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Original paper

Garden composters as refuges for myriapods: environmental factors shaping species distribution

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Summary. Home composting has become an increasingly popular method for organic waste management; however, the invertebrate communities inhabiting garden compost remain poorly studied. The present study focused on myriapod (centipede and millipede) communities in 61 home composters in the Moravian-Silesian Region, Czech Republic. Heat extraction yielded 82 centipede individuals representing seven species and 36 millipede individuals representing five species. The most abundant species were *Lithobius microps* Meinert, 1868, *Lithobius forficatus* (Linnaeus, 1758), *Polydesmus inconstans* Latzel, 1884, and *Choneiulus palmatus* (Němec, 1895). Canonical correspondence analysis revealed that myriapod distribution was significantly influenced by composter design (where open systems appears better for myriapods), waste composition (particularly animal residues and garden waste), phosphorus content, and waste addition frequency. Generalized additive models identified species-specific responses: *Stenotaenia linearis* (C. L. Koch, 1835) was strongly associated with animal waste (R^2 = 66.2%), while *Geophilus flavus* (De Geer, 1778) and *C. palmatus* preferred compost containing garden waste only. Our results demonstrate that garden composters function as concentration points for myriapod species from surrounding habitats, providing favourable microhabitat conditions and food resources. Despite low overall myriapod abundance (1.5% of all sampled invertebrates), species richness was relatively high, and management practices significantly influenced community composition. The present study highlights the ecological significance of home composters as potential biodiversity refuges in urban habitats, and calls for greater research attention to invertebrate communities in garden compost.

Key words: centipedes, Central Europe, Chilopoda, Diplopoda, home composting, millipedes, organic waste management, synanthropic species, urban biodiversity.

INTRODUCTION

Organic waste management has become a critical environmental and public health concern in modern society (de Sousa Antunes et al. 2022). Composting, which has been practiced for centuries, now ranges from small-scale backyard operations to large-scale automated systems in industrial facilities (Petruccioli et al. 2011). Today, home composting has become increasingly popular, with many households utilizing various types of composters to process organic waste into valuable organic substrates.

The composting process is governed by several key factors: temperature, oxygen availability, moisture content, and the carbon-to-nitrogen (C:N) ratio (Amuah et al. 2022). Temperature is particularly critical, because it directly influences decomposition rates and, at higher values, eliminates pathogenic microorganisms. Optimal moisture content (50–60%) is essential for microbial and chemical processes. Insufficient moisture inhibits biological activity, while excess moisture impairs aeration and limits oxygen availability (Nemet et al. 2021). In addition, the frequency of mechanical turning of composted materials significantly affects the decomposition rate.

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While vermicomposting remains the most widely recognized invertebrate-assisted composting method, alternative approaches exist. Blatticomposting (using cockroaches) and millicomposting (using millipedes) represent emerging biotechnologies for organic waste transformation. Millicomposting, in particular, is an environmentally friendly method that converts plant residues into stable organic matter (Ashwini and Sridhar 2006; Karthigeyan and Alagesan 2011; Sridhar and Ambarish 2013; Revathy and Manohara 2018; de Sousa Antunes et al. 2025; Ribeiro et al. 2024), using millipedes such as *Harpaphe haydeniana* (Wood, 1864), *Xenobolus carnifex* (Fabricius, 1775), *Arthrosphaera magna* Attems, 1936, and or *Trigoniulus corallinus* (Eydoux & Souleyet, 1842).

Home composting is typically conducted using household and garden materials, including garden waste, grass clippings, manure, animal remains, and kitchen waste. The invertebrate fauna in garden composters is largely uncontrolled; while some gardeners introduce earthworms, such as *Eisenia andrei* (Bouché, 1972) and or *Eisenia fetida* (Savigny, 1826), most invertebrates colonize composters naturally from surrounding environments or are introduced with added materials. On the other hand, the specific conditions in the composter (especially higher temperature and high organic matter content) allow non-native or introduced species to survive, which may be associated with the risk of development and potential spread of alien species into the surrounding landscape, especially in today's changing climate (Ødegaard and Tømmerås 2000; Jouquet and Doan 2014).

In Central Europe, only a few pilot studies have addressed the composition of invertebrates in compost substrates (e.g. Rudy and Mock 2016); and our understanding of the species composition and factors influencing invertebrate communities in composters remains poorly documented.

The present study provides information on soil invertebrate communities, with particular attention to myriapod representatives in home composters across a model region. We aimed (1) to document the spectrum of myriapods occurring in composters, (2) to evaluate compost quality in relation to composter design (open vs. closed systems), and (3) to assess the influence of temperature, management practices, and compost composition on myriapod communities.

MATERIAL AND METHODS

Study area and sampling design

The present study was conducted in the Moravian-Silesian Region, Czech Republic, focusing on the town of Jablunkov (lat 49.5727208°, lon 18.7583272°) and surrounding villages (the easternmost territory of the Czech Republic). Participating households were recruited through an informative leaflet campaign, where information was distributed to residents with garden composters. During personal visits in May 2021, compost samples were collected, and owners completed a structured questionnaire regarding composter management practices. The questionnaire recorded: (1) the frequency of biomass addition (number of additions per month), (2) composter type (open vs. closed), and (3) composition of added materials; categorized as garden waste (leaves, weeds, etc.), cut grass, animal remains, and kitchen waste.

Sample collection and processing

Approximately four liters of material from the upper layers (roughly 10 – 20 cm deep) were collected from each composter (n = 61) for invertebrate extraction using Tullgren funnels. Myriapod specimens were identified to the species level and deposited in the collection of the first author. Furthermore, mature compost samples from deeper layers were obtained using a soil probe for chemical analysis. The content of organic carbon (Corg), nitrogen (N), phosphorus (P), potassium (K), and pH of the mature compost samples were analyzed in the laboratory of the Department of Ecology and Environmental Sciences at the Palacký University Olomouc, using standard pedological methods. At each site, ambient air temperature and compost temperature were measured. Compost temperature was recorded as absolute temperature, while the difference between compost and air temperature was calculated as relative temperature.

Data analysis

Statistical analyses were performed using CANOCO for Windows (version 5.0). Species abundance data, corresponding to the number of individuals per species, served as response variables. Environmental predictors included chemical parameters (pH, Corg, N, P, K), waste type presence (garden, animal, kitchen; binary coded: 0 = absent, 1 = present), absolute and relative temperature, frequency of waste addition (number of additions per month), and composter design (0 = open/without lid, 1 = closed/with lid).

Based on gradient length analysis, unimodal methods were deemed appropriate. Canonical correspondence analysis (CCA) was used to assess relationships between species composition and environmental variables. Additionally, generalized additive models (GAM) were fitted to evaluate individual species responses to environmental predictors.

RESULTS

Myriapod community composition

Heat extraction of 61 compost samples yielded 8,073 invertebrates in total, including: 82 centipede individuals representing seven species, and 36 millipede individuals representing five species (Fig. 1). Myriapods were absent in 36 composters; while in the remaining 25 composters, their abundance ranged from 1 to 22 individuals representing 1 to 6 species per composter (Fig. 2).

The most abundant centipede species were *Lithobius microps* Meinert, 1868 (28 individuals) and *Lithobius forficatus* (Linnaeus, 1758) (20 individuals), while *Stenotaenia linearis* (C. L. Koch, 1835) and *Cryptops hortensis* (Donovan, 1810) were the least abundant, with each represented by only two individuals. Among the considerably less abundant millipedes, *Polydesmus inconstans* Latzel, 1884, and *Choneiulus palmatus* (Němec, 1895) were the most common species (16 and 13 individuals, respectively), whereas *Blaniulus guttulatus* (Fabricius, 1798) was only represented by a single individual.

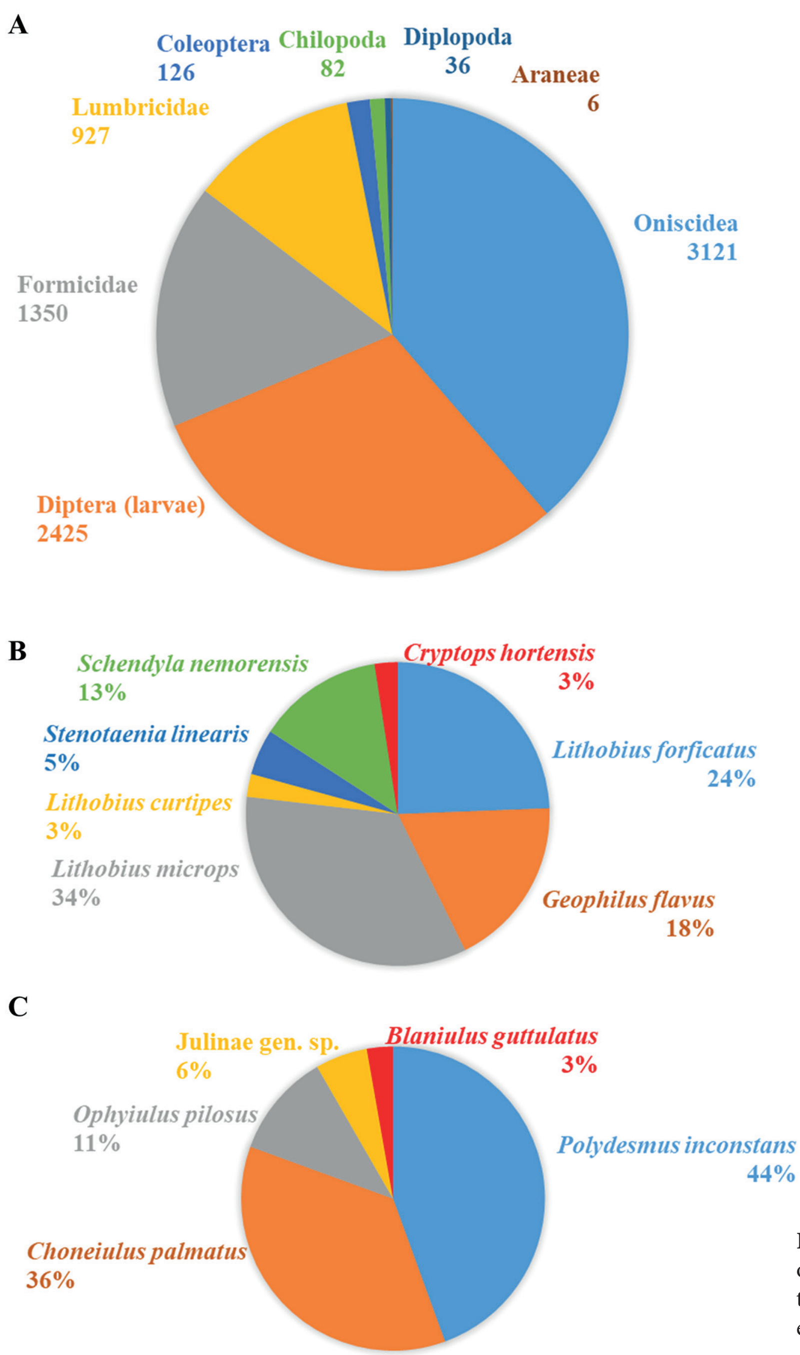

Fig. 1. Composition and numbers of individuals of invertebrate groups (**A**), and species composition of centipedes (**B**) and millipedes (**C**) extracted from 61 compost samples.

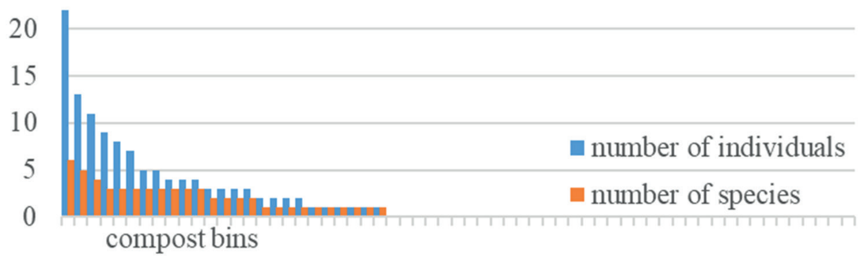

Fig. 2. Histogram of the numbers of individuals and species of myriapods obtained from 61 compost samples. Myriapods were recorded in only 25 composters.

Environmental factors influencing myriapod distribution

Simple term effects analysis revealed that composter lid presence and waste addition frequency were the most important predictors of myriapod abundance, while animal residue content, garden waste, and potassium content showed marginal significance ($p < 0.1$; Table 1).

Canonical correspondence analysis (CCA) revealed a significant relationship between myriapod distribution and environmental variables (pseudo-F = 1.4, $p = 0.026$). However, the model was able to explain only 9.86% of the adjusted variability in species composition. With respect to the multicollinearity among predictors (conditional term effects; Table 2), the most important factors were the presence of a composter lid (3.7% of variability), garden waste content (3.4%), and phosphorus content (3.1%). Animal residue content (6.2%) and waste addition frequency (3.5%) approached statistical significance.

The CCA ordination (Fig. 3) indicated that *S. linearis* and *Geophilus flavus* (De Geer, 1778) were associated with composters containing higher proportions of animal waste. In contrast, *Schendyla nemorensis* (C. L. Koch, 1837), *L. forficatus*, *L. microps*, and the millipede *Ophyiulus pilosus* (Newport, 1842) were associated with phosphorus-rich composts and avoided closed composter bins.

Species-specific responses to environmental variables

Generalized additive models (Fig. 4) identified the response of individual species to specific environmental factors. Animal waste content was the strongest predictor of centipede distribution: *S. linearis* abundance was strongly positively associated with meat residue proportion (R^2 = 66.2%, $F = 49.1$, $p < 0.001$; Fig. 4A), explaining 66% of the variability.

Table 1. Results of simple term effects tests within canonical correspondence analysis (CCA). The values represent the marginal influence of individual environmental variables on community composition. Explains % – proportion of total variability explained by a given variable, pseudo-F – test statistic obtained using the Monte Carlo permutation test, P – level of statistical significance (obtained on the basis of 999 permutations).

Name of environmental variable	Explains %	pseudo-F	P
animal residual	6.2	3.3	0.074
lid presence	3.7	1.9	0.02
addition frequency	3.4	1.8	0.05
garden litter	3.2	1.7	0.076
potassium	3.0	1.6	0.096
cut grass	2.7	1.4	0.134
relative temperature	2.3	1.2	0.232
phosphorus	2.0	1.1	0.4
absolute temperature	1.9	1.0	0.434
nitrogen	1.9	1.0	0.484
carbon organic	1.2	0.6	0.718
pH	1.0	0.5	0.812
kitchen waste	0.8	0.4	0.93

Table 2. Results of conditional term effects tests for environmental variables in CCA analysis. Variables are ranked according to the results of the forward selection procedure. Explains % – proportion of additional variability explained by the variable after taking into account the influence of all the above factors, pseudo-F – test statistic for a given selection step, P – level of statistical significance based on the Monte Carlo permutation test (999 permutations).

Name of environmental variable	Explains %	pseudo-F	P
animal residual	6.2	3.3	0.056
lid presence	3.7	2.1	0.018
addition frequency	3.5	2.0	0.06
garden litter	3.4	1.9	0.034
potassium	2.6	1.5	0.11
phosphorus	3.1	1.9	0.03
cut grass	1.8	1.1	0.352
kitchen waste	2.4	1.4	0.21
relative temperature	1.4	0.9	0.55
absolute temperature	2.0	1.2	0.254
nitrogen	1.3	0.8	0.65
carbon organic	1.6	1.0	0.452
pH	0.6	0.3	0.98

Conversely, composters receiving only garden waste supported higher abundances of *G. flavus* ($R^2 = 22.0\%$, $F = 7.1$, $p = 0.0019$), *C. palmatus* ($R^2 = 17.2\%$, $F = 5.2$, $p = 0.0088$), and *Lithobius curtipes* C. L. Koch, 1847 ($R^2 = 13.3\%$, $F = 3.8$, $p = 0.0281$; Fig. 4B). *Cryptops hortensis* showed the opposite pattern, preferring composters with low garden waste content ($R^2 = 22.8\%$, $F = 7.4$, $p = 0.0015$).

Waste addition frequency influenced millipede and centipede distributions. *Polydesmus inconstans* ($R^2 = 14.5\%$, $F = 4.2$, $p = 0.0198$) and *L. curtipes* ($R^2 = 19.6\%$, $F = 6.1$, $p = 0.0043$) were more abundant in composters replenished on an approximately daily basis (Fig. 4C). High potassium levels negatively affected *L. microps* ($R^2 = 21.9\%$, $F = 7.0$, $p = 0.0021$) and *S. nemorensis* ($R^2 = 15.1\%$, $F = 4.4$, $p = 0.0169$; Fig. 4D).

DISCUSSION

The occurrence of myriapods in composters has not been a common focus of current research. Compared to other invertebrate groups, their presence in domestic compost is rather sporadic, which is reflected in their low overall abundance in our samples, where myriapods accounted for only 1.5% of all invertebrates extracted (Fig. 1). Despite this low number of individuals, species richness was relatively high. Individual composters harbored between zero and six myriapod species, which is very similar to the numbers

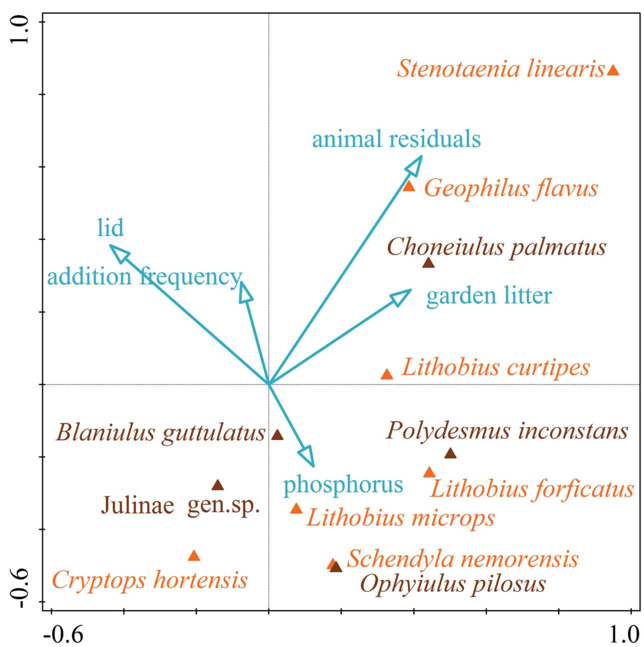

Fig. 3. Canonical correspondence analysis of the distribution of centipedes (orange) and millipedes (brown) in garden composters depending on the composition of the compost and the parameters of the composter. Only environmental factors that significantly contribute to the model's predictive power are shown.

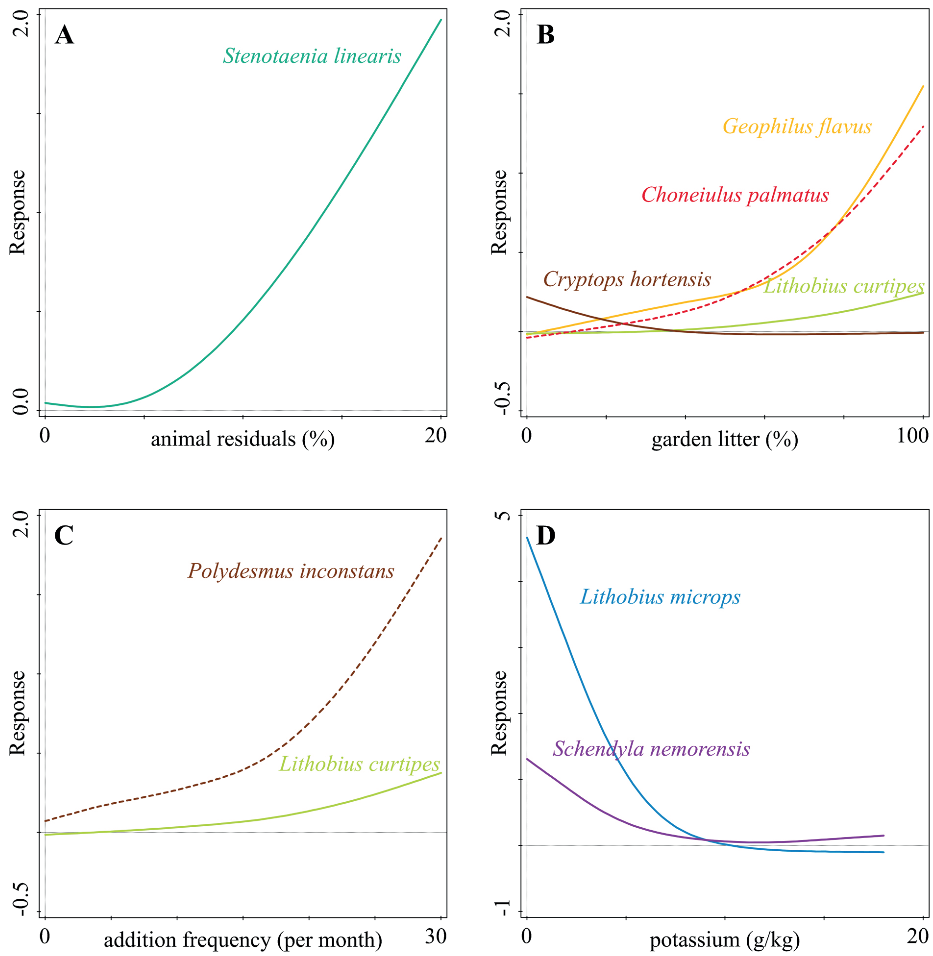

Fig. 4. Generalized additive models predicting the abundance of individual species of centipedes (solid lines) and millipedes (dashed lines) using (**A**) the content of animal residuals in compost, (**B**) the proportion of garden litter in compost, (**C**) frequency of adding composted material to compost (times per month), and (**D**) amount of potassium. Only variables that significantly predict the distribution of myriapods are shown and only species with significant responses are illustrated.

recorded in Finnish compost heaps by Rantala (1985), where one to five myriapod species were found. In that study, the author demonstrated that piles of decaying compost can serve as hibernation sites, as winter temperatures inside compost heaps remained substantially higher than the surrounding air temperature. A similar number of species and relatively high diversity (7 millipedes belonging to 6 species) were also recorded by Rudy and Mock (2016) in Slovak composters.

It is noteworthy that the most abundant centipede species in composters evaluated in the present study are the same as those predominantly found in Finnish compost heaps, which were represented by the synanthropic *L. microps* and the eurytopic *L. forficatus*. Likewise, *C. palmatus*, one of the three millipede species reported by Rantala (1985), was also among the most frequent millipede species observed in our samples.

The presence of millipedes in decomposing organic matter is not surprising, as they represent a key group of macro-detritivores (David and Handa 2010). This property can be exploited for active sampling. Ožanová (2001) tested through the use of grass traps for millipede sampling, consisting of a small heap of cut, decaying grass, which can be considered to be comparable or similar to the contents of compost bins. Several days of trap exposure yielded 2–6 millipede species, while a six-week exposure substantially increased both the number of individuals and species. The species *O. pilosus*, which was also recorded in composter samples from the present study, was dominant in these grass traps as well.

A similar principle is used in hay-bait traps tested in fields, meadows, and forests (Tuf et al. 2015). These traps consist of a mesh bag filled with hay which is buried in the soil for 8–10 weeks. The decomposing plant biomass is gradually colonized by numerous species of millipedes and centipedes. Using hay-bait traps in the study area, 14 millipede species and 11 centipede species were recorded. Interestingly, the dominant species caught in these traps largely overlapped with those found in composters. The millipedes *B. guttulatus* and *P. inconstans* were very abundant in traps installed in a meadow, whereas *O. pilosus* dominated in traps set in an alfalfa field. These habitats are structurally similar to the gardens of family houses, where the composters in our study were located. Hay-bait traps on the meadow also contained high numbers of the centipedes *G. flavus*, *S. nemorensis*, and especially *L. microps* (Tuf et al. 2015). In this respect, composters can also be considered as artificial traps, i.e. similar to those used, with various modifications, to specifically capture myriapod arthropods.

Taken together, these findings suggest that the recorded species actively seek out local accumulations of organic matter, where they encounter both a rich food supply and relatively stable microclimatic conditions. In composters, Diptera larvae (Fig. 1) developing on meat and skin residues may represent an important food resource for predatory centipedes.

The species composition in composters largely reflects the composition of assemblages of local fauna, and composters may serve as refuges offering favorable microhabitat conditions, particularly during periods of environmental stress (Rantala 1985). Composters can also provide suitable conditions for non-native and introduced species and poses a risk associated with the spread of invasive species into surrounding habitats (Ødegaard and Tømmerås 2000) or, conversely, composting can help address the issue of already widespread alien species (Jouquet and Doan 2014). The composition of the total catch clearly shows that terrestrial isopods dominated in the composters, including a number of highly synanthropic species. Terrestrial isopods, like millipedes, are macrodecomposers, but they have a much higher tendency toward aggregative behavior (Ďurajková et al. 2022; Martinka and Tuf 2025). The same pattern, consisting of a much higher representation of isopods compared to millipedes, was also observed by Rudy and Mock (2016) in Slovakia. The relatively low abundance of myriapods and other invertebrates is apparently associated with specific conditions in the composted material, where only certain zones with favorable humidity and acceptable temperature conditions supports the activity of these invertebrates. Our observations agree in basic parameters with earlier findings (Rantala 1985). However, clarification of these relationships and the distribution of invertebrates in the entire profile of composted materials will require further investigations.

Despite the relatively low abundance of myriapods in composters, their consistent presence and the influence of specific management practices (e.g., waste composition, addition frequency, composter design) on species distribution highlight the ecological significance of these anthropogenic structures. Given the increasing popularity of home composting and the potential role of composters in supporting local biodiversity, this topic deserves greater research attention. Future studies should investigate the seasonal dynamics of myriapod communities in composters, their functional role in decomposition processes, and the potential of composters as biodiversity hotspots in urbanized landscapes.

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REFERENCES

Amuah EEY, Fei-Baffoe B, Sackey LNA, Douti NB, Kazapoe RW. 2022. A review of the principles of composting: Understanding the processes, methods, merits, and demerits. Organic Agriculture. 12:547–562. https://doi.org/10.1007/s13165-022-00408-z.

Ashwini KM, Sridhar KR. 2006. Evalution of pill millipede (*Arthrosphaera magna*) compost on plant growth and dry matter yield. Electronic Journal of Environmental, Agricultural and Food Chemistry. 5:1323–1329.

David J-F, Handa IT. 2010. The ecology of saprophagous macroarthropods (millipedes, woodlice) in the context of global change. Biological Reviews. 85:881–895. https://doi.org/10.1111/j.1469-185X.2010.00138.x.

de Sousa Antunes LF, de Sousa Vaz AF, da Costa Rodrigues dos Santos G, dos Santos Ferreira TS, Rodrigues dos Santos R, dos Santos Alves R, Carvalho de Almeida J, de Almeida Leal MA, Fernandes Correia ME. 2025. Replacing commercial substrate with millicompost: A sustainable approach using different green wastes combined with millicompost for bell pepper seedling. Production in Urban Agriculture. 10:43129–43140. https://doi.org/10.1021/acsomega.5c06388.

de Sousa Antunes LF, Fernandes LS, de Sousa Vaz AF, de Andrade da Silva MSR, dos Santos Ferreira TS, dos Santos DMT, Correia MEF. 2022. Millicomposting: Sustainable technique for obtaining organic compost for the cultivation of broccoli seedlings. Cleaner Engineering and Technology. 7:100442. https://doi.org/10.1016/j.clet.2022.100442.

Ďurajková B, Hladký R, Tuf IH. 2022. Higher temperature and substrate vibrations as stress factor for terrestrial isopods – model species matter. ZooKeys. 1101:71–85. https://doi.org/10.3897/zookeys.1101.77549.

Jouquet P, Doan T. 2014. Vermicompost reduces the invasiveness of the earthworm species *Dichogaster bolaui* compared to the use of compost in a degraded tropical soil in Northern Vietnam. European Journal of Soil Biology. 64:46–52. https://doi.org/10.1016/j.ejsobi.2014.08.003.

Karthigeyan M, Alagesan P. 2011. Millipede composting: A novel method for organic waste recycling. Recent Research in Science and Technology. 3:62–67.

Martinka M, Tuf IH. 2025. The relationship between abundance and actual spatial distribution of terrestrial isopods (Oniscidea). Diversity.

17:790. http://doi.org/10.3390/d17110790.
Nemet F, Perić K, Lončarić Z. 2021. Microbiological activities in the composting process. Columella – Journal of Agricultural and Environmental Sciences. 8:41–53. https://doi.org/10.18380/SZIE.COLUM.2021.8.2.41.
Ødegaard F, Tømmerås BA. 2000. Compost heaps — refuges and stepping-stones for alien arthropod species in northern Europe. Diversity and Distributions. 6:45–59. https://doi.org/10.1046/j.1472-4642.2000.00071.x.
Ožanová J. 2001. Utilization of grass traps for the study of millipedes. Myriapodologica Czecho – Slovaca. 1:69–71. (in Czech with English abstract)
Petruccioli M, Raviv M, Di Silvestro R, Dinelli G. 2011. 6.42 - Agriculture and agro-industrial wastes, byproducts, and wastewaters: Origin, characteristics, and potential in bio-based-compounds production. In: Moo-Young M, editor. Comprehensive Biotechnology (Second Edition). Academic Press, Burlington. p. 531–545. https://doi.org/10.1016/B978-0-08-088504-9.00389-5.
Rantala M. 1985. Hibernating Myriapoda in compost in Tampere (Finland) (Diplopoda; Chilopoda; Symphyla). Contributions to Zoology. 55:171–176.
Revathy S, Manoharam J. 2018. New wonderful method of recycling vermmilli composting. A study. International Journal of Management, Technology and Engineering. 8:828–833.
Ribeiro SA, de Sousa Antunes LF, de Almeida Cardoso E, dos Santos Souza W, Carneiro dos Santos Pires MJF, Correia MEF. 2024. Evaluation of the consumption of agricultural and urban waste by the diplopod *Trigoniulus corallinus* as a strategy for formulating new combinations for the millicomposting process. Environmental Science and Pollution Research International. 31:25500–25507. https://doi.org/10.1007/s11356-024-32778-0.
Rudy J, Mock A. 2016. Makrosaprofágy (Oniscidea, Diplopoda) ako súčasť fauny kom postovísk. In: Krumpálová Z, Zigová M, Tulis F, editors. Proceedings of the scientific congress „Zoológia 2016“, Nitra (Slovakia). Constantine the Philosopher University, Nitra, 184–186. (in Slovak with English abstract)
Sridhar KR, Ambarish CN. 2013. Pill millipede compost: a viable alternative to utilize urban organic solid waste. Current Science. 104:1543–1547.
Tuf IH, Chmelík V, Dobroruka I, Hábová L, Hudcová P, Šipoš J, Stašiov S. 2015. Hay-bait traps are a useful tool for sampling of soil dwelling millipedes and centipedes. ZooKeys. 510:197–207. https://doi.org/10.3897/zookeys.510.9020.