ORIBATID MITES (Acari: Oribatida) IN CASTS AND BURROWS OF AN ENDEMIC EARTHWORM *Dendrobaena mrazeki* AND IN LITTER OF THERMOPHILOUS OAK FORESTS

JOSEF STARÝ, VÁCLAV PIŽL

Institute of Soil Biology, Academy of Sciences of the Czech Republic, Na Sádkách 7, CZ – 370 05 České Budějovice, Czech Republic; e-mail: jstary@upb.cas.cz; pizl@upb.cas.cz

Abstract

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Oribatid mite (Acari: Oribatida) communities were studied in casts and burrows of an endemic earthworm *Dendrobaena mrazeki* and compared with that in oak litter. The study was carried out at four experimental plots located in thermophilous oak forests of the Pálava Biosphere Reserve, Southern Moravia, Czech Republic. In total, the material of 3256 oribatids was collected during the study and identified into the species level. 55 oribatid species were recorded from litter samples, and 25 and 24 from burrows and casts of *D. mrazeki*, respectively. Average density of oribatid communities was significantly higher in leaf litter (12 188 ind.m^{-2}) than in both burrows (7638 ind.m^{-2}) and casts (4656 ind.m^{-2}) of *D. mrazeki*. Similar tendency was found for species richness. Panphytophagous eurytopic *Tectocepheus velatus* (dominance of 24.0%), *Microppia minus* (12.2%) and *Dissorhina ornata* (9.4%) belonged to most common species in the oak litter, while small euedaphic *Microppia minus* (29.3%) and *Ceratozetes minutissimus* (12.1%) represented dominant species in earthworm burrows. Microphytophagous mites with broad ecological valence, *Tectocepheus velatus* (44.1%) and *Scheloribates laevigatus* (6.3%) predominated in earthworm casts. *Tectocepheus velatus, Scheloribates laevigatus, Oribatula pannonica* and *Dissorhina ornata* preferred earthworm casts over burrows. *Zygoribatula exilis, Eniochthonius minutissimus, Parachipteria punctata* and *Quadroppia quadricarinata* were exclusively recorded from casts; however, all of them occurred there in relatively low densities.

Key words: soil oribatid mites, earthworms, casts and burrows, South Moravia, oak forest

Introduction

Dendrobaena mrazeki (Černosvitov, 1935) is recognised as an endemic earthworm distributed across relatively small part of C Europe (Pižl, 2002). Its ecology seems to be very untypical. In contrast to most of other earthworms, *D. mrazeki* shows preferences for thermophilous forest-steppe biotopes or even pine forests on sandy soils (Zajonc, 1980; Pižl, 2002). It may reach a remarkable density in xerophilous oak forests or other dry habitats (Pižl, unpublished), where it produces characteristic surface casts composed of well recognisable small pellets. Due to its extensive casting and burrowing activity, *D. mrazeki* may have a potential to affect substantially the soil environment in such ecosystems, as well as other soil organisms.

The effects of earthworm activity on microarthropods, especially on soil mites including oribatids, have been reviewed recently by Brown (1995). He concluded that the main effect was the decrease of oribatid density and diversity unless the soil mites are able to use earthworm residues such as casts. McLean, Parkinson (1998) showed that the effect of *Dendrobaena octaedra* on oribatid mites in forest soils was more complicated and specifically dependent on both the autecology of individual oribatid species and the length of earthworm influence.

The goals of the study were (i) to compare quantitative and qualitative parameters of oribatid communities inhabiting earthworm casts and burrows with those living in litter and soil, and (ii) to identify the effects of different earthworm activities on the density of dominant species of oribatid mites.

Material and methods

The investigation was done in the Milovice hills, the eastern part of the Pálava Biosphere Reserve (S Moravia, Czech Republic). The area belongs to the Mikulov highland, the westernmost part of the Carpathians, and its bedrock consists of flysch clays and sandstones, and of Upper Tertiary clay sediments. The climate of the area is dry and warm, with average annual temperature and precipitation of 9.6 °C, and 337 mm, respectively. Four experimental plots (100x100 m) were established in thermophilous oak stands (alliance *Quercion pubescenti-petraeae*). The soil of all plots was Orthic Luvisol on tertiary sediments, humus form – mull. Chemical characteristics of the substrates under study are as follows: soil: pH(H_2O) 7.85–7.92 , pH(KCl) 7.33–7.57, $P_{(total)}$ 605–969 mg.kg^{-1}, $P_{(available)}$ 33–84 mg.kg^{-1}, $P_{(water\text{-}soluble)}$ 10–16 mg.kg^{-1}, C_{ox}. 1.97–5.43 %, Na 2–20 mg.kg^{-1}, K 52–60 mg.kg^{-1}, Ca 3160–9200 mg.kg^{-1}, earthworm casts: pH(H2O) 7.57–7.61, pH(KCl) 7.40–7.48, $P_{(total)}$ 670–813 mg.kg^{-1}, $P_{(available)}$ 68–81 mg.kg^{-1}, $P_{(water\text{-}soluble)}$ 22–25 mg.kg^{-1}, C_{ox}. 3.00–5.52 %, Na 30–38 mg.kg^{-1}, K 148–156 mg.kg^{-1}, Ca 8020–10060 mg.kg^{-1}, soil surrounding earthworm burrows: pH(H2O) 7.88–7.92, pH(KCl) 7.55–7.66, $P_{(total)}$ 682–969 mg.kg^{-1}, $P_{(available)}$ 49–68 mg.kg^{-1}, $P_{(water\text{-}soluble)}$ 9–18 mg.kg^{-1}, C_{ox}. 2.29–4.48 %, Na 17–18 mg.kg^{-1}, K 52–74 mg.kg^{-1}, Ca 3300–7540 mg.kg^{-1}.

Casts of *Dendrobaena mrazeki*, soil close to *D. mrazeki* burrow (drilosphere *sensu lato*) and unaffected litter were collected using a corer of 10 cm^2 in area in spring 2003 and 2004. Eight replicate samples of each substrate were randomly taken from each experimental plot, i.e. a total of 288 quantitative samples were analysed. Oribatid mites were extracted using a modified high-gradient Tullgren funnels (Marshall, 1972), fixed in 80% ethanol, cleared in temporary slides with 60% lactic acid and identified at the species level. Determined material was transferred into glycerol and deposited in the comparative collection of the Institute of Soil Biology, AS CR, České Budějovice, Czech Republic.

The Principal co-ordinates analysis (PCA) with Sørensen index of species identity (SYNTAX 5.02, Podani (1994)) was used for similarity and heterogeneity analyses of oribatid communities. Statistical analysis of oribatid mite density was carried out by means of the analysis of variance (ANOVA). Student-Newman-Keuls post hoc test was performed for comparison of means.

Results

In total, 3256 oribatid mites were collected during the study, representatives of 62 species. Of those 55 species were recorded from litter, and 25 and 24 from earthworm burrows and casts, respectively.

Average density of oribatid communities was significantly higher (ANOVA, $p < 0.05$) in leaf litter than in both burrows and casts of *Dendrobaena mrazeki* (Fig. 1). The actual densities ranged from 7875 to 17 875 ind.m^{-2} in litter, and between 2500–11125 ind.m^{-2} and 2000–7500 ind.m^{-2} in earthworm burrows and casts, respectively. Similar tendency was found for species richness (Fig. 1).

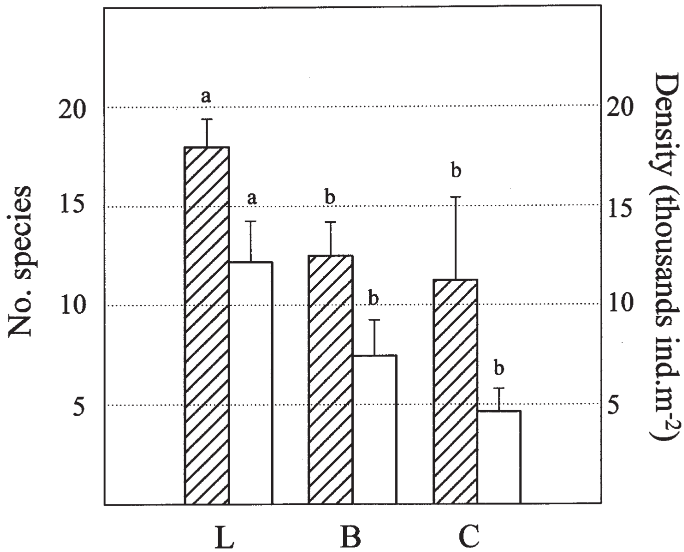

Fig. 1. Density (hatched columns) and species numbers (white columns) of oribatid mites (mean ± S.E) in oak litter (L), burrows (B) and casts (C) of *Dendrobaena mrazeki* earthworms. Different letters above columns indicate significant differences (ANOVA, Student-Newman-Keuls test, $p < 0.5$) between values.

The results of PCA ordination (Fig. 2) show that oribatid communities in litter possess high species heterogeneity between experimental plots. The groups of samples from casts and burrows of *D. mrazeki* are limited to distinctly smaller ordination space inside that occupied by litter samples, which means that oribatid communities in casts and burrows are much more homogenous than those in litter and are mainly composed of some litter-inhabiting species. Samples from casts and burrows, at least from the first two plots, do not overlap, so their species structure is different.

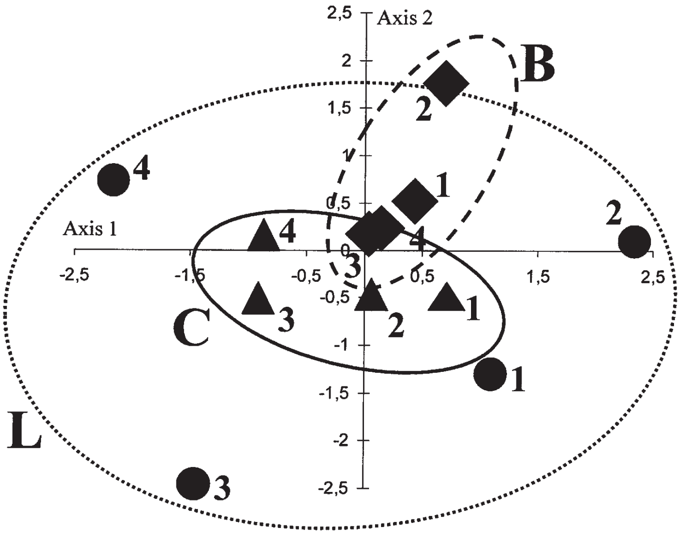

Fig. 2. PCA biplot (Syn-tax programme, Ordplot) of oribatid communities in oak litter (L, circles), burrows (B, rhombi) and casts (C, triangles) of *Dendrobaena mrazeki* earthworms. 1–4 = experimental plots.

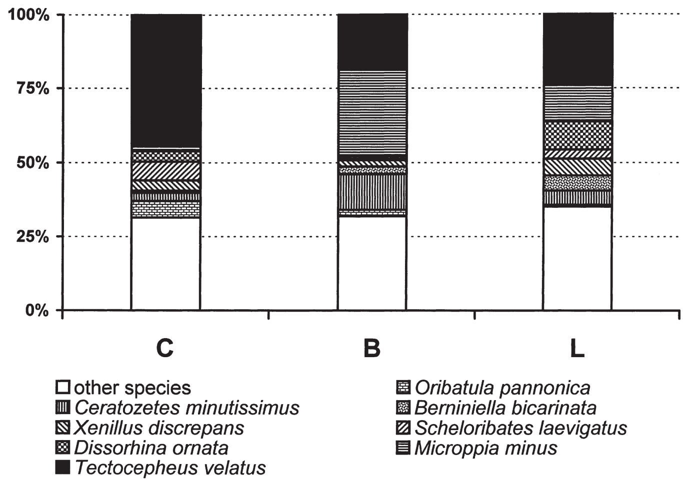

Fig. 3. Dominance structures of oribatid communities in casts (C) and burrows (B) of *Dendrobaena mrazeki*, and in oak litter (L).

The dominance structure of oribatid communities inhabiting individual substrates could be seen from Fig. 3. Panphytophagous eurytopic *Tectocepheus velatus* (dominance of 24.0%), *Microppia minus* (12.2%), *Dissorhina ornata* (9.4%), *Punctoribates punctum* (6.9%), *Xenillus discrepans* (5.6%), *Berniniella bicarinata* (5.1%) belonged to most common species in the oak litter, while small euedaphic *Microppia minus* (29.3%) and *Ceratozetes minutissimus* (12.1%) were dominant in earthworm burrows. Microphytophagous mites with broad ecological valence, *Tectocepheus velatus* (44.1%), *Scheloribates laevigatus* (6.3%) and *Oribatula pannonica* (5.6%), predominated in earthworm casts. *Tectocepheus velatus, Scheloribates laevigatus, Oribatula pannonica* and *Dissorhina ornata* preferred obviously earthworm casts over burrows. *Zygoribatula exilis, Eniochthonius minutissimus, Parachipteria punctata* and *Quadroppia quadricarinata* were exclusively recorded from the casts; however, all of them occurred there in relatively low densities.

Discussion

Little is known on the impacts of earthworms on mesofauna communities, and on soil mites in particular. Brown (1995) stated in his review that the main effect of earthworms on microarthropods is a reduction in their density and species diversity due to their competition for food sources. However, Scheu, Schultz (1996) assumed that high diversity of oribatid mites observed in a beechwood was related to instability of the mineral soil caused by earthworm activity, and Loranger et al. (1998) observed significantly higher microarthropod density and diversity in patches of high density of earthworm *Polypheretima elongata* than in those with few earthworms in the vertisol soil. In small cylinders placed in the field (Lagerlöf, Lofs-Holmin, 1987), higher numbers of mites were observed initially (2 months) in the presence of *Lumbricus terrestris* but later (3 months) they were lower. McLean, Parkinson (2000) studied the effects of epigeic *Dendrobaena octaedra* on oribatid mites in different soil horizons of pine forest and found that high worm biomass correlated positively with mites species richness and diversity in the L layer but negatively with species richness and density of oribatids in the FH layer. In the A(h) and B-m horizons, the densities of *Oppiella nova* and several other mites increased with increasing of C-N ratio, i.e. the result of the mixing of less decomposed organic matter into the soil by *Dendrobaena octaedra*. The same authors found the decrease in oribatid dominance by *Oppiella nova* but overall oribatid diversity increase in their earlier mesocosm study with *Dendrobanea octaedra* (McLean, Parkinson, 1998). In contrast, Maraum et al. (2001) found the decline of oribatid density in soil of a beechwood on limestone after the carbon and nutrient addition and assumed that it was due to indirect effects caused by the increased number and biomass of earthworms. They concluded that in the forest studied litter consumption, bioturbation and mucus excretion by earthworms negatively affected the habitable space of oribatid mites and other microarthropods and that earthworms are important ecosystem engineers in mull forest soils.

There may be however more pronounced effects of earthworm activity on the spatial distribution of soil microarthropods. Many authors (Bayoumi, 1978; Hamilton, Sillman, 1989; Schrader, Seibel, 2001) recognised earthworm middens as preferential microhabitats or hot spots for soil mites. However, Maraum et al. (1999) stated that, in contrast to other groups of micro- and mesofauna, most oribatid mite taxa (Brachychthoniidae, Oppiidae) preferred the non-midden soil in a beechwood on limestone. In addition, Hamilton, Sillman (1989) demonstrated both site (mowed meadow *vs.* woodlot) and seasonal (spring *vs.* autumn) specificity in influence of worm middens on oribatid community. However, the effect of earthworm middens may also differ with mite species. In oak-hornbeam forests, Bayoumi (1978) found that oribatid density in earthworm middens was greater than in surrounding soil, nevertheless some species (e.g. *Oppia* spp., *Hermannia gibba*, *Liacarus coracinus*) were very attracted to the middens, while other species were less attracted, and *Tectocepheus velatus* was found in lower numbers in middens than in soil. Similarly, Tiunov (2000) observed that *Atropacarus striculus* was clearly associated with earthworm burrows while most oribatids preferred non-midden soil in lime, oak and beech forest. Most of above data concern *Lumbricus terrestris* and no information is available on the effects of middens of other anecic earthworms. There were also no data in the literature on the influence of earthworm casts on oribatid mites, as well as on the effects of the drilosphere (s.s.) of other worm species than *L. terrestris*.

In our study, oribatid density was found significantly lower in the samples of casts and burrows in comparison with that in litter samples. This corresponds well with the finding by some authors (Brown, 1995; McLean, Parkinson, 1997, 1998; Maraum et al., 2001) that earthworm activity reduces oribatid mite populations. Oribatid mites appear to be typical k-strategists with slow ontogeny and low potential for fast expansion and colonisation of new habitats. They are highly sensitive to most disturbances of soil (Norton, Palmer, 1991) and therefore suffer from intensive bioturbation activity of *Dendrobaena mrazeki* in mull soil of studied forests.

Oribatid mites of the temperate forest soils prefer generally upper F and L soil horizons and do not penetrate into deeper mineral soil layers. Hence, most of oribatid species live in upper 5 cm (85–95%), and their occurrence in deeper layers is limited by soil pore miniaturising as well as incapability of these animals to burrow actively through the mineral soil (Lebrun, 1971). The chance of oribatid mites to use vertical burrows of earthworms for entering deeper soil layers was not studied yet. It seems however, that the migration of oribatid mites through fresh burrows may be limited due to their sticking to burrow walls lined with mucus produced by earthworms. Absence of soil algae and low density of microscopic fungi, i.e. important food sources, in older burrows could affect oribatid mites later on. In addition, low oribatid density in burrows probably reflects natural stratification pattern of oribatid mites in mull forest soils. High dominance of small euedaphic species *Microppia minus* and *Ceratozetes minutissimus* in burrow samples supports that opinion.

Earthworm middens and casts differ from adjacent soil in a number of chemical, microstructural and microbial characteristics. In general, they possess higher content of carbon, nitrogen and phosphorus, higher moisture and microbial biomass (Syers et al., 1979) than soil, which may cause the increase in density of some groups of soil mites (Gamasina, Uropodina) and mycophagous collembolans in those structures. As seen from the discussion above, literature data about the density and composition of oribatid communities are often contradictory. Nevertheless, casts of *Dendrobaena mrazeki* differ from both middens of anecic species and casts of most other earthworms markedly. In particular, they are much more compacted and susceptible to drying, which may affect negatively their colonisation by both soil microorganisms and microarthropods. We consider that as the main reason for low density and species richness found in cast in this study. Hostile conditions in the casts of *D. mrazeki* are also documented by predominance of eurytopic, parthenogenetic and microphagous oribatid species *Tectocepheus velatus*, which represents one of a few oribatid species capable to tolerate strong soil disturbances and unfavourable habitats (Skubala, 1997, 1998, 1999; Scheu, Schulz, 1996; Starý, 1999). On the other hand, some oribatid species, e.g. *Zygoribatula exilis, Eniochthonius minutissimus, Punctoribates punctata*, *Quadroppia quadricarinata*, may profit from lower competition or even from specific microhabitats in casts.

The results of our study support the conclusion by Maraum et al. (2001) that the effects of earthworms on soil mites may depend largely on soil, ecosystem type, worm and/or mite community structures and on feeding guilds of earthworms and mites.

Translated by the authors

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References

Bayoumi, B.M., 1978: Significance of the microhabitat on the distribution of oribatid mites in oak-hornbeam mixed forest. Opusc. Zool., *15*: 51–59.

Brown, G.G., 1995: How do earthworms affected microbial and faunal community diversity? Plant and Soil, *170*: 209–231.

Hamilton, W.E., Sillman, D.Y., 1989: Influence of earthworm middens on the distribution of soil microarthropods. Biol. Fertil. Soils, *8*: 279–284.

Lagerlöf, J., Lofs-Holmin, A., 1987: Relationships between earthworms and soil mesofauna during decomposition of crop resudues. In Striganova, B.R. (ed.), Soil fauna and soil fertility. Nauka, Moscow, p. 377–381.

Lebrun, P., 1971: Écologie et biologie de quelques peuplements d'arthropodes édaphiques. Mém. Inst. Sci. Nat. Belg., *165*: 1–203.

Loranger, G., Ponge, J.F., Blanchart, E., Lavelle, P., 1998: Impact of earthworms on the diversity of microarthropods in a vertisol (Martinique). Biol. Fertil. Soils, *27*: 21–62.

Maraum, M., Alphei, J., Bonkowski, M., Buryn, R., Migge, S., Maren, P., Schaefer, M., Scheu, S., 1999: Middens of the earthworm *Lumbricus terrestris* (Lumbricidae): microhabitats for micro- and mesofauna in forest soil. Pedobiologia, *43*: 276–287.

Maraum, M., Alphei, J., Beste, P., Bonkowski, M., Buryn, R., Migge, S., Peter, M., Schaefer, M., Scheu, S., 2001: Indirect effects of carbon and nutrient amendments on the soil meso- and microfauna of a beechwood. Biol. Fertil. Soils, *34*: 222–229.

Marshall, V.G., 1972: Comparison of two methods of estimating efficiency of funnel extractors for soil microarthropods. Soil Biol. Biochem., *4*: 417–426.

McLean, M.A., Parkinson, D., 1997: Changes in structure, organic matter and microbial activity in pine forest soil following the introduction of *Dendrobaena octaedra* (Oligochaeta, Lumbricidae). Soil Biol. Biochem., *29*: 537–540.

McLean, M.A., Parkinson, D., 1998: Impacts of epigeic earthworm *Dendrobaena octaedra* on oribatid mite community diversity and microarthropod abundances in pine forest floor: a mesocosm study. Appl. Soil Ecol., *7*: 126–136.

McLean, M., Parkinson, D., 2000: Introduction of the epigeic earthworm *Dendrobaena octaedra* changes the oribatid community and microarthropod abundances in a pine forest. Soil Biol. Biochem., *32*: 1671–1681.

Norton, R.A., Palmer, S.C., 1991: The distribution, mechanisms and evolutionary significance of parthenogenesis in oribatid mites. In Schuster, R., Murphy, P.W., (eds), The Acari: Reproduction, development and life-history strategies. Chapman and Hall, London, p. 107–136.

Pižl, V., 2002: Earthworms of the Czech Republic. Uherské Hradiště, 155 pp.

Podani, J., 1994: Multivariate analysis in ecology and systematics. SPB Academic Publishing, The Hague, 316 pp.

Scheu, S., Schulz, E., 1996: Secondary succession, soil formation and development of a diverse community of oribatids and saprophagous soil macro-invertebrates. Biodiv. Conserv., *5*: 235–250.

Schrader, S., Seibel, C., 2001: Impact of cultivation management in an agroecosystem on hot spot effects of earthworm middens. Eur. J. Soil Biol., *37*: 309–313.

Skubala, P., 1997: Oribatid mite communities (Acari, Oribatida) on postindustrial dumps of different kinds. I. Abundance and species richness. Abhandlungen und Berichte des Naturkund., Görlitz, *69*, 6: 63–68.

Skubala, P., 1998: Oribatid mite comunities (Acari: Oribatida) on postindustrial dumps of different kinds. II. Community organization. Fragm. Faun., *41*, 14: 193–207.

Skubala, P., 1999: Colonization of a dolomitic dumps by oribatid mites (Acari, Oribatida). Pedobiologia, *43*: 145–159.

Starý, J., 1999: Changes of oribatid mite communities (Acari: Oribatida) during secondary succession on abandoned fields in South Bohemia. In Tajovský, K., Pižl, V. (eds), Soil Zoology in Central Europe. ISB AS CR, České Budějovice, p. 315–323.

Syers, J.K., Sharpley, A.N., Keeney, D.R., 1979: Cycling of nitrogen by surface-casting earthworm in a pasture ecosystem. Soil Biology and Biochemistry, *11*: 181–185.

Tiunov, A.V., 2000: Soil organisms around earthworm burrows: from microflora to macrofauna. In Abstracts. XIII International Colloquium on Soil Zoology, České Budějovice, p. 11.

Zajonc, I., 1980: Earthworms (Oligochaeta, Lumbricidae) of Slovakia (in Slovak). Biol. Práce, *27*: 1–133.

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