The Earthworm Communities and Microbial Activities in Coniferous Forests of Estonia

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Ivask M., Truu J., Truu M., Lõhmus K., Ostonen I. 1999. The Earthworm Communities and Microbial Activities in Coniferous Forests of Estonia. *Baltic Forestry.* 2: 32–36.

The forest floor is an important compartment in soil processes and nutrient cycling. The decomposer communities in four Norway spruce (*Picea abies* (L.) Karst) forests and in two Scots pine (*Pinus silvestris* L.) forests were studied. The number of earthworm individuals (0...88) and species (0...5) was variable in forest floor of studied coniferous forests. 0...28 earthworm individuals per 1 m^2 and 0...3 species was found in mineral soil of studied conifer forests and 104±7 individuals per 1 m^2 and 7 species, as exception, in the spruce forest with abundant grass layer. In spruce forests the total number of earthworm individuals was 15...124 per 1 m^2 and the total number of species was 2...8, in pine forests - 0...8 individuals per 1 m^2 and 0...2 species was found. The mean microbial activity in the forest floor of spruce forests was 4,636±1,04 OD/g, in pine forests 3,094±0,69 OD/g.

Key words: earthworm community, forest floor, microbial activity, Norway spruce, Scots pine.

Introduction

Litter decomposition is a key process in all terrestrial ecosystems because it controls nutrient availability and hence primary production (Rutigliano et al., 1996). Litter quality is therefore an important factor in the transfer of energy and plant nutrients to forest soils. The abundance and composition of soil organisms in forest floor and upper soil layer may also influence the rate of decomposition, and subsequently the release of mineral nutrients. In the same time, the community structure and composition of soil and litter organisms is affected by tree species (Saetre, 1998). The community of decomposers consists of micro-organisms and soil faunal organisms; soil fauna are known to be responsible for as much as 30% of the N and C mineralisation (Görres et al, 1998). Earthworms have frequently been considered as one of the most important faunal decomposers in soil because of their effects on soil structure formation and on nutrient cycling.

The aim of the present study is to describe the structure of earthworm community and the microbial activity in spruce and pine forests in Estonia, and to examine the influence of characteristics of forest floor on the parameters of earthworm communities.

Materials and methods

The structure and the relationships of the main decomposer, microbial and earthworm communities in four Norway spruce (*Picea abies* (L.) Karst) forests and in two Scots pine (*Pinus silvestris* L.) forests were studied. Characteristics of stands and soil are given in table 1, descriptions of study areas are published in Lõhmus et al. (1995). The study areas were selected according to the results of our earlier studies on long-term decomposition of fine roots (Lõhmus et al, 1995). The forest floor and soil samples for chemical and microbiological analysis were collected in May and June, on the quadrates 50 x 50 cm or on the rings ∅ 104 mm. The thickness of forest floor layer was measured. The number of sample areas was 10...25, depending on the variability of samples (the mean error of thickness of forest floor does not exceed 10%). The samples were cleaned, sorted, weighed and dried at 75°C. The oven-dry weight and moisture content in all samples, and organic matter content (in muffel oven at 360°C), nitrogen concentration (by Kjehldal method) and soluble phosphorus concentration (by lactate method) in a composite sample were determined. Soil samples were taken on the same quadrates or the rings, in the upper soil layer 0...15 cm. In all samples moisture content, in a composite sample organic matter content (in muffel oven at 360°C), nitrogen concentration (by the Kjeldahl method) and soluble phosphorus concentration (by lactate method) were determined.

Total activity of microbial community as one of essential factors of habitat for earthworms has been measured using fluorescein diacetate method that estimates the activity of dehydrogenase enzymes in a composite sample (Schnürer and Roswall, 1985). Total activity of microorganisms measured in optical density units (OD) characterises metabolic activity of microbial community and correlates well with CO_2 evolution from soils. The total activity of soil microbes is expressed per 1 g of dry soil, but organic matter content has been also recommended for normalisation of soil microbiological parameters, because the microorganisms are associated with organic matter of substrate.

Earthworm communities are characterized by high seasonal variability in the number of individuals, they were collected in October at the time of maximum density, greatest activity and lowest variability of individuals (Nordström and Rundgren, 1973). The samples were collected from five soil blocks measuring 50 × 50 × 40 cm, by hand sorting (Satchell, 1967), separately from forest floor and soil; the earthworms were washed and identified to species.

For all sampling occasions and earthworm species mean numbers of individuals per 1 m^2 and their standard errors were calculated. Regression analysis was used and the correlation coefficients were established. Variables were checked for variance homogeneity.

Results and discussion

The stands are characterised by different age (43...143 years), site quality class (I...V) and humus form (mull, moder-mull, moder-mor or mor) (Table 1). Decomposition rate of fine roots was highest in Värska pine forest and lowest in Kuusnõmme spruce forest (table 1). In studied spruce forests, the forest floor layer was thickest in Vigala (88,7±4,5 mm, 11,4±0,97 kg m^{-2}) study area. On the study area Kuusnõmme the forest floor layer on the surface of soil is missing but the ground vegetation of grasses is abundant. In pine forests, the forest floor layer was the thickest in Nõva (50,8±2,7 mm, 10,3±1,4 kg m^{-2}) (Table 2). All studied forests differed by dry matter and organic matter content in forest floor (22,8...39,1% and 41,6...76,8%, respectively) and soil (49,4...96,0% and 0,7...22,2%, respectively) (Table 3). The mean pH of forest floor and soil was 5,1±0,2 and 4,7±1,0 in spruce forests, and 3,5±0,3 and 4,3±0,1 in pine forest, respectively. The mean nitrogen content of forest floor and mineral soil was 1,61±0,22% and 0,56±0,16% in spruce forests and 1,09±0,16% and 0,02±0,01% in pine forests. The mean soluble phosphorus content was very variable: from 5,0 to 22,7 mg P per 100 g of dry substrate in forest floor and from 0,4 to 40,1 mg P per 100 g dry substrate in soil of all studied forests.

The activity of microbes was higher in forest floor layer as compared to soil on all studied sites (Table 3).

Table 1. Characteristics of stand and soil on study areas (by Lõhmus et al., 1995).

Site	Canopy composition	Age (years)	Site quality class	Soil type	Humus form	Remaining amount of roots after five years (% from the initial weight)
Voore	9S1B	50	I	Umbric Luvisol	mull	54
Vigala	6S3P	43	I	Dystric Gleysol	moder-mull	61
Putkaste	9S1B	64	II	Gleyic Podzol	moder-mor	49
Kuusnõmme	5S5P	73	IV-V	Rendzic Leptosol	mull	73
Nõva	10P	143	V	Sombri-Ferric-Gleyic-Podzol	mor	69
Värska	10P	54	III	Podzol	mor	40

S - *Picea abies*, P - *Pinus silvestris*, B - *Betula pubescens*

Table 2. Characteristics of forest floor.

Site	Stand	Thickness of layer, mm	Dry weight per 1 m^2
Voore	Spruce	24,2±2,5	1520±190
Vigala	Spruce	88,7±4,5	11400±970
Putkaste	Spruce	31,1±1,8	1700±220
Kuusnõmme	Spruce	~0	~0
Nõva	Pine	50,8±2,7	10300±1400
Värska	Pine	63,4±1,8	3850±170

Table 3. Activity of micro-organisms in the soil and forest floor calculated per 1 g of dry soil (Activity 1, OD/g) and per organic matter content (Activity 2, OD/OM), and ratios of microbial activities in the soil and forest floor and soil on different sites.

Site	Fraction	Activity 1 OD/g (mean±SE)	Activity 2 OD/OM (mean±SE)	Ratio1	Ratio 2
Voore	soil	0,868±0,012	8,092±0,147	3,860	0,251
Voore	forest floor	3,352±0,019	2,034±0,179		
Vigala	soil	3,008±0,244	9,763±1,593	2,227	0,257
Vigala	forest floor	6,697±0,205	2,509±0,291		
Putkaste	soil	2,384±0,157	6,222±0,354	1,618	0,261
Putkaste	forest floor	3,859±0,201	1,626±0,145		
Kuusnõmme	soil	1,161±0,004	9,593±0,035	-	-
Kuusnõmme	forest floor	-	-		
Nõva	soil	0,065±0,006	8,857±0,407	58,005	0,125
Nõva	forest floor	3,746±0,249	1,110±0,164		
Värska	soil	0,271±0,014	12,629±0,325	9,007	0,104
Värska	forest floor	2,442±0,22	1,312±0,224		

The highest value was found in the forest floor sample from the Vigala site. The greatest difference between the soil and litter activities was found at site Nõva due to extremely low soil activity. The use of organic matter content in normalisation yielded highest activity values for soils from sites Värska, Kuusnõmme and Vigala. Low activities were recorded for forest floor samples from sites Nõva and Värska. When soil dry weight was used in calculations our results indicate that the microbial activity was higher in forest floor layer on all sites. When organic matter content of substrate (forest floor, soil) was considered then it was possible to depict differences between and within sites (ratio 1 and ratio 2 in table 3). The low activity of microbes in the litter layers of pine forests (sites Nõva and Värska) indicates the effect of substrate type on litter decomposing micro-organisms.

Earthworm community is the most important component of soil fauna attending in the regulation of decomposition and nutrient cycling (Edwards, Bohlen, 1996). All species are participating in decomposition and mixing of the organic and inorganic components but their effect on the soil differs (Edwards, 1985). During the unfavourable period the anecic earthworms live in deep burrows, endogeic live in topsoil, while epigeic earthworms depend on the humidity of the habitat (Bouche, 1977). The number and species composition of earthworm community in different stands was variable (Table 4). In spruce stands the numbers of individuals and species in the Voore study area were highest (116...120 individuals per 1 m^2, 8 species). Different endogeic and epigeic species of earthworms were found on this areas (*Allolobophora caliginosa, Allolobophora rosea, Lumbricus rubellus, Lumbricus castaneus, Dendrodrilus rubidus, Dendrobaena octaedra*). Timm and Frey (1979) have studied the earthworms in spruce forests in Estonia and for the Voore study site, they have published the number of individuals (50...190 individuals per m^2) and species (7). On the study area at Vigala the number of earthworms was low (15...33) and we found only 3 epigeic species (*Dendrodrilus rubidus, Lumbricus rubellus, Dendrobaena octaedra*) and 1 endogeic species (*Allolobophora rosea*) in forest floor. On the Putkaste study area, 3 epigeic species (*Dendrodrilus rubidus, Lumbricus rubellus, Lumbricus castaneus)* in forest floor and 2 endogeic species (*Allolobophora caliginosa, Allolobophora rosea*) in mineral soil were found. On the study area at Kuusnõmme with abundant grass layer, the numbers of earthworm individuals and endogeic species were large, and the typ-

Table 4. Number of individuals and species of earthworms in the forest floor and in the soil of study sites, in October 1997.

		Species*							
Site	Fraction	*A.cal*	*A.ros*	*A.chl*	*L.rub*	*L.cas*	*D.rub*	*D.oct*	Total
		Number of ind. per 1 m^2 (mean±SE)							
Voore	forest floor	12±2.	4±2	0	12±5	4±1	56±9	0	88±28
	soil	20±10	4±1	0	4±1	0	0	0	28±10
Vigala	forest floor	3±2	0	0	4±1	0	24±4	4±2	37±9
	soil	0	0	0	0	0	0	0	0
Putkaste	forest floor	0	0	0	8±2	12±2	28±5	0	48±11
	soil	6±2	2±1	0	0	0	0	0	8±2
Kuusnõmme	forest floor	4±1	0	0	8±2	2±1	6±2	0	20±3
	soil	84±9	12±5	8±4	0	0	0	0	104±7
Värska	forest floor	0	0	0	0	0	0	0	0
	soil	0	0	0	0	0	0	0	0
Nõva	forest floor	0	0	0	0	0	8±4	0	8±4
	soil	0	0	0	0	0	0	0	0

*
A.cal – Allolobophora caliginosa
A.ros – Allolobophora rosea
A.chl – Allolobophora chlorotica
L.rub – Lumbricus rubellus
L.cas – Lumbricus castaneus
D.rub – Dendrodrilus rubidus
D.oct – Dendrobaena octoedra

ical species of grasslands dominated (*Allolobophora caliginosa, Allolobophora chlorotica, Allolobophora rosea, Lumbricus rubellus*). In pine stands the forest floor was quite acidic and only few earthworm species tolerate such conditions. After Lee (1985), the earthworms are not able to live in medium with pH<3.5, and the pH range 3,5...4,5 is suitable for few epigeic earthworm species (*Dendrodrilus rubidus)*. On the Värska study area where the pH of the forest floor and soil were low (3,6...4,4) no earthworms were found during the year. A very small number of earthworms was found in forest floor layer (*Dendrodrilus rubidus, Allolobophora caliginosa*) on the Nõva study site.

There was found significant linear relationships for soil between the number of species and pH (r = 0,86) and number of individuals per 1 m^2 and pH (r = 0,91), respectively. For forest floor significant multiplicative relationships between the number of species and pH (r = 0,94) and number of individuals per 1 m^2 and pH (r = 0,93) were found. The level of significance p<0,0001 in all cases. The effect of the nitrogen content, organic matter content and soluble phosphorus content of forest floor and soil on the earthworm community was statistically insignificant.

Conclusions

1. The number of earthworm individuals (0...88) and species (0...5) was variable in forest floor of coniferous forests. The number of earthworm individuals and species in mineral soil of all studied forests was 0...28 and 0...3, respectively, and 104±7 individuals per m^2 and 7 species, as exception, in the spruce forest with abundant grass layer.

2. In spruce forests the number of earthworm individuals was 15...124 per 1 m^2 and the number of species was 2...8, in pine forests the numbers were: 0...8 individuals per m^2 and 0...2 species.

3. The mean microbial activity in the forest floor of spruce forests was 4,636±1,04 OD/g, that of pine forests 3,094±0,69 OD/g (or, 2,056±0,26 OD/OM and 1,211±0,10 OD/OM, respectively). The mean microbial activity in the soil of the spruce forests was 1,855±0,55 OD/g and that of the pine forests 0,168±0,10 OD/g, (or, 8,418±0,82 OD/OM and 10,743±1,89 OD/OM, respectively).

4. The significant linear relationships for soil between the number of species and pH (r = 0,86) and number of individuals per 1 m^2 and pH (r = 0,91) in soil, significant multiplicative relationships between the number of species and pH (r = 0,94) and number of individuals per 1 m^2 and pH (r = 0,93) in forest floor were found

Acknowledgements

Support for this work came from grant No 2726 from Estonian Science Foundation.

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СТРУКТУРА И АКТИВНОСТЬ СООБЩЕСТВ МИКРООРГАНИЗМОВ И ДОЖДЕВЫХ ЧЕРВЕЙ В ХВОЙНЫХ ЛЕСАХ ЭСТОНИИ

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Резюме

Изучены сообщества разлагателей в лесной подстилке и в гумусевом горизонте в ельниках и сосняках. Структура сообщества дождевых червей зависит от свойств лесной подстилки. В то же время, травянистая растительность также влияет на численность червей и разнообразия их видов. В ельниках, численность дождевых червей намного выше чем в сосняках, 15...124 и 0...8 особей на 1 м^2, соответственно. Число видов также было выше в ельниках по сравнений с числом видов в сосняках (2...8 и 0...2, соответственно). Активность сообщества микроорганизмов в ельниках выше чем в сосняках.

Ключевые слова: сообщества дождевых червей, лесная подстилка, активность микроорганизмов, ель еропейская, сосна обыкновенная.