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Observations on the Feeding Biology of Some Collembola Under Laboratory Conditions

By

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Introduction

For a long time past, many studies have been conducted on the role of soil animals in the process of litter breakdown and humus formation. Nevertheless, there are still some problems to be clarified.

It is now agreed that litter inhabitant Diplopods and Isopods have an important role in the breakdown of litter (DUDICH, BALOGH and LOKSA, 1952; DUNGER, 1956; 1958; 1964; GERE, 1956; 1959; 1963; BALOGH, 1958; EDWARDS and HEATH, 1963; VAN DER DRIFT, 1964; NAGLITSCH, 1965; KEVAN, 1967; STRIGANOVA, 1959; 1971; EDWARDS, REICHLE and CROSSLEY, 1970; MCBRAYER and REICHLE, 1971; ANDERSON, 1973). It is also known that Lumbricidae (KEVAN, 1967; ZICSI, HARGITAI and POBOZSNY, 1970; LOKSA and ZICSI, 1972; VÉGH, 1974), as well as dipterous larvae (PEREL, KARPACHEVSKY and YEGOROVA, 1971) have a special role in the humification of litter. However, this does not apply so unambiguously to micro- and mesofauna of the soil. Some authors are of the opinion that in the humification of litter the mesofauna plays a similar role to thet of the macrofauna (DUDICH, BALOGH and LOKSA, 1952; BALOGH, 1958; HARTENSTEIN, 1962; MCMILLAN and HEALEY, 1971; GERE and GYURJÁN, 1972; SZENTKIRÁLYI, 1972). However, the role of the mesofauna may be secondary, as these animals do not directly consume litter leaves but the fragmented leaves previously contaminated with the excrements of larger soil arthropods (DUNGER, 1956; 1964; BALOGH, 1958; POOLE, 1959; NAGLITSCH, 1965; GERE and GYURJÁN, 1972).

According to MCBRAYER and REICHLE (1971) about 60% of the soil mesofauna belong to fungal feeders. In addition to, other authors reported, that Collembola and soil mites fed on fungi and bacteria (DUDICH, BALOGH and LOKSA, 1952; DUNGER, 1956; POOLE, 1959; HARTENSTEIN, 1962; KEVAN, 1967; KNIGHT and ANGEL, 1967, SINGH, 1969; COLEMAN and MCGINNIS, 1970; BÖDVARSSON, 1971; MCMILLAN and HEALEY, 1971). ENGELMANN (1961) reported

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that Oribatids feeding on fungal mycelia stimulated the productivity of fungi, which indirectly promoted the decomposition of litter.

The present work is aimed to assess the role of Collembola in the metabolism of the forest soil. Naturally, it was impossible to deal with all the collembolan species present in the ecosystem under investigation at once. Thus I selected two predominant species, namely *Folsomia quadrioculata* TULLB. and *Onychiurus subcancellatus* GISIN for my examinations.

Three kinds of the naturally present food were made available for the Collembola in the experiment: litter leaves, fungi and excrements of macroarthropods. There is no doubt, that under natural conditions, Collembola have a wide opportunity to feed on other food materials, still, the three kinds of food selected for the present investigation seem the most significant ones.

So that excrements of macroarthropods could be ensured, Collembola was reared in the laboratory together with the Diplopod *Chromatoiulus projectus* VERH. The Diplopod was also reared alone. Thus, if there was a difference in weight of the diplopodan excrements, then one could conclude that Collembola had consumed it.

Matherial and methods

Collembola and Diplopoda were collected from a hornbeam – oak mixed forest near Szendehely (about 50 km. north-east of Budapest). The soil of this forest is brown forest soil infiltrated with clay. Its botanical characters were described by ISÉPY(1974).

Rearing was conducted in unglazed earthen pots (5 cm. in diameter and 5 cm. in deep). Known weights of freshly fallen air-dried hornbeam leaves *(Carpinus betulus)* were placed into the pots. The leaves were selected to be of identical size and colour. Before placing the experimental animals into the pots, the leaves were moistened with distilled water. The pots were then covered with nylon nets of small mesh size (175 micron), to prevent the escape of the animals. The rearing pots were placed in a large vessel containing sand. The sand was kept damp by spraying with water every two or three days. GERE (1959; 1962) pointed out that rearing in plant pots creates a good microclimat, as air and moisture can easily diffuse trough the pores of these pots.

The pots were kept in the laboratory for 30 days at a temperature of 8 – 11 °C.

Three experimental series were conducted. Ih the first one both species of Collembola, namely *F. quadrioculata* and *O. subcancellatus*, were placed into separate rearing pots. The number of individuals placed in the pots ranged between 10 to 40, so that the relationship between loss in littor weight and the number of individuals could be assessed.

In the second series 1 to 4 individuals of the Diplopod *C. projectus*, were put alone in separate pots. Here the loss in litter weight as well as the quantity of excrements produced were estimated. It is worthy to note that the quantity of excrement produced in this series of the experiment is used as control for the following experimental series.

In the third experimental series 1 to 4 individuals of *C. projectus* and 10 to 40 individuals of *O. subcancellatus* were placed together into the same rearing pot. At the end of the experiment the loss in litter weight and the produced excrements of Diplopods were determined.

Table 1. Litter consumption of Onychiurus subcancellatus (in grams)

Number of individuals	Weight of air-dried litter at the beginning of the experiment	Weight of completely dried litter at the beginning of the experiment	Weight of air-dried litter at the end of the experiment	Weight of completely dried litter at the end of the experiment	Loss in weight of completely dried litter	Mean values of the parallel samples	Litter consumed by the animals
10	1,0661	1,0021	1,0638	1,0000	0,0021		
10	1,0757	1,0111	0,9217	0,8664	0,1447	0,0584	0,0233
10	1,0385	0,9762	1,0101	0,9494	0,0268		
20	1,0451	0,9824	1,0118	0,9511	0,0283		
20	1,0724	1,0078	1,0576	0,9941	0,0137	0,0219	– 0,0132"
20	1,0589	0,9954	1,0337	0,9716	0,0238		
30	2,1585	2,0899	2,0911	1,9656	0,1243		
30	2,0875	1,9606	1,9971	1,8772	0,0834	0,0963	0,0612
30	2,0095	1,8889	1,9228	1,8075	0,0817		
40	2,0636	1,9398	1,9665	1,8485	0,0913		
40	2,0899	1,9645	1,9968	1,8770	0,0857	0,0852	0,0501
40	2,0201	1,8989	1,9382	1,8220	0,0769		

Table 2. Litter consumption of Folsomia quadrioculata (in grams)

Number of individuals	Weight of air-dried litter at the beginning of the experiment	Weight of completely dried litter at the beginning of the experiment	Weight of air-dried litter at the end of the experiment	Weight of completely dried litter at the end of the experiment	Loss in weight of completely dried litter	Mean values of the parallel samples	Litter consumed by the animals
10	0,9858	0,9266	0,9659	0,9079	0,0187		
10	1,1158	1,0488	1,0088	0,9483	0,1005	0,0733	0,0382
10	1,0706	1,0063	0,9634	0,9056	0,1007		
20	1,0114	0,9507	0,8804	0,8276	0,1232		
20	1,0190	0,9578	0,8640	0,8121	0,1457	0,1200	0,0849
20	1,0614	0,9977	0,9642	0,9064	0,0913		
30	2,0229	2,0952	2,0644	1,9405	0,1547		
30	2,0582	1,9347	1,9219	1,8066	0,1281	0,1422	0,1071
30	2,0916	1,9661	1,9384	1,8221	0,1440		
40	2,0758	1,9512	1,8755	1,7630	0,1882		
40	2,0536	1,9303	1,8429	1,7323	0,1980	0,1879	0,1528
40	2,0928	1,9672	1,9039	1,7897	0,1775		

Table 3. Litter consumption and produced excrements of Chromatoiulus projectus (in grams)

Number of individuals	Weight of air-dried litter at the beginning of the experiment	Weight of completely dried litter at the beginning of the experiment	Weight of air-dried litter at the end of the experiment	Weight of completely dried litter at the end of the experiment	Loss in weight of completely dried litter	Mean values of the parallel samples	Litter consumes by the animals	Weight of Diplopodan excrements	Mean valeus of the parallel samples
1	1,0291	0,9674	0,9405	0,8840	0,0834			0,0267	
1*	1,0570	0,9936	0,9940	0,9344	0,0529	0,1046	0,0659	0,0072	0,0371
1	1,0396	0,9772	0,9056	0,8513	0,1259			0,0475	
2	2,9346	2,7585	2,5117	2,3609	0,3976			0,2022	
2	3,1459	2,9563	2,8355	2,6654	0,2999	0,3443	0,3091	0,2018	0,2020
2*	2,9626	2,7843	2,2413	2,1068	0,6780			0,0779	
4	5,1057	4,7993	4,2470	3,9922	0,8071			0,3716	
4	5,0372	4,7349	4,1127	3,8659	0,8593	0,6133	0,5782	0,5669	0,4952
4	5,6021	5,2659	3,6336	4,0758	0,7871			0,5472	

(The data marked with* were not taken into cosideration, because in these samples the animals had died before the experiment had been firisked.)

Table 4. Litter consumption by Chromatoiulus projectus and Onychiurus subcancellatus together, and the produced excrements of Chromatoiulus projectus (in grams)

Number of individuals	Weight of air-dried litter at the beginning experiment	Weight of completely dried litter at the beginning experiment	Weight of air-dried litter at the end of the experiment	Weight of completely dried litter at the end of the experiment	Loss in weight of completely dried litter at the end of the experiment	Mean values of the parallel samples	Litter consumes by the animals	Weight of Diplopodan excrements	Mean valeus of the parallel samples
1+10	1,0259	0,9643	0,9225	0,8612	0,0971			0,0218	
1+10	1,0601	0,9965	0,9646	0,9068	0,0897	0,0961	0,0610	0,0225	0,0248
1+10	1,0413	0,9788	0,9400	0,8771	0,1017			0,0301	
2+20	3,2554	3,0600	2,7705	2,6043	0,4017			0,0997	
2+20	3,0659	2,8819	2,7920	2,6245	0,2574	0,3620	0,3269	0,0972	0,0873
2+20	3,1602	2,9706	2,7988	2,6308	0,3971			0,0751	
4+40	4,9838	4,6848	4,0562	3,8129	0,8719				
4+40	5,0609	4,7572	4,1508	3,9018	0,8554	0,8263	0,7892	0,1875	0,2368
4+40	5,1056	4,7993	4,3059	4,0476	0,7517			0,2791	

By comparing the results if the aboce experimental series some idea may be formed about the feeding preference of Collembola i. e. wether it prefers feeding on leaf material or the excrements of Diplopods.

Another set of experiments was conducted to assess the role of microorganisms in the breakdown of litter leaves, and to be used as control. Thus a konwn weight of leaves was placed into the pots without animals. Unfortunately, by this set of experiments I was unable to determine the consumed fungi present on the surface of leaves.

The gut content analysis was also performed for Collembola. The individuals were placed into 75% ethyl alcohol, then cleared in lactic acid for 2 to 3 days. The gut was dissected out on a slide and squashed under a cover slip. The gut content was then examined microscopically.

Three parallels were conducted for each series of experiment and the mean values were calculated.

Results

Table 1 shows the litter breakdown due to *Onychiurus subcancellatus*. From this table it is clear that the litter loss values do not show higher values than those of the controll experiment (where only litter was placed into the pots). Besides, there is no realationship between the number of individuals and the quantity of litter lost.

In the case of *Folsomia quadrioculata*, altough the quantity of litter lost is small, there is a certain directly proportional relationship between the number of individuals and the loss of litter leaves (Table 2).

The data of litter breakdown due to *Chromatoiulus projectus* are presented in Table 3. From this table it is apparent that the quantity of litter lost is directly proportional to the number of individuals and hence to the quantity of excrements produced. The quantity of litter consumed by 1 individual of *Chromatoiulus projectus* was found to be 2,16 mg/day. Gere (1959), in his experiments with light-brown and dark-brown oak leaves, estimated the quantity of leaves consumed by 1 individual of Diplopoda to range between 1,01 – 2,37 mg/day.

Table 4 presents the breakdown of litter by C. projectus and *O. subcancellatus* together, as well as the quantity of excrements produced by the Diplopods. If these data are compared with those in Table 3, it appears that the quantity of consumed leaves is directly proportional to the number of individuals. This may be attributed to the activity of the Diplopods. Similarly, one can notice increase in the amount of excrements produced by Diplopods. However, it should be mentioned here that the absolute quantity of excrements is less than in pots containing only Diplopods (Fig. 1).

Table 5 shows the loss in litter weight due to microorganisms only (in pots without animals). This, by extracting these values of litter loss from those obtained in pots containing animals obtains the litter loss only due to the animals.

In Table 6 the results of the gut content analysis of Collembola are shown. Three collembolan population were examined: the *Folsomia* population, the Onychiurus population without Diplopods and the Onychiurus population reared together with Diplopods. From the first two columns in this table it is

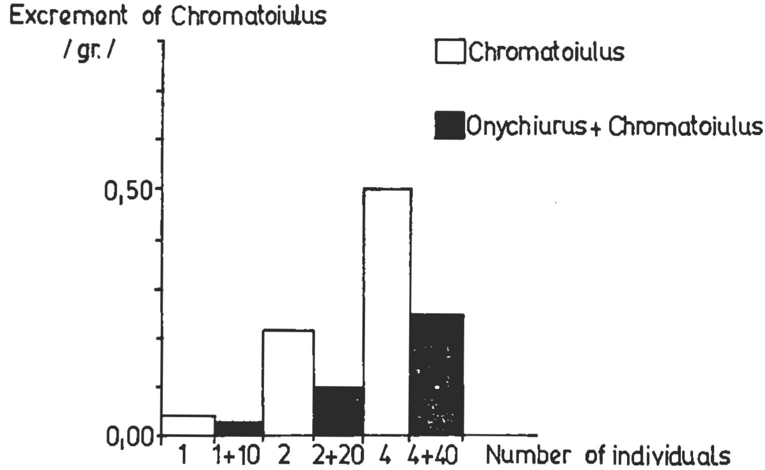

Fig. 1. The quantity of diplopodan excrements in the two sets of experiment

clear that at the end of the experiment about one half of the studied population showed filled guts. My results coincide with those of BÖDVARRSON (1970).

The materials contained in the gut were: *1.* Fungal mycelia were present: *a)* only in traces, *b)* in large quantity in the gut. — *2.* Fungal spores. — *3.* Higher plant material (litter fragments) was prepresent: *a)* only in traces, *b)* in large quantity in the gut. — *4.* Unidentifiable amorphous material.

The percentages of the individuals containing the above mentioned materials in their guts shown in the further columns of Table 6.

The analysis of the gut content revealed that the fungal mycelia were the most significant elements present. These results are in agreement with those obtained by other workers (e. g. POOLE, 1959; KNIGHT and ANGEL, 1967; BÖDVARSSON, 1970; McMILLANN and HEALEY, 1971). GILMORE and RAFFENSPERGER (1970), in a similar gut content analyses, estimated the quantities of litter and humus in large collembolan species.

When comparing the results obtained by the gut content analysis in the case of *Folsomia* with that of *Onychiurus* (reared without Diplopods) it is

Table 5. Loss of weight in litter due to microbial activity (control) (in grams)

Number of samples	Weight of air dried litter at the beginning of the experiment	Weight of completely dried litter at the beginning of the experiment	Weight of air dried litter at the end of the experiment	Weight of completely dried litter at the experiment	Loss in weight due to microbial activity	Mean values of the parallel samples
1	1,0917	1,0262	1,0673	1,0032	0,0230	
2	1,0826	1,0176	1,0421	0,9795	0,0381	0,0351
3	1,0713	1,0070	1,0244	0,9627	0,0443	

found that the quantity of fungal mycelia in the gut of *Folsomia* was much less than in *Onychiurus*; on the other hand there are much more litter fragments than in *Onychiurus*. This coincides with the results obtained dealing with litter breakdown data of the two collembolan species (Table 1 and 2), and indicates that *Folsomia quadrioculata* contributes little in the disappearence of litter, while *Onychiurus subcancellatus* has no role in this process.

Table 6. Results of the gut content analysis of three collembolan populations

Populations	% of Collembola with empty gut	% of Collembola with full gut	Few fungal mycelia in the gut content	Large amount of fungal mycelia in the gut content	Fungal spores in the gut content	Small quantity of litter in the gut content	Large amount of litter in the gut content	Unidentifiable material in the gut content
Folsomia	54,7	45,83	19,5	37,5	1,2	15,6	7,7	88,4
Onychiurus 1	46,05	53,95	7,2	42,5	–	3,7	5,2	81,4
Onychiurus 2	42,77	57,22	8,1	36,2	1,2	4,4	10,2	79,9

If the results of the gut content analysis of the two *Onychiurus* populations (reared with and without Diplopods respectively) are compared, it can be observed that the gut of *Onychiurus* reared with Diplopods contains more litter fragments than that of *Onychiurus* reared without Diplopods. Probably, the litter consumed by Diplopods is discharged with their excrements. This supports the results of feeding Collembola and Diplopoda together which show, that in this case the excrements of Diplopoda are much smaller in quantity than that in of Diplopods reared alone (Fig. 1).

Discussion

As mentioned above, the aim of the present work is primarily to trow light on the feeding habits of two predominant collembolan species from a hornbeam-oak woodland. There are numerous different opinions of many authors on the feeding habits of Collembola. Poole (1959) stressed that Collembola are not specialized feeders, since they can consume any food material available to them.

It is apparent the results obtained that both species of Collembola under investigation preferred feeding on fungal mycelia to leaf litter. This preference was especially noticable in the case of *Onychiurus subcancellatus*. *Folsomia quadrioculata* plays a small role in the breakdown of litter.

A small amount of Diplopoda excrements was consumed also by *Onychiurus* reared together with Diplopods, while it consumed a larger amount of litter than the individuals reared alone. Inspite of this, *Onychiurus subcancellatus* prefers fungal mycelia to Diplopoda excrements.

By way of conclusion one can state that the two investigated euedaphic collembolan species are pimarily fungal feeders.

Naturally, these results cannot be generalized for all Collembola, especially not for the large-bodied epiedaphic species.

It should be mentioned that leaves in a more advanced stage of decay may be preferred to those in an initial stage of decay, as were selected for my experiment.

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ZUSAMMENFASSUNG

Laboratoriumsbeobachtungen der Ernährungsbiologie der Collembolen

Die unter Laboratoriumsverhältnissen durchgeführten ernährungsbiologischen Untersuchungen bezweckten, um festzustellen, welche von den unter natürlichen Umständen uns zur Verfügung stehenden drei Hauptnahrungsquellen (Fallaub, Makrofauna-Exkrement, Pilzfäden) die in einem Hainbuchen-Eichenwald in großer Zahl lebenden Arten *Folsomia quadrioculata* und *Onychiurus subcancellatus* (Collembola) bevorzugen. In den Untersuchungen standen diese drei Nahrungsquellen der beiden Collembolenart zur Verfügung. Das Makrofauna-Exkrement lieferte *Chromatoiulus projectus.*

Aus dem Experiment ging hervor, daß beide Arten im Gegensatz zu den übrigen Nahrungen vor allem die Myzelien der Mikropilze bevorzugt haben, dann folgte das Exkrement der Makrofauna und erst zuletzt das Fallaub. *Folsomia quadrioculata* verzehrte in etwas größerer Menge das Fallaub, als *Onychiurus subcancellatus.* Es muß jedoch in Betracht gezogen werden, daß das zu den Versuchen benutzte Fallaub zu Beginn des Winters eingesammelt wurde und deshalb die Ergebnisse nur für das in der Anfangsphase des mikrobiologischen Abbaues befindliche Fallaub eine Gültigkeit haben.

REFERENCES

1. Anderson, J. M. (1973): *The breakdown and decomposition of sweet chestnut (Castanea sativa Mill.) and beech (Fagus sylvatica L.) leaf litter in two decidous woodland soils.* — Oecologia (Berl.) 12: 251–274.
2. Anderson, J. M. & Healey, I. N. (1972): *Seasonal and interspecific variation in major components of the gut contents of some woodland Collembola.* — J. Anim. Ecol., 41: 359–368.
3. Balogh, J. (1958): *Lebensgemeinschaften der Landtiere.* — Budapest–Berlin: 1–560.
4. Bödvarsson, H. (1970): *Alimentary studies of seven common soil inhabiting Collembola of southern Sweden.* — Ent. Scand., 1: 74–80.
5. Coleman D. C. & McGinnis, J. T. (1970): *Quantification of fungus - small arthropod food chains in the soil.* — Oikos, 21: 134–137.
6. Dudich, E., Balogh, J. & Loksa, I. (1952): *Erdőtalajok ízeltlábúinak produkciósbiológiai vizsgálata.* — MTA. Biol. Agrártud. Oszt. Közlem., 3: 505–523.
7. Dunger, W. (1956): *Untersuchungen über Laubstreuzersetzung durch Collembolen.* — Zool. Jb. (Syst.), 84: 75–98.
8. Dunger, W. (1958): *Über die Zersetzung der Laubstreu durch die Boden-Makrofauna im Auenwald.* — Zool. Jb. (Syst.), 86: 139–180.
9. Dunger, W. (1964): *Die Bedeutung der Bodenfauna für die Streuzersetzung.* — In: Tagungsberichte Nr. 60, Berlin: 99–114.
10. Edwards, C. A. & Heath. G. W, (1963): *The role of soil animals inbreakdown of leaf material* — In: Doeksen, J. and van der Drift, J.: Soil Organisms. — Amsterdam: 76–84.

11. Edwards, C. A., Reichle, D. E. & Crossley, D. A. Jr. (1970): *The role of soil invertebrates in turnover of organic matter and nutrients.* – Ecological Studies. Analysis and Synthesis, 1: 148–171.

12. Engelmann, M. D. (1961): *The role of soil arthropods in the energetics of an old field community.* Ecological Monographs, 31: 221–238.

13. Gere, G. (1956): *The examination of the feeding biology and the humificative function of Diplopoda and Isopoda.* – Acta Biol. Hung., 6: 257–271.

14. Gere, G. (1969): *Tanulmányok az erdőtalajok produkciósbiológiájáról.* – Budapest: 1–269 (Manuscript).

15. Gere, G. (1962 *a*): *Ernährungsbiologische Untersuchungen an Diplopoden.* – Acta Zool. Hung., 8: 25–38.

16. Gere, G. (1962 *b*): *Nahrungsverbrauch der Diplopoden und Isopoden in Freilandsuntersuchungen.* – Acta Zool. Humg., 8: 385–415.

17. Gere, G. (1963): *Über einige Faktoren des Streuabbaues.* – In: Doeksen, J. & van der Drift, J. Soil Organisms. Amsterdam: 67–75.

18. Gere, G. & Gyurján, I. (1972): *Ernährungsuntersuchungen detritophager Collembolen mit hilfe 14C-Isotop.* – Ann. Univ. Sci. Budapest, Sect. Biol., 14: 212–218.

19. Gilmore, S. G. & Raffensperger, E. M. (1970): *Food ingested by Tomocerus ssp. in relation to habitat.* – Pedobiologia, 10: 134–144.

20. Hartenstein, R. (1962): *Soil Oribatei. Feeding specificity among forest soil Oribatei (Acarina).* – Ann. Entom. Soc. Amer., 55: 202–206.

21. Isépy, I. (1974): *Avarprodukció és avarlebomlás-vizsgálatok mezofil lomboserdőkben.* – Bot. Közlem. (in press).

22. Kevan, D. K. Mce. (1967): *Soil and humus formation.* – Int. Congr. Soil Sci. Transactions, 2: 1–10.

23. Knight, C. B. and Angel, R. A. (1967): *A preliminary study of the dietary requirements of Tomocerus (Collembola).* – Amer. Midl. Naturalist, 77: 510–517.

24. Kurcheva, G. F. (1971): *Die Rolle der Bodenwirbellosen in der Zersetzung der Grasvegetation.* – In: Organismes du sol et production primaire IV. Coll. Pedobiol., 361–369.

25. Loksa, I. and Zicsi, A. (1972): *A zooedaphon szerepének vizsgálata terepen és modellkísérletekben.* – MTA. Biol. Oszt. Közlem., 15: 45–50.

26. McBrayer, J. F. and Reichle, D. E. (1971:) *Trophic structure and feeding rates of forest soil invertebrate populations.* – Oikos, 22: 381–388.

27. McMillan, J. H. and Healey, I. N. (1971): *A quantitative technique for the analysis of the gut contents of Collembola.* – Rev Ecol. Biol. Sol, 8: 295–300.

28. Naglitsch, F. (1965): *Methodische Untersuchungen über den Einfluss von Bodenarthropoden auf die Humifizierung organischer Substanzen.* – Pedobiologia, 5: 50–64.

29. Perel, T. S., Karpachevsky, L. O. and Yegorova, E. V. (1971): *The role of Tipulidae (Diptera) larvae in decomposition of forest litter-fall.* – Pedobiologia, 11: 66–70.

30. Poole, T. B. (1959): *Studies on the food of Collembola in a Douglas fir plantation.* – Proc. Zool. Soc. London, 132: 71–82.

31. Singh, G. B. (1969): *Preliminary observations on the food preference of certain Collembola (Insecta).* – Red. École. Biol. Sol, 6: 461–467.

32. Striganova, B. R. (1969): *The evaluation of assailability of different leaf litter by millipedes (Diplopoda).* – Zool. Zhurn., 68: 812–826.

33. Striganova, B. R. (1971): *Significance of Diplopoda activity in leaf litter decomposition.* – In: Organismes di sol et droduction primaire. IV. Coll. Pedobiol., 409–415.

34. Szentkirályi, F. (1972): *Collembolák laboratóriumi ökológiai vizsgálatai.* – Budapest; 1–144 (Manuscript).

35. VAN DER DRIFT, J. (1964): *The effects of animal activity in the litter layer.* – in: Hallsworth, E. G. and Crawoford, D. V.: Experimental Pedology. London: 227 – 235.

36. VÉGH, K. (1974): *A Lumbricus polyphemus Fitz. hatása mezofil lomboserdők avarjának lebontására.* – Budadest: 1 – 60. (Manuscript).

37. ZICSI, A., HARGITAI, L. & POBOZSNY, M. (1971): *Über die Auswirkung der Tätigkeit des Regenwurmes Lumbricus polyphemus Fitz. auf die Veränderungen der Humusqualität im Boden.* – In: Organismes du sol et production promaire. IV. Coll. Pedobiol., 398 – 408.