EARTHWORM POPULATION RESPONSES TO DECIDUOUS FOREST SOIL ACIDITY AND VEGETATION COVER

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This paper shows results of earthworm specimens and biomass investigation in relationship to vegetation cover and soil pH values in sixty plots in broadleaved forests of Gaume region, south Belgium. Standard combination of behavioural and direct methods to catch earthworm specimens were used during the fieldwork – soil and earthworm samples were taken to the lab for pH measurement and species determination. The investigation revealed no significant influence of vegetation cover, but the fact that pH very strongly influenced the density and biomass of earthworms. Variables number of earthworms and earthworm biomass were strongly correlated with each other; therefore only the biomass was used as dependent variable in the statistical tests.Results from this study are useful for updating data of species living in acid forests in Europe and for following studies on forest production and forests soil fertility.

soil fauna; biodiversity; acidification; species ecology; abundance; biomass

INTRODUCTION

Soil is a natural component of terrestrial ecosystems and is in a long-term equilibrium with climate and vegetation. Soil biota is a very important part of soil. In particular soil invertebrate animals are good indicators of soil conditions, because of their specific ecological demands (Lavelle, Spain, 2001; Oehlmann, Schulte-Oehlmann, 2003; Garcia-Ruiz et al., 2009). Their activities provide significant ecosystem services, such as recycling of nutrients, soil water availability, erosion control, or pest control (Neuerburg, Padel, 1994; Lavelle et al., 2006). Soil fauna both affects the soil properties, and is sensitive to soil property changes (Barrios, 2007).

A significant taxonomic group living in soils are, among others, the earthworms (Lumbricidae, Annelida). These organisms are commonly used as bioindicators, mainly for soil quality (e.g. acidification, heavy metal and pesticide pollution) studies (Lavelle et al., 1997; Muys, Granval, 1997; Paoletti, 1999). Their ecosystem function consists in organic matter fragmentation, nutrient recycling, bioturbation, and soil aggregate forming (Zhang, Schrader, 1993; Scullion, Malik, 2000; Jongmans et al., 2001).

Forest soil degradation and acidification is a threat to many forests in Europe (Blum, 1990; Van Lynden, 1995). Forest soil acidification is often the combined result of long-term biomass extraction, atmospheric pollution, and changes in tree species composition in the canopy cover (Ferrier et al., 1993; Hovmand, Bille-Hanssen, 1999). Acidification of forest soils may lead to decrease of soil biological activity (Persson et al., 1987; Tischer, 2010), retarded nutrient cycling, and productivity losses. Most lumbricid earthworms, particularly soil inhabiting ecological groups like endogeics and anecics, are very sensitive to soil acidity (Muys, Granval, 1997). In acid soils only some acid-tolerant epigeic species are generally found, but in lower abundance and thus the overall diversity is lower (Wallwork, 1983). An acidification process may therefore lead to extinction of endogeic and anecic species, given their slow recolonization rates (Potthoff et al., 2008).

There is the importance of soil fauna investigation, not only because of its ecological demands and interaction with soil. The aim of this paper was to evaluate the influence of vegetation cover and soil acidity on earthworm populations in deciduous broadleaved forest. For this study, we selected a study site with a large broadleaved forest in south Belgium because of the two reasons: first, in its sandy soils acidification processes are expected to have a quick effect on soil biological activity, second, differences in acidity are mainly caused by differences in site conditions or forest cover, since forest management has been homogeneous over the area, and atmospheric deposition levels are moderate and expected to be rather homogeneous over the forest. The obtained data may help understanding the basic biological behaviour of worms and finding a way to describe the relationship between forest soil variability and tree cover management and diversity of fauna living in these soils. Results of the present study may also serve as a reference material for future

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Table 1. Species mean and standard deviations of biomass and density per plot (m^2)

Species	Biomass($g.m^{-2}$)	Density (m^{-2})
Aporrectodea caliginosa (Savigny, 1826)	6.19 ± 12.32	45.20 ± 91.92
Aporrectodea rosea (Savigny, 1826)	0.17 ± 0.71	2.13 ± 7.17
Dendrobaena attemsi Michaelsen, 1902	0.08 ± 0.24	0.87 ± 2.64
Dendrobaena octaedra (Savigny, 1826)	0.75 ± 1.35	8.70 ± 15.56
Dendrobaena pygmea (Savigny, 1826)	0.004 ± 0.02	0.08 ± 0.33
Dendrodrilus rubidus (Savigny, 1826)	0.63 ± 1.36	8.07 ± 16.85
Lumbricus castaneus (Savigny, 1826)	0.81 ± 2.41	3.53 ± 9.08
Lumbricus rubellus Hoffmeister, 1843	2.52 ± 7.85	8.07 ± 24.40
Lumbricus terrestris Linnaeus, 1758	0.07 ± 0.49	0.1 ± 0.57
Octolasion cyaneum (Savigny, 1826)	1.17 ± 6.41	0.83 ± 4.62
Octolasion lacteum (Örley, 1881)	0.16 ±0.85	0.67 ± 3.62
Aporrectodea sp.	0.61 ±2.80	15.30 ± 56.06
Dendrobaena sp.	0.24 ± 0.61	7.00 ± 17.86
Dendrodrilus sp.	0.42 ± 1.03	8.23 ± 16.16
Lumbricus sp.	1.22 ± 2.65	21.2 ± 46.51
Octolasion sp.	0.11 ± 0.45	0.80 ± 2.66

studies of soil fauna diversity in both types of forests (coniferous and deciduous).

MATERIAL AND METHODS

Sampling of soil fauna was carried out in the broad-leaved forests in the south of Belgium (the Gaume region, around the town of Virton – GPS WGS84: 49°36′N; 5° 33′E). In each of 30 sites two regular grids (0.5 m²) were randomly selected for earthworm sampling. Earthworms were collected by a combination of handsorting of the litter layer, mustard extraction (on the whole sampling area of 0.5 m^2), followed by hand sorting of a soil sample. The litter and soil hand sorting was carried out on a subsample of 31.7 × 31.7 cm (0.1 m²; soil sample to a 20 cm depth) (Valckx et al., 2010). The samples of earthworms were labelled by a unique code related to the site and the method used. Reached earthworms were immediately taken into the pot with alcohol (70% ethanol), later in the lab transported into formalin solution (5% formaldehyde), and finally after two weeks back to alcohol. Specimens were determined according to the determination key in Sims, Gerard (1999).

Percentage of the vegetation cover was measured in three vegetation layers (herb, shrub, and tree layer). Homogenized soil samples were taken from 0–15 cm depths, dried, and pH – H_2O measurements of the soil were carried out in the lab.

Obtained data on earthworms abundance and their fresh biomass were used as dependent variable in our analysis. As an explanatory pH and vegetation cover were used. Because of possible variables correlations we had checked the independence by partial correlations before using a multiple regression analysis. All tests were performed using STATISTICA software for MS Windows (Version 9.1, 2010) with the chosen level of significance α = 0.05.

RESULTS

Altogether 1114 specimens representing eleven species with biomass of 134.37 g were found. Mean biomass ($g\cdot m^{-2}$) and mean density (individuals per m^2) are shown in Table 1. The average specimens number per locality (m^2) was 37.13, however the number of individuals between sites strongly fluctuated (SD = 52.96, min–max = 2–261). Similarly unbalanced was also biomass, where the mean number was 4.48 g per locality (SD = 7.03, min–max = 0.02–34.11). Compared with the adults, juveniles dominated in our samples in the rate of 2.81 : 1; however despite the higher abundance the total weight of juveniles (58.00 g) was lower than that of the adults (76.37 g), and/or 7.26 and 7.92 g mean in m^2.

Average pH value was 3.79 (min–max = 3.16–4.07, SD = 0.44). At the localities, tree vegetation dominated in the three levels of the vegetation cover (mean cover = 89.8%, min–max = 60–95%), less herb level vegetation (mean = 67.3%, min–max = 20–95%), and the lowest number showed a shrub layer (mean = 37.2%, min–max = 0–80%).

Table 2. Correlation matrix of vegetation characteristics

Variables	Herb	Shrub	Trees
Herb		r = - 0.14 P = 0.46	r = - 0.14 P = 0.46
Shrub	r = - 0.14 P = 0.46		r = - 0.57 P < 0.001
Trees	r = - 0.14 P = 0.46	r = - 0.57 P < 0.001	

Table 3. The multiple regressions of the influence of vegetation cover and pH on the earthworm biomass

R	R^2 adj.	*F*	*P*
0.75	0.51	11.32	< 0.001

	β	*t*	*P*
Herb	0.009	0.27	0.79
Trees	0.024	0.26	0.79
pH	11.911	5.62	< 0.001

Variables number of earthworms and earthworm biomass were strongly correlated with each other $r = 0.95$; $P < 0,001$), therefore only the biomass was used as dependent variable in the statistical tests. The correlation matrix (Table 2) shows that the observed value of the herb vegetation cover is uncorrelated with shrubs and trees, but these two are mutually correlated. Therefore the factor of the vegetation cover is represented by a proportion of herbaceous vegetation and tree cover in our study.

Factors which may affect biomass – pH, cover of trees, and herb cover – were uncorrelated. The multiple regressions revealed that only pH significantly influenced the biomass of earthworms (Table 3). For better understanding the distribution of earthworm biomass among chosen soil pH categories was analyzed. Three categories of pH were set: A (lower) pH 3.20–3.78; B (medium) pH 3.78–3.94; C (higher) pH 3.94–4.75. The highest earthworm biomass belonged to the third category – higher pH (ANOVA, $F = 7.836$, $P < 0.001$) (Fig. 1).

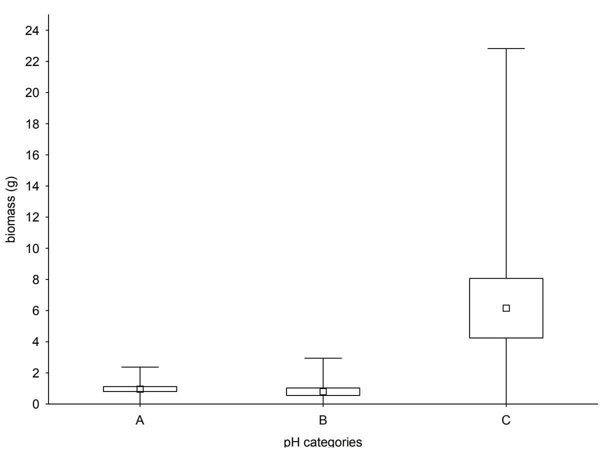

Fig. 1. Distribution of earthworm biomass among pH categories. Means + SD. A = lower pH: 3.20–3.78; B = medium pH: 3.78–3.94; C = higher pH: 3.94–4.75

DISCUSSION

The results show that pH has a significant impact on the biomass of earthworms. The sensitivity of earthworms to the pH depends on the species; but most species are neutrophile with optimal soil reaction pH 6–7 (Satchell, 1955). Earthworm communities living in forest soils consist mainly of acid-tolerant species (Satchell, 1955; Pižl, 2002). This is confirmed by the species composition in the monitored area where unassuming ubiquists from the genus Aporrectodea and epigeic acid-tolerant species dominate, mainly *Dendrodrilus rubidus*, *Dendrobaena octaedra,* and *Lumbricus rubellus*. Our research proved that at low pH values increases the number of juvenile at the expense of the number of adult individuals (ratio 2.81 : 1). This fact may be due to pH values lower than optimal for the growth and reach of sexual maturity of earthworms and often even the survival of anecic earthworm species that are in general acido-intolerant is prevented (similar studies of Muys et al., 1992; Muys, Granval, 1997; Reich et al., 2005). We can submit that acidity in forest sites significantly influences earthworm communities. It is a very important fact in term of soil fertility and soil-forming processes. pH influences not only changing of the species composition of these communities, but also the number of individuals, biomass, and the ratio of ontogenetic stages (Hagvar, 1990). This fact is supported by the distribution of biomass showed in Fig. 1, where significantly higher biomass (and also abundance) was found in the third category with higher pH values. A negative reaction of earthworm coenosis to low pH is confirmed by other studies (Satchell, 1955; Standen, 1979; Enckell, Rundgren, 1988). In the next several years, these facts can reduce the mineralization of organic matter and thus degrade the physical properties of soils in forest habitats, and thus the total forest production (Marshall, 1971).

In the present study no influence of vegetation (herb and trees) cover on earthworms was proved. Generally, vegetation cover has only slight, statistically insignificant, effect on earthworm population, although Zaller, Arone (1999) found that reduction of vegetation cover leads to worse microclimatic conditions and less availability of adequate food.

CONCLUSION

Earthworms are influenced more by pedological properties than by the vegetation structure and density (and potentially a humus layer). In the present study pH value appeared as a decisive factor. The pH value, of course, is very strongly influenced by forest management. For example we think that management of the coniferous forest could strongly influence pedochemical (namely acid soil reaction) character of a locality. Inclusion of coniferous trees into semi-natural forests could lead to continuous decreasing of pH value and consequently to earthworm biodiversity decrease in the forest sites.

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