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ROLE OF *APORRECTODEA CALIGINOSA* IN THE PROCESSES OF SOIL ORGANIC MATTER TRANSFORMATION UNDER THE CONDITION OF MONOCULTURE AND MULTISPECIES PLANT COMMUNITY***

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Abstract. The study has been carried out in the experimental field of the Centre for Ecological Research of the Polish Academy of Sciences, PAN, located in Dziekanów Leśny (north of Warsaw). Six hundred lysimeters were installed covering the experimental area. The surface of the experimental plots (both lysimeters and their vicinity) was sown with either one grass (*Festuca rubra*) on half of the area, or with a mixture of 8 grass species on the other half of the area. In the next year, geophagous earthworms *A. caliginosa* were introduced to half of the lysimeters. The content of C-org, N-total, and the fractional composition of soil humus, were first determined at the beginning; at the end of the experiment also pH and the capacity of sorption complex were identified. The empirical results were subject to statistical analyses. After two years of the study, in comparison to red fescue sodding, the grass mixture sodding caused an increase in the content of organic carbon, total nitrogen and carbon of the humus fraction. The differences between the mean values of both soddings were not statistically significant. In soils under grass mixture, *A. caliginosa* caused an increase in the contents of organic carbon and fulvic acids carbon in relation to the initial soil; the CHA/CFA ratio significantly decreased. A slight increase in the degree of organic matter humification was observed in both soddings in combination with earthworms.

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The diversity of organism assemblages dwelling in soil is determined by the physical and chemical properties of the habitat, climate, vegetation and interrelationships between the particular components [15]. Both in a global and regional scale, vegetation is considered the crucial factor shaping soil biodiversity. Numerous studies indicate that reduction of plant species diversity in the ecosystem causes depletion of the edaphone composition [1, 10]. Other studies show that this fact is probably related only to higher trophic levels [14]. This is evidenced by the decrease in the density and biomass of earthworms in monocultures in comparison to variable systems and the preference of the latter by rodents. A rich and diverse assemblage of soil organisms has a very strong influence on the formation of plant communities and their production. In this case, a unique role is played by earthworms, a soil engineering species, that may cause significant changes in the physical, chemical and biotic properties of a habitat.

The role and significance of various earthworm species may vary in an ecosystem. The most important differences occur between detritophags and geophags. Detritophags, represented by Poland common species *Lumbricus rubellus* (Hoffm.), dwell in the litter or the sub-surface part of soil, feeding on partly decomposed plant material with a small admixture of mineral parts. In comparison to the surrounding soil, coprolites of this species are enriched in organic carbon, total and mineral nitrogen, soil humus, macro- and microelements, as well as microorganisms. They become centres of mineralization and humification of the organic matter [5, 6, 8, 9].

A typical geophagous species in Polish fauna is *Aporrectodea caliginosa* (Sav.), a common organism of arable soils. It dwells down to a depth of 20 cm and feeds on strongly decomposed organic matter, including parts of root systems and humus from the consumed soil [12]. Food intake is linked with continuous burrowing activities in the soil. The low energetic value of the food means that 24-hour consumption often exceeds the body mass of an individual. The short passage of the food mass through the intestine (1 h) does not favour the growth of microflora in it [3].

The objective of this paper is an attempt to check if food intake by *A. caliginosa* may cause a decrease in humus resources, particularly in light soils, and what the contribution of plant biodiversity in this phenomenon is.

MATERIAL AND METHODS

The experiment was carried out in 2004 in the Centre for Ecological Research, Polish Academy of Sciences in Dziekanów Leśny under Project No. PBZ-KBN-087/P04/2003. About 600 lysimeters were installed; each was 30 cm in diameter and 45 cm in height with a double perforated bottom allowing gathering of the filtered material and its transportation to the surface. Lysimeters were filled with homogenous soil removed from the study field to the depth of 30 cm. Prior to inserting in the lysimeters, the soil was cleaned of earthworms, cocoons, root fragments and stones. Earlier the soil had neither been treated with fertilizers nor pesticides. The soil is represented by light soil – slightly clayey sand texture, organic carbon content 6 g kg^{-1}, total nitrogen content 0.5 g kg^{-1} and low pH values – pH_{KCl} 4.45. Lysimeters were inserted in the soil and in Spring 2004, half of them were sown with red fescue grass (*Festuca rubra*) and the other half with a mixture of 8 grass species, comprising: *Festuca pratensis* (15%), *Phleum pratense* (20%), *Dactylis glomerata* (10%), *Festuca arundinacea* (5%), *Bromus inermis* (5%), *Lolium perenne* (10%), *Poa pratensis* (15%), and *Festuca rubra* (20%). Both sowings were made from an identical number of seeds. In May 2005, the earthworm *A. caliginosa* at 15 individuals per lysimeter was introduced to half of the lysimeters in each sowing combination. Lysimeters without earthworms were treated as the control batch.

Samples for analysis were collected in the beginning of the experiment (initial soil) and from the lysimeters in September 2006 after the experiment. The samples were collected randomly, 10 samples per combination.

The following parameters were determined in the soil samples: soil reaction in 1M KCl, sorption capacity, organic carbon and total nitrogen contents; extraction of humic acids was made using the simplified method of Kononowa-Bieliczkowa [2]. Carbon in soils and in particular fractions was determined using the Tiurin method, total nitrogen was determined using the Kjeldahl method with the use of the Kieltec-Tecator apparatus. The results were analyzed using the ANOVA variance analysis (Statgraphic Plus 5.1 software), and the mean values were compared using the Tukey test.

RESULTS AND DISCUSSION

Changes in some chemical properties of the soil were noted after the 2.5-year experiment (Table 1). The reaction of soils with mono- and multispecific sodding had increased by 0.35 in comparison to the initial soil. The difference between the soils of both soddings was insignificant in ANOVA; the influence of earthworms on pH was not observed. More significant changes took place in the soil sorption capacity. In relation to the initial soil, sodding with red fescue caused a 3.5-fold increase in the sum of alkaline cations (S), whereas the multispecific sodding caused 2.9-fold increase. The difference between the sodding systems was statistically significant. In the combination with earthworms no significant changes in the S value were found in either of the soddings. Hydrolytic acidity (Hh) was higher than in the soil before the treatment and significantly higher in comparison to the S values, in soils with multispecific sodding. Earthworms did not cause any significant change in this characteristic. In consequence, in

TABLE 1. CHEMICAL PROPERTIES OF SOIL FROM LYSIMETERS AFTER 30 MONTHS OF SODDING FORMATION AND 18 MONTHS AFTER THE EARTHWORM *APORRECTODEA CALIGINOSA* INTRODUCTION

Sodding	pH_{KCl}	BEC	Hh	CEC	BS (%)
		(cmol (+) kg^{-1})			
Without earthworms					
Red fescue	4.79	6.01	2.43	8.44	71.21
Grass mixture	4.81	5.01	2.52	7.53	66.53
$LSD_{0.05}$	n.s.	0.405	0.061	0.370	1.810
With earthworms					
Red fescue	4.78	6.15	2.44	8.59	71.59
Grass mixture	4.82	5.03	2.49	7.52	66.89
$LSD_{0.05}$	n.s.	0.626	n.s.	0.627	2.250
Initial soil (before treatment)					
Without sodding	4.45	1.75	1.84	3.59	48.75

x – mean values from 10 lysimeters, BEC – base exchange capacity, Hh – hydrolytic acidity, CEC – cation exchange capacity, BS – base saturation.

comparison to the initial soil, the total sorption capacity (T) was over 2.5-fold higher under monospecific sodding, reaching 8.44 $cmol^+ kg^{-1}$, and 2 times higher under multispecific sodding, reaching 7.53 $cmol^+ kg^{-1}$. The difference between the sodding systems was statistically insignificant. The soil under monospecific sodding had higher saturation of the sorption complex by alkaline cations (71.06%) in comparison to the soil under multispecific sodding (66.51%). The difference between the soddings was significant but no earthworm influence was found in this case either.

With regard to the content of organic carbon, total nitrogen and the fraction content of humus (Table 2) in soil under soddings without earthworms, it is to be concluded that values of all the parameters are higher under the grass sodding (except for total nitrogen and CHA). The content of organic carbon in soil under grass mixture exceeds that in soil under monospecific sodding (*Festuca rubra*) by 6.4%, CFA – by 12.5% and CR – by 5.7%. The differences are, however, statistically not significant. The increase in organic carbon content was probably caused by higher biomass production in relation to monospecific sodding [11].

A fact worth noting is that the organic carbon content under red fescue and in the initial soil were maintained at the same level. The 2.5-year lasting red fescue sodding formation did not cause any increase in the organic carbon content in the

TABLE 2. CONTENT OF ORGANIC CARBON AND TOTAL NITROGEN AND FRACTION COMPOSITION OF THE SOIL HUMUS IN TWO SODDING SYSTEMS WITH EARTHWORMS ($g\ kg^{-1}$)

Sodding	C-org	N-total	C:N	CHA+CFA	CHA	CFA	CR	CHA+CFA
Without earthworms								
Red fescue	6.08	0.69	8.81	2.56	1.12	1.44	3.52	0.78
Grass mixture	6.47	0.72	8.99	2.75	1.13	1.62	3.72	0.70
$LSD_{0.05}$	n.s.							
With earthworms								
Red fescue	5.93	0.81	7.32	2.59	1.14	1.45	3.34	0.79
Grass mixture	6.55	0.68	9.63	2.86	1.08	1.78	3.69	0.61
$LSD_{0.05}$	0.337	0.105	1.10	0.14	n.s.	0.13	0.27	0.09
Initial soil (before treatment)								
Without sodding	6.00	0.50	12.00	2.71	1.15	1.56	3.29	0.74

CHA – C humic acids, CFA – C fulvic acids, CR – C residuum.

TABLE 3. PERCENTAGE CONTENT OF SELECTED CARBON FRACTIONS IN SOIL ORGANIC CARBON

Sodding	CHA	CFA	CR	HS
Without earthworms				
Red fescue	18.42	23.68	57.90	42.10
Grass mixture	17.47	25.04	57.49	42.51
$LSD_{0.05}$	n.s.			
With earthworms				
Red fescue	19.22	24.45	56.33	43.67
Grass mixture	16.49	27.18	56.33	43.67
$LSD_{0.05}$	1.77	1.54	n.s.	n.s.
Initial soil (before treatment)				
Without sodding	19.17	26.00	54.83	45.17

HS – degree of humification (CHA+CFA)/C-org 100%.

soil of the lysimeters; only slight changes in the fraction content of humus were observed. A characteristic feature of the fraction composition is the prevalence of fulvic acids over humic acids, which was testified by CHA/CFA values below 1.

Most probably, an increased mineralization of the decomposed organic matter and the biomass of fresh undecomposed grass roots takes place in the first stages of sodding formation. This is evidenced by the 2.5-fold increase of exchangeable cations in the soil that are released during this process (Table 1).

The introduction of *A. caliginosa* earthworms into the soddings caused an insignificant increase in the organic carbon content in the soil, under the grass mixture only. The content of carbon of fulvic acids (CFA) rose also in this combination, resulting in a significant decrease in the CHA/CFA ratio in comparison to the control batch. In soil with red fescue the earthworms caused a decrease in the residual carbon content (CR). In this combination all the differences (except CHA) between the average values from both soddings were statistically significant.

The percentage content of particular humus fractions in the soil organic carbon indicates slight changes that took place in the soil of both soddings following the introduction of *A. caliginosa* earthworms. In comparison to the initial soil (Table 3), the combinations of both soddings with earthworms showed a 1.0–1.5% increase in organic matter humification, and a similar increase in the content of carbon from fulvic acids (CFA); the content of residual carbon (CR) in organic carbon decreased in the same time. In relation to the initial soil, the content of carbon from humic acids (CHA) increased under red fescue and decreased under the grass mixture.

Such slight changes in the content and quality of soil humus under the influence of *A. caliginosa* earthworms result from the feeding strategies and digestion physiology of this species. Typically, 2 to 6 species of *Lumbricidae* occur in meadow areas [4]. In the early stages of the meadow succession *Aporrectodea caliginosa* dominates, whereas in the progressed succession the assemblage is dominated by *Lumbricus rubellus,* a species characteristic of a completely different trophy pattern. In comparison to *A. caliginosa*, its coprolites are enriched in organic matter at different decomposition stages and contain high amounts of various bacterial flora, thus favouring humus formation. The age of the soddings is also an important factor. According to Makulec and Kusińska [4, 6], the organic carbon content grows with meadow maturity, as well as the content of carbon of fulvic acids in the earthworm coprolites. The 2.5-year long experiment represents a very early stage of the succession with only one geophagous species of the *Lumbricidea*, therefore it seems that the type of sodding is much more influential for the soil organic matter than the presence of *A. caliginosa*. The life activity of this species causes an improvement in the physical properties of soil (aeration, structure improvement), which ensures better development of the grass root system and larger biomass increase [11], and leads in consequence to the observed increase of organic matter in the soil (mainly under grass mixture sodding).

CONCLUSIONS

1. Following the formation of soddings composed of red fescue and a mixture of 8 grass species, the soil pH and its sorption capacity, particularly with regard to alkaline cations, increased in relation to the initial soil. Both T and BS were significantly higher in soil under red fescue. No influence of *A. caliginosa* on these properties was observed.

2. In comparison to red fescue sodding, the grass mixture sodding caused an increase in the content of organic carbon, total nitrogen and carbon of the humus fraction. The differences between the mean values of both soddings were statistically insignificant.

3. In soils under grass mixture, *A. caliginosa* caused an increase in the content of organic carbon and fulvic acids carbon in relation to the initial soil; the CHA/CFA ratio significantly decreased.

4. In soil covered with red fescue, *A. caliginosa* caused a decrease in the residual carbon (CR) and C:N ratio.

5. A slight increase in the degree of organic matter humification was observed in both soddings in combinations with earthworms.

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ROLA *APORRECTODEA CALIGINOSA* W PRZEMIANACH MATERII ORGANICZNEJ W GLEBIE W WARUNKACH MONOKULTURY I WIELOGATUNKOWEGO ZESPOŁU ROŚLINNEGO

Badania przeprowadzono na poletku doświadczalnym w Centrum Badań Ekologicznych PAN w Dziekanowie Leśnym. Na powierzchni około 200 m^2, po uprzednim zdjęciu wierzchniej warstwy gleby do głębokości 30 cm, ustawiono 600 lizymetrów. Lizymetry o podwójnym dnie uzupełniono glebą z tego poletka po uprzednim wybraniu dżdżownic, ich kokonów i resztek systemu korzeniowego. Jest to gleba lekka o składzie granulometrycznym piasku gliniastego lekkiego. Podwójne dno lizymetrów pozwalało na odprowadzenie nadmiaru odcieków i skierowanie ich powrotnie na ich powierzchnię. Powierzchnia lizymetrów oraz ich otoczenie zostały obsiane trawą – połowa jednym gatunkiem (*Festuca rubra*) a pozostałe ośmioma gatunkami. Po ukształtowaniu się darni w następnym roku do połowy lizymetrów wprowadzono dżdżownice geofagiczne *A. caliginosa*. Lizymetry bez dżdżownic stanowiły kontrolę. Na początku i pod koniec doświadczenia przeprowadzono oznaczenie zawartości C-org, N-og i składu frakcyjnego humusu glebowego. Wykonano także oznaczenie pH i pojemności kompleksu sorpcyjnego. Wyniki opracowano statystycznie wykorzystująca analizę wariancji ANOVA w programie Statgraphics Plus 5.1, do porównania średnich zastosowano test Tukey'a.

Po dwóch latach obserwacji stwierdzono zdecydowanie wyraźniejsze zmiany pod wpływem dżdżownic w glebie o zadarnieniu wielogatunkowym w porównaniu do monokultury. Zadarnienie mieszanką spowodowało w stosunku do zadarnienia kostrzewą czerwoną wzrost zawartości C-org, N-og i C frakcji próchnicy. Różnice między średnimi z obu zadarnień nie były jednak istotne statystycznie. Pod wpływem *A. caliginosa* w glebie pod mieszanką traw nastąpił wzrost, w stosunku do kontroli, zawartości C-org oraz węgla kwasów fulwowych i istotne obniżenie wartości CHA/CFA. W kombinacji z dżdżownicami stwierdzono nieznaczne zwiększenie stopnia humifikacji materii organicznej w obu zadarnieniach. Tak niewielkie zmiany w zawartości materii organicznej w tym eksperymencie wynikają ze specyficznego rodzaju trofii *A. caliginosa* i bytowania w glebie tylko tego gatunku.