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BIOMANIPULATION OF MACROARTHROPODS – EFFECT ON FOOD WEB				

Anna KAJAK

Institute of Ecology PAS, Dziekanów Leśny near Warsaw, 05-092 Łomianki, Poland,
e-mail: ekolog@warman.com.pl

EXPERIMENTAL APPROACH FOR STUDYING INTERRELATIONSHIPS BETWEEN MACROARTHROPODS, SOIL BIOTA, DECOMPOSION RATE OF LITTER AND ORGANIC MATTER ACCUMULATION IN SOIL

ABSTRACT: The paper presents expermental design applied to analyse the role of macroarthropods patrolling soil surface on decomposition rate of grass litter (*Dactylis glomerata*). In the experiment density of micro- and mesofauna and microbial abundance in mesocosms accessible (open – O) and not accessible (closed – C) for large arthropods was compared. Mass loss of litter, mineralization rate of carbon and nitrogen, humus acid storage in sandy substratum underlying litter was estimated also. Results are presented in several papers. Effect of exclosures on the intensity of surface patrolling by macroarthropods and on their density in mesocosms is also presented.

KEY WORDS: biomanipulation, mesocosms, patrolling intensity of macroarthropods, biomass, proportion of predatory taxa.

1. INTRODUCTION

Several field experiments done in agroecosystems focus on contribution of soil biota to the dynamics of carbon and nutrients (Hendrix *et al.* 1986, Paustian *et al.* 1990, Brussard *et al.* 1988, Beare *et al.* 1992, Juma 1993). The papers in this volume present results of the field experiment the objective of which was to analyse the role of macroarthropods patrolling soil surface in the carbon storage in grassland soil. Macroarthropods are often neglected in the investigations of energy flow because the amount of energy consumed by them is relatively small as compared with other ecosystem components (Hunt *et al.* 1987, Andren *et al.* 1990, Moore 1994, Beare *et al.* 1997).

Macroarthropods include a wide range of trophic groups: detritophages, phytophages, microbiphages and predators. Some detritophagic taxa are known as important in humus formation, mostly in forests. Higher humus acid content was found in their feces, than in their food (Bal 1970, Kozlovskaja 1976, Webb 1977, Striganova 1980). The proportion of predators is high in this group, especially among mobile macroarthropods patrolling soil surface (Kajak *et al.* 1991, Paustian *et al.* 1990). The review of the literature data suggests, that slow decomposition rate of organic matter in any ecosystem is often accompanied by a relatively large proportion of predatory macroarthropods (Kajak and Jakubczyk 1977, Kajak 1978). Our hypothesis is that predatory macroarthropods feeding mostly on fun-

givorous mesofauna, can decrease density of this trophic group, and in consequence change proportions between bacteria and fungi and contribute to the decomposition rate of organic matter. Non predatory macroarthropods can influence decomposition by comminution of plant material, by microbial grazing and deposition of feces. We tried to analyse cascading effect of macroarthropods on lower trophic levels and on organic matter accumulation in soil by using the exclusion field experiment. In numerous experiments relations between microbial groups have been changed by biocides (Beare *et al.* 1997). We tried to obtain similar effect without chemicals. The other advantage of our experiment was, that it was performed in the field, so climatic conditions have been changed as little as possible and the procedure has not affected microbial and faunal species diversity. The results provide information on the role of the whole group. Based on this material it is difficult to consider the role of particular taxa.

2. EXPERIMENTAL DESIGN

The experiment was performed in field mesocosms containing soil cores or sand (Fig. 1). Soil cores were taken in the meadow with a cylindrical sampler (100 cm^2 in area, 15 cm deep) and immediately, without changing their structure put into netting exclosures (mesh size 0.24 mm) and inserted into soil profile, exactly in the same places from which they were taken. Two types of mesocosms were applied – closed (C), not accessible to macrofauna and open ones (O), accessible, by several (5) holes (each about 2 cm in diameter) cut in the exclosure at the soil-litter interface. The mesocosms were inserted in pairs, open and closed alternately. Samples were taken from each pair of mesocosms simultaneously.

Mesocosms with soil cores (S)

Three treatments were applied:

S_1 – Intact soil cores to analyse numbers of microbes, microfauna (Nematoda), mesofauna (Enchytraeidae, Collembola, Acarina) and macrofauna (Lumbricidae, Araneae, insect adults and larvae).

S_2 – Soil cores with litterbags on their surface to analyse litter disappearance rate, C content and litter colonization by microbes and fauna.

S_3 – Soil cores with inserted pitfall traps (3.2 cm in diameter, 6 cm deep) to analyse numbers of individuals patrolling the soil surface of the cores.

The litter bags consisted of a plastic ring (10 cm in diameter, 4.5 cm high) with bored holes (1 cm diameter, 1.5 cm apart) enabling litter colonization. The bottom was made of a steelon mesh screen (mesh size 1 mm), the top of the ring was uncovered. Each bag contained at the beginning of the experiment 9.5 g dry mass of dead leaves and stems of *Dactylis glomerata* of predetermined C, N and humus acid content.

Mesocosms with sand (Sd)

Substrate of low organic matter content was applied to measure carbon accumulation during the experiment. The exclosures were filled with sand (of predetermined C and N contents) and then inserted into pits done with the same corer as in the treatment S. The top layer (0–3 cm) contained loamy sand, the deeper layer (3–15 cm) loose sand, similarly to the adjacent meadow soil. Two treatments were applied:

Sd_1 – Mesocosms covered by litterbags as in the treatment S_2, were applied to analyse litter disappearance rate, C and humus acid contents in sand and in the litter and colonization rate of these substrates by microorganisms and fauna.

Sd_2 – Mesocosms without litterbags, treated as control of organic matter accumulation.

The number of replicates and the time of exposure of all the treatments are given in Table 1. The experiment was repeated twice.

Fig. 1. Experimental mesocosms inserted in meadow soil (photo S. Stanuszek).

Table 1. Treatments, time of exposure (T), and number of replicates (Re) in field experiments

Symbol	Treatment	Type of mesocosm	Experiment I		Experiment II	
			T	Re	T	Re
S_1	Soil cores	open O	May 92-Oct.92	100	April 93-Sept.93	60
		closed C		100		60
S_2	Soil cores	open O	June 92-April 92	75	April 93-May 94	75
	+ litter bags	closed C		75		75
S_3	Soil cores	open O	May 92-Oct.92	20	April 93-Sept.93	10
	+ pitfall traps	closed C		20		10
Sd_1	Sand	open O	June 92-April 93	90	June 92-May 94 *	90
	+ litter bags	closed C		90		90
Sd_2	Control sand	open O	June 92-April 93	10	April 93-May 94	10
		closed C		10		10

* the same sand was used in Experiment I and II.

Experiment I lasted from June 1992 till April 1993, Experiment II from April 1993 till May 1994. Soil cores and litter bags were changed in every experiment, sand was used during both the experiments (I and II). Mesocosms were filled with sand in June 1992 and lasted till May 1994 (Table 1). The distribution in the area of mesocosms representing different

treatments and their sequence were determined using tables of random numbers.

The surface area of the experimental mesocosms was small (100 cm^2) compared with sample sizes (625–1000 cm^2) used for the analysis of macrofauna density in the soil. The following arguments were considered in the decision of the mesocosms size:

1) the experiment focus on the effect of area patrolling by macroarthropods, this parameter can be recorded properly independently of the size of the area isolated;

2) the effect of patrolling on the density of small organisms (microbes, micro- and mesofauna) was mainly considered, for this purpose the mesocosm size was adequate;

3) the small surface area allowed application of relatively high number of replicates.

3. BIOMANIPULATION: CHANGES IN NUMBER AND BIOMASS OF MACROARTHROPODS CAUSED BY EXCLOSURES

It was checked by pitfall traps inserted in soil cores inside mesocosms (treatment S_3), that intensity of surface patrolling by macrofauna (> 0.25 mm in width) was significantly higher in open (O) compared to closed (C) series (Table 2). The mean mass of individuals captured per day in the pitfalls inserted in the open mesocosms was many times higher than in the closed ones (Table 2). Mainly predatory arthropods, larger and more mobile than non-predatory, were affected by exclosures (O/C ratio of predators was 230 and 120 in the two years respectively and of non-predatory taxa 12 and 9.7). In the Experiment I open mesocosms were patrolled mostly by the predatory taxa, 74.4% of the total mass of captured individuals comprised predators whereas in the closed mesocosms only 11%. In the Experiment II (1993) proportion of predators was lower, in a response to serious drought and food deficiency in the first year of the experiment (1992) (Kajak 1997). The mass of predators caught by traps was only half as high, as it was in the first year, but it still comprised 48% in open mesocosms and only 7% in the closed series (Table 2). Among predators captured in open mesocosms two taxa predominated – Carabidae (46.8% and 32.1% in two years respectively) and Araneae (22.4% and 13.4%) (Table 2). The number of individuals captured in closed

Table 2. Total mass of individuals caught by pitfall traps (mg d. wt $trap^{-1}$ day^{-1}) and proportions (% by weight) of predators in open (O) and closed (C) mesocosms

	Experiment I		Experiment II	
	O	C	O	C
Total mass	**9.3** ***	**0.23**	**7.50** ***	**0.43**
Predatory arthropods	**6.9** ***	**0.03**	**3.6** ***	**0.03**
Non predatory arthropods	**2.4** ***	**0.2**	**3.9** ***	**0.40**
Proportions of taxa (%)				
Predatory arthropods:				
Carabidae	46.8	0.9	32.1	0.5
Araneae	22.4	7.6	13.4	3.8
Formicidae	4.9	0.5	2.5	1.2
Staphylinidae	0.3	2.0	0.1	1.4
Total	**74.4**	**11.0**	**48.1**	**6.9**
Non predatory arthropods:				
Acridoidea	4.6	0.0	10.9	0.0
Coleoptera	14.4	54.5	31.6	62.7
Homoptera	4.1	21.7	5.8	21.0
Diptera	2.5	12.8	3.6	9.4
Total	**25.6**	**89.0**	**51.9**	**93.1**

*** $P<0.001$.

mesocosms depended very much on individual size, proportions of large individuals (e.g. Carabidae, Acridoidea) were especially low.

The intensity of soil surface patrolling by predators varied considerably during a season. In the first year it was high in May, the second peak was recorded at the end of June and lasted till the half of July, the third peak was noted at the middle of August. In the next year patrolling intensity shifted towards later period, peaks were noted in July and August. The very weak patrolling was recorded in both years at the early spring and autumn. The number of non-predatory individuals was less variable during season, the peak numbers were recorded in both years in June. Small Coleoptera (mainly Curculionidae) were the most important (Table 2).

The number of the other macrofauna component – earthworms was extremely low in pitfall traps, 0 in the Experiment I, 0.001 per trap per day in the Experiment II.

Differences found between open and closed mesocosm series in the density and biomass of macroarthropods were much lower, than in the intensity of patrolling (Tables 3 and 4). Differences in biomass of predators were higher (O/C ratio 4.8 in both years), than in non-predatory taxa (O/C ratio 2.7 and 1.3 in respective years).

Both methods applied, showed higher mean numbers as well as biomass of total group of macroarthropods in the open mesocosms, but the scale shown by the compared methods was quite different. The closed mesocosms, covered by exclosures could contain only those individuals that were present inside soil cores at the beginning of the experiment, developed there from eggs or entered as very small, young specimens. Pitfall trap data are based on constant captures from spring till autumn, so are more reliable, than the density data based on the number of individuals extracted from relatively small areas of soil cores, several times during the season (Table 4).

Table 3. Mean over season biomass of predatory and nonpredatory macroarthropods (mg d. wt 100 cm^{-2} ± SE, 0–15 cm) in soil cores located in open (O) and closed (C) mesocosms. Data from two years of experiment

Total biomass	Year	O	C	*P*
Predatory	1992	12.9±3.6	2.7±1.1	<0.01
Nonpredatory		3.2±0.6	1.2±0.3	<0.01
Predatory	1993	2.9±1.6	0.6±0.2	ns
Nonpredatory		7.1±2.8	6.4±1.6	ns

P – *t* test applied in analysis.

Table 4. Mean density (N ind. 100 cm^{-2} ± SE, 0–15 cm) and intensity of area patrolling (N ind. pitfall $trap^{-1}$ day^{-1}) of macrofauna in soil cores located in open (O) and closed (C) mesocosms

Year	Density Number ind. 100 cm^{-2}				Area patrolling Number ind. $trap^{-1}$ day^{-1}			
	O	C	n	*P*	O	C	n	*P*
1992	2.6±0.4	1.1±0.2	50	<0.001	2.9±0.1	0.2±0.003	248	<0.001
1993	4.4±0.9	3.1±0.6	30	ns	2.2±0.1	0.3±0.03	195	<0.001

n – number of samples per mesocosm type, *t* test applied to analyse differences between O and C.

4. SCOPE OF STUDIES

Papers in this volume present results concerning effect of macroarhropod exclusion on carbon storage in sand and on the number and biomass of soil biota in the litter and soil. The important question whether the environmental conditions were similar in both series of mesocosms is analysed in the paper by Szanser (2000a). Two parameters have been treated as indicators of environmental conditions and compared at several sampling occasions: moisture content (in soil, sand and litter) and plant biomass. The next two papers (Szanser 2000b, Kusińska and Kajak 2000) have analysed decomposition pattern, namely mass loss of grass litter exposed in bags and of below ground detritus in both mesocosm series. Changes in carbon, nitrogen and humus fractions in sand and litter have been tested also. Stefaniak *et al.* (2000) have estimated microbial numbers and enzymatic activity in the litter, sand and soil in mesocosms and in adjacent grassland soil. The density of nematodes in soil cores was analysed by Wasilewska (2000). The changes in the biomass of other fauna components and synthesis of all the results are presented in the last paper (Kajak *et al.* 2000).

5. SUMMARY

The aim of the paper was to present programme on studying in the field conditions the effect of macroarthropods patrolling soil surface on decomposition processes, composition and numbers of biota. Experimental design was presented (Table 1). The number of macroarthropods was manipulated by applying two types of field mesocosms (Fig. 1): O – open, accessible to large invertebrates (with holes cut in exclosures at soil/litter interface), and C – closed to them (without holes). Litter bags containing 9.5 g dry mass of aboveground parts of *Dactylis glomerata* were used to analyse mineralization and humification of litter and its colonization by microbes and by micro- and mesofauna in mesocosms. The mesocosms contained soil cores (100 cm^2, 15 cm deep) sampled from meadow soil and inserted into the soil profile, or similar volume of sand with admixture of clay in top layer in mesh exclosures. Treatment with soil cores (S) was used to analyse abundance of microbes, density of fauna and patrolling intensity of macrofauna. Treatment with sand (Sd) was applied to determine changes in carbon content and of humus fractions during the experiment. Two experiments were performed, each lasted approximately one year.

Effectiveness of manipulation with numbers of macroarthropods was checked by pitfall traps inserted into O and C mesocosms (Table 2). Biomass of macroarthropods was estimated by destructive sampling of soil cores. Both methods showed higher numbers of macroarthropods in open mesocosms (Tables 2, 3 and 4). Mesocosms affected size and trophic structure of fauna, in the open mesocosms proportion of predatory taxa and of large individuals was higher than in closed ones (Table 2). Results of the experiments have been presented in 6 papers of this volume.

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