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Effects of cypermethrin on the taxonomic diversity of soil and litter invertebrates in the agrocoenoses of Lithuania

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We assessed the degree to which cypermethrin impacts the taxonomic diversity of non-target groups of soil and litter invertebrates in the agrocoenoses of Kėdainiai District, Lithuania. The studies were conducted in three agrosystems, two of which have been farmed conventionally, with the use of insecticides (cypermethrin), and one where no chemical means had been applied. It was the first time that a modern graphic analysis was conducted for the distribution of the invertebrates depending on their average body length and their total abundance in an agrocoenosis. By number of species and their abundance, the most diverse group in all the examined agrocoenoses was Coleoptera, with a significant dominance of Carabidae. The dominant species of invertebrates in the studied agrocoenoses were *Nebria rufescens*, *Loricera pilicornis*, *Metallina lampros*, *Poecilus cupreus*, *P. versicolor*, *Pterostichus melanarius*, *Amara aenea*, *A. communis*, *A. convexiuscula*, *Calathus ambiguous*, *C. fuscipes*, *Anchomenus dorsalis*, *Harpalus griseus*, *H. rufipes*, *H. distinguendus*, *Coccinella septempunctata*, *Lasius niger*, and *Pardosa lugubris*. The conventionally farmed agrocoenoses of rapeseed and wheat were characterized by impoverished taxonomic compositions, with prevalence of several eudominant and dominant species (*Pterostichus melanarius*, *Poecilus versicolor*, and *Calathus fuscipes*). The size structure was significantly uneven. Most of the species recorded in these plots were zoophages, represented by flying and non-flying forms. In the ecologically farmed wheat agrocoenosis, which had not been treated with insecticides, we observed a relative eveness in the size structure, absence of eudominant species, and increase in the taxonomic diversity due to the distribution of non-target groups of arthropods that are more sensitive to cypermethrin (Porcellionidae, Lithobiidae, Tetrigidae, Acrididae, Coreidae, Lygaeidae, Cydnidae, Pentatomidae, Scarabaeidae, Elateridae, Chrysomelidae, Curculionidae, and Thomisidae). The percentages of zoophages declined, while the shares of phytophages and polyphages that are able to fly increased.

Keywords: taxonomic diversity; non-target species of soil and litter invertebrates; pyrethroids; cypermethrin; sensitivity to insecticide; dominance structure; size structure; Shannon's diversity index; Pielou's eveness index.

Introduction

The intensification of the agriculture, especially utilization of insecticides, considerably impacts the terrestrial ecosystems, reducing their biological diversity. Although combating arthropod pests is necessary for ensuring high yields and the quality of plant products, chemical methods of plant protection decrease not only the populations of pests but also those of beneficial invertebrates. For example, Hymenoptera, predatory Coleoptera, and parasitoids perform important functions in pollination and pest control (Komlyk & Brygadyrenko, 2019; Puchkov et al., 2020). Therefore, the main goal of modern agricultural farming is finding a balance between the ways of increasing yields and preserving biodiversity. Modern eco-friendly systems of plant protection must include effective ecologically safe chemical compounds, the search for which is ongoing (Gunstone et al., 2021; Sánchez-Bayo, 2021).

Of the existing insecticides, many groups do not comply with the mentioned requirements. For example, organochlorine, organophosphorus, and carbamate insecticides are able to accumulate in environmental objects and are toxic to vertebrates and people. Furthermore, many populations of pests have become resistant to those chemical compounds (Le Goff & Giraudo, 2019). Some of the most popular and economically efficient insecticides are pyrethroids, which are considered to have a number of advantages, such as the absence of systemic action, high biological activity even at minimal application norms per unit area, low solubility in water, notable sorption capacities that decrease their bioavailability in the environment, relative photolability, and low toxicity to warm-blooded animals (Ruberti, 2024). However, the absence of a selective action and powerful insecticide activity towards non-target species of invertebrates are significant side-effects of pyrethroid insecticides, including cypermethrin (Serrão et al., 2022). According to the ecological assessment of impacts of pesticides on non-target arthropods (using the PRIMET model), cypermethrin was found to be the second most dangerous after imidacloprid among the 39 examined compounds (Kenko et al., 2022). In this context, a poorly researched aspect is the impact of pyrethroids in relation to many groups of soil and litter invertebrates, first of all, discretely living predators (Shaw et al., 2006; Desneux et al., 2007).

By diversity and abundance, the dominating epigean arthropods living in agricultural lands in Northern, Eastern, and Western Europe are coleopterans of the families Carabidae and Staphylinidae, as noted on the examples of Austria (Kromp, 1989), Norway (Andersen & Eltun, 2000), Lithuania (Tamutis et al., 2004), and Ukraine (Brygadyrenko, & Reshetniak, 2014; Putchkov et al., 2020). Other common beetles on the soil surface are representatives of the families Silphidae, Elateridae, Cantharidae, Scarabaeidae, Histeridae, Cocccinelidae, Chrysomelidae, Curculionidae, and others (Letschert, 1986; Pileckis & Monsevičius, 1995, 1997; Tamutis, 1999; Tamutis et al., 2007). The dominant groups of epigean spiders are Linyphiidae and Lycosidae (Pullen et al., 1992; Feber et al., 1998).

Ecological-faunistic research on soil and litter invertebrates in agrocoenoses of Lithuania is scarce. The main studies on the complexes of epigean coleopterans in agrolandscapes of the country were conducted by Professor V. Tamutis, who carried out in-detail research of the Coleoptera complexes in fields of rapeseed and barley (Tamutis, 1999; Tamutis et al., 2007). Other agrocoenoses were only analyzed in the aspect of several families – ground beetles and staphylinids (Tamutis 2002a, 2002b; Tamutis et al., 2004). In Kaunas District, Lithuania, ground beetles dominate in many types of agroecosystems of wheat, barley, and rapeseed. The commonest species are those of the genus *Pterostichus* (Tamutis, 2002a). In the fields of conventionally and ecologically farmed winter wheat in central Lithuania, the species diversity of ground beetles and staphylinids insignificantly varied, with the diversity of coleopterans greater in the fields where no insecticides had been used (Tamutis et al., 2004). A comparative analysis of the taxonomic diversity of the epigean coleopterans in agrocoenoses of spring barley with different practices revealed significant differences. The diversity of Coleoptera was higher in the barley fields that had not been treated with insecticides. A positive effect of ecological farming was especially notable on staphylinids and some ground beetles (*Carabus cancellatus* Illiger, 1798). The eudominants *Poecilus cupreus* (Linnaeus, 1758), *Pterostichus melanarius* (Illiger, 1798), and *Harpalus rufipes* (De Geer, 1774) were found in all the plots (Tamutis et al., 2007). The staphylinids in the agrocoenoses of grasses were formed by saprobiont and geobiont species. The dominant species included the eurytopic species *Philonthus rotundicollis* (Ménétriés, 1832), *Ph. varians* (Paykull, 1789), *Ph. cognatus* Stephens, 1832, *Gyrohypnus scoticus* (Joy, 1913), *Lathrobium geminum* Kraatz, 1857, *Anotylus rugosus* (Fabricius, 1775), *Tachyporus hypnorum* (Fabricius, 1775), *T. chrysomelinus* (Linnaeus, 1758), and *Tachinus rufipes* (Linnaeus, 1758) (Tamutis, 2002b). Different regimes of soil treatment and schemes of crop rotation were also found to affect the taxonomic diversity of ground beetles living in fields of winter wheat in Latvia. The dominants were observed to be *Loricera pilicornis* (Fabricius, 1775), *Bembidion guttula* (Fabricius, 1792), *B. obtusum* Audinet-Serville, 1821, *Poecilus cupreus*, *Harpalus rufipes*, *Pterostichus melanarius*, *P. niger* (Schaller, 1783), and *Amara plebeja* (Gyllenhal, 1810) (Gailis & Turka, 2014; Gailis et al., 2017). Extensive application of pyrethroids in the farm agrocoenoses of Lithuania and a number of other European countrшes necessitates the assessment of potential side-effects of these insecticides. The objective of our study was to evaluate the degree of impact of cypermethrin on the taxonomic diversity of non-target groups of soil and litter invertebrates.

Material and methods

Brief characteristic of the area of the studies. The climate of Lithuania is moderately mild, transitioning from a maritime climate along the coast to a continental climate in the east. The area of the studies is located in the central part of the country. The average temperatures are 2.1 °C in January and +18.1 °C in July. The current tendency is warming and growth of maximal temperatures (Jaagus et al., 2014). The amount of precipitations over the year varies 645 to 670 mm. The vegetation period lasts 169 to 202 days. The amount of precipitation falling in Kėdainiai District over the period of the study – according to the Lithuanian Hydrometeorological Service (2023) – was 5–15 mm in May, 25–50 mm in June, 40–160 mm in July, and 80–120 mm in August (https://beta.meteo.lt/?pid=archivas).

The relief of Lithuania is characterized by an alternation of lowland plains and highlands. Traces of old glaciations are observed. Most of Kėdainiai District is situated in the lowland of the Nevėžis, bordering with the Žemaitija Plateau (the height above sea level ranges 21 to 113 m). Four percent of Kėdainiai District comprises internal water (the largest river is Nevėžis). Among others, typical soil-forming materials in the country are Quaternary deposits (the average thickness is 80–120 m). As a result of natural exogenous processes of soil formation, different groups of soil of different age and origin have developed: glacial, glacial-river, glacial-lake, alluvial, and organic-peaty. The soil-forming material and upper soil layers in the central part of Lithuania are carbon-saturated and poorly alkalized (Calcaric Cambisols, Calcaric Luvisols, and Gleyic Luvisols dominate, more rarely Eutric Gleysols) (Buivydaite, 2005; Pustelnikovas et al., 2007). The physical-geographic characteristic of the test plots is presented in Table 1.

Unstable agricultural methods have led to soil degradation in Europe (up to 70%). In Lihuania, soil degradation is mostly caused by acidification, erosion, and contamination with various chemical compounds of technogenic origin (Kochian et al., 2015; Baude et al., 2019; Mockeviciene et al., 2024). In central districts of the country, eroded soils occupy up to 7% of the areas. The average concentrations of heavy metals in the upper soil horizons in Lithuania vary depending on the soil type. Loamy and clayey soils are characterized by high parameters compared with sandy soils (Eidukevičienė & Vasiliauskienė, 2001; Slepetiene et al., 2020).

Kėdainiai District is an economically developed region of the country. The most developed spheres are the chemical and food industries and agriculture. The main sources of soil contamination in the study area are potentially the industrial enterprises, oil terminals, located there, and also transport (Miceikienė et al., 2019). The largest industrial objects include AB Lifosa (production of mineral fertilizers, sulfuric and phosphate acids), AB Nordic Sugar Kėdainiai (production of sugar), UAB Vesiga (sauces and mayonnaises), UAB Vikeda (ice creams), UAB Kėdainių konservų fabrikas (canned vegetables), UAB Kėdainių duona (baked goods), AB Kėdainių grūdai (grain-based mixed feeds for cattle, fodders), UAB Krekenavos agrofirma (meat products), UAB Progresas (metal constructions), UAB Medžio plokštė (wood-processing operations), UAB JGB (furniture), UAB Natūrali oda (leather goods), large oil terminal UAB Lukoil Baltija, and other. The territory of Kėdainiai District is crossed by a railroad Vilnus-Šiauliai (Staniuliene & Dickute, 2017).

Over 65% of the municipality's area is comprised of agricultural lands, including 93% arable land, 5% pastures, and 1% gardens. Over 65% of the yields from agricultural crops comes from grain crops (wheat), over 10% from perennial herbs, 6% from beet, and 3% from potatoes. Another developed sphere in Kėdainiai District is growing vegetables (Atkoceviciene et al., 2011; Jarasiunas, 2016).

Field studies. The field studies were conducted on the territory of private farms located in Kėdainiai District of Lithuania. For the studies, we selected three model plots, each accounting for the area of 5,000 m^2. The first and the second plots in the fields of winter rapeseed and winter wheat, respectively, had been treated with cypermethrin (Cyperkill 500 EC in the concentration for fields recommended by manufacturer, which is 0.05 L/ha). The third plot was in the territory of an ecologically farmed (no insecticide treatment) agrocoenosis of spring wheat. In each of the three test plots, for the period from May to August (70 days) of 2023, 40 Barber pitfall traps were installed, containing 20% solution of NaCl. The invertebrates were extracted each 10–15 days (depending on the weather conditions). Then, the material was rinsed, dried, and distributed on cotton padding for further identification. The general agrochemical analysis of the soil samples collected at the test plots was performed at the Agrochemical Scientific Research Laboratory of the Institute of Agriculture of the Lithuanian Research Centre for Agriculture and Forestry in Kaunas (Table 2).

Analysis of the data. The levels of domination of arthropods were classified according to the Engelmann's scale (1978), which takes into account the share (%) of the species in the total number of the invertebrates (eudominants accounting for 40.0-100.0%, dominants for 12.5–39.9%; subdominants for 4.0–12.4%; recendents for 1.3–3.9%; and subrecendents for less than 1.3 %). The statistical analysis of the results was performed through a set of Statistica 8.0 (StatSoft Inc., USA).

Table 1
Physical-geographic characteristic of the test plots (Kėdainiai District, Lithuania)

Plot	Coordinates	Type of soils	Granulometric composition
Rapeseed field with pesticide treatment	55º 23' 26.8'' N, 24º 03' 18.5'' E	clays (Gleysols), podzols (Albeluvisols)	sandy and light loamy sand
Wheat field with pesticide treatment	55º 23' 24.8'' N, 24º 01' 58.2'' E	reddish-brown (Cambisols)	loamy sand and light loam
Wheat field without pesticide treatment	55º 23' 29.7'' N, 24º 01' 51.6'' E	illuviated soils (Luvisols)	Loamy sand

Note: the data are retrieved from the Lithuanian portal of geospatial data geoportal.lt.

Table 2
General agrochemical analysis of the soil samples (Kėdainiai District, Lithuania)

Concentration of elements and compounds	Rapeseed field with pesticide treatment	Wheat field with pesticide treatment	Wheat field without pesticide treatment
Cd, mg/kg	0.046	0.041	0.045
Pb, mg/kg	7.60	7.20	5.60
Cr, mg/kg	15.7	15.8	11.6
Ni, mg/kg	9.63	10.20	7.43
Cu, mg/kg	8.07	8.53	7.27
Zn, mg/kg	23.0	29.5	24.0
Mn, mg/kg	141	333	241
Fe, mg/kg	11451	12697	9724
Hg, mg/kg	0.090	0.078	0.066
pH in the suspension of KCl	7.1	7.2	7.1
Concentration of mobile phosphorus (P_2O_5), mg/kg	132	268	193
Concentration of mobile potassium (K_2O), mg/kg	276	266	340
C org, %	1.50	1.00	0.91
Ca, mg/kg	3476	11472	11642
Mg, mg/kg	776	2036	4112
N, total, %	0.218	0.147	0.137
Concentration of nitrogen (sum of nitrates + sum of nitrites)	7.80	57.56	6.32
Concentration of nitrogen (ammonia), mg/kg	3.12	3.83	3.93
Concentration of mineral nitrogen, mg/kg	10.92	61.39	10.25

Results

As a result of account of non-target soil and litter arthropods in the three agrocoenoses of Lithuania (Kėdainiai District), 109 species of invertebrates were found, belonging to 5 classes, 11 orders, and 37 families. The number of arthropods in the examined plots significantly varied, which first of all was due to the species composition, specificity of the microclimatic conditions of habitat, and sensitivity to cypermethrin (Table 3). By numbers of species and their abundance, insects (Insecta) dominated in the taxonomic structure of the communities of invertebrates in all the examined agrocoenoses. Especially notable was the diversity of Coleoptera. This order was represented by 16 families, including Carabidae, which were eudominants in all the test plots in the fields.

Table 3
Results of the account of litter invertebrates in the pitfall traps in three agrocoenoses of Lithuania

Species	Rapeseed field with pesticide treatment						Wheat field with pesticide treatment						Wheat field without pesticide treatment					
	25.05 – 08.06	09.06 – 20.06	21.06 – 06.07	07.07 – 23.07	24.07 – 04.08	Sum	25.05 – 08.06	09.06 – 20.06	21.06 – 06.07	07.07 – 23.07	24.07 – 04.08	Sum	25.05 – 08.06	09.06 – 20.06	21.06 – 06.07	07.07 – 23.07	24.07 – 04.08	Sum
Porcellio laevis Latreille, 1804	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
Porcellio scaber Latreille, 1804	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	2
Lithobius forficatus (Linnaeus, 1758)	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	2
Cylindroiulus truncorum (Silvestri, 1896)	0	0	0	0	0	0	10	1	0	0	0	11	0	1	0	0	0	1
Forficula auricularia Linnaeus, 1758	0	0	0	0	0	0	0	3	0	0	2	5	0	0	0	1	0	1
Tetrix tenuicornis (Sahlberg, 1893)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	2
Chorthippus sp.	0	0	0	0	0	0	0	0	0	3	11	14	0	0	17	16	85	118
Evacanthus sp.	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0
Coreus marginatus (Linnaeus, 1758)	0	0	0	0	0	0	0	1	0	0	0	1	0	0	6	2	12	20
Rhyparochromus phoeniceus (Rossi, 1794)	0	0	0	0	0	0	0	1	0	0	0	1	2	0	0	4	1	7
Canthophorus sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	2
Tritomegas sp.	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0
Aelia acuminata Linnaeus, 1758	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	1	1
Dolycoris baccarum (Linnaeus, 1758)	0	1	0	0	0	1	0	0	0	0	0	0	0	0	1	0	1	2
Eurygaster integriceps Puton, 1881	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
Nebria rufescens (Stroem, 1768)	0	2	6	3	0	11	13	12	13	0	0	38	3	6	4	0	0	13
Nebria brevicollis (Fabricius, 1792)	0	15	2	1	0	18	2	5	8	0	0	15	0	1	1	0	0	2
Notiophilus palustris (Duftschmid, 1812)	1	0	0	0	0	1	3	3	2	0	0	8	0	0	0	0	3	3
Calosoma auropunctatum (Herbst, 1784)	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Carabus granulatus Linnaeus, 1758	0	3	0	2	0	5	4	4	0	0	1	9	4	0	0	0	0	4
Carabus hortensis Linnaeus, 1758	0	1	0	0	0	1	0	0	0	0	0	0	1	0	1	0	0	2
Carabus nemoralis O. F. Müller, 1764	1	0	0	0	0	1	1	7	2	0	1	11	1	2	0	0	0	3
Loricera pilicornis (Fabricius, 1775)	21	52	16	0	1	90	2	2	1	0	0	5	1	3	2	0	1	7
Clivina fossor (Linnaeus, 1758)	15	0	0	0	0	15	3	1	0	0	0	4	5	6	1	0	3	15
Trechus quadristriatus (Schranck, 1781)	0	0	0	0	0	0	0	1	1	0	0	2	0	0	0	0	0	0
Metallina lampros (Herbst, 1784)	28	0	3	0	0	31	17	12	0	0	0	29	99	9	14	15	11	148
Poecilus cupreus (Linnaeus, 1758)	4	51	4	1	0	60	11	14	3	2	5	35	6	0	0	1	5	12
Poecilus versicolor (Sturm, 1824)	31	239	74	49	0	393	16	19	16	11	3	65	52	0	5	3	19	79
Pterostichus melanarius (Illiger, 1798)	32	133	41	197	378	781	14	11	415	472	1156	2068	7	9	3	0	9	28
Pterostichus niger (Schaller, 1783)	0	3	0	0	2	5	0	0	0	1	0	1	0	0	0	0	1	1
Amara aenea (De Geer, 1774)	3	0	0	0	0	3	1	2	0	0	0	3	10	12	0	38	4	64
Amara communis (Panzer, 1797)	2	1	21	1	4	29	5	1	3	0	3	12	10	0	4	25	16	55

Species	Rapeseed field with pesticide treatment						Wheat field with pesticide treatment						Wheat field without pesticide treatment					
	25.05 – 08.06	09.06 – 20.06	21.06 – 06.07	07.07 – 23.07	24.07 – 04.08	Sum	25.05 – 08.06	09.06 – 20.06	21.06 – 06.07	07.07 – 23.07	24.07 – 04.08	Sum	25.05 – 08.06	09.06 – 20.06	21.06 – 06.07	07.07 – 23.07	24.07 – 04.08	Sum
Amara convexiuscula (Marsham, 1802)	0	5	0	20	72	97	0	1	0	0	0	1	1	1	0	0	3	5
Amara eurynota (Panzer, 1796)	0	1	0	0	0	1	0	1	0	0	0	1	0	0	0	0	0	0
Amara similata (Gyllenhal, 1810)	1	3	3	1	1	9	3	5	2	0	1	11	3	2	3	12	3	23
Calathus ambiguus (Paykull, 1790)	0	0	2	0	8	10	0	3	15	9	65	92	1	2	3	1	10	17
Calathus erratus (C. R. Sahlberg, 1827)	0	0	0	0	0	0	0	0	2	0	37	39	0	0	0	0	1	1
Calathus fuscipes (Goeze, 1777)	4	0	0	0	322	326	0	0	34	43	234	311	5	4	37	5	54	105
Calathus melanocephalus (Linnaeus, 1758)	0	0	0	0	0	0	0	0	0	0	25	25	0	0	0	0	2	2
Dolichus halensis (Schaller, 1783)	0	0	0	0	3	3	0	0	0	0	4	4	0	0	0	1	9	10
Anchomenus dorsalis (Pontoppidan, 1763)	18	3	11	0	0	32	7	4	0	1	0	12	1	4	2	1	0	8
Agonum sexpunctatum (Linnaeus, 1758)	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	1	0	1
Harpalus calceatus (Duftschmid, 1812)	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1
Harpalus griseus (Panzer, 1796)	2	9	20	26	39	96	3	7	7	5	41	63	22	3	19	5	214	263
Harpalus rufipes (De Geer, 1774)	5	8	6	11	44	74	1	2	11	16	23	53	7	6	11	10	32	66
Harpalus affinis (Schrank, 1781)	0	0	0	1	0	1	0	6	0	0	1	7	3	3	3	21	3	33
Harpalus distinguendus (Duftschmid, 1812)	5	5	0	4	0	14	8	23	11	12	5	59	30	22	24	35	14	125
Harpalus smaragdinus (Duftschmid, 1812)	0	0	0	0	0	0	0	4	1	0	0	5	1	2	2	4	2	11
Harpalus tardus (Panzer, 1796)	1	1	0	0	0	2	1	1	1	0	0	3	1	1	0	3	1	6
Sphaeridium scarabaeoides (Linnaeus, 1758)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hister unicolor Linnaeus, 1758	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1
Margarinotus ventralis (Marseul, 1854)	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Thanatophilus sinuatus (Fabricius, 1775)	0	0	0	0	0	0	0	0	0	1	4	5	0	0	0	0	2	2
Silpha obscura Linnaeus, 1758	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Silpha tristis Illiger, 1798	0	0	0	0	0	0	1	2	0	0	0	3	0	2	0	0	0	2
Nicrophorus vespillo (Linnaeus, 1758)	0	0	0	3	2	5	0	0	0	2	5	7	0	0	0	0	0	0
Nicrophorus vespilloides Herbst, 1784	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Anotylus rugosus (Fabricius, 1775)	0	0	0	0	0	0	4	0	0	0	0	4	14	1	0	0	1	16
Oxytelus sculptus Gravenhorst, 1806	0	0	0	0	0	0	0	2	0	0	0	2	0	0	0	0	0	0
Xantholinus longiventris Heer, 1839	11	0	0	0	0	11	3	2	0	0	0	5	0	2	0	1	0	3
Xantholinus tricolor (Fabricius, 1787)	0	0	0	0	0	0	0	4	0	0	0	4	0	0	0	1	1	0
Bisnius fimetarius (Gravenhorst, 1802)	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Gabrius osseticus (Kolenati, 1846)	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Philonthus carbonarius (Gravenhorst, 1802)	3	0	0	0	0	3	2	1	0	0	0	3	8	0	0	1	0	0
Philonthus cognatus Stephens, 1832	0	0	0	0	0	0	12	4	0	1	0	17	0	0	0	0	3	0
Philonthus rotundicollis (Ménétriés, 1832)	2	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0
Philonthus laevicollis (Lacordaire, 1835)	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0
Philonthus coprophilus Jarrige, 1949	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0
Tachinus signatus Gravenhorst, 1802	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0
Tachinus laticollis Gravenhorst, 1802	0	0	0	0	0	0	2	0	0	0	0	2	0	0	0	0	0	0
Tachyporus hypnorum (Fabricius, 1775)	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Bolboceras armiger (Scopoli, 1772)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
Dorcus parallelepipedus (Linnaeus, 1758)	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Agrilinus rufus (Moll, 1782)	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1
Liothorax plagiatus (Linnaeus, 1767)	0	0	0	0	0	0	0	1	1	0	0	2	1	4	0	0	0	5
Onthophagus fracticornis (Preyssler, 1790)	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0
Melolontha melolontha (Linnaeus, 1758)	0	0	0	0	0	0	1	2	0	0	0	3	1	1	0	0	0	2
Oxythyrea funesta (Poda, 1761)	0	0	0	0	0	0	0	2	0	0	0	2	2	0	0	0	0	2
Valgus hemipterus (Linnaeus, 1758)	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0
Byrrhus pilula (Linnaeus, 1758)	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0
Agrypnus murinus (Linnaeus, 1758)	0	0	0	0	0	0	0	0	0	0	0	0	3	1	1	0	1	6
Melanotus villosus (Geoffroy, 1785)	0	0	0	0	0	0	0	0	1	11	0	12	0	0	0	0	0	0
Agriotes lineatus (Linnaeus, 1767)	0	0	0	0	0	0	6	7	0	2	0	15	5	8	0	8	0	21
Cantharis rustica Fallén, 1807	0	1	0	0	0	1	3	4	7	0	0	14	0	1	0	0	0	1
Silis nitidula (Fabricius, 1792)	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0
Dermestes laniarius Illiger, 1801	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
Coccinella septempunctata Linnaeus, 1758	0	0	0	0	0	0	0	21	9	6	6	42	0	14	0	3	4	21
Notoxus monoceros (Linnaeus, 1761)	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	3
Cassida flaveola Thunberg, 1794	0	0	0	0	0	0	0	0	0	0	0	0	4	5	0	1	0	10
Cassida nebulosa Linnaeus, 1758	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	3
Galeruca pomonae (Scopoli, 1763)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	1	4
Galeruca tanaceti (Linnaeus, 1758)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
Bothynoderes affinis (Schrank, 1781)	0	0	0	0	0	0	0	1	0	0	0	1	2	3	0	3	0	8
Hypera conmaculata (Herbst, 1759)	0	0	0	0	0	0	5	5	0	0	0	10	6	5	0	4	6	21
Larinus sturnus (Schaller, 1783)	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1
Polydrusus mollis (Ström, 1768)	0	0	0	0	0	0	0	2	0	0	0	2	2	1	0	3	4	10
Ostrinia nubilalis (Hubner, 1796)	0	0	0	0	0	0	0	2	0	0	0	2	3	0	0	1	4	8
Tenthredo sp.	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	1	0	1
Apis mellifera Linnaeus, 1758	0	2	0	0	0	2	0	8	0	0	0	8	3	5	3	1	3	15

Species	Rapeseed field with pesticide treatment						Wheat field with pesticide treatment						Wheat field without pesticide treatment					
	25.05 – 08.06	09.06 – 20.06	21.06 – 06.07	07.07 – 23.07	24.07 – 04.08	Sum	25.05 – 08.06	09.06 – 20.06	21.06 – 06.07	07.07 – 23.07	24.07 – 04.08	Sum	25.05 – 08.06	09.06 – 20.06	21.06 – 06.07	07.07 – 23.07	24.07 – 04.08	Sum
Bombus terrestris (Linnaeus, 1758)	1	0	0	0	0	1	0	1	0	0	0	1	0	0	0	0	0	0
Ammophila sabulosa (Linnaeus, 1758)	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0
Myrmica ruginodis Nylander, 1846	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2
Formica cinerea Mayr, 1853	0	0	0	0	0	0	0	0	0	0	0	0	4	5	2	4	3	18
Lasius niger (Linnaeus, 1758)	0	0	0	0	0	0	0	2	0	0	0	2	15	8	15	115	0	153
Phoridae sp.	15	0	0	0	0	15	0	4	0	0	0	4	0	0	0	4	3	7
Sarcophaga carnaria (Linnaeus, 1758)	0	0	0	0	0	0	0	5	0	0	0	5	17	3	0	2	1	23
Pardosa lugubris (Walckenaer, 1802)	0	1	0	0	0	1	47	8	0	0	0	55	50	14	7	19	15	105
Trochosa terricola Thorell, 1856	0	1	0	0	0	1	6	2	0	0	0	8	2	2	6	1	1	12
Ozyptila lugubris (Kroneberg, 1875)	0	1	0	0	0	1	3	9	0	0	0	12	19	1	1	2	2	25
Sum	206	523	201	315	876	2121	189	236	544	595	1619	3183	434	182	171	361	475	1607

The percentages of ground beetles in the cypermethrin-treated rapeseed and wheat agrocoenoses approached 100% (accounting for 97.8% and 91.0%, respectively). The share of Carabidae in the plot in the wheat field that had not been treated with insecticides was much lower, measuring 62.2%, which indicates the presence of other dominant groups of arthropods in the agrocoenosis that are less resistant to insecticides, namely, Hymenoptera (Formicidae), accounting for 9.7%, Orthoptera (Acrididae), forming 6.6%, Araneae (Lycosidae) measuring 6.5%, and other. In the wheat field that had not been treated with insecticides, the share of spiders (Lycosidae) increased to 6.5% (subdominants). A similar tendency was typical for many other taxonomic groups, including woodlice and predatory millipedes. In the ecologically farmed wheat agrocoenosis, these invertebrates formed a share of 0.17% (subrecendents). By contrast, they were completely absent in the cypermethrin-treated fields. In the field conditions, the number of some groups of Coleoptera were unaffected by cypermethrin. The percentage ratio of Silphidae and Staphylinidae was practically the same, depending on the type of agrocoenosis, and even insignificantly increased in the test plots that had been treated with the insecticide. Perhaps, this can be related to the trophic specialization and high flying activity of saprotrophic and predatory beetles. For example, Silphidae and Staphylinidae could be attracted from the neighboring biocoenoses by the smell of dead invertebrates captured in the pitfall traps (Table 4).

Table 4
Taxonomic structure of the communities of invertebrates (%) in the fields that had and had not been treated with insecticides in Lithuania

Class	Order	Family	Rapeseed field with pesticide treatment	Wheat field with pesticide treatment	Wheat field without pesticide treatment
Malacostraca	Isopoda Latreille, 1817	Porcellionidae Brandt & Ratzeburg, 1831	0.00	0.00	0.17
Chilopoda	Lithobiomorpha Pocock, 1895	Lithobiidae Newport, 1844	0.00	0.00	0.11
Diplopoda	Julida Brandt, 1833	Julidae Leach, 1814	0.00	0.33	0.06
Insecta	Dermaptera De Geer, 1773	Forficulidae Latreille, 1810	0.00	0.15	0.06
	Orthoptera Latreille, 1793	Tetrigidae Rambur, 1838	0.00	0.00	0.11
		Acrididae MacLeay, 1819	0.00	0.43	6.60
	Hemiptera Linnaeus, 1758	Cicadellidae Latreille, 1802	0.00	0.03	0.00
		Coreidae Amyot & Serville, 1843	0.00	0.03	1.12
		Lygaeidae Schilling, 1829	0.00	0.03	0.39
		Cydnidae Billberg, 1820	0.00	0.03	0.11
		Pentatomidae Leach, 1815	0.05	0.03	0.17
		Scutelleridae Leach, 1815	0.00	0.00	0.06
	Coleoptera Linnaeus, 1758	Carabidae Latreille, 1802	97.78	91.00	62.21
		Hydrophilidae Latreille, 1802	0.00	0.00	0.00
		Histeridae Gyllenhal, 1808	0.05	0.00	0.06
		Silphidae Latreille, 1806	0.28	0.46	0.28
		Staphylinidae Latreille, 1802	0.79	1.22	1.06
		Geotrupidae Latreille, 1806	0.00	0.00	0.06
		Lucanidae Latreille, 1806	0.05	0.00	0.00
		Scarabaeidae Latreille, 1802	0.00	0.27	0.56
		Byrrhidae Latreille, 1804	0.00	0.03	0.00
		Elateridae Leach, 1815	0.00	0.82	1.51
		Cantharidae Imhoff, 1856 (1815)	0.05	0.46	0.06
		Dermestidae Latreille, 1804	0.00	0.00	0.06
		Coccinellidae Latreille, 1807	0.00	1.28	1.17
		Anthicidae Latreille, 1819	0.00	0.00	0.17
		Chrysomelidae Latreille, 1802	0.00	0.00	1.01
		Curculionidae Latreille, 1802	0.00	0.40	2.24
	Lepidoptera Linnaeus, 1758	Crambidae Latreille, 1810	0.00	0.06	0.45
	Hymenoptera Linnaeus, 1758	Tenthredinidae Latreille, 1802	0.00	0.03	0.06
		Apidae Latreille, 1802	0.14	0.27	0.84
		Sphecidae (Latreille, 1802)	0.00	0.03	0.00
		Formicidae Latreille, 1809	0.00	0.06	9.67
	Diptera Linnaeus, 1758	Phoridae Curtis, 1833	0.70	0.12	0.39
		Sarcophagidae Macquart, 1834	0.00	0.15	1.29
Arachnida	Araneae Clerck, 1757	Lycosidae Sundevall, 1833	0.09	1.92	6.54
		Thomisidae Sundevall, 1833	0.05	0.36	1.40
Sum			100.00	100.00	100.00

In all the studied agrocoenoses, 75% of the species that were considerably abundant (eudominants, dominants, and subdominants) were represented by ground beetles. In fact, some species of Carabidae in the conventionally farmed, cypermethrin-treated fields were characterized by abnormally high abundance. As eudominant, we should note *Pterostichus melanarius* (Illiger, 1798). The percentage ratio of this species in the conventionally farmed field accounted for 62.9%. *Poecilus versicolor* (Sturm, 1824) and *Calathus fuscipes* (Goeze, 1777) were dominants in the agrocoenosis of rapeseed (18.2% and 15.1%, respectively). In the ecologically farmed wheat field, we observed a more even structure of dominance of communities of epigean invertebrates and absence of eudominants. The dominant in this agrocoenosis was *Harpalus griseus* (Panzer, 1796), measuring 14.7%, and the subdominants were *Metallina lampros* (Herbst, 1784) and *Harpalus distinguendus* (Duftschmid, 1812), accounting for 8.3% and 7.0%, respectively. The absence of insecticide use significantly increased the abundance of sensitive groups of arthropods, the share of which in the conventionally farmed wheat agrocoenosis did not exceed or was slightly above 1%. Thus, the percentage ratio of the ants *Lasius niger* (Linnaeus, 1758) increased to 8.6%, that of the acridoids *Chorthippus* sp. to 6.6%, and that of the spiders *Pardosa lugubris* (Walckenaer, 1802) to 5.9% (Table 5).

Table 5
Dominant species of invertebrates (%) in the fields that had and not had been treated with insecticides in Lithuania

Species	Rapeseed field with pesticide treatment	Wheat field with pesticide treatment	Wheat field without pesticide treatment
Chorthippus sp.	0.0	0.4	6.6
Nebria rufescens (Stroem, 1768)	0.5	1.2	0.7
Loricera pilicornis (Fabricius, 1775)	4.2	0.2	0.4
Metallina lampros (Herbst, 1784)	1.4	0.9	8.3
Poecilus cupreus (Linnaeus, 1758)	2.8	1.1	0.7
P. versicolor (Sturm, 1824)	18.2	2.0	4.4
Pterostichus melanarius (Illiger, 1798)	36.2	62.9	1.6
Amara aenea (De Geer, 1774)	0.1	0.1	3.6
A. communis (Panzer, 1797)	1.3	0.4	3.1
A. convexiuscula (Marsham, 1802)	4.5	0.0	0.3
Calathus ambiguus (Paykull, 1790)	0.5	2.8	1.0
C. fuscipes (Goeze, 1777)	15.1	9.5	5.9
Anchomenus dorsalis (Pontoppidan, 1763)	1.5	0.4	0.4
Harpalus distinguendus (Duftschmid, 1812)	0.6	1.8	7.0
H. griseus (Panzer, 1796)	4.4	1.9	14.7
H. rufipes (De Geer, 1774)	3.4	1.6	3.7
Coccinella septempunctata Linnaeus, 1758	0.0	1.3	1.2
Lasius niger (Linnaeus, 1758)	0.0	0.1	8.6
Pardosa lugubris (Walckenaer, 1802)	0.0	1.7	5.9
Other species	5.1	10.0	22.2
Sum	100.0	100.0	100.0

An important criterion for assessing ecosystems is the pattern of the distribution of epigean mesofauna according to the size characteristics. Unevenness of the distribution of inveretebrates was seen in all the examined plots of the fields. However, it was the most pronounced in the insecticide-treated agrocoenoses, first of all, due to extremely abundant eudominants. Also, in those agrocoenoses, there was observed an increase in the average-sized invertebrates and decline in large species of invertebrates (Fig. 1). The unevenness of the size structure of an invertebrate community, along with the disappearance of certain size groups, indicates the degradation of the biogeocoenosis, its unstable state, and that the ecosystem is in various stages of succession.

The distribution of species by abundance in a multi-species community is characterized by biodiversity metrics. The Shannon index was maximal in the ecosystems with the highest number of species and the absence of notable eudominants and dominants in the community of invertebrates. The closer the value of Pielou's index is to 1, the more even the species in the community are in terms of abundance. In the context of our study, the closest area exhibiting these characteristics was the ecologically farmed wheat agrocoenosis, for which the Shannon index equaled 4.46 bits and the Pielou index measured 0.752 bits (Fig. 1c). The low and average values of the Pielou index suggest a significant degree of transformation of the agrocoenoses farmed conventionally (0.425 bits in the wheat field and 0.571 bits in the rapeseed field) (Fig. 1a, 1b). This demonstrates the high degree to which the introduction of insecticides disturbs the balance in the agroecosystem.

The analysis of distribution of invertebrates in relation to their trophic specialization and the ability to fly revealed that the dominants in the insecticide-treated agrocoenoses were zoophages, mostly represented by predatory Carabidae. In the conventionally farmed wheat agrocoenosis, the share of non-flying zoophages was 67.1%, and in the rapeseed field it was almost twice lower. By contrast, in the conventionally farmed rapeseed field, the share of actively flying zoophages significantly increased, measuring 45.9%. Perhaps, this is related to the microclimate conditions formed in the above-soil horizon of the agroecosystems: rapeseed is a herbaceous plant with sprawling leaves that cast considerable shade and retain humidity. The soil under the cover of grasses is less moist and shaded. The distribution of predatory species of arthropods that are low-sensitive to cypermethrin in the conventionally farmed agrocoenoses was due to their ecological preferences. In the wheat field that had not been treated with cypermethrin, the share of zoophages moderately declined. At the same time, the percentages of flying phytophages (Acridoidea, Heteroptera, Chrysomelidae, Curculionidae, and others) and flying polyphages (ground beetles of the *Harpalus* genus, Elateridae, and other) significantly increased, measuring 24.8% and 20.0%, respectively (Table 6).

Discussion

In our studies, we observed impoverishment of the diversity of non-target mesofauna and complete or partial disappearance of some significant groups of invertebrates from the taxonomic structure in the conventionally farmed agrocoenoses. In the cypermethrin-treated rapeseed field, only several species of Staphylinidae were noted. Perhaps, the decline in the species diversity of staphilinids was due to the competetition with the growing number of dominant species of ground beetles (Andersen & Eltun, 2000). Among the taxonomic groups of arthropods that were observed in the ecologically farmed field, but were not found or were observed singularly in the cypermethrin-treated agrocoenoses, we should note isopods (Porcellionidae), millipedes (Lithobiidae), orthopterans (Tetrigidae, Acrididae), hemipterans (Coreidae, Lygaeidae, Cydnidae, Pentatomidae), coleopterans (Scarabaeidae, Elateridae, Chrysomelidae, Curculionidae), ants (Formicidae), spiders (Lycosidae, Thomisidae), and other.

The studies on the influence of cypermethrin on non-target species of soil and litter invertebrates in a laboratory experiment revealed that many of the aforementioned groups were moderately resistant to this insecticide, for example, predatory millipedes and terrestrial isopods, spiders, and ants (Faly et al., 2023). However, some groups of invertebrates evade territories where insecticides have been used. For instance, the assessment of the behavioral reaction of *Porcellio scaber* Latreille, 1804 (Porcellionidae) to pyrethroids in soil revealed that isopods tend to avoid areas that have been exposed to insecticides, except for the lowest tested dose (10 µL/g) (Zidar et al., 2012). At the same time, most groups of epigean insects are quite sensitive to pyrethroids.

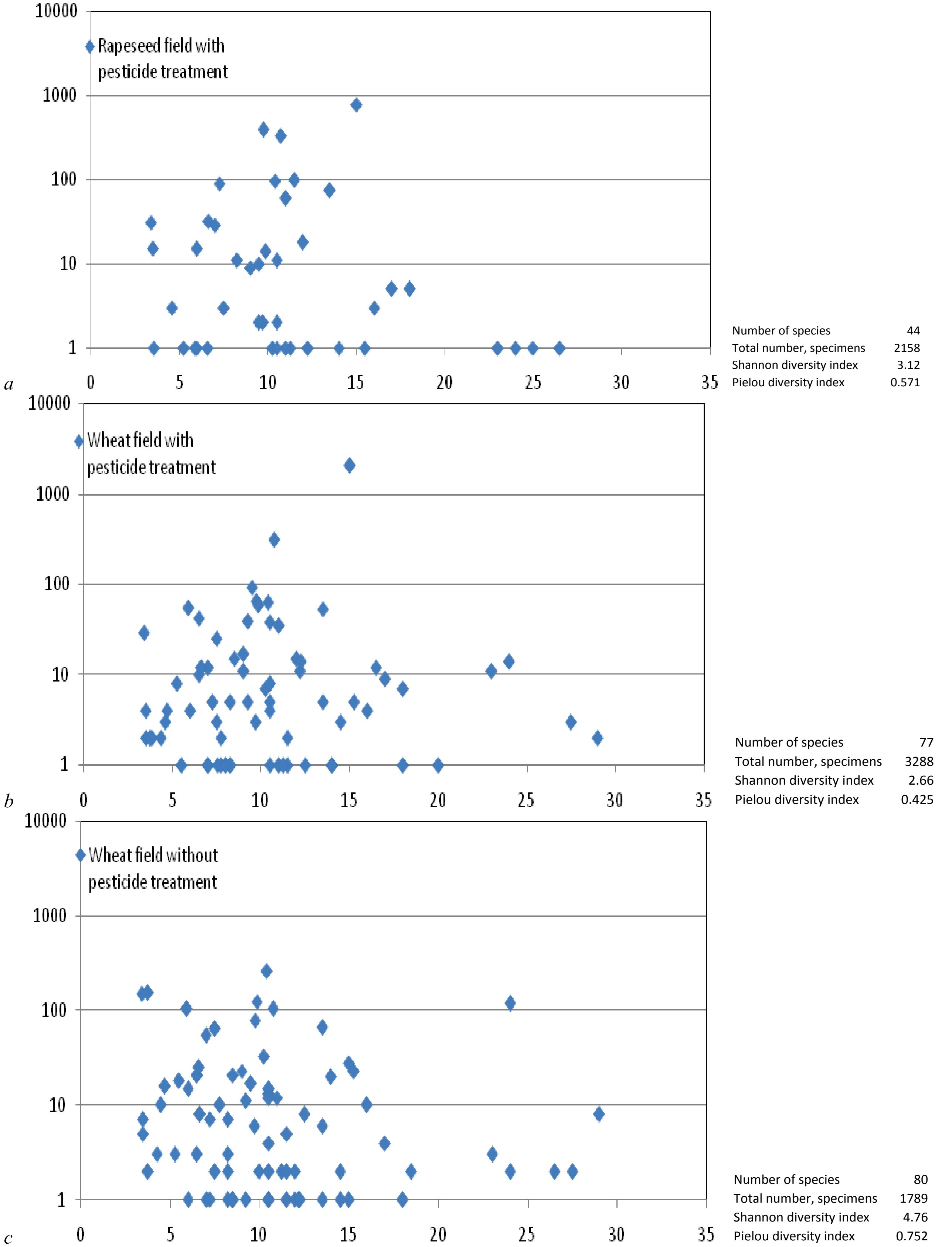

Fig. 1. Distribution of the invertebrates (each point corresponds to one species of invertebrates) depending on their average body length (on the abscissa axis, mm) and their total abundance in the agrocoenosis (the ordinate axis indicates the number of specimens collected over 70 days using 40 traps): *a* – rapeseed field with pesticide treatment, *b* – wheat field with pesticide treatment, *c* – wheat field without pesticide treatment

Table 6
Distribution of the invertebrates (%) in agrocoenoses in Lithuania according to their trophic specialization and the ability to fly

Trophic group and ability to fly	Rapeseed field with pesticide treatment	Wheat field with pesticide treatment	Wheat field without pesticide treatment
Phytophages (run)	0.00	0.43	6.60
Phytophages (fly)	7.46	4.23	24.76
Saprophages (run)	0.00	0.33	0.22
Saprophages (fly)	0.97	0.76	2.24
Zoophages (run)	37.77	67.12	10.73
Zoophages (fly)	45.92	22.48	25.60
Polyphages (run)	0.00	0.30	9.89
Polyphages (fly)	7.88	4.35	19.96
Sum	100.00	100.00	100.00

Note: run – invertebrates that are unable to fly; fly – invertebrates that are able to fly.

Cypermethrin exerted negative effects on the functional reactions of the assassin bug *Acanthaspis pedestris* Stål, 1863 (Reduviidae), which was observed to have reduced predation effectiveness, prolonged mating, and at increased concentrations – abnormal behavior (Claver et al., 2003). Subject to two pyrethroid insecticides (fenvalerate and cypermethrin), the predatory assassin bug *Rhynocoris marginatus* (Fabricius, 1794) (Reduviidae) underwent changes in the formula of hemolymph. Both pyrethroids caused increase in the number of prohemocytes and granular hemocytes and decrease in the number of plasmatocytes. Fenvalerate exerted a toxic effect on this species of Reduviidae (George et al., 2021).

The detrimental impact of pyrethroid insecticides on agroecosystems was reported in a number of studies, most of which focused on their action towards non-target aquatic organisms (Kozak et al., 2020; San Juan et al., 2020; Crowley et al., 2021). For most soil and litter non-target groups of insects, the toxicity of insecticides of this class was found to be high as well (Faly et al., 2023). Only scarce data are available regarding the hazard of these insecticides for soil organisms, but considering the fact that most of the applied pyrethroids enter the soil, they pose a potential threat to the soil ecosystem (Diao et al., 2011; Zortéa et al., 2015). Research on individual and combined toxic effects of cypermethrin and chlorpyrifos on the worm *Eisenia fetida* andrei (Savigny, 1826) (Lumbricidae) revealed that the mixture of these compounds was much more toxic than either pesticide alone, especially in terms of the worm's chronic reactions (Zhou et al., 2011). Cypermethrin is known to be more toxic to non-target species of Isopoda and Pseudoscorpionida than the growth regulator of insects – metoxyfenozide (Loetti & Bellocq, 2017). The measurements of residual toxicity of some insecticides in soil for microarthropods revealed that residuals of cypermethrin, unlike chlorpyrifos, caused less than 10% mortality in Collembola (Wiles & Frampton, 1996).

Predatory arthropods can be exposed to pesticides directly when they are sprayed, or indirectly through the consumption of chemically treated prey (Elhamalawy et al., 2024). As is known, earwigs Dermaptera and spiders Lycosidae are less sensitive to cypermethrin than most species of litter-dwelling Coleoptera (Curtis & Horne, 1995; Faly et al., 2023). In laboratory experiments on the spider *Pardosa amentata* (Clerck, 1757), the toxic effects of this insecticide applied in the field doses manifested in disruptions in the locomotor activity and feeding behavior of the individuals. These effects were the same for both sexes and persisted for up to 3–5 days (Shaw et al., 2006). By contrast, the spiders of the family Linyphiidae turned out to be the most sensitive to pyrethroids used in the agrocoenoses of winter wheat among the other groups of mesofauna (Pullen et al., 1992). Faunistic studies conducted in the organically and conventionally farmed (cypermethrin-treated) fields of winter wheat in Southern England determined a significantly higher taxonomic diversity of spiders in the organically farmed agrocoenoses (Feber et al., 1998).

The scientific literature rarely describes the sublethal effects of pyrethroids (impairments in spatial orientation, locomotor activity, feeding and mating behaviors, reproduction, etc.) on non-target species of invertebrates. Most often, studies focus on the lethal effects over short periods of time. The sublethal doses of pyrethroids (deltamethrin) impaired maternal egg care in *Forficula auricularia* Linnaeus, 1758 (Forficulidae), in particular reducing its duration (Meunier et al., 2020). There are data regarding a positive sublethal effect of beta-cypermethrin on the development and fertility of *Harmonia axyridis* (Pallas, 1773) (Coccinellidae) (prolongation of the period of egg laying, significant increase in fertility by almost 50%, compared with the control) (Xiao et al., 2016). An experiment with a pyrethroid spray Ektoban® revealed no ecotoxic effects on the dung beetle *Euoniticellus intermedius* (Reiche, 1849) (Scarabaeidae). The study also found no significant differences in the survival of imagoes and larvae, egg production, fecundity, and fertility between the control and experimental groups (Kryger et al., 2006).

A number of published studies focused on comparative analysis of species diversity of invertebrates in ecologically (non-chemically treated) and conventionally farmed agrocoenoses treated with insecticides belonging to different chemical classes. Compared with pyrethroids, neonicotinoids imposed severer impacts, substantially impoverishing the composition of non-target fauna in the fields (Cruces et al., 2021). In the field studies of agrocoenoses of winter grasses that had been treated with cypermethrin, there was observed a significant decline in the population of predators with broad feeding range (Carabidae, Staphylinidae, and Linyphiidae). The density of the communities of invertebrates partly recovered due to the migration of several abundant species of arthropods from other territories (Purvis et al., 1988).

Conclusion

In the taxonomic structure of the arthropod communities in the examined agrocoenoses, by number of species and their abundance, the dominants were coleopterans, represented by 16 families. Ground beetles were eudominants in all the test plots in the fields. In the conventionally farmed agroecosystems, highly abundant species were carabids such as *Pterostichus melanarius*, *Poecilus versicolor*, and *Calathus fuscipes*. These agrocoenoses were observed to have impoverished taxonomic diversity, disappearance of individual taxa from the communities of invertebrates. The low values of the Pielou index (measuring 0.425 in the conventionally farmed wheat field and 0.571 bits in the rapeseed field) indicated significant transformation of these plots. The size structure was uneven, with prevalence of average-sized species of arthropods. In the structure of dominance, there were pronounced eudominants – predatory Carabidae that appeared in abnormally high numbers. Therefore, the dominating group in the trophic structure was zoophages, represented by both flying and non-flying species.

The ecologically farmed wheat field, non-treated with insecticides, was characterized by higher values of the Shannon diversity indicex and the Pielou eveness index (4.76 and 0.752 bits, respectively). The size structure of the community of litter and soil invertebrates was more even, with no eudominants. The dominant was *Harpalus griseus*, subdominants – *Metallina lampros* and *Harpalus distinguendus*. The common taxonomic groups of arthropods in this plot were those that are more sensitive to cypermethrin: Porcellionidae, Lithobiidae, Tetrigidae, Acrididae, Coreidae, Lygaeidae, Cydnidae, Pentatomidae, Scarabaeidae, Elateridae, Chrysomelidae, Curculionidae, Thomisidae, and others. In the trophic structure, the share of zoophages declined and the percentage of flying phytophages and polyphages increased.

Application of cypermethrin in conventionally farmed agrocoenoses is detrimental to the non-target mesofauna, as it disturbs the ecological balance and leads to degradation of ecosystems. Therefore, well-thought use of modern insecticides that are low-toxic to non-target fauna and the search for alternative eco-friendly methods of countering pests are matters of high priority .

References

Andersen, A., & Eltun, R. (2000). Long-term developments in the carabid and staphylinid (Col., Carabidae and Staphylinidae) fauna during conversion from conventional to bilogivcal farming. Journal of Applied Entomology, 124(1), 51–56.

Atkoceviciene, V., Gudritiene, D., & Dudoniene, V. (2011). The analysis on the change of farming lands in the territory of Middle Lithuania. Baltic Surveying, 11, 25–36.

Baude, M., Meyer, B. C., & Schindewolf, M. (2019). Land use change in an agricultural landscape causing degradation of soil based ecosystem services. Science of the Total Environment, 659, 1526–1536.

Brygadyrenko, V. V., & Reshetniak, D. Y. (2014). Morphological variability among populations of *Harpalus rufipes* (Coleoptera, Carabidae): What is more important – the mean values or statistical peculiarities of distribution in the population? Folia Oecologica, 41(2), 109–133.

Buivydaite, V. V. (2005). Soil survey and available soil data in Lithuania. European Soil Bureau – Research Report, 9, 211–223.

Claver, M. A., Ravichandran, B., Khan, M. M., & Ambrose, D. P. (2003). Impact of cypermethrin on the functional response, predatory and mating behaviour of a non-target potential biological control agent *Acanthaspis pedestris* (Stål) (Het., Reduviidae). Journal of Applied Entomology, 127(1), 18–22.

Crowley, D., Penk, M. R., Macaulay, S. J., & Piggott, J. J. (2021). Acute toxicity of the insecticide cypermethrin to three common European mayfly and stonefly nymphs. Limnologica, 88, 125871.

Cruces, L., de la Peña, E., & De Clercq, P. (2021). Field evaluation of cypermethrin, imidacloprid, teflubenzuron and emamectin benzoate against pests of quinoa (*Chenopodium quinoa* Willd.) and their side effects on non-target species. Plants, 10(9), 1788.

Curtis, J. E., & Horne, P. A. (1995). Effect of chlorpyrifos and cypermethrin applications on non-target invertebrates in a conservation-tillage crop. Australian Journal of Entomology, 34(3), 229–231.

Desneux, N., Decourtye, A., & Delpuech, J. M. (2007). The sublethal effects of pesticides on beneficial arthropods. Annual Review of Entomology, 52(1), 81–106.

Diao, J., Xu, P., Liu, D., Lu, Y., & Zhou, Z. (2011). Enantiomer-specific toxicity and bioaccumulation of alpha-cypermethrin to earthworm *Eisenia fetida*. Journal of Hazardous Materials, 192(3), 1072–1078.

Eidukevičienė, M., & Vasiliauskienė, V. (2001). Lietuvos dirvožemiai. Lietuvos Mokslas, Vilnius. Kn. 32. 1223 p.

Elhamalawy, O., Bakr, A., & Eissa, F. (2024). Impact of pesticides on non-target invertebrates in agricultural ecosystems. Pesticide Biochemistry and Physiology, 202, 105974.

Engelmann, H. D. (1978). Zur Dominanzklassifizierung von Bodenarthropoden. Pedobiologia, 18, 378–380.

Faly, L. I., Brygadyrenko, V. V., Orzekauskaite, A., & Paulauskas, A. (2023). Sensitivity of non-target groups of invertebrates to cypermethrin. Biosystems Diversity, 31, 393–400.

Feber, R. E., Bell, J., Johnson, P. J., Firbank, L. G., & Macdonald, D. W. (1998). The effects of organic farming on surface-active spider (Araneae) assemblages in wheat in Southern England, UK. Journal of Arachnology, 26(2), 190–202.

Gailis, J., & Turka, I. (2014). The diversity and structure of ground beetles (Coleoptera: Carabidae) assemblages in differently managed winter wheat fields. Baltic Journal of Coleopterology, 14(1), 33–46.

Gailis, J., Turka, I., & Ausmane, M. (2017). Soil tillage and crop rotation differently affect biodiversity and species assemblage of ground beetles inhabiting winter wheat fields. Agronomy Research, 15(1), 94–111.

George, P. E., Ravichandran, B., Jesudurai, A., & Ambrose, D. P. (2021). Relative toxicity and haematological impact of insecticides cypermethrin and Fenvalerate to a non-target reduviid predator *Rhynocoris marginatus* (Fabricius) (Heteroptera: Reduviidae). Journal of Entomology and Zoology Studies, 9(1), 2040–2043.

Gunstone, T., Cornelisse, T., Klein, K., Dubey, A., & Donley, N. (2021). Pesticides and soil invertebrates: A hazard assessment. Frontiers in Environmental Science, 9, 643847.

Jaagus, J., Briede, A., Rimkus, E., & Remm, K. (2014). Variability and trends in daily minimum and maximum temperatures and in the diurnal temperature range in Lithuania, Latvia and Estonia in 1951–2010. Theoretical and Applied Climatology, 118(1–2), 57–68.

Jarasiunas, G. (2016). Assessment of the agricultural land under steep slope in Lithuania. Journal of Central European Agriculture, 17(1), 176–187.

Kenko, D. B. N., Ngameni, N. T., & Kamta, P. N. (2022). Environmental assessment of the influence of pesticides on non-target arthropods using PRIMET, a pesticide hazard model, in the Tiko municipality, Southwest Cameroon. Chemosphere, 308, 136578.

Kochian, L. V., Piñeros, M. A., Liu, J., & Magalhaes, J. V. (2015). Plant adaptation to acid soils: The molecular basis for crop aluminum resistance. Annual Review of Plant Biology, 66(1), 571–598.

Komlyk, V. O., & Brygadyrenko, V. V. (2019). Morphological variability of *Bembidion minimum* (Coleoptera, Carabidae) populations under the influence of natural and anthropogenic factors. Biosystems Diversity, 27(3), 250–269.

Kozak, V. M., Romanenko, E. R., & Brygadyrenko, V. V. (2020). Influence of herbicides, insecticides and fungicides on food consumption and body weight of *Rossiulus kessleri* (Diplopoda, Julidae). Biosystems Diversity, 28(3), 272–280.

Kromp, B. (1989). Carabid beetle communities (Carabidae, Coleoptera) in biologically and conventionally farmed agroecosystems. Agriculture, Ecosystems and Environment, 27, 241–251.

Kryger, U., Deschodt, C., Davis, A. L., & Scholtz, C. H. (2006). Effects of cattle treatment with a cypermethrin/cymiazol spray on survival and reproduction of the dung beetle species *Euoniticellus intermedius* (Coleoptera: Scarabaeidae). Bulletin of Entomological Research, 96(6), 597–603.

Le Goff, G., & Giraudo, M. (2019). Effects of pesticides on the environment and insecticide resistance. In: Picimbon, J. F. (Ed.). Olfactory concepts of insect control – Alternative to insecticides. Springer, Cham. Pp. 51–78.

Letschert, D. (1986). Untersuchungen zur Arthropoden-und Annelidenfauna von Weizen-und Zuckerruebenfeldern in einem konventionellen und einem biologisch-dynamischen Anbau. Zeitschrift für Angewandte Zoologie, 73(1), 93–113.

Loetti, V., & Bellocq, I. (2017). Effects of the insecticides methoxyfenozide and cypermethrin on non-target arthropods: A field experiment. Austral Entomology, 56(3), 255–260.

Meunier, J., Dufour, J., Meyel, S. V., Rault, M., & Lécureuil, C. (2020). Sublethal exposure to deltamethrin impairs maternal egg care in the European earwig *Forficula auricularia*. Chemosphere, 258, 127383.

Miceikienė, A., Rimkuvienė, D., & Gesevičienė, K. (2019). Assessment of the environmental pollution determinants in the economy sectors of Lithuania. Copernican Journal of Finance and Accounting, 8(4), 171–184.

Mockeviciene, I., Karcauskiene, D., Vilkiene, M., Repsiene, R., Feiza, V., & Budryte, O. (2024). Assessment of management practices to prevent soil degradation threats on Lithuanian acid soils. Sustainability, 16(14), 5869.

Pileckis, S., & Monsevičius, V. (1995). Lietuvos fauna. Vabalai (Fauna of Lithuania. Coleoptera). Vol. 1. Vilnius. 303 p. (in Lithuanian).

Pileckis, S., & Monsevičius, V. (1997). Lietuvos fauna. Vabalai (Fauna of Lithuania. Coleoptera). Vol. 2. Vilnius. 216 p. (in Lithuanian).

Pullen, A. J., Jepson, P. C., & Sotherton, N. W. (1992). Terrestrial non-target invertebrates and the autumn application of synthetic pyrethroids: Experimental methodology and the trade-off between replication and plot size. Archives of Environmental Contamination and Toxicology, 23, 246–258.

Purvis, G., Carter, N., & Powell, W. (1988). Observations on the effects of an autumn application of a pyrethroid insecticide on non-target predatory species in winter cereals. In: Cavalloro, R. (Ed.). Integrated crop protection in cereals. CRC Press, London. Pp. 153–166.

Pustelnikovas, O., Švedas, K., & Švedienė, I. (2007). Estimation of geochemical profile of soil and sediments in Lithuanian terrestrial and aquatic landscapes. Geologija, 59, 30–46.

Putchkov, A. V., & Brygadyrenko, V. V. (2022). Rare species of Carabidae and Cicindelidae in Dnipropetrovsk Region, Ukraine. Biosystems Diversity, 30(3), 310–337.

Putchkov, A. V., Brygadyrenko, V. V., Faly, L. I., & Komaromi, N. A. (2020). Staphylinids (Coleoptera, Staphylinidae) of Ukrainian metropolises. Biosystems Diversity, 28(1), 41–47.

Ruberti, M. (2024). One hundred years of pyrethroid chemistry: A still-open research effort to combine efficacy, cost-effectiveness and environmental sustainability. Sustainability, 16(19), 8322.

San Juan, M. F., Cortelezzi, A., Albornoz, C. B., Landro, S. M., Arrighetti, F., Najle, R., & Lavarías, S. M. L. (2020). Toxicity of pyrethroid cypermethrin on the freshwater snail *Chilina parchappii*: Lethal and sublethal effects. Ecotoxicology and Environmental Safety, 196, 110565.

Sánchez-Bayo, F. (2021). Indirect effect of pesticides on insects and other arthropods. Toxics, 9(8), 177.

Serrão, J. E., Plata-Rueda, A., Martínez, L. C., & Zanuncio, J. C. (2022). Side-effects of pesticides on non-target insects in agriculture: A mini-review. The Science of Nature, 109(2), 17.

Shaw, E. M., Waddicor, M., & Langan, A. M. (2006). Impact of cypermethrin on feeding behaviour and mortality of the spider *Pardosa amentata* in arenas with artificial 'vegetation.' Pest Management Science, 62(1), 64–68.

Slepetiene, A., Volungevicius, J., Jurgutis, L., Liaudanskiene, I., Amaleviciute-Volunge, K., Slepetys, J., & Ceseviciene, J. (2020). The potential of diges-

tate as a biofertilizer in eroded soils of Lithuania. Waste Management, 102, 441–451.
Staniuliene, S., & Dickute, V. (2017). Business clusters formation for region development in Lithuania. Research for Rural Development, 2, 118–125.
Tamutis, V. (1999). The entomofauna of soil surface in rape agrobiocenoses. Ekologija, 1, 18–24 (in Lithuanian).
Tamutis, V. (2002a). *Pterostichus* (Col.: Carabidae) abundance dynamics and distribution in different agrobiocenoses. Ekologija, 3, 44–49 (in Lithuanian).
Tamutis, V. (2002b). Rove beetles (Col.: Staphylinidae) in cereals. LZUU Mokslo Darbai "Vagos", 55(8), 62–66 (in Lithuanian).
Tamutis, V., Monsevičius, V., & Pekarskas, J. (2004). Ground and rove beetles (Coleoptera: Carabidae, Staphylinidae) in ecological and conventional winter wheat fields. Baltic Journal of Coleopterology, 4(1), 31–40.
Tamutis, V., Žiogas, A., Šaluchaitė, A., Kazlauskaitė, S., & Amšiejus, A. (2007). Epigeic beetle (Coleoptera) communities in summer barley agrocenoses. Baltic Journal of Coleopterology, 7(1), 83–98.
Wiles, J. A., & Frampton, G. K. (1996). A field bioassay approach to assess the toxicity of insecticide residues on soil to Collembola. Pesticide Science, 47(3), 273–285.
Xiao, D., Zhao, J., Guo, X., Li, S., Zhang, F., & Wang, S. (2016). Sublethal effect of beta-cypermethrin on development and fertility of the Asian multicoloured ladybird beetle *Harmonia axyridis*. Journal of Applied Entomology, 140(8), 598–608.
Zhou, S., Duan, C., Michelle, W. H. G., Yang, F., & Wang, X. (2011). Individual and combined toxic effects of cypermethrin and chlorpyrifos on earthworm. Journal of Environmental Sciences, 23(4), 676–680.
Zidar, P., Hribar, M., Žižek, S., & Štrus, J. (2012). Behavioural response of terrestrial isopods (Crustacea: Isopoda) to pyrethrins in soil or food. European Journal of Soil Biology, 51, 51–55.
Zortéa, T., Baretta, D., Maccari, A. P., Segat, J. C., Boiago, E. S., Sousa, J. P., & Da Silva, A. S. (2015). Influence of cypermethrin on avoidance behavior, survival and reproduction of *Folsomia candida* in soil. Chemosphere, 122, 94–98.