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BIOMANIPULATION OF MACROARTHROPODS – EFFECT ON FOOD WEB				

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ENVIRONMENTAL CONDITIONS AND PLANT BIOMASS IN A FIELD EXPERIMENT – BIOMANIPULATION OF MACROARTHROPODS

ABSTRACT: Changes of environmental conditions in mesocosms differentiated in the accessibility for epigean arthropods (closed and open for animals) were compared on a meadow of the Arrhenatheretalia order. In general, moisture of the exposed litter and of the underlying substrate did not differ between the open and closed treatments. Plant biomass, considered as an index of the environmental conditions, did not differentiate the two mesocosm types, either aboveground (total and subdivided into dead and living) or belowground. The open mesocosms were characterised by higher weight of fragmented plant material and of invertebrate faeces than the closed treatment.

KEY WORDS: mesocosms, moisture, plant biomass, organic matter.

1. INTRODUCTION

In the last years, experiments using microcosms and mesocosms are becoming increasingly popular. In most cases they conduct studies of laboratory-designed systems in strictly controlled conditions (Hågvar 1988, Huhta *et al.* 1988, Uvarov 1993, Beyers and Odum 1993, Fraser and Keddy 1997). Performing field experiments of this type is difficult because of the disturbances due to habitat variability. Registering environmental changes and monitoring the responses of biological systems are necessary in an experiment to avoid misinterpretation of results.

The present experiment was carried out in field located mesocosms, which were isolated from macrofauna patrolling (closed – C) or accessible for soil macrofauna (open – O). It was essential to make sure whether the obtained results of the studied treatments were not due to habitat differences inside the two types of mesocosms. In particular the moisture value was considered, since it is a major factor that modifies survival and hence the abundance of organisms as well as the pattern of soil processes. Moisture was measured in the three substrates applied in the experiment: litter, soil and sand, and in the soil of the adjacent meadow.

2. STUDY SITE AND METHODS

The research was carried out on a permanent meadow of the Arrhenatheretalia order, localised in the border of Kampinos National Park in Łomna near Warsaw. The soil (acid,

pH = 4,4) of this site was composed of loamy sand underlain by loose sand (gleyed black-earth) (Kusińska and Kajak 2000). The top soil layer of 0–3 cm contained 8.6% of total C and the layer 3–15 cm – only 1.9%.

Mesocosms (cylindrical bags) made of steelon netting with mesh size of 0.24 mm contained soil cores (15 cm high and 11 cm of diameter) or were filled with organic matter poor substrate (sand with loam). The field experiments were performed: the Experiment I in 1992/93, Experiment II in 1993/94 and Experiment III in 1996/98. The mesocosms open (O) were perforated on the border between soil and litter with holes of 2-cm diameter, which gave the soil fauna free access into the bags; the remaining were closed (C). In the Experiment III, 2-cm horizontal incisions in the net were made in order to minimise potential microclimate differences between the two types of mesocosms. In the Experiment III an additional treatment was applied: litter in the closed mesocosms was manured with fecal pellets of insects (CM). For this purpose, excreta of fungivorous cockchafer larvae – *Osmoderma eremita* (Scarabeidae) and of locust – *Locusta migratoria* (Oedipodidae) were used (Szanser 2000). In all experiments control treatments (Co) without the litter were applied. At the start of each experiment, litter of grass (*Dactylis glomerata*) was exposed into the mesocosms. Portions of 5-g air dried grass (c.a. 4.7 g dry wt) were weighted out to PVC rings (diameter 11 cm, height 5 cm, with a row of holes of 1.0 cm diameter, in distance of 1.5 cm). The rings were open at the top and they were sealed from below, to prevent litter's falling out, with a steelon net with mesh size of 1 × 2 mm (Szanser 2000).

The moisture analyses of litter and underlying substrate were performed by the weighting method. Results of litter analyses are presented in the paper by Szanser (2000). Substrate moisture in mesocosms was measured 5 times in Exp. I, 3 times in Exp. II and 8 times in Exp. III.

Aboveground plant biomass in Exp. I and II was determined in autumn terms, respectively after 5 and 16 months after establishment of the experiments. For Exp. II the same sand filled isolators were used that had been installed for Exp. I. In Exp. III plant biomass was determined at the end of the experiment in spring, after 24 months from the mesocosm installation. Four fractions of the aboveground biomass were distinguished: (1) living fraction, containing green parts of plants; (2) fraction of yellowing material; (3) dead brown material attached to a plant; (4) the litter. This categorisation followed Traczyk (1976). In the sand-filled mesocosms the biomass of roots ingrowing from the surroundings was analysed in autumn and spring periods. The roots were obtained by rinsing the sand in sieves with mesh diameter of 1 mm and 0.28 mm (Szanser 1997). At each sampling time 6–10 mesocosms were analysed from each experimental treatment. At the same dates analogous samples were taken from the surrounding soil for above- and belowground biomass analyses. For determination of plant and soil dry weights material was dried at 100°C.

3. RESULTS

3.1. MESOCOSMS IRRESPECTIVELY OF TREATMENT *VS.* SURROUNDINGS

3.1.1. SUBSTRATE MOISTURE

During the experiments I and II the rainfall was lower than averages over one hundred years (Fig. 1). In Exp. I this deficit occurred between April and August 1992 and in Exp. II – between April and June 1993. The rainfall deficit of the first experiment was accompanied by occurrence of higher average air temperatures during the growing season than multiannual averages (Fig. 2).

The influence of summer drought on the biological activity was severe in both years, as the soil moisture at the studied meadow de-

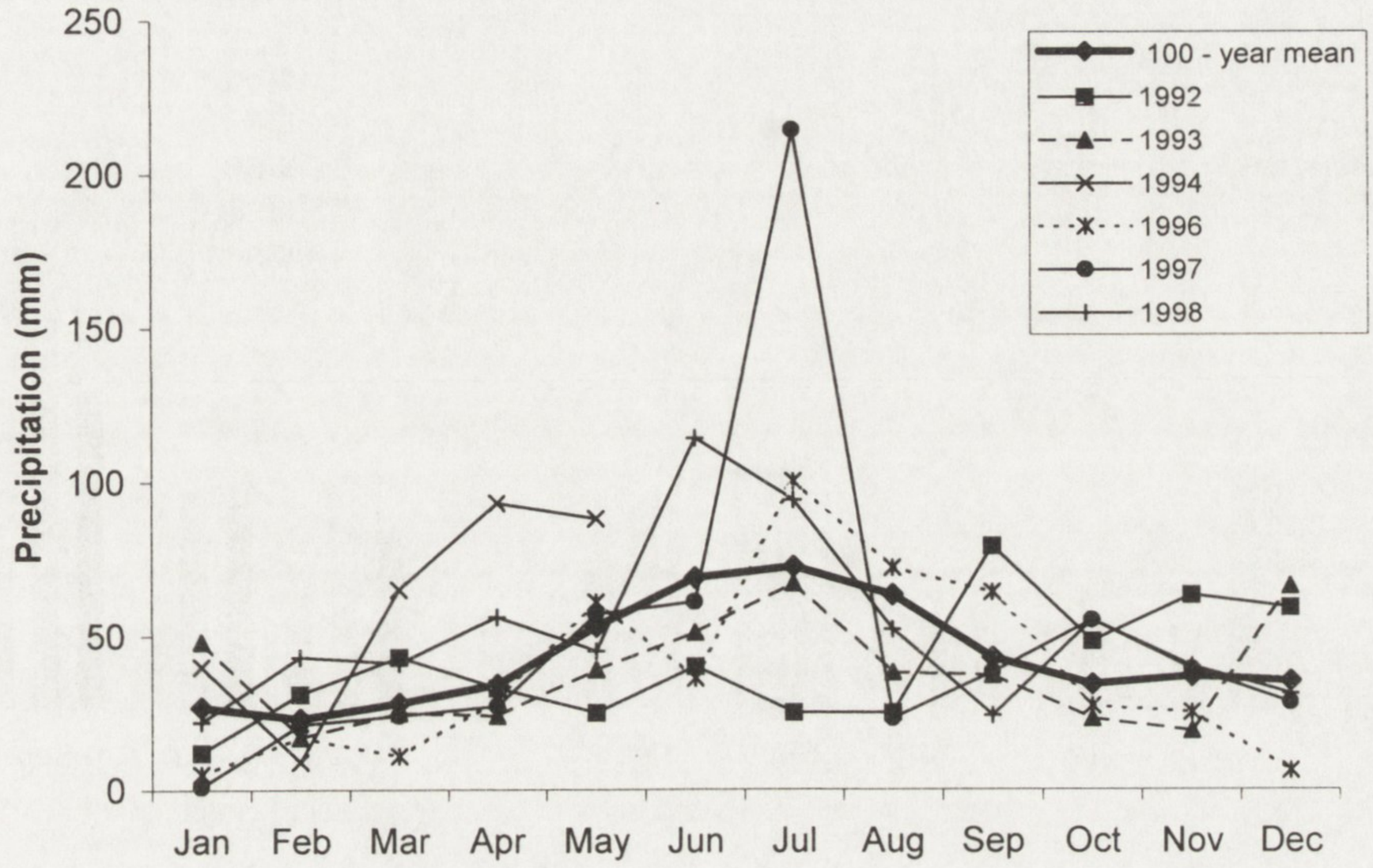


Fig. 1. Mean monthly precipitation rates during Experiments I (1992/93), II (1993/94) and III (1996/98)

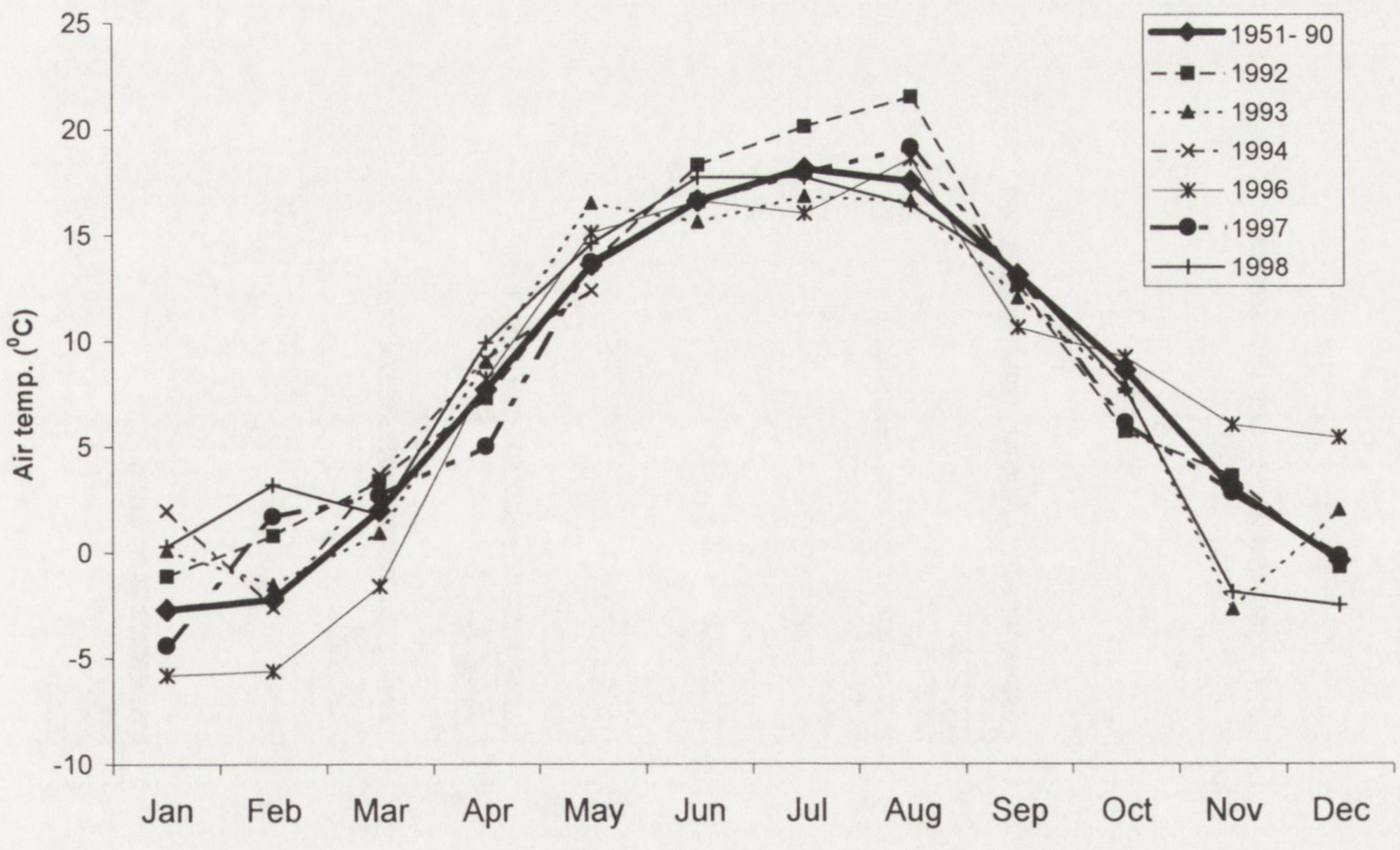


Fig. 2. Air temperatures during Experiments I (1992/93), II (1993/94) and III (1996/98)

pended mainly on rainwater. A capilary rise was very prohibited because of loose sand occurring in the subsoil (Kusińska and Kajak 2000). The lowest soil moisture in mesocosms with soil cores was recorded in June and July 1992 (Fig. 3). In Exp. III the weather conditions were much more convenient for the biota. Both the rainfall and the soil moisture in the surroundings of the experiment were higher as compared to the previous period (Figs 1 and 4).

3.1.2. ABOVEGROUND BIOMASS OF PLANTS

Aboveground biomass of plants reflected the differences occurring between the

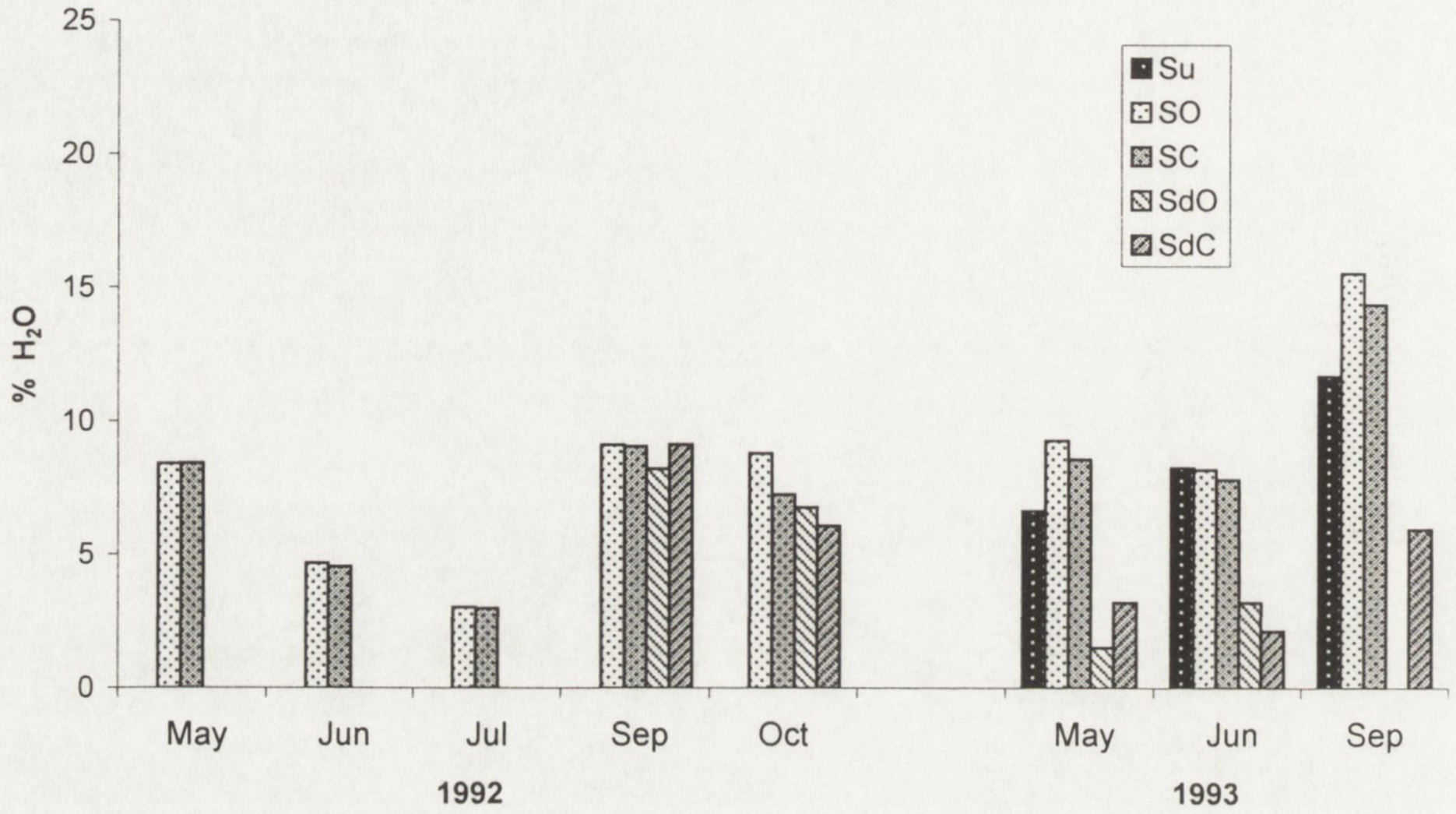


Fig. 3. Moisture of surrounding soil and in mesocosm substrate during Experiments I (1992/93) and II (1993/94). Surrounding meadow (Su), soil mesocosms open (SO) and closed (SC), sandy mesocosms with litter laid out: open (SdO) and closed (SdC)). Differences between treatments are not significant. Data after Stefaniak unpubl.

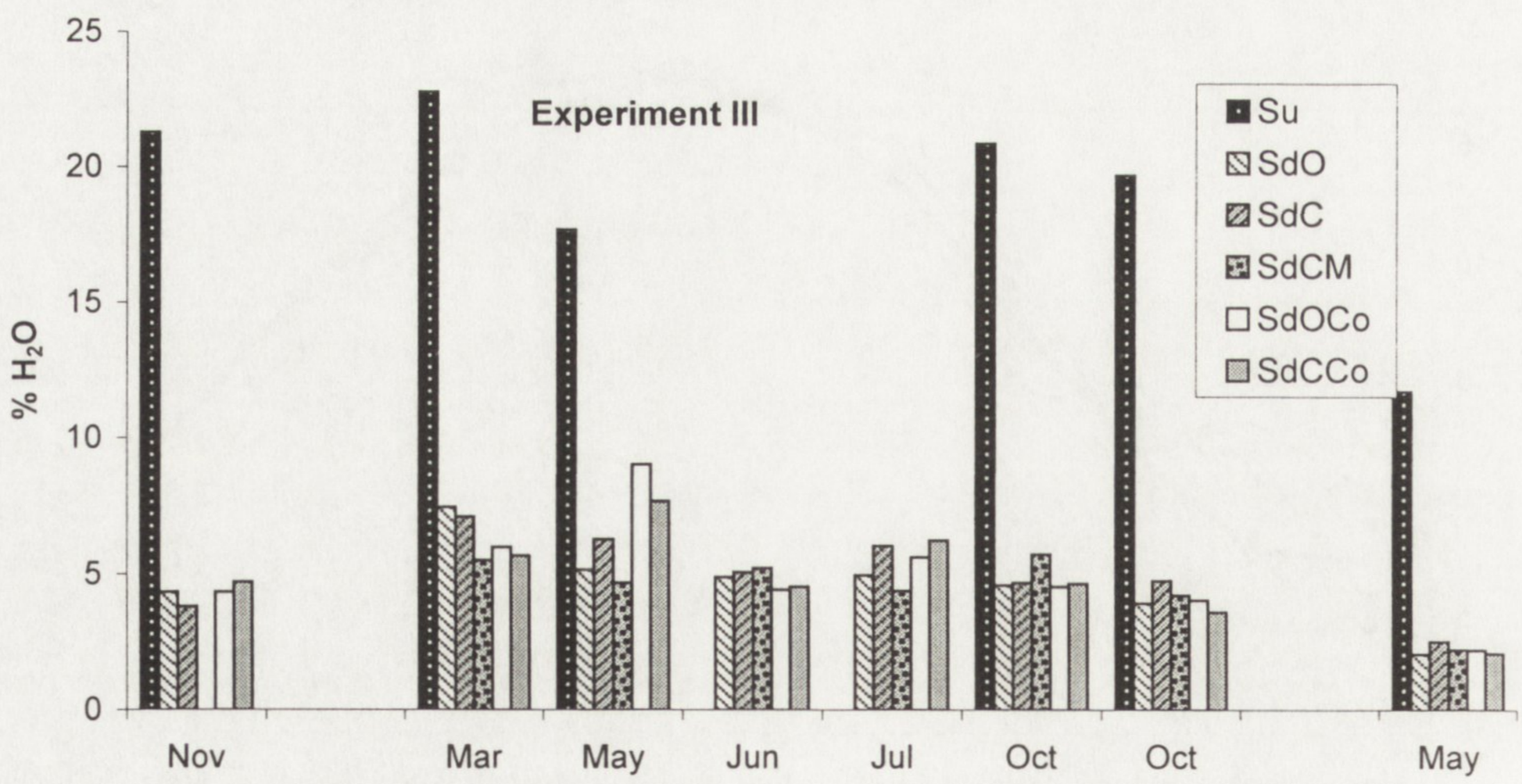
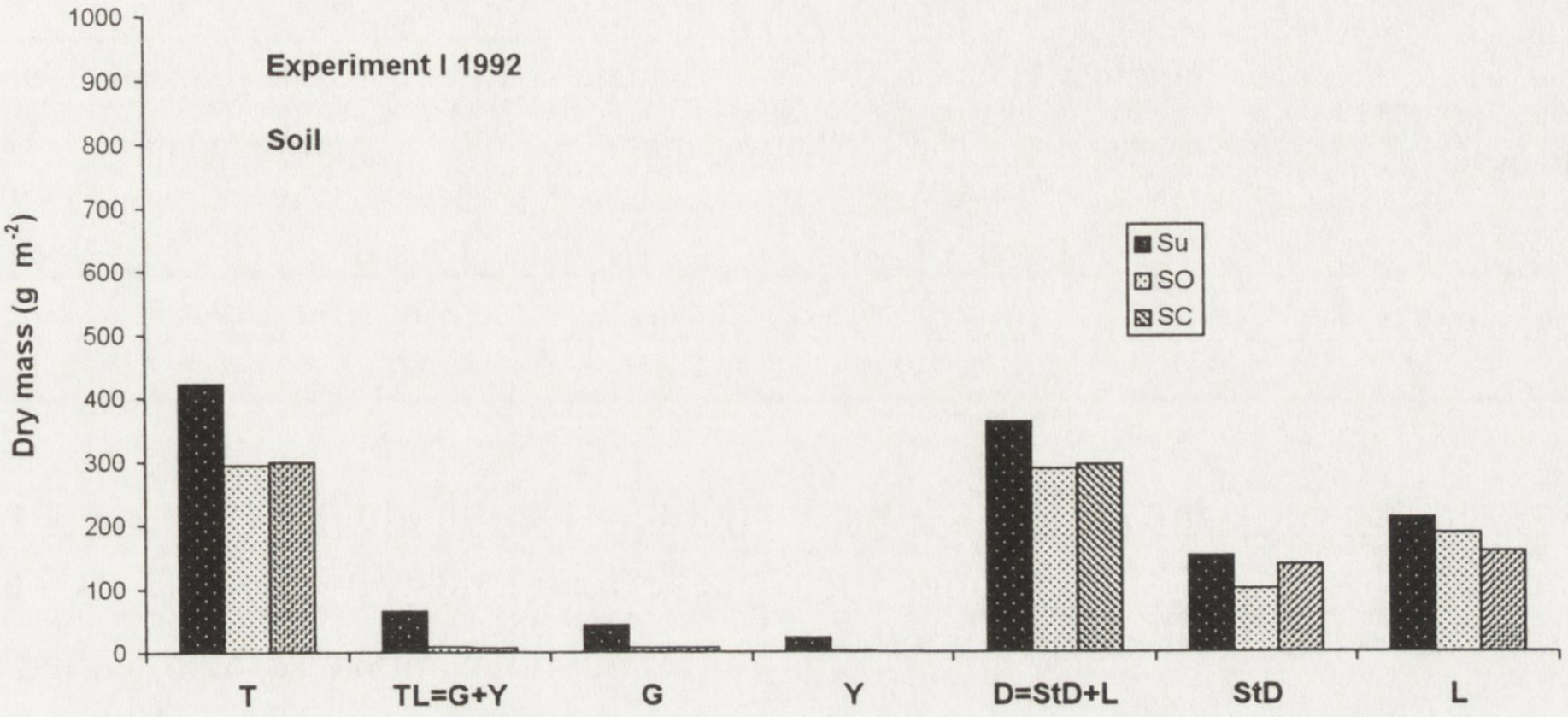
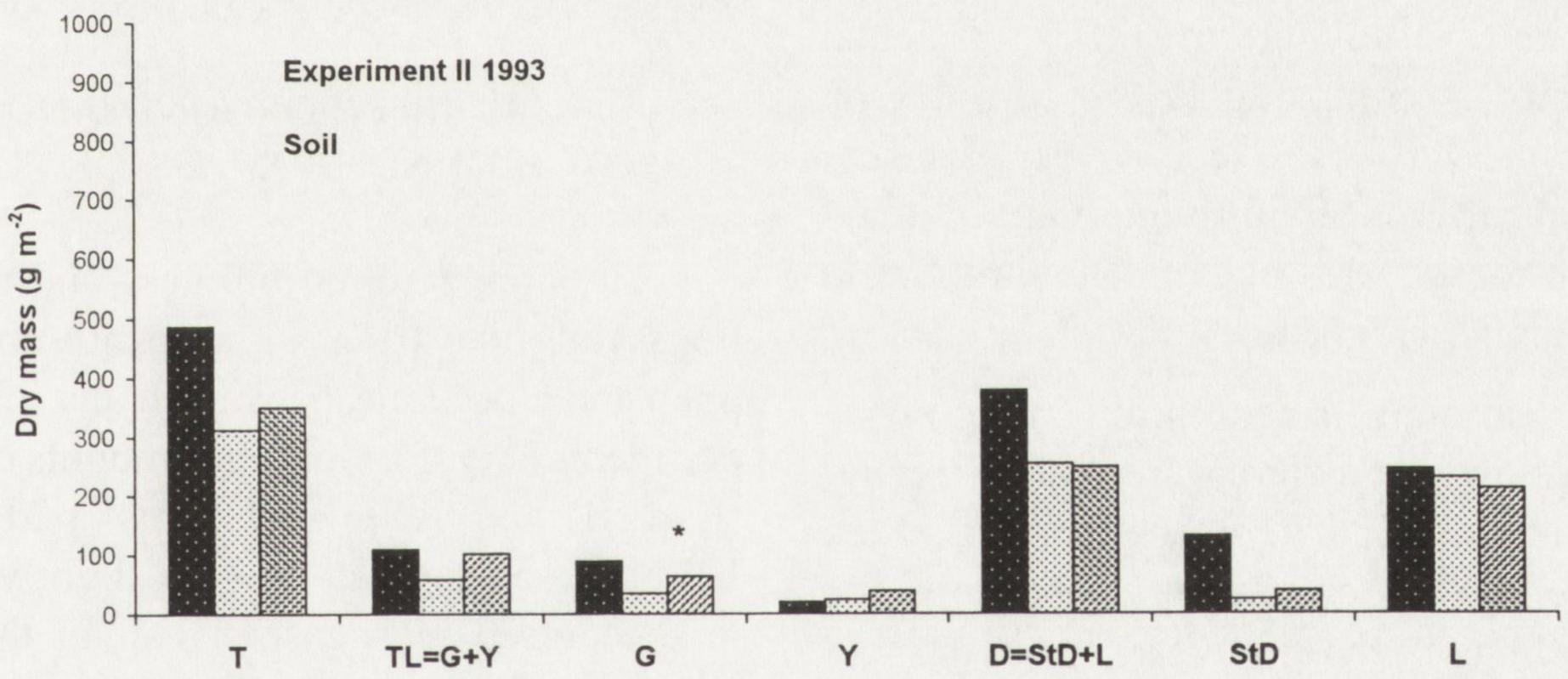


Fig. 4. Moisture of surrounding soil and of sand in mesocosms during Experiment III (1996/98) (surrounding soil (Su), mesocosm with litter: open (SdO), closed (SdC) and closed + added insect's faeces (SdCM), control mesocosms without the litter: open (SdOCo) and closed (SdCCo))

experiment's surrounding and the mesocosms. The total aboveground biomass of plants was usually higher in the surroundings than in the isolators (Fig. 5). The aboveground biomass of plants in the mesocosms with soil (Exp. I and II) reached on average 60–70% of the aboveground biomass in the surrounding vegetation, both after 5 and 16 months after start of the experiment. In the treatments with sandy substrate (Exp. III), which were gradually colonised by plants, the aboveground biomass was equal to 3.5–6.3% of the surrounding aboveground plant biomass. Plant colonisation on the poor sandy substrate occurred very slowly. A significant relationship was found between the weather





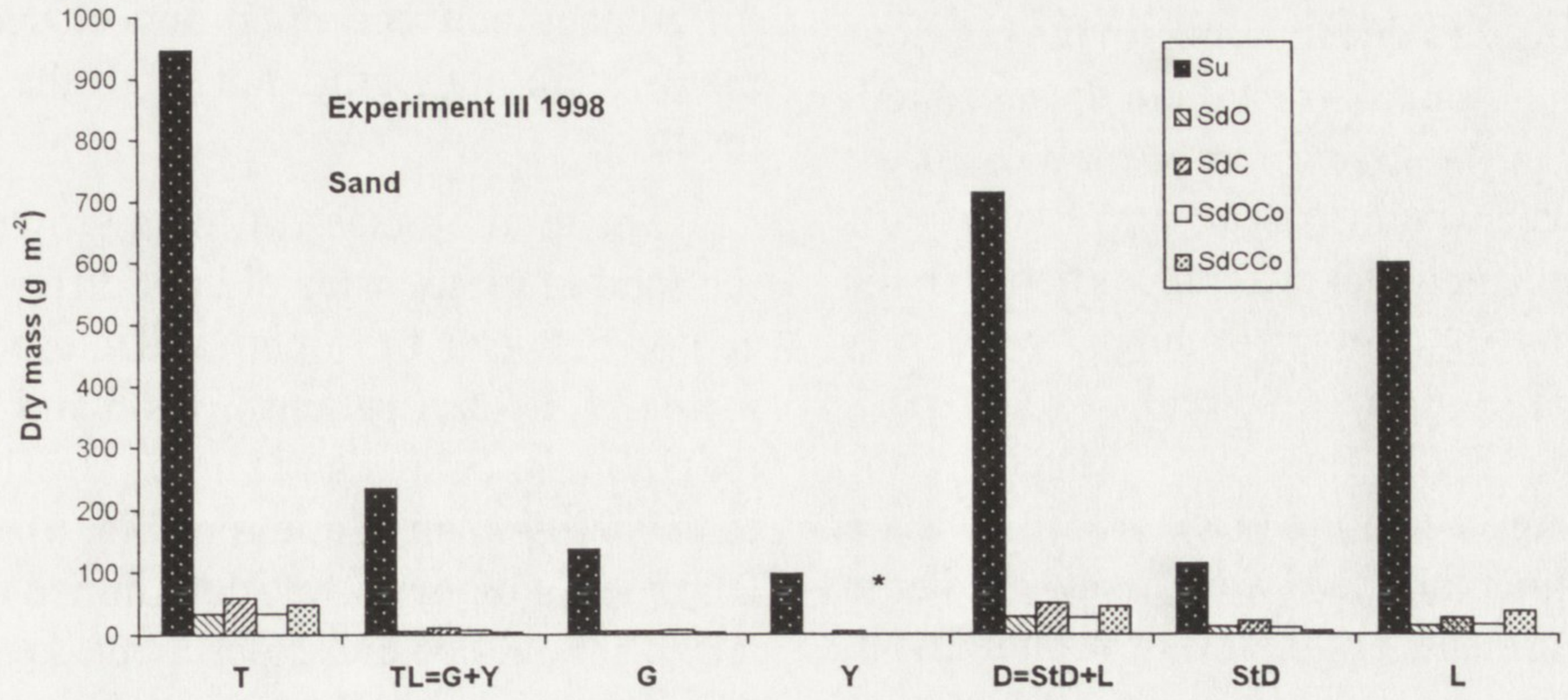


Fig. 5. Aboveground biomass of plant fractions during Experiments I, II and III in surrounding meadow (Su) and in soil mesocosms with litter: open (SO) and closed (SC) and in sandy mesocosms with litter: open (SdO), closed (SdC) and in control (Co) without the litter: open (SdOCo) and closed (SdCCo)). T – total biomass, TL – total live, G – green, Y – yellowing, D – total dead, StD – standing dead, L – litter. Differences between O and C treatments are denoted by asterisks (* $P < 0.1$).

Table 1. Ratio of dead to live aboveground plant biomass (B_d/B_l) in Experiments I, II, III

Parameter	Autumn 1992			Autumn 1993			Spring 1998		
	Surroundings	Soil mesocosms		Surroundings	Soil mesocosms		Surroundings	Sand mesocosms	
		Open	Closed		Open	Closed		Open	Closed
Number of samples	9	9	9	8	8	8	10	20	20
B_d/B_l	5.6	42.9	39.6	3.4	4.3	2.8	3.0	4.4	6.5

conditions and the scale of differences between the mesocosms and surroundings. In the first year, when periods of extreme drought occurred, the analyses conducted at the beginning of November showed significantly lower biomass of plant living parts (green and yellowing) in all experimental treatments as compared to the surrounding vegetation. Only in the second year of the experiment differences in living plant biomass between mesocosms and surroundings were much smaller (Fig. 5).

The amount of dead biomass (brown + litter) followed a different trend than the living biomass. No differences were recorded between the experimental mesocosms and surroundings in the first year, but in the second year the surrounding vegetation was characterised by higher mass of the brown fraction as compared to the plants in mesocosms. This was due to larger, in the previous year, living biomass fraction in the surroundings than in the experiment. Analysis of the ratio between plants' dead and living parts (B_d/B_l) indicated that differences between the mesocosms and surroundings were extremely large in the first year of the experiment. The B_d/B_l ratio was lower in the surrounding vegetation (Table 1). In the Exp. II and III the B_d/B_l ratio was already similar in all the treatments and in the surroundings.

3.2. CLOSED AND OPEN MESOCOSMS

3.2.1. SUBSTRATE AND LITTER MOISTURE

Moisture values fluctuated similarly in the open and closed system, both with litter exposed and in the control mesocosms without litter. No significant differences between these treatments were found (Figs 3 and 4).

The litter moisture also varied among particular dates of analysis. Yet, no significant differences were found among the open, and closed mesocosms (Szanser 2000).

3.2.2. ABOVEGROUND AND BELOWGROUND BIOMASS OF PLANTS

The aboveground biomass and its fractions did not differ significantly between open and closed mesocosms in any of the experiments (Fig. 5). Only the amounts of green (Exp. II) and yellowing plants' parts (Exp. III) analysed seperately were slightly higher in the closed mesocosms than in the open ones ($P < 0.1$) (Fig. 5). When the whole living aboveground biomass of plants was considered (green and yellowing), the differences between open and closed treatments were not significant in all the experiments.

The total biomass of roots growing into the sand in mesocosms did not differ significantly between the open and closed treatments of the experiment (Figs 6 and 7). The root biomass (Exp. I and II) was clearly lower in the spring than in autumn (Fig. 6). In Exp. III, the root biomass was determined only after 24 months of the experiment, i.e. after a similar period as in Experiment II (the part of installed in the Experiment I sandy mesocosms was analysed during two years). In both cases the harvesting was in the spring and the amounts of roots were similar. Hence, the plant growth process during the experiment was similar in the two types of mesocosms.

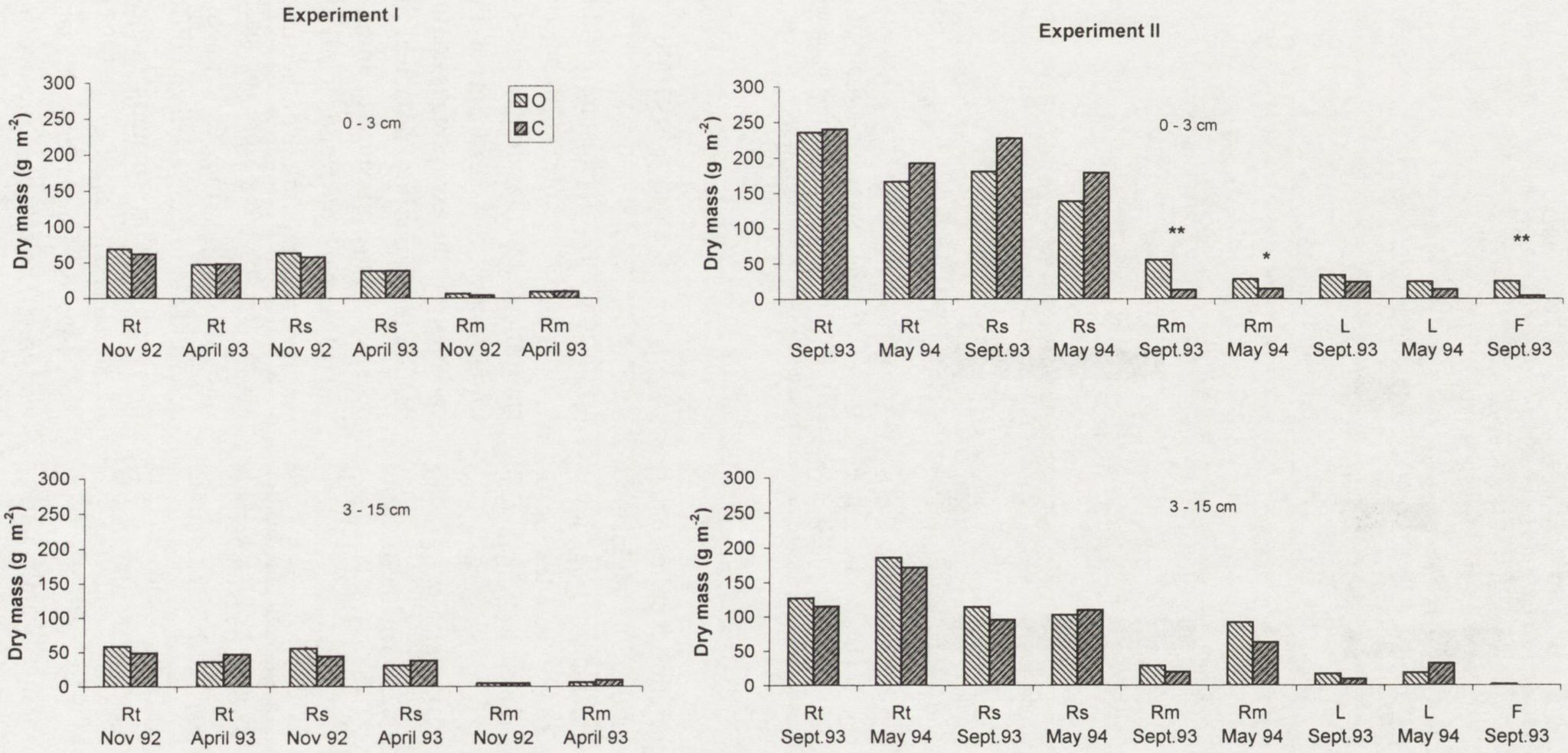


Fig. 6. Belowground biomass of plant fractions and of invertebrate faeces in sandy mesocosms: open (SdO) and closed (SdC) in 0–3 cm and 3–15 cm sand layers, during Experiments I (a, b) and II (c, d). Rt – total roots, Rs – roots, Rm – root fine material, L – litter, F – invertebrate faeces. Differences between the treatments are denoted by asterisks (* $P < 0.1$, ** $P < 0.05$)

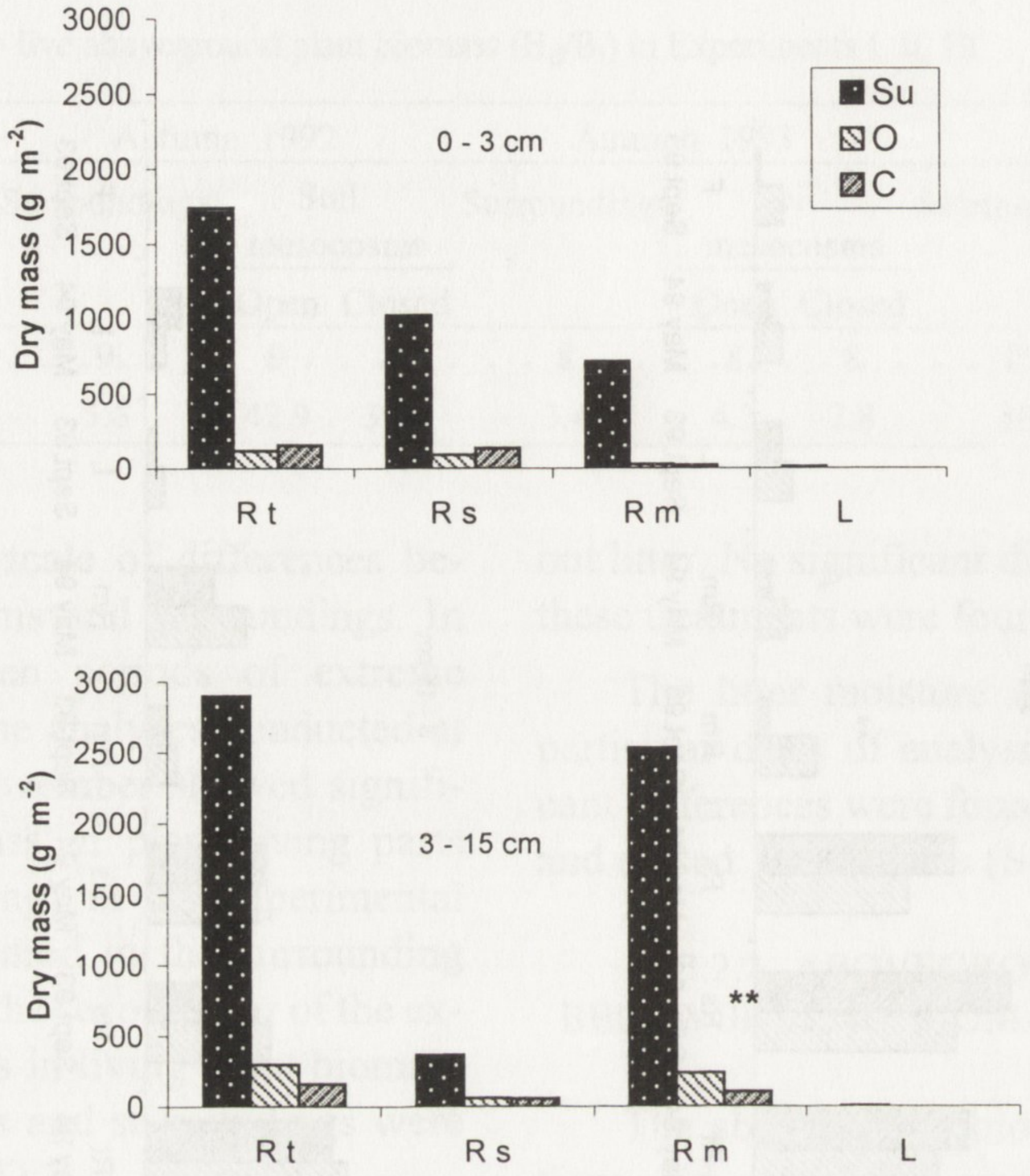


Fig. 7. Belowground biomass of plant fractions in sandy mesocosms; open (SdO) and closed (SdC) in 0–3 cm and 3–15 cm layers, during Experiment III. Rt – total roots, Rs – roots, Rm – root fine material, L – litter belowgrand. Differences between treatments are denoted by asterisks (** $P < 0.05$).

At the end of all the three experiments, it was found that higher amounts of fragmented root organic matter remained on the sieves (mesh diameter of 0.28 mm) from the mesocosms open for macrofauna patrolling than in the closed ones (Figs 6 and 7). Furthermore, higher amounts of macrofauna faeces and bodies were found in the open mesocosms than in the closed ones in Exp. II and III (Fig. 6; Szanser in prep.). At the end of the Experiments II and III it was observed that higher amounts of decomposed organic matter were present in the lower layer (3–15 cm) than in the upper one (0–3 cm) (Figs 6 and 7). This could be due to leaching the organic matter into the lower parts of the mesocosms.

Thus, there was a significantly higher amount of decomposed organic matter and organic matter transformed by macrofauna in the open systems than in the closed ones.

4. DISCUSSION

Variability of moisture conditions was high during the whole research period, which was reflected in the soil processes occurring in mesocosms. Assessment of the habitat conditions in the experiments confirmed that, despite the variability, no actual differences occurred in the moisture of litter, sand and soil between the open and closed series. This was observed regardless of the substrate type and of the litter exposure (or lack of exposure). Also a previous experiment with soil cores did not reveal significant differences in the moisture of litter material in the two types of mesocosms (Kajak *et al.* 1991). In all of the described experiments the same netting was used. The design of mesocosms differed only with respect to the openings above the soil surface enabling an access of fauna into the mesocosms: in Exp. I and II round holes

were made, while in Exp. III – horizontal incisions. Thus, comparable site conditions were obtained in all the mesocosms, irrespective of the substrate used (sand or soil) inside.

No differences of the aboveground or the belowground biomass were detected between the treatments, although the vegetation growth was suppressed in Exp. I as compared to the surrounding vegetation. That was due to the drought, which hampered plant regeneration in the soil cores. Poor sandy substrate applied in the experiments was slowly colonised by plants, which was clearly shown in Experiment III. Very low biomass of plants in Exp. III was caused by slow succesional processes that occurred in the poor substrate. It is important that in all experiments, the vegetation was affected by light suppression on the netting of mesocosms. Light absorbency of net can reach 25%, which was described by Müller-Schärer (1991) in a technically similar experiment. The author reported that air moisture and temperature patterns did not differentiate mesocosms from the surroundings. The similarity of litter decomposition rate in all experiments of the first year also confirms the resemblance of site conditions in the two types of isolators (Szanser 2000). Analysis of the sandy substrate of mesocosms revealed that open mecocosms were characterised by higher organic matter content in the substrate as compared to the closed systems. In the autumn of Exp. II, in the open mesocosms, the sand layer 0–3 cm had a higher content of fine organic matter originated from roots (3.2 times more), invertebrates faeces (5.7 times more) and litter (1.7 times more) than in the closed mesocosms. At the end of the Experiments II and III more organic matter was moved to the bottom of mesocosms, although it was still evident that the open treatments were richer in organic matter than the closed ones. The higher mass of root fine organic matter was found in the open treatments but also its decomposition was faster there than in the closed mesocosms. This is also confirmed by the ratio between values of this fraction of organic material mass in autumn and in the following spring in upper sand layer in Exp. I and II. This ratio was on average 1.34 in the open treatments (0.71 in Exp. I, 1.97 in Exp. II) and 0.89 in the closed treatments (0.45 in Exp. I, 0.91 in Exp. II). It demonstrates how large the differences between the experimental series are. Further analyses are necessary to interpret the background of these differences. Also contents of total carbon and fulvic acids in the sandy substrate were higher in the open treatments than in the closed ones (Kusińska and Kajak 2000, Kusińska in prep.).

In the open mesocosms higher amounts of insect remains were found than in the closed ones. This is not only a result of the higher area-patrolling by macrofauna in the open series as compared to the closed mesocosms, but also – of higher predatory activity in the open treatments than in the closed ones (Szanser in prep.).

It is postulated that faecal pellets of soil fauna can in time become a reserve of organic matter that is hardly available for microbes (Webb 1977, Martin and Marinissen 1993). This fraction of organic matter is of large importance for soil structure composition and organic matter storage in soil (Rusek 1975, Pawluk 1985, Tajovský *et al.* 1992).

It was found hence, that large invertebrates have a major influence on the soil organic matter, due to detritus fragmentation as well as depositing faeces and dead mass.

5. CONCLUSIONS

1. The moisture of litter and underlying substrate did not differ significantly between the open (accessible for macrofauna) and closed mesocosms and the closed manured ones, during all years of the experiment.

2. Open and closed systems generally did not differ between each other in respect to the total aboveground biomass of plants or in the ratio between living and dead aboveground plant material and the total biomass of roots.

3. Higher amounts of fine organic matter of root origin and of soil invertebrates faeces and dead remnants were found in the substrate of open mesocosms than in the substrate of the closed ones.

4. The aboveground as well as the belowground biomass of vegetation from the experiment surrounding was higher than the biomass of the plants in the mesocosms. This was caused by: the drought in the first year, which delayed plants' regeneration in the soil cores and in all years – lower light supply to plants under the nettings. Colonisation of the sandy substrate of mesocosms was slow; after two years the plant biomass was much lower in the mesocosms than in the surroundings.

6. SUMMARY

The influence of meadow epigean fauna on the processes of grass litter decomposition was studied in field experiments carried out in years 1992–93, 1993–94 and 1996–98. Two types of mesocosms were used: isolated from patrolling by macrofauna (closed – C) and accessible for macrofauna (open – O). During the research period longlasting droughts as well as large rainfalls occurred (Figs 1 and 2). It was necessary to verify whether the environmental conditions differed in the isolators of two types. Particularly the moisture was considered, as it is the major factor that affects organisms' survival and the pattern of soil processes. Moisture was measured in three substrates applied in the experiment: litter, soil and sand (Figs 3 and 4; Szanser 2000). Simultaneously the plant biomass was analysed, both in the experiment and in the surrounding vegetation, as a sensitive indicator of environmental conditions. The litter moisture did not differ significantly between the open, closed, and closed manured isolators, during the whole research period (Szanser 2000). The substrate moisture showed the same tendency (Figs 3 and 4).

The aboveground plant biomass was higher in the surroundings than inside the isolators (Fig. 5). This was due to the drought in Exp. I, which delayed regeneration of plants in the soil-cores, and was also due to lower light intensity obtained by plants inside the isolators during all the experiments. On the poor substrate the succession of vegetation proceeded in a similar way, the two types of mesocosms were not different according to the total aboveground biomass of plants and neither according to the living to dead biomass ratio (Fig. 5). After the first years of experiments the living/dead aboveground plant biomass ratio in mesocosms and in the surroundings tended to be similar in time (Table 1).

In the sand-filled mesocosms the main root mass did not differ between the two types of isolators (Figs 6 and 7). It was found however that the mass of organic matter in the substrate of open isolators significantly increased in time, much more than in the closed mesocosms (Figs 6 and 7).

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