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THE PRESENCE OF MITES (ACARI) IN PINE WOOD CHIPS ENRICHED WITH PEAT AND LIGNITE INOCULATED WITH FOREST LITTER AND IRRIGATED

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Abstract

The aim of the study was to analyze the presence of mites (*Acari*), with special focus on indicator oribatid mites (*Oribatida*), in control pine wood chips and pine wood chips enriched with peat and lignite inoculated with forest litter and irrigated. The study was conducted in 2013 on microplots (1 x 1 m) located within a belt of trees in a nursery in Białe Błota. The experiments included the following variants: C – pine wood chips, Ec – pine wood chips inoculated with forest litter, Ec+Pe – pine wood chips enriched with deacidified high peat (20%) (pH 5.5-6.5) and inoculated with forest litter, Ec+Ca – pine wood chips enriched with granulated lignite (20%) (granule size 1-10 mm) inoculated with forest litter.

The addition of forest litter caused an increase in total number of mites in the control pine wood chips and those enriched with peat. Mites belonging to *Mesostigmata* order prevailed in control chips and those enriched with forest litter and peat, while *Oribatida* were dominant mites in the other variants. Considering the results for the entire year, 20% addition of peat and lignite negatively affected the presence of oribatid mites, thus indicating a reduced biological activity of the substrates. The populations of oribatid mites on all microplots were clearly dominated by *Oribatula tibialis*, and *Tectocepheus velatus* and *Adoristes ovatus* were slightly less common.

Key words: soil regeneration, wood chips, soil organic horizon, mesofauna, *Oribatida*.

INTRODUCTION

Biodiversity of degraded forest soils is usually significantly reduced. The treatments aimed at regeneration of such soils by enriching them and accelerating forest succession (e.g. via organic fertilization, introduction of herbaceous plants, trees and bushes) do not result in recovery of the entire forest ecosystem. Restoration of natural forest soil mesofauna seems to the most challenging issue. After a few (Klimek and Kowalska 2013, Klimek and Rolbiecki 2011), and even several years (Andrés and Mateos 2006) since reclamation treatments, the abundance and species diversity of soil microarthropods, particularly of oribatid mites (*Oribatida*), was significantly lower as compared with the same succession stage in the forest soil. Possible causes of this situation include a lack of forest litter layer typical for forest soils and limited possibilities of spreading and colonizing new sites by the soil microarthropods (Beckmann 1988, Lehmitz *et al*. 2011, Wanner and Dunger 2002).

Therefore, new effective methods for acceleration of soil reclamation processes involving microarthropods are constantly searched for. There are two ways of using these animals during reclamation (Haimi 2000). The first is their direct (feeding) and indirect (stimulation of microorganisms) influence on soil metabolism. Secondly, microarthropods may be used as bioindicators of biological condition of the soil. Oribatid mites are known to play many important functions in the soil ecosystems, they improve pedogenic processes and propagation of bacteria and fungi, and they indirectly affect the formation of endo – and ectomycorrhizas (Klironomos and Kendrick 1996, Behan-Pelletier 1999, Remén *et al*. 2010, Schneider *et al*. 2005).

Haimi (2000) claimed that soil fauna was crucial for restoring biological activity during the reclamation of degraded soils and that these processes might be reinforced by means of soil inoculum. Our previous studies investigated development of acarofauna in forest litter harvested from a pine forest and shredded with a garden shredder and in pine wood chips (Klimek and Chachaj 2015). This study and other experiments conducted in forest nurseries (Klimek 2010, Klimek *et al.* 2008, 2011, 2012, 2013a,b) confirmed high usefulness of forest litter in inoculation of degraded soils with edaphon. In practice, soil regeneration requires high volumes of organic matter as a substrate for the growth of the inoculated edaphone. Harvesting large batches of forest litter seems unrealistic, as it is indispensable during forest renewal following forest stand cutting. The referenced studies demonstrated that effective soil inoculation with edaphon required just 1 cm thick layer of forest litter introduced onto a suitable substrate. Previous works (Klimek and Chachaj 2015, Klimek *et al*. 2014a,b) confirmed that wood chips could serve as such a substrate. This material may be collected in the forests in large quantities from post-logging sites or in the form of waste generated by timber industry.

The aim of this study was to analyze the presence of mites (*Acari*), with special focus on indicator oribatid mites (*Oribatida*), in control pine wood chips and pine wood chips enriched with peat and lignite inoculated with forest litter and irrigated.

MATERIAL AND METHODS

The study was conducted in the year 2013, within a belt of trees in a nursery in Białe Błota belonging to Bydgosz Forest District (53.103667°N 17.929611°E). The belt was 20 m wide and included the following species: Scots pine (*Pinus sylvestris* L.), oak (*Quercus* L.) and European ash (*Fraxinus excelsior* L.), and the underbush layer was composed of European ash, silver birch (*Betula pendula* Roth) and oak. The forest stand mitigated the influence of atmospheric factors, such as sun exposure, temperature changes, or intense precipitation. The soil type was albic brunic arenosol (Bydgoszcz Forest Inspectorate data).

The experiment was established on 16 April 2013 on four microplots (1x1 m). The experiments included the following variants: C – pine wood chips, Ec – pine wood chips inoculated with forest litter, Ec+Pe – pine wood chips enriched with deacidified high peat (20%) (pH 5.5-6.5) and inoculated with forest litter, Ec+Ca – pine wood chips enriched with granulated lignite (20%) (granule size 1-10 mm) inoculated with forest litter.

Each microplot was surrounded with 18 cm high wooden frame. Forest litter was removed and the frame was placed directly on the mineral soil (Photo 1). Rodent protection was implemented in the form of plastic net and non-woven fabric mounted to the bottom of the frame. The microplots were covered with 150 dm^3 of pine wood chips with or without additions. The chips were obtained with TIMBERJACK BRUKS 805.2 wood chipper from a post-logging site located in a fresh coniferous forest. Then, the substrate in variants Ec, Ec+Pe and Ec+Ca was supplemented with 10 dm^3 of fresh forest litter that was mixed with the chips. The forest litter (O horizon) was collected from fresh coniferous forest site. During collection, it was sieved through sieves with 10 x 10 mm mesh.

To maintain optimum moisture content throughout the study, the microplots were watered by micro sprinklers as per the guidelines and schedule for the irrigation of nurseries. Mean soil moisture was kept at ca. 10%. Moisture was monitored with the FieldScout TDR 300.

Samples for acarological analyses were collected three times: in the spring, summer and autumn on 8 May 2013, 12 August 2013 and 23 October 2013. Ten samples were harvested from each microplot. A total of 30 samples of 50 cm^3 each were collected from every variant. Mite extraction was carried out over 7 days using Tullgren funnels. Then, the mites were preserved in 70% ethanol. All the mites were classified into orders and oribatid mites into species or genera, with regard to juvenile stages. A total of 1417 mites were determined, including 539 oribatid mites.

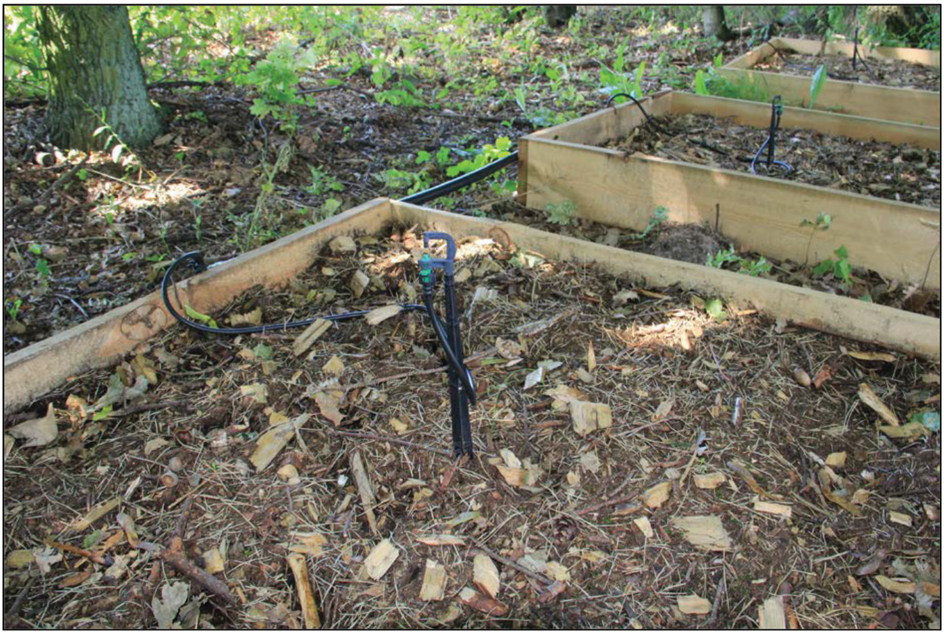


Photo 1. Microplot irrigated with micro sprinklers located in the belt of trees in the nursery in Białe Błota – variant Ec (photo by A. Klimek)

Average density (*N*) of the mites was provided for 50 cm^3 of the substrate, and the species dominance index (*D*) was given in percentage. Species diversity was determined based on the mean number of species per sample (*s*). Prior to statistical analysis, the numerical data were subjected to a logarithmic transformation – ln (x+1) (Berthet and Gerard 1965). The statistical analysis was performed using Statistica 12 software: a compliance of the measurable parameters with the normal distribution was assessed using Kolmogorov-Smirnov test. As the normal distribution was not confirmed, a non-parametric analysis of variance (Kruskal-Wallis *H* test) was performed. For statistically significant differences ($p<0.05$) a analysis for each pair was carried out (Mann-Whitney *U* test) to identify significantly different means.

RESULTS AND DISCUSSION

Earlier studies have repeatedly demonstrated that forest forest litter is a perfect substrate for soil inoculation with mesofauna (Klimek 2010, Klimek et al. 2008, 2011, 2012, 2013a,b). Wood chips turned out to be a suitable substrate eagerly colonized by mites, particularly oribatid mites (Klimek and Chachaj 2015, Klimek et al. 2014a,b). Physical, chemical and structural properties of a substrate may be improved with various additives. In our study, they included 20% supplementation with peat or lignite that are classified as natural fertilizers containing macro – and micronutrients. Both substrates serve as a rich source of organic matter and humus substances on degraded soils (Sas Paszt et al. 2013). They protect soil environment from the effects of heavy metal contamination, which indicates their possible usefulness in reclamation of degraded soils. Moreover, lignite positively affects soil microflora and higher plants. It is considered a better fertilizer than peat (Kwiatkowska and Maciejewska 2008).

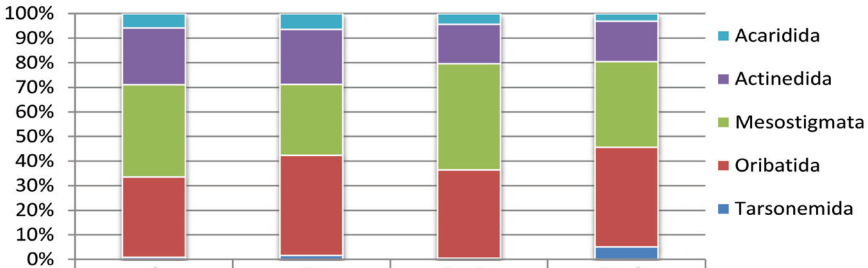
Abundance of mite community. Abundance of mites in individual variants ranged from 7.93 to 15.97 individuals per 50 cm^3 of the substrate (Table 1). The lowest number of mites was recorded on the control microplot (C). Forest litter application improved the mite abundance on the other microplots. However, the increase was significant only for Ec and Ec+Pe variants. In C and Ec+Pe variants, the most common were *Mesostigmata* mites, accounting for 37.4 and 43.2% of all mites, respectively (Fig. 1). The other variants were dominated by oribatid mites (40.6-40.7%). A slightly less common group were *Actinedida* (16.4-23.1%), for which a significantly improved density was observed on microplot Ec (3.57 individuals per 50 cm^3). *Acaridida* and *Tarsonemida* were much less common in the investigated substrates. A similar experiment covering a two-year cycle revealed comparable density of mites colonizing the chips in the first year of the study (Klimek and Chachaj 2015). In the second year, their density grew up to 18.4-27.5 individuals per 50 cm^3.

Species diversity of oribatid mites. In total, 26 species of oribatid mites were reported in all experimental variants (Table 2). Twelve of them inhabited the control chips alone, and following inoculation with forest litter up to 15 were reported for Ec+Pe variant and up to 22 for Ec variant (Table 1). The highest mean number of species per sample *s* (3.57) in Ec variant was significantly higher than in the other variants. In a previously mentioned similar experiment (Klimek and Chachaj 2015), this parameter was similar (3.40-4.00) in the second year of the study. Similarly to other measures of species diversity, diversity index *H* was the highest on microplot Ec. The structure of species diversity and density of oribatid mites in individual variants indicated a negative effect of 20% addition of peat and lignite to the pine wood chips. This might be due to the fact that the benefits of fertilization, especially with lignite, become visible only after a few years (Sas Paszt et al. 2013). A one-year study might be too short to observe its positive effects on the growth of microorganisms and indirectly on the presence of *Oribatida*.

Table 1. Abundance of mites (individuals 50 cm^{-3}), number of *Oribatida* species (*S*), average number of *Oribatida* species (*s*) and *H* index in the research variants

Index – Taxon	Variant				Kruskal-Wallis test	
	C	Ec	Ec+Pe	Ec+Ca	*H*	*p*
N – Acaridida	0.47	1.03	0.57	0.33	5.96	0.113
N – Actinedida	1.83^{A}	3.57^{B}	2.03^{A}	1.73^{A}	8.83	0.031
N – Mesostigmata	2.97^{A}	4.60^{A}	5.50^{A}	3.70^{B}	16.71	0.001
N – Oribatida	2.60^{A}	6.50^{B}	4.57^{A}	4.30^{A}	10.52	0.014
N – Tarsonemida	0.07	0.27	0.07	0.53	3.73	0.291
N – Acari total	7.93^{A}	15.97^{B}	12.73^{B}	10.60^{A}	18.45	0.000
S – Oribatida	12	22	15	18	-	-
s – Oribatida	1.40^{A}	3.07^{B}	2.13^{A}	1.97^{A}	14.17	0.002
H – Oribatida	1.69	1.94	1.70	1.48	-	-

Explanations: A, B, C – the same letter means non-significant difference (Mann-Whitney *U* test, $p<0.05$)
Source: own research data



	C	Ec	Ec+Pe	Ec+Ca
Acaridida	5.9	6.5	4.5	3.1
Actinedida	23.1	22.3	16.0	16.4
Mesostigmata	37.4	28.8	43.2	34.9
Oribatida	32.8	40.7	35.9	40.6
Tarsonemida	0.8	1.7	0.5	5.0

Source: own research data

Figure 1. Dominance of taxonomic groups of mites in pine chips in the experimental variants

Table 2. Abundance of oribatid mites (individuals 50 cm^{-3}) in the experimental variants

Species	C	Ec	Ec+Pe	Ec+Ca	Kruskal-Wallis test *H*	Kruskal-Wallis test *p*
Adoristes ovatus (Koch)	0.27	0.57	0.43	0.27	2.17	0.537
Carabodes forsslundi Sellnick	0	0.10	0.03	0.03	3.93	0.268
Carabodes labyrinthicus (Michael)	0	0.07	0	0	6.05	0.109
Carabodes minusculus Berlese	0	0.03	0	0	3.00	0.391
Carabodes subarcticus Trägardh	0	0.03	0.03	0.13	6.26	0.099
Chamobates schuetzi (Oudemans)	0.20	0.30	0.03	0.17	6.19	0.102
Dissorhina ornata (Oudemans)	0	0.07	0	0.03	3.72	0.292
Eremaeus oblongus C.L. Koch	0	0.13	0.20	0.13	4.41	0.220
Eupelops occultus (C.L. Koch)	0.03	0	0	0	3.00	0.391
Eupelops torulosus (C.L. Koch)	0	0.27^{A}	0	0.10^{A}	11.92	0.007
Gymnodamaeus bicostatus (C.L. Koch)	0	0.03	0	0.03	2.01	0.568
Hemileius initialis (Berlese)	0.03	0.13	0.07	0.03	1.71	0.633
Heminothrus peltifer (C.L. Koch)	0.07	0.13	0.07	0.03	1.11	0.773
Lauroppia neerlandica (Oudemans)	0	0	0.03	0	3.00	0.391
Liochthonius sp.	0.03	0.03	0.03	0.03	0.00	1.00
Metabelba pulverulenta (C.L. Koch)	0.13	0.03	0	0.03	3.98	0.262
Micreremus brevipes (Michael)	0.10	0	0	0	6.05	0.109
Microzetorchestes emeryi (Coggi)	0	0	0	0.03	3.00	0.391
Oppiella nova (Oudemans)	0	0.03	0.10	0	6.15	0.104
Oribatula tibialis (Nicolet)	1.33^{A}	3.27^{B}	2.27^{A}	2.87^{A}	13.25	0.004
Pergalumna nervosa (Berlese)	0.03	0.13	0.03	0	3.98	0.262
Quadroppia quadricarinata (Michael)	0	0.03	0.03	0.03	1.01	0.797
Scheloribates latipes (C.L. Koch)	0	0.10	0	0.13	7.56	0.055
Suctobelba sp.	0	0.17^{A}	0.53^{B}	0.03^{A}	16.36	0.001
Tectocepheus velatus (Michael)	0.33	0.80	0.67	0.17	5.99	0.112
Trichoribates trimaculatus C.L. Koch	0.03	0.03	0	0	2.01	0.568

Explanations: see Table 1.
Source: own research data

Analysis of occurrence of selected *Oribatida* species. The populations of oribatid mites on all microplots were clearly dominated by *Oribatula tibialis* (*D*=50.26-66.67%). This species was most common in Ec variant (3.27 individuals per 50 cm^3), and differences in its abundance between Ec and other variants were significant (Table 2). *Oribatula tibialis* is classified as eurytopic species (Weigmann 1991, Weigmann and Kratz 1981), with preference for forest soils (Rajski 1968). Interestingly, it was the most abundant in birch nursery mulched with forest litter and irrigated (Klimek *et al.* 2013a).

The second most common oribatid mite on Ec, Ec+Pe and Ec+Ca microplots was *Tectocepheus velatus*. It was detected on all microplots in fairly similar numbers of 0.17-0.80 individuals per 50 cm^3. It is a common soil oribatid mite present in various biotopes (Weigmann and Kratz 1981), particularly popular in Scots pine forests (Klimek 1999). *Adoristes ovatus*, a typical oribatid mite of pine forests, was slightly less common in the pine wood chips. Apart from those mentioned above, the following species were present on all experimental plots: *Chamobates schuetzi*, *Hemileius initialis*, *Heminothrus peltifer* and *Liochthonius* sp.

SUMMARY

The addition of forest litter caused an increase in total number of mites in the control pine wood chips and those enriched with peat. Mites belonging to *Mesostigmata* order prevailed in control chips and those enriched with forest litter and peat, while *Oribatida* were dominant mites in the other variants.

Considering the results for the entire year, 20% addition of peat and lignite negatively affected the presence of oribatid mites, which indicated a reduced biological activity of the substrates.

The populations of oribatid mites on all microplots were clearly dominated by *Oribatula tibialis*, and *Tectocepheus velatus* and *Adoristes ovatus* were slightly less common.

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