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BIOMANIPULATION OF MACROARTHROPODS – EFFECT ON FOOD WEB				

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EFFECT OF MACROARTHROPODS PATROLLING SOIL SURFACE ON DECOMPOSITION RATE OF GRASS LITTER (*DACTYLIS GLOMERATA*) IN A FIELD EXPERIMENT

ABSTRACT: The rate of grass decomposition was analysed in three field experiments (I, II and III) in mesocosms where patrolling of area by large epigean invertebrates was unlimited (O – open) or restricted (C – closed). The mesocosm contained soil cores (100 cm^2, 15 cm deep) or were filled with poor substrate (sand with clay) and placed in a meadow soil profile. In Experiment III an additional treatment was applied, i.e. litter manuring with insect faeces (of cockchafer larvae *Osmoderma eremita* (Scarabeidae) and of locust *Locusta migratoria* (Oeolipodidae). The last treatment aimed at determining the effect of macrofauna faeces on litter decomposition rate. To exclude influence of roots' ingrowth into the substrate on the rate of litter decay the mesocosms with restricted ingrowth were applied. The litter exposed on the soil surface decayed faster than when exposed on sand. Patrolling of the area by large soil invertebrates had no effect on the litter decay rate during the first 8-13 months from the exposure (Exp. I and II). In the experiment, where litter remained longer in the field, i.e. 24 months (Exp. III), in 13- months after grass exposure it was found that the amount of remaining matter was significantly higher and the daily decay rate was lower in the closed mesocosms than in the open ones. These differences were maintained in the second year up to the end of the experiment. Litter manuring with insects' faeces accelerated decomposition. The effect of manuring with insects' faeces was clear only in the treatment without roots' ingrowth into the substrate.

KEY WORDS: decomposition, insects' faeces, macroarthropods, grass litter.

1. INTRODUCTION

The processes of litter decomposition depend on numerous environmental abiotic and biotic factors. Their rate depends on the litter type, habitat, communities of soil organisms and of the agricultural practices (Curry 1973, Jakubczyk 1976, Breymeyer 1990, Hopkins *et al.* 1990, Kajak *et al.* 1991, Rychnovská 1993, Bogdanowicz and Szanser 1997). Various authors differ in their assessment of the effect soil fauna have on the litter decomposition. In the previous experiment on decomposition of *Dactylis glomerata* on several meadows, it was found that in the initial stage of decomposition, contribution of soil fauna was low, until, after several months, litter was invaded by invertebrates (Kajak and Wasilewska 1997). The role of large, mobile epigean invertebrates in the decomposition process is poorly known. Earlier studies have shown that predators' activity could have an impact on decomposition through lowering of the number of saprophages (Kajak and Jakubczyk 1976, Poser 1988, Kajak 1997a) as well as on the fungi/bacteria ratio in the litter (Kajak 1997b).

The influence of various groups of predators on decomposition may differ. Experimental research showed that decomposition, as well as mineralization, are accelerated in the presence of predatory microfauna (*Nematoda, Protozoa*) (Santos *et al.*, 1981, Setälä *et al.*, 1991, Bouwman *et al.*, 1994). The influence of predatory mezo- and macrofauna differs; one can observe slowing down of the process of mineralization, its regulation or no effect at all, what was described by (Kajak 1995, Wardle and Lavelle 1997).

The aim of the present study was to specify whether patrolling of the soil surface by epigean macroarthropods influences the rate of grass litter decay. An attempt was also made to test whether depositing faeces by large invertebrates in the litter and in the underlying substrate can accelerate the litter decomposition. Faeces, as a source of nutrients and as a habitat for microbes and microfauna, stimulate organic matter decomposition in the soil (Tajovský *et al.*1992, Martin and Marinissen 1993).

In the experiment, the rate of grass litter decay was estimated in mesocosms accessible and inaccessible for large epigean arthropods.The effect of manuring with arthropods' faeces on the decay rate was analysed in a system closed for penetration by animals.

2. STUDY SITE AND METHODS

The research was carried out on a permanent meadow of the Arrhenatheretalia order, localized at the edge of Kampinos National Park (Central Poland). The soil (gleyed black-earth, acid, pH = 4.4) of this stand was composed of loamy sand underlined by loose sand (Kajak and Kusińska 2000).

Mesocosms (cylindrical bags) made of steelon netting with mesh diameter of 0.24 mm contained soil cores (15 cm high and 11 cm in diameter) or were filled with the substrate poor in organic matter (sand with clay). The three field experiments (Exp. I in 1992/93, Exp. II in 1993/94 and Exp. III in 1996/98) were performed. Half of the number of mesocosms were open (O), i.e. netting was perforated on the border between soil and litter with holes of 2 cm diameter, which gave the soil macrofauna free access inside; the other mesocosms were closed (C) i.e. without holes. In Experiment III, 2 cm in length incisions in the net were made instead of round holes to minimise potential microclimate differences between the two types of mesocosms. In the closed mesocosms the experimental system was colonized by animals present in the soil at the beginning of the experiment. In the Exp. I and II all the mesocosms filled with sand were open for the first two weeks, to allow colonizing by fauna. In the Exp. III where mesocosms filled with sand were also used such colonization was allowed for one month.

The following treatments were applied:

1. open (O) and closed (C) mesocosms with soil cores covered by litter bags (S);
2. (O) and (C) mesocosms filled with sandy substratum covered by litter bags (Sd);
3. (O) and (C) mesocosms with restricted ingrowth of roots (L) (Table 1);
4. the closed mesocosms manured with insects' faecal pellets. Faeces of fungivorous cockchafer larvae – *Osmoderma eremita* (Scarabeidae) and of herbivorous locust – *Locusta migratoria* (Oedipodidae) were used for manuring. In the first case the faeces were collected from a rotten willow tree in a neighbourhood of the investigated site. The locust's faeces were provided from a culture in the Poznań Zoological Park. The litter was manured twice, i.e. in December 1996 with 5.0 g dry wt of cockchafer larvae faeces and in August 1997, when 2 g dry wt of locust's faeces per mesocosm were applied: an influx of insects' faeces into the environment during the two consecutive seasons.

In the treatments (L), without rooting into the substrate, the litter was placed in

Table 1. Litterbag treatments used in three mesocosm Experiments: I 1992/93, II 1993/94, III 1996/98

Treatment	Type of mesocosm	Experiment
S – soil cores covered by litter bags	O – open	I, II
	C – closed	I, II
Sd – sand with admixture of clay, covered by litter bags	O – open	I, II, III
	C – closed	I, II, III
	CM – closed and manured with insect's faeces	III
L – sand with restricted root ingrowth covered by litter bags (lysimeters)	O – open	I, III
	C – closed	I, III
	CM – closed and manured with insect's faeces	III

funnels filled with sand. In that treatment the access of macrofauna could be treated as the only variable.

The *Dactylis glomerata* grass litter for the experiments was collected at the heading time from a field plantation of the Warsaw Agricultural University's Field Station in Jaktorów near Warsaw. The material collected was exposed in the Exp. I (June 1992) and Exp. II (April 1993), directly after the mesocosm exposure. Grass for Exp. III was collected in 1996 and exposed in autumn (September 1996), 2.5 months after installation of the isolators. The grass before exposure was air dried for 1 week. Two portions of 5 g air dried material (ca. 4.7 g dry wt) were weighted out into litter bags (PVC rings, diameter 11 cm, height 5 cm, with row of holes of 1.0-cm diameter with a distance of 1.5 cm between them). The rings had an open top and they were sealed from below against litter falling out with a steelon net (mesh size of 1 × 2 mm). Each of the rings contained a dividing bar to enable putting two portions of grass samples inside. The litterbags were placed on the substrate surface of mesocosms and lysimeters.

The litter samples were dried for three days at 65°C before weighting. The daily decay rate was determined according to Wiegert and Evans (1964):

$$r = \frac{\ln(W_{n-1} / W_n)}{t}$$

where:
r – daily decay rate of litter in mg g^{-1} day^{-1} in periods between subsequent samplings;
W_{n-1} – initial dry weight or dry weight at each preceding sampling time;
W_n – dry weight of litter at a sampling time;
t – time between subsequent samplings (in days).

In all experiments samples were taken three or four times a year, 3 to 43 samples at each time for each treatment. 181 replicates were used in Exp. I, 150 – in Exp. II and 292 – in Exp. III.

For statistical analyses of data the *t* Student test was applied.

3. RESULTS

3.1. CLIMATIC CONDITIONS DURING THE EXPERIMENT

The whole period of the research was characterised by outstanding weather conditions. The year 1992 and – to smaller extent also 1993 had long drought periods and temperatures higher than the 100-year mean (Szanser 2000). As a result of this situation the activity of soil biocoenosis was significantly suppressed. In the years 1994 and

1996–1998 the weather conditions were characterised by above average rainfall, which was optimal for activity of the soil organisms (Szanser 2000).

3.2. LITTER MOISTURE IN THE EXPERIMENT

The litter moisture was highly variable during the research time. In the spring and summer of Exp. I and II the litter moisture was low (Table 2a). In Exp. III, at the time of sampling, the litter moisture was generally high (Table 2b). Despite high variability of this parameter during the whole studied period, no actual differences in litter water content among all open and closed mesocosms, and closed manured treatments were observed, neither when rooting into the substrate was enabled nor when disabled (Table 2a, b).

3.3. LITTER DECOMPOSITION

The process of litter decomposition varied largely between treatments during the first several months from litter exposure. The highest decay of litter was observed after c.a. 80 days of decomposition in the Experiments I and II and during the initial 60 days of the Experiment III (Figs 1 and 2, Tables 3, 4, 5 and 6). This variability in the time of maximum decay rate was related to the weather conditions, very different in the research periods. In the case of the litters exposed in spring (Exp. I and II) the maximum decay rate was observed in autumn. In the meantime periods of drought occurred and an increase of litter decay was not observed until the first rainfall. In Exp. III, when the litter was exposed in autumn, the highest decay rate was noticed already in the first 60 days after exposure, when the moisture conditions were good. Thus, the time of maximum decay rate in the experiment depended on weather conditions rather than on the duration of litter exposure.

It was found that properties of underlying substrate significantly affected the process of grass decay. At the end of

Table 2a. Litter moisture in % H_2O (SEM given in parentheses) in open (O) and closed (C) mesocosms. Experiment I and II. Number of samples per treatment – see Table 3

Time of sampling	Soil			Sand		
	O	C	Student *t* test	O	C	Student *t* test
Experiment I (1992–93)						
2 Jun 92	4.8 (0.22)	4.7 (0.15)	n.s.	ND	ND	ND
10 Sep 92	47.0 (2.57)	49.9 (3.64)	n.s.	50.3 (2.31)	50.2 (2.32)	n.s.
20 Oct 92	55.3 (3.09)	55.1 (3.5)*	n.s.	46.5 (2.59)	45.1 (2.9)	n.s.
25 Mar 92	ND	ND		24.6 (2.43)[a]	25.8 (2.44)[a]	n.s.
5 Apr 93	75.1 (1.04)	70.0 (2.96)*	n.s.	65.7 (3.79)	64.8 (3.26)	n.s.
Experiment II (1993–94)						
10 May 93	6.0 (0.68)	6.8 (0.9)	n.s.	7.6 (0.72)	7.6 (0.5)	n.s.
21 Jun 93	16.3 (2.42)	19.82 (5.52)	n.s.	15.9 (1.34)	19.3 (1.69)	n.s.
27 Sep 93	56.1 (3.66)	55.8 (3.68)	n.s.	55.7 (5.42)	55.5 (11.53)	n.s.
12 May 94	30.6 (3.08)	25.98 (3.46)	n.s.	28.8 (2.39)	31.4 (1.51)	n.s.

* differences between sand and soil $P < 0.05$; [a] data from mesocosms without root ingrowth (L): n.s. – not significant; ND – not determined.

Table 2b. Litter moisture in % H_2O (SEM given in parentheses) in open (O), closed (C) and closed manured with insect's faeces (CM) sand filled mesocosms. Experiment III (litter exposure 17–25 September 1996)

Time of sampling	O	C	Student *t* test O *versus* C	Number of samples (O–C)	CM	Student *t* test CM *versus* C	Number of samples CM
22 Sep 96	51.5 (3.46)	53.1 (50.35)	n.s.	8–8	ND	ND	ND
5–6 Mar 97	21.9 (0.64)	23.1 (1.78)	n.s.	17–13	ND	ND	ND
21 May 97	51.0 (2.53)	51.0 (2.47)	n.s.	27–26	ND	ND	ND
16 Jun 97	25.2 (1.15)	25.4 (1.86)	n.s.	5–5	22.0 (4.40)	n.s.	5
10 Oct 97	59.6 (4.15)	49.4 (4.76)	n.s.	5–5	47.9 (5.68)	n.s.	5
27 Oct 97	41.2 (5.39)	56.2 (1.87)	n.s.	5–5	52.8 (3.38)	n.s.	3
20 May 98	8.6 (0.98)	8.3 (0.57)	n.s.	5–5	ND	ND	ND
22 May 98	19.3 (1.94)	19.2 (1.53)	n.s.	6–6	24.1 (3.83)	n.s.	6
10 Jun 98[a]	9.0 (1.21)	8.2 (1.00)	n.s.	7–6	8.9 (1.39)	n.s.	6
24 Sep 98	30.7 (2.08)	28.6 (1.79)	n.s.	21–20	ND	ND	ND

[a] treatment without roots (L); n.s. – not significant; ND – not determined.

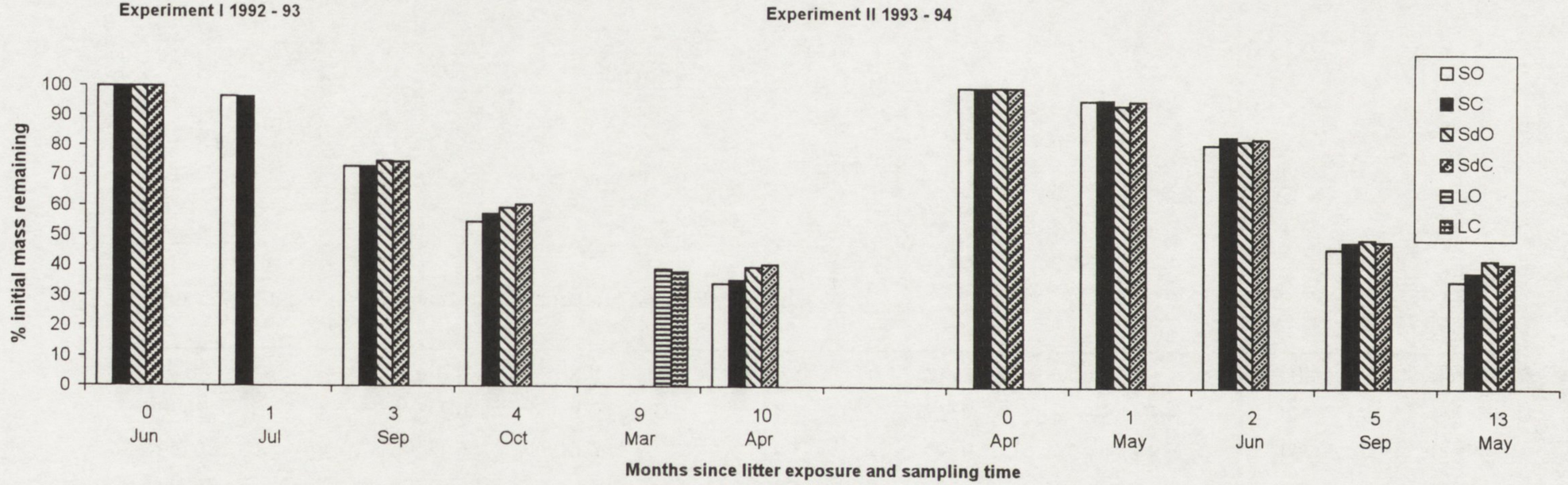

Fig. 1. Percentage of remaining litter mass in Experiments I and II.
Soil mesocosms: open (SO), closed (SC); sand mesocosms: open (SdO), closed (SdC); mesocosms without roots: open (LO),closed (LC).

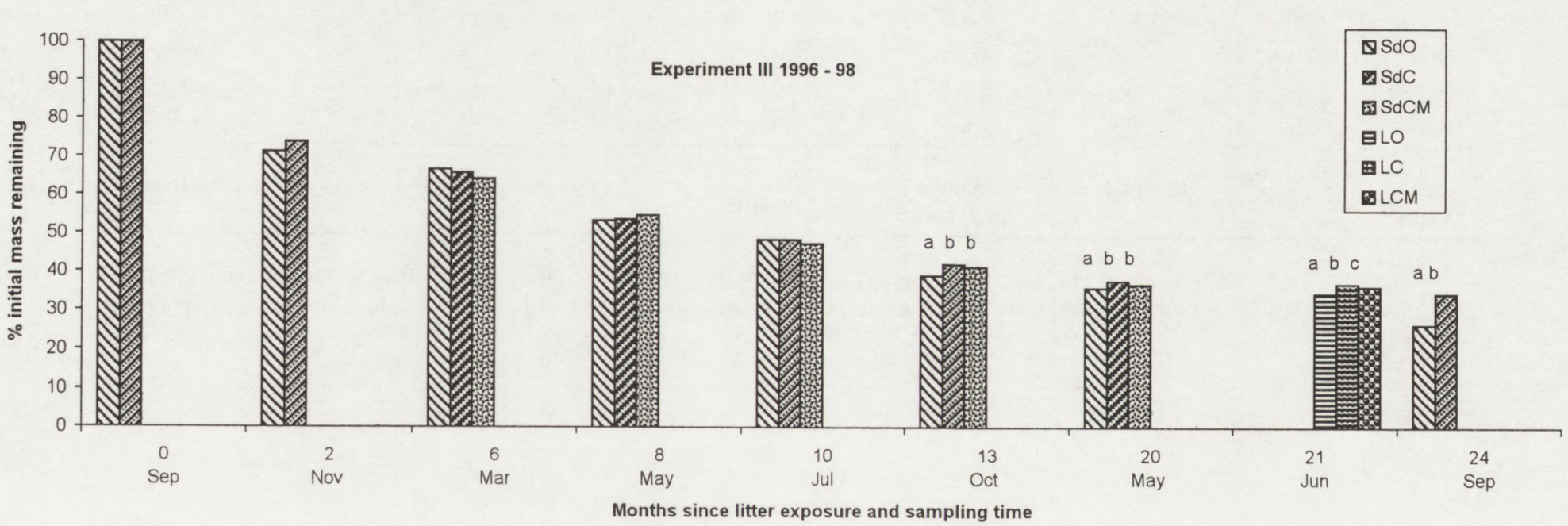

Fig. 2. Percentage of remaining litter mass in the Experiment III.
Sand mesocosms: open (SdO), closed (SdC), closed manured (SdCM); mesocosms without roots: open (LO), closed (LC), closed, manured (LCM); a,b,c – different letters denote significant differences between treatments (see Table 5).

Table 3. Mass of litter remains in g dry wt (SEM given in parentheses) in mesocosms with soil (S) or sand (Sd) and sand without root ingrowth (L) in the Experiments I and II (O – open mesocosm, C – closed mesocosm)

Time of litter exposure and sampling	Soil (S)		Sand (Sd)		Number of samples per treatment
	O	C	O	C	
	Experiment I 1992/93				
11–19 Jun 92	4.7 (0.004)	4.7 (0.004)	4.7 (0.004)	4.7 (0.004)	
2 Jul 92	4.5 (0.03)	4.5 (0.03)	ND	ND	10
2 Sep 92	3.4 (0.1)	3.4 (0.14)	3.5 (0.08)	3.5 (0.06)	10
20 Oct 92	2.6 (0.08)	2.7 (0.09)	2.8 (0.08)	2.8 (0.08)	10
25 Mar 93[a]	ND	ND	1.8 (0.04)	1.8 (0.06)	24–26
5 Apr 93	1.6 (0.03)	1.7 (0.04)	1.9 (0.18)	1.9 (0.03)[b]	14–21
	Experiment II 1993/94				
8–15 Apr 93	4.8 (0.006)	4.8 (0.006)	4.8 (0.006)	4.8 (0.006)	
10 May 93	4.6 (0.05)	4.6 (0.03)	4.5 (0.07)	4.6 (0.09)	10
21 Jun 93	3.9 (0.06)	4.0 (0.14)	3.9 (0.12)	4.0 (0.11)	10
27 Sep 93	2.2 (1.10)	2.3 (0.09)	2.4 (0.11)	2.3 (0.01)	10
12 May 94	1.7 (0.08)	1.8 (0.07)	2.0 (0.09)	2.0 (0.04)[b]	11–14

[a] litter mass in mesocosms with restricted root ingrowth;
[b] significance of differences between soil and sand treatments irrespectively of mesocosms opening $P<0.05$;
ND – not determined.

Experiments I and II the litter decomposition was significantly slower on sand and more litter remnants were found on this substrate than on soil surface (Tables 3 and 4). The daily decay rate during the growing season ranged between 3.3 and 6.1 mg g^{-1} day^{-1} on soil, and 3.2–5.5 mg g^{-1} day^{-1} on sand.

The total amount of litter remaining in Exp. I was lower than in Exp. II (at n = 61; $P < 0.01$ on sand) and Exp. III after 10 months (Tables 3 and 5).

The litter decomposition rate was compared between the treatments where the roots did not grow into the substrate and with free ingrowth of roots. It is characteristic that the amount of remaining litter is generally similar in the treatments with and without roots (Tables 3 and 5). Thus, separation of the litter from root ingrowth and from immigration of the soil animals did not suppress the litter decay rate.

A significant effect of patrolling by epigean macrofauna on the decomposition rate was found, despite the variability of environmental conditions and substrate applied. At the end of Exp. I and II the tendency for lower amount of grass remaining in the open mesocosms than in closed ones, was observed in soil mesocosms (Table 3). In the long lasting Experiment III these differences were significant and were found in all the treatments after 13, 20 and 24 months (Table 5). The daily decay rates were also higher in the open series (Table 6). At the end of the experiment, 24 months from the date of grass exposure, 74% of the litter was decomposed in the open treatment and 65% – in the closed one (Fig. 2).

Hence, significant differences in the litter decay rate between the open and closed

Table 4. Litter decay rate in mg g^{-1} day^{-1} (SEM given in parentheses) in open (O) and closed (C) mesocosms. Experiments I and II

Time of litter exposure and sampling	Number of days between sampling times	SOIL (S)				SAND (Sd)			
		O	C	Significance of differences O *versus* C	Number of samples	O	C	Significance of differences O *versus* C	Number of samples
Experiment I 1992/93									
11–19 Jun 92	0								
2 Jul 92	18	2.90 (0.31)	2.3 (0.33)	n.s.	10	ND	ND	n.s.	ND
2 Sep 92*	62	4.5 (0.47)	4.6 (0.65)	n.s.	10	3.5 (0.23)	3.7 (0.21)	n.s.	10
20 Oct 92	48	6.1 (0.64)	5.2 (0.71)	n.s.	10	4.9 (0.41)	4.4 (0.62)	n.s.	10
5 Apr 93**	167	2.8 (0.10)	2.9 (0.13)	n.s.	14	2.4 (0.14)	2.4 (0.09)	n.s.	19
Experiment II 1993/1994									
8–15 Apr 93	0								
10 May 93	30	1.6 (0.64)	1.8 (0.64)	n.s.	10	1.5 (0.33)	1.4 (0.19)	n.s.	10
21 Jun 93	42	4.2 (1.65)	3.3 (0.88)	n.s.	7	3.2 (0.73)	3.4 (0.66)	n.s.	10
27 Sep 93	98	5.7 (0.41)	5.6 (0.39)	n.s.	9	5.0 (0.47)	5.5 (0.41)	n.s.	10
24 May 94*	227	1.2 (0.21)	1.0 (0.18)	n.s.	5	0.7 (0.17)	0.7 (0.07)	n.s.	11–14

Significance of differences between soil and sand treatment irrespectively of mesocosm opening: * $P < 0.025$; ** $P < 0.0005$; ND – not determined.

Table 5. Mass of litter remains in g dry weight (SEM given in parentheses) in mesocosms open (O), closed (C), and closed and manured with insect faeces (CM). Experiment III

Time of litter exposure and sampling	O	C	Student test O *versus* C	Number of samples	CM	Student test CM *versus* C	Number of samples
17–25 Sep 96	4.72 (0.01)	4.72 (0.01)			4.72 (0.01)		
22 Nov 96	3.4 (0.11)	3.5 (0.10)	n.s.	21–22	ND	ND	ND
6 Mar 97	3.1 (0.07)	3.1 (0.12)	n.s.	29–33	3.0 (0.12)	n.s.	3
21 May 97	2.5 (0.06)	2.5 (0.08)	n.s.	41–45	2.6 (0.09)	n.s.	4
22 Jul 97	2.3 (0.06)	2.3 (0.06)	n.s.	25–27	2.2 (0.08)	n.s.	8
27 Oct 97	1.8 (0.06)	2.1 (0.07)	$P < 0.014$	31–32	2.0 (0.55)	n.s.	3
22–26 May 98	1.7 (0.05)	1.8 (0.04)	$P < 0.035$	40–43	1.7 (0.04)	n.s.	10
9 Jun 98[a]	1.7 (0.07)	1.9 (0.07)	$P < 0.032$	23–26	1.6 (0.06)	$P < 0.0045$	24
24 Sep 98	1.2 (0.06)	1.6 (0.07)	$P < 0.00004$	20–26	ND	ND	ND

[a] data for treament without root ingrowth (L);
n.s. – not significant;
ND – not determined.

Table 6. Litter decay rate in mg g^{-1} day^{-1} (SEM given in parentheses) in open (O) and closed (C) and in closed manured with insect's faeces (CM) mesocosms. Experiment III

Time of litter exposure and sampling analyses	Number of days between sampling time	O	C	Student *t* test O *versus* C	Number of samples	CM	Student *t* test CM *versus* C	Number of samples
17–25 Sep 96	0							
22 Nov 96	61	4.6 (0.40)	4.6 (0.39)	n.s.	21–22	ND	ND	ND
5–6 Mar 97	104	2.1 (0.23)	2.0 (0.17)	n.s.	29–33	2.2 (0.40)	n.s.	3
21 May 97	76	3.1 (0.35)	3.0 (0.39)	n.s.	41–45	2.1 (0.45)	n.s.	4
22 Jul 97	62	1.9 (0.35)	2.0 (0.36)	n.s.	25–27	3.2 (0.59)	n.s.	8
27 Oct 97	87	3.1 (0.60)	1.7 (0.31)	$P < 0.036$	31–32	3.2 (3.20)	n.s.	3
22–26 May 98	207	0.6 (0.17)	0.6 (0.10)	n.s.	40–43	0.5 (0.10)	n.s.	10
22–26 May 98 [a]	604	1.7 (0.07)	1.6 (0.04)	$P < 0.036$	40–43	1.7 (0.04)	n.s.	10
9 Jun 98[b]	619	1.67 (0.07)	1.5 (0.06)	$P < 0.044$	23–26	1.6 (0.07)	$P < 0.011$[c]	24
24 Sep 98	125	2.9 (0.45)	1.1 (0.36)	$P < 0.003$	20–26	ND	ND	ND

[a] calculated for the Sd treatment, for the period Sep 96 – May 98;
[b] calculated for the L treatment, for the period Sep 96–Jun 98;
[c] significance of differences between CM and C;
n.s. – not significant;
ND – not determined.

series were observed only in the second year of decomposition. These differences increased in time.

Litter manuring with insect faeces in the closed mesocosms of the Experiment III caused a significantly higher decay as compared to the closed non manured treatment. This was observed in the treatment with restricted rooting. This effect was not shown in the mesocosms with root ingrowth. It is likely, that number of manured mesocosms with roots was too low for proper comparing with other treatments (Tables 5 and 6). The amount of remaining litter and the decay rate were similar in the manured treatment and in the treatment open for patrolling by animals (Tables 5 and 6, Fig. 3). Hence, an addition of insect faeces may accelerate the grass decomposition process.

It can be stated on above results that environmental conditions affected the decay rate more than differentiated accessibility of the grass for epigean macroarthropod fauna during the first year of the experiments. Since the second year differences between open and closed treatments increase with time which may be attributed to fauna patrolling.

4. DISCUSSION

Several papers report that the equation for analyses of the decomposition rate of plant material should be adapted to the parameters being analysed, litter composition and habitat considered (Wieder and Lang 1982, Úlehlová 1985, Andren 1987, Paustian *et al.* 1997).

For the present study I used Wiegert and Evans coefficient (1964), because it was previously applied to meadow litter decomposition analyses (Jakubczyk 1976, Abougendia and Whitman 1979, Tormala and Eloranta 1982, Bogdanowicz and Szanser 1997). Wiegert and Evans (1964) used this equation to analyse decomposition pattern of plant material placed in bags or loosely on the soil surface of an old field.

Most studies investigating the decomposition rate of litters show, that this process proceeds rapidly in the initial period (Jenkinson *et al.* 1987, Hopkins *et al.* 1990, Wise and Schaefer 1994, Scheu 1993). In my studies, presented in this paper, decomposition proceeded differently in the three, compared experiments. In Exp. I and II the highest decay rates were noted after the initial period of 80–100 days from the litter exposure. In Exp. III the maximum decay rate was observed during the first 60 days after the exposure. The process was dependent on the weather conditions. As an effect of severe drought periods in 1992 and 1993, the soil moisture increased only in the autumn, three months after the exposure and the litter decay rate increased then. In the Experiment III, soil moisture was high already at the beginning of the investigations, the decay rate at this period was the highest. Thus, the weather conditions affected the decay rate more than the duration of the litter exposure in the field. The similar dependence of litter decomposition on moisture conditions report Bogdanowicz and Szanser (1997).

In Exp. I and II, 46–57% of litter remained after 5 months in mesocosms containing soil cores and 49–60% in mesocosms with sand. In Exp. III after the same time remained 64–67% of litter on sandy substrate. Somewhat higher range of decay rates of grass and sward litter exposed on the soil surface were found using similar methods by Ward and Wilson (1973), Vossbrinck *et al.* (1979), Jensen (1985), Parmelee *et al.* (1989) Beare *et al.* (1992). After 3–5 months from the litter exposure, irrespectively in spring or autumn, 47 to 87% of organic matter remained in the mesocosms. Contrarily, Siepel and van Wieren (1990) report that litter of young grass *Avenella flexuosa*, exposed in June between the litter and soil layer, decomposed by 50% during the first month. Wardle *et al.* 1997 found higher decay rate of *Dactylis glomerata* litter, than reported by me. After a year they found

24% of the initial value whereas 36-43% of the litter remained in mesocosms analysed by me. The differences between the results presented by Wardle *et al.* (1997) and mine come probably from different quality of litter. These authors used the dead grass collected in autumn while in our research litter was made of mowed and air dried green, living parts of grass. Secondly the amount of litter per bag in our experiment was much larger.

The decay rates of grass litter during growing season found in this study lie in the ranges reported from the investigations carried out on meadows from the Arrhenatheretalia order, localised in various parts of Poland (Jakubczyk 1976, Pomianowska-Pilipiuk 1976, Bogdanowicz and Szanser 1997). The authors determined loss of litter dry weight using the bag method, unlike the method of three-dimensional containers used for this study.

The data also indicate that the three-dimensional open-top containers used in this study, did not suppress the grass decomposition.

Significantly higher litter weight loss in the open treatment (accessible for epigean fauna) than in the closed one (inaccessible) occurred in the second year of the litter exposure in the field.

The manuring with insect faeces also caused an acceleration of litter decay in the field mesocosms. Similar results were obtained in a laboratory experiment, where locust's faeces caused an acceleration of litter decay compared to the treatment without faeces (Szanser in prep.). Insect faeces and remnants of dead insects were deposited in the open mesocosms in significantly higher amounts, than in the closed series (Szanser 2000). Faeces may stimulate organic matter decomposition in the soil as a source of nutrients and as a habitat for microbes and microfauna (Tajovský *et al.* 1992, Martin and Marinissen 1993). In contrast Webb (1977) did not found the influence of Myriapoda faeces on oak leaves decomposition. He used similar amounts of faeces as in the presented experiment, but the litter was placed in the plot, which was previously manured instead of directly manuring the litter as it was done in my experiment. So this methodological difference was probably an important reason for obtaining different results.

The data suggest that soil macroarthropods can affect the litter decomposition process indirectly, through depositing liquid and particulate faeces and perhaps also fragmenting of dead plant material, therefore enhancing the development of microflora and fauna, both in the soil and in the litter.

Hence, the influence of macroarthropods can be assessed only in the later phase of decomposition. The lack of large invertebrates can, after a longer period, lead to the impediment of the processes of organic matter mineralization and humification. Significance of this group of animals in the indirect regulation of the processes of organic material's mineralization is shown by the data of Moore and Walter (1988), Kajak 1997a, Wardle and Lavelle 1997).

It can be stated then, that the longer the duration of the experiment the larger differences in litter decomposition between the closed and open systems were found.

5. CONCLUSIONS

1. Environmental conditions (soil moisture) affected the decay rate of litter more, than the duration of time since the litter exposure in the first several months of the experiment.

2. Higher decay rate of litter was recorded in the mesocosms accessible for macroarthropods than in unaccessible ones, in the second year of the experiment.

3. The litter decomposition rate was indirectly accelerated by the deposition of faeces

and remnants of dead individuals by macroarthropods in the soil.

4. Manuring of the litter by insect faeces accelerated its decay as compared to the unmanured litter.

6. SUMMARY

The research aimed at determining changes in decomposition rate of grass litter (*Dactylis glomerata*) in conditions of differentiated area patrolling by large epigean invertebrates. A field experiment was established, in which the decay of litter was measured. Dead grass was exposed in two types of cylindrical mesocosms made of a steelon netting (mesh diameter 0.24 mm). The investigations were carried out on a permanent meadow of the Arrhenatheretalia order in the buffer zone of Kampinos National Park (Central Poland).

The experiments were performed three times in 1992/93, 1993/94 and 1996/1998.

The isolators applied (open and closed for animals' access) contained soil cores or were filled with poor substrate (sand with clay) and inserted into the soil horizon. The following treatments with litter-bags were applied for the grass decomposition study in variants open (O) and closd (C) for macroarthopods: soil (S), sand without roots' ingrowth (L), sand with roots' ingrowth (Sd), sand without roots' ingrowth + litter + insects' faeces (LCM), sand with roots' ingrowth + insects' faeces (SdCM) (Table 1).

In the Experiment I samples from 181 mesocosms were taken, in the Experiment II – from 150 and in the Experiment III – from 292. The litter was placed in three dimensional litter bags, divided into two parts. In each compartment portion of 4.7 g dry wt of grass was put.

The litter moisture did not differ between the experimental treatments during the entire research period (Table 2a).

Litter exposed on soil decomposed faster than on sand (Tables 3 and 4). The maximum decay rate after the grass exposure occurred during periods of good moisture conditions of the stand, in autumn, i.e. after about three months of spring-summer drought in the Exp. I and II, and during the first two months after litter exposure in autumn – in Exp. III (Tables 3, 4, 5 and 6, Figs 1 and 2).

During the first 10–13 months after the litter exposure, the differences between the decay rate in mesocosms open and closed for patrolling by macrofauna were not significant. In the second year after the litter exposure in Exp. III lower amounts of litter were detected in the open mesocosms than in the closed ones (Tables 5 and 6, Fig. 2).

Higher loss of litter mass was observed in the open systems as compared to the closed ones, both in the treatments with enabled- and disabled roots' ingrowth into the substrate (Tables 5 and 6). The roots' ingrowth into the substrate had no effect on lowering the amount of litter remains (Tables 3 and 5).

Manuring with insects' faeces accelerated the decay of litter inaccessible for macrofauna as compared to the unmanured litter closed for macrofauna access (Tables 5 and 6, Fig.2).

The impact of epigean macrofauna on litter decomposition is discussed on the base of the experiments performed. The influence of macroarthropods, in the circumstances given in the experiments, seems to be in the processes of accelerating plant matter decomposition through depositing faeces in the soil.

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