus (*Platynothrus*) *peltifer peltifer* (Koch, 1839)	-	1	-	2
Hypochthonius rufulus rufulus Koch, 1835	-	2	-	-
Lauroppia falcata falcata (Paoli, 1908) [Lfal]	7	34	37	31
Metabelba (*M.*) *papillipes* (Nicolet, 1855)	2	11	-	-
Metabelba (*M.*) *pulverulenta* (Koch, 1839)	-	1	1	3
Microppia minus minus (Paoli, 1908) [Mmin]	92	24	89	7
Microtritia minima (Berlese, 1904)	-		1	1
Moritzoppia (*M.*) *keilbachi* (Moritz, 1969)	1	12	-	-
Moritzoppia (*M.*) *unicarinata unicarinata* (Paoli, 1908)	2	-		-

Nanhermannia (*N.*) *nana* (Nicolet, 1855)	3	16	-	-
Nothrus silvestris silvestris Nicolet, 1855	-	2	2	-
Ophidiotrichus vindobonensis Piffl, 1961	1	-	-	-
Oppiella (*O.*) *nova nova* (Oudemans, 1902) [Onov]	65	88	83	44
Pergalumna nervosa nervosa (Berlese, 1914)	-	5	-	-
Phthiracarus (*P.*) *longulus* (Koch, 1841)	-	2		1
Porobelba spinosa (Sellnick, 1920)	-	2	-	1
Protoribates (*P.*) *capucinus capucinus* Berlese, 1908	-	1	-	-
Punctoribates (*P.*) *punctum* (Koch, 1839)	-	2	-	-
Quadroppia (*Q.*) *maritalis* Lions, 1982)	-	1	-	-
Rhinoppia obsoleta (Paoli, 1908)	2	-	-	-
Rhinoppia subpectinata (Oudemans, 1900) [Rsub]	-	2	16	15
Scheloribates (*S.*) *pallidulus pallidulus* (Koch, 1841) [Spal]	1	25	-	-
Sellnickochthonius cricoides (Weis-Fogh, 1948)	-	1	-	-
Subiasella (*Lalmoppia*) *quadrimaculata* (Evans, 1952)	-	-	-	1
Suctobelba secta Moritz, 1970	-	1	-	-
Suctobelbella (*Flagrosuctobelba*) *baloghi* (Forsslund, 1958)	-	5	-	-
Suctobelbella (*Flagrosuctobelba*) *nasalis* (Forsslund, 1941)	-	2	1	4
Suctobelbella (*S.*) *acutidens acutidens* (Forsslund, 1941) [Sacu]	5	17	8	10
Suctobelbella (*S.*) *acutidens sarekensis* (Forsslund, 1941)	1	6	4	1
Suctobelbella (*S.*) *longicuspis longicuspis* Jacot, 1937	-	1	-	-
Suctobelbella (*S.*) *perforata* (Strenzke, 1950)	5	2	1	1
Suctobelbella (*S.*) *prominens* (Moritz, 1966)	-	-	-	1
Suctobelbella (*S.*) *singularis* (Strenzke, 1950)	1	-	-	-
Suctobelbella (*S.*) *subcornigera subcornigera* (Forsslund, 1941) [Ssub]	12	44	7	9
Suctobelbella (*S.*) *subcornigera vera* (Moritz, 1964)	-	-	1	-
Suctobelbella (*S.*) *subtrigona* (Oudemans, 1900)	1	8	-	1
Tectocepheus alatus Berlese, 1913	-	2	-	1
Tectocepheus minor Berlese, 1903	-	-	-	2
Tectocepheus velatus velatus (Michael, 1880)	-	1	1	-
Oribatida juveniles	30	80	28	34
Astigmata	3	348	24	57
Prostigmata	25	144	8	39
Mesostigmata	20	113	31	31

Species codes used in Figure 2 are given in square brackets.