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The impact of agricultural on the spatial structure of epigeic arthropods depending on management and crop cultivation methods

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Abstract

The study provides a comprehensive view of the agroecosystems of the Danube Uplands during 2017–2020. The research analyses in detail the impact of the spatial structure of stands and combined management practices on the abundance and biodiversity of epigeic arthropods under climate change conditions. During the monitored period, 25,709 individuals were recorded, classified into 23 taxonomic groups. 22 groups were identified in organic management and 21 groups in integrated management. The results show that the occurrence and abundance of individuals varied depending on the type of management, the crop grown and the monitored year. The overall abundance was clearly higher in favor of organic management, where 16,073 individuals were obtained, compared to integrated management with 9,636 individuals. In terms of crops, the combination of Vicia faba & Medicago sativa (thicker stand with better microclimatic conditions) proved to be more suitable for supporting biodiversity compared to Zea mays. Climatic factors also had a significant impact on population dynamics. The years 2019 and 2020 were the most significant in terms of abundance, which directly correlated with higher precipitation (625 mm and 669 mm) and stable average temperatures (8.5°C and 8.8°C). On the contrary, the drier years 2017 and 2018 lagged significantly in abundance. The ecological system in conjunction with the favorable climate demonstrated a positive impact on the dominant groups, especially Coleoptera, Acarina and Collembola. The identified epigeic groups represent a diversified component of the soil fauna with different sensitivity to environmental stress.

Introduction

Agricultural landscapes are characterized by varying topography, crop cultivation systems, and management intensity, while agriculture represents one of the key threat factors, or loss of biodiversity (Dudley and Alexander 2017).

Soil is a complex environmental system where numerous processes occur between organic and inorganic phases. It belongs to the most species-rich habitats, providing a fundamental source of a wide range of ecosystem services beneficial to the entire population. These services are provided by a broad spectrum of soil organisms (Lavelle et al. 2006). Consequently, soil biodiversity represents the diversity of living organisms and is an important indicator of "soil health." The present soil fauna is an indispensable part of the soil ecosystem, playing a significant role in the decomposition of organic matter within the biogeochemical cycles of elements such as carbon, nitrogen, sulfur, and phosphorus. Their presence is crucial for the sustainability of the soil ecosystem due to the transformation and degradation of waste and toxic substances. The response of soil organisms is a key component of soil ecosystem sustainability (Porhajašová et al. 2015; Ivanič Porhajašová et al. 2018; Zazharskyi et al. 2019; Langraf et al. 2020a). Soil communities ensure cycling of nutrients, drive ecosystem functions, contribute to soil fertility, and are considered bioindicators of the environment as they respond to changes in agricultural management. Bioindicators are useful organisms used to highlight changes in complex systems. It is known that environmental indicators provide synthesized information about the state of the environment (Langraf et al. 2020a; Yeates 2003; Schoenholz et al. 2000). Epigeic Arthropoda are an important component of agroecosystem biodiversity as they perform a wide range of ecological roles that significantly affect ecosystem functioning, and their presence in the agroecosystem is heterogeneous, and can depend on the

management regime and surrounding vegetation (Langraf et al. 2020b). Additionally, they are part of trophic chains, where in terms of trophic preferences, they act as predators, parasitoids, and also include phytophagous species that can act as pests targeted by insecticides. Despite this, arthropod communities are the foundation of agroecosystems, and their seasonal dynamics are typical, especially in areas with climatic seasonality (Langraf et al. 2021). The intensity of agricultural management affects soil-dwelling communities primarily in terms of species composition and abundance. With this need concerns are associated regarding the reduction of the impact of increasingly intensive agriculture on biodiversity. In crop rotation practices, clover crops restrict the activity and density of soil-dwelling groups compared to cereals, root crops, and legumes (Eyre et al. 2016; Ribera et al. 2001). The spatial structure and distribution of soil-dwelling groups, as well as their activity, are influenced by the type of crop and weed cover (Navntoft et al. 2006).

Complex studies that include mapping large geographical areas and subsequent evaluation over a longer time period are rare, as most research is limited to one or two crops (Fuller et al. 2005). Agricultural practices significantly influence the functional and structural attributes of ecosystems. Tillage, the application of industrial fertilizers, and pesticides have the potential to disrupt the elemental balance of the system, reduce species diversity, and alter the soil trophic network (Moore and Ruiter 2012).

The decline in biodiversity is a global issue. Agricultural practice is one reason for species extinction. In Central Europe, agricultural intensification is one of the main causes of species extinction and biodiversity decline. One possible solution is the preference for organic farming in landscape management to prevent further biodiversity degradation (Irmler 2022; Tscharntke et al. 2005; Poschod et al. 2005; Bengtsson et al. 2005). Biodiversity is necessary within ecosystems as it increases their stability and productivity. Agricultural production intensification causes its decline (Wall et al. 2015; Ivanič Porhajašová et al. 2022). Therefore, organic farming represents a modern management system that, compared to conventional or integrated management, has significantly more positive effects on the conservation of natural elements and the landscape. The system preserves environmental elements, maintains a high level of biodiversity, and supports the production of natural substances and processes (Langraf et al. 2022). The global application of management methods minimizing the negative effects of pesticides and fertilizers on biodiversity ensures better ecosystem balance (Ruscoe 2021).

The aim of this study is to evaluate and compare the impact of management systems on arable land (ecological and integrated management systems) depending on the cultivated crop (*Vicia faba & Medicago sativa, Zea mays*) on the presence or absence, spatial structure, and biodiversity of epigeic groups, in connection with the influence of environmental variables. Since the observed groups indicate the current and trophic conditions of the environment and simultaneously serve as part of complex mechanisms. The goal is also to predict the richness of zoocoenoses and the homeostasis of agroecosystems.

Hypothesis

It is highly likely that an organic management system with the absence of inorganic fertilizers will show higher biodiversity and abundance of epigeic arthropods compared to an integrated system. At the same

time, the cultivation of Vicia faba and Medicago sativa is expected to have a more positive impact on community structure than the cultivation of Zea mays.

Materials and methods

Experimental site and design

Small-plot experiments were conducted within the experimental base of FAPZ SPU Nitra – Dolná Malanta (48°31´67´´N, 18°15´00´´E), within an ecological and an integrated farming system. The study area was located in the Podunajská pahorkatina, Danubian upland geomorphological unit, in southwestern Slovakia. The area is situated in the western part of the Žitava upland, with its typical triangular shape bordered by the Tribeč mountains and the rivers Nitra and Žitava. The monitored study base site has the character of a plain, with a slope facing south. The altitude of the area is 177–178 meters above sea level. The experimental area is classified as a warm, dry, lowland climate region, with the sum of average daily temperatures above 10°C 2 800 to 3 000°C, and a period of air temperatures above 5°C for 237 days in a year. The average long-term (1961–1990) annual rainfall is 532.5 mm, the average annual temperature is 9.6°C, and the average temperature during the growing season is 16.4°C (Linkeš et al. 1996; Špánik et al. 2002). The average temperature ranges observed during individual months over the years were: January − 9.1 to -0.2°C, February − 3.2 to 1.8°C, March 0.9 to 6.2°C, April 7.0 to 13.2°C, May 9.3 to 16.0°C, June 17.8 to 18.7°C, July 18.0 to 19.5°C, August 18.4 to 20.9°C, September 12.0 to 15.4°C, October 8.1 to 9.7°C, November 2.2 to 5.0°C, December − 1.7 to 0.8°C. The average temperature in 2017 was 7.9°C, in 2018 9.0°C, in 2019 8.5°C, and in 2020 8.8°C. The average precipitation for each month was: January 27 mm, February 30.5 mm, March 37 mm, April 16.7 mm, May 56.5 mm, June 56.7 mm, July 44 mm, August 41 mm, September 73.7 mm, October 58 mm, November 43 mm, December 58.5 mm. In 2017 the total rainfall was 489 mm, 390 mm in 2018, 625 mm in 2019, and 669 mm in 2020 (Čimo, unpublished – FZKI SPU Nitra).

Pedological characteristics of the territory

The soil type is luvisol, and the subtype is luvisol cultizemic. The main soil unit is pseudogleyic luvisol on loess and polygenic loams. The weight is in the range of 2.6–2.63 $t.m^{-3}$. The arable part of the soil profile is slightly compacted (porosity: p = 45–48%), and the plough pan is compacted (p = 42%). The soil has high capillary absorption (36–40%) and high maximum water-holding capacity (MKVK = 30–34%). The soil reaction is acidic to slightly acidic, with a pH_{KCl} value of 4.76–5.56. (Hanes et al. 1993; Hanes 1995).

Characteristics of the monitored area and crop husbandry

At the monitored site, field research was conducted within two farming systems ecological and integrated (Ecological farming = Ecol. farm., Integrated farming = Int. farm.), with alternating crops, corresponding to the local soil-climatic conditions. The primary goal of implementing crop rotations was to replace chemical inputs with biological ones. In both farming systems, identical varieties of cultivated crops were used, in accordance with proper agricultural practice. The differences were in the methods of pest control and the

application of industrial fertilizers, which were applied in the integrated farming system. The monitored area for one crop was 50 m². The crops in which ground traps were used within the observed farming systems over the four-year period included *Vicia faba* with *Medicago sativa* and *Zea mays*.

The crop rotation was as follows, in the ecological farming system: *Vicia faba* with *Medicago sativa*, *Medicago sativa*, *Triticum aestivum*, *Pisum sativum*, *Zea mays*, and *Hordeum vulgare*. In the integrated system: *Triticum aestivum*, *Pisum sativum*, *Triticum aestivum*, *Zea mays*, *Hordeum vulgare*, and *Medicago sativa* (Ivanič Porhajašová et al. 2019). The following plant density was used: *Medicago sativa* 450 plants.m^{-2}, *Triticum aestivum* 350 plants.m^{-2}, *Pisum sativum* 90 plants.m^{-2}, *Zea mays* (for silage) 12 plants.m^{-2}, *Hordeum vulgare* 300 plants.m^{-2} (Ivanič Porhajašová and Babošová 2022).

Economic management

The differences between the farming systems were in applied nutrition, fertilization, and plant protection. In the integrated farming system, manure with corn silage was applied at a rate of 40 t.ha^{-1}, along with industrial fertilizers. The application rates were determined using the balance method based on the average yield of the cultivated crops and the nutrient content in the soil. Plant protection focused on the rational use of products permitted within integrated production. In the ecological farming system, manure with corn silage was applied at a rate of 40 t.ha^{-1}, and fertilization was done using products compliant with organic agricultural production. The method of plant protection adhered to preventive, indirect, and mechanical principles. Soil cultivation in both farming systems was based on plowing, but with elements of minimization.

Data collection

Biological material collecting was done using pitfall traps, which were exposed in the field during the growing season (April to October). The pitfall traps were renewed at monthly intervals, and the material was subsequently identified at the Institute of Plant and Environmental Sciences (FAPZ - SPU). We established the nomenclature of the epigeic fauna according to the work of Schierwater and DeSalle (2021). The results were then statistically evaluated. The pitfall trap method (Stašiov 2015) involves placing 1-liter glass bottles (with an opening diameter of 10 cm) buried at ground level, which were filled with a concentrated 4% fixing solution of formaldehyde and covered with a metal roof, protecting the pitfall traps from precipitation and partially from small rodents. Within the two types of farming systems and monitored crops, 2 pitfall traps were used, located at the beginning and in the middle of the crop stand, meaning that in each monitored year, a total of 8 pitfall traps were placed. Within the two types of management and monitored crops, 4 ground traps were exposed, placed in the crop line, with a spacing of 1.5 m within the crop. A total of 16 ground traps were placed in each monitored year.

Statistical analys

In the studied population of epigeic groups, quantitative and qualitative indicators were evaluated, including abundance, dominance, species identity calculated according to Jaccard (IJ), dominance identity according

to Renkonen (ID), diversity level according to Shannon-Weaver (d), and the overall assessment of populations and biodiversity (Losos et al. 1984).

The results were statistically evaluated using the STATISTICA 10 application, and since the data set did not have a normal distribution, even after applying transformations, the non-parametric Kruskal-Wallis test was used to test the number of individuals between traps during the months (Vrábelová and Markechová 2001). The index calculations were done using Past 3.05 (Hammer 2015).

A database of the collection and environmental variables was created in Microsoft SQL Server 2017 (Express Edition). The matrices for statistical calculations were created in Microsoft SQL Server Management Studio (SSMS).

Results

The presented paper brings a new and comprehensive view of agroecosystems through four-year monitoring, during the years 2017 to 2020, thus surpassing the short-term studies of the previous literature. The research analyzes in detail the impact of the spatial structure of stands and combined management practices on the abundance and biodiversity of epigeic arthropods under climate change conditions in the Danube Uplands.

During the monitored period, a total of 25,709 specimens (ex) of the epigeic component of animals were recorded within both types of management. They were classified into 23 taxonomic groups, 22 belonged to Evertebrata, the Larvae group was not determined, these are the developmental stages of the present epigeic groups. In the ecological type of management (Ecol. farm.) there were 22 and in the integrated type of management (Integ. farm.) there were 21 epigeic groups, i.e. almost identical occurrence, the difference was Ensifera, whose share was minor.

From the obtained results, it can be stated that the occurrence and number of individuals fluctuated depending on the type of management, the cultivated crop and the monitored years. The abundance of epigeic groups was clearly in favor of Ecol. farm., where 16,073 ex were obtained, compared to Integ. farm., with a number of 9,636 ex. The values of abundance, dominance and activity tendencies of the present epigeic groups are presented in Tables 1, 2, 3.

Based on the results of the cumulative abundance of epigeic groups (Table 1,2,3) when comparing the implemented management methods and monitored crops, for the monitored period, the ecological type of management with a number of 16,073 ex, for the crop Vicia faba & Medicago sativa...9,319 ex and Zea mays...6,754 ex, can be characterized as more suitable in terms of supporting biodiversity. The results obtained clearly confirmed that the highest biodiversity of the present epigeic groups was in crops with denser growth, i.e. in the crops Vicia faba & Medicago sativa, which provided more suitable microclimatic, topical and trophic conditions.

In connection with the action of all participating factors (climatic conditions, type of management, cultivated crop), which influenced the abundance and representation of the present epigeic groups, the years 2019 and 2020 were clearly demonstrable (Table 2,3). In 2019, 4,917 ex (2,058 ex Vicia faba & Medicago sativa, 2,859

ex Zea mays) were obtained in Ecol. farm. 4,917 ex (2,058 ex Vicia faba & Medicago sativa, 2,859 ex Zea mays). Within Int. farm., a total of 3,867 ex (2,071 ex Vicia faba & Medicago sativa, 1,796 ex Zea mays) were obtained. The maximum abundance was recorded in 2020 within Ecol. farm. 8,037 ex (5,395 ex Vicia faba & Medicago sativa, 2,642 ex Zea mays). In Int. farm., a total of 3,867 ex (2,071 ex Vicia faba & Medicago sativa, 1,796 ex Zea mays) were recorded in 2019. The years 2017 and 2018 lag significantly behind in the abundance of epigeic groups. The climatic characteristics are also clearly positive, which benefit the years 2019 and 2020, when the maximum amount of precipitation was recorded (2019–625 mm, 2020–669 mm) and almost identical average temperatures (2019–8.5°C, 2020–8.8°C). For comparison, the years 2017 (Ø t = 7.9°C, total precipitation = 489 mm) and 2018 (Ø t = 9.0°C, total precipitation = 390 mm). The results show that the ecological management system, in conjunction with other determining factors, mainly climatic, has a positive impact on the abundance of present epigeic groups, especially the dominant groups of Coleoptera, Acarina, Collembola. Based on the results, it can be stated that the impact of the implemented management and the cultivated crop had a significant impact on the presence of present epigeic groups. Even gentle management methods within Int. farms negatively affected biodiversity. It can be stated that the identified epigeic groups represent a diversified component of soil fauna, with different adaptations to the soil environment and different sensitivity to stress.

Table 1
Cumulative abundance and dominace of epigeic groups in ecological and integrated farming in the crops *Vicia faba & Medicago sativa* and *Zea mays*, during the years 2017 to 2020, on the locality Nitra-Dolná Malanta

Ecological farming system	***Vicia faba & Medicago sativa***	***Zea mays***	**Σ**	**%**
Acarina	1239	771	**2010**	**12,51**
Araneida	489	497	**986**	**6,15**
Auchenorrhyncha	6	6	**12**	**0,07**
Caelifera	177	56	**233**	**1,45**
Cicadoidae	18	22	**40**	**0,25**
Coleoptera	3033	2620	**5653**	**35,2**
Collembola	2271	1480	**3751**	**23,31**
Dermaptera	128	81	**209**	**1,29**
Diplopoda	91	74	**165**	**1,03**
Diptera	195	107	**302**	**1,88**
Formicoidea	764	561	**1325**	**8,22**
Heteroptera	138	54	**192**	**1,19**
Hymenoptera	43	39	**82**	**0,51**
Chilopoda	27	24	**51**	**0,32**
Isopoda	42	8	**50**	**0,31**
Larvae	283	126	**409**	**2,55**
Lepidoptera	2		**2**	**0,01**
Lumbricidae	12	10	**22**	**0,14**
Opilionida	353	217	**570**	**3,55**
Siphonaptera	5	1	**6**	**0,04**
Stylomatophora	1		**1**	**0,01**
Thysanoptera	2		**2**	**0,01**
Σ	**9319**	**6754**	**16 073**	**100**
Integrated farming system	**Vicia faba & Medicago sativa**	**Zea mays**	**Σ**	**%**
Acarina	858	878	**1736**	**18,01**
Araneida	364	312	**676**	**7,02**
Auchenorrhyncha	4		**4**	**0,04**

Ecological farming system	*Vicia faba & Medicago sativa*	*Zea mays*	Σ	%
Caelifera	95	26	**121**	**1,26**
Cicadoidea		7	**7**	**0,07**
Coleoptera	1113	1124	**2237**	**23,22**
Collembola	1007	1214	**2221**	**23,02**
Dermaptera	120	97	**217**	**2,25**
Diplopoda	41	46	**87**	**0,9**
Diptera	81	55	**136**	**1,41**
Ensifera	13		**13**	**0,13**
Formicoidea	640	501	**1141**	**11,84**
Heteroptera	64	26	**90**	**0,93**
Hymenoptera	30	35	**65**	**0,67**
Chilopoda	26	21	**47**	**0,49**
Isopoda	2	21	**23**	**0,24**
Larvae	189	79	**268**	**2,81**
Lepidoptera		2	**2**	**0,02**
Lumbricidae	10	6	**16**	**0,17**
Opilionida	282	235	**517**	**5,38**
Siphonaptera	12		**12**	**0,12**
Σ	**4951**	**4685**	**9636**	**100**

Table 2
Abundance of epigeic groups in the ecological farming on the locality Nitra-Dolná Malanta, in the years 2017 to 2020

Years	**2017**		**2018**		**2019**		**2020**	
Crop / Epigeic groups	***Vicia faba & Medicago sativa***	***Zea mays***	***Vicia faba & Medicago sativa***	***Zea mays***	***Vicia faba & Medicago sativa***	***Zea mays***	***Vicia faba & Medicago sativa***	***Zea mays***
Acarina	128	63	102	81	342	295	667	332
Araneida	57	45	51	70	91	161	290	221
Auchenorrhyncha	6	6						
Caelifera	26	1			43	28	108	27
Cicadoidea			17	21			1	1
Coleoptera	1082	642	182	137	507	1445	1262	396
Collembola					501	466	1770	1014
Dermaptera	30	24	45	31	19	18	34	8
Diplopoda	8	10	5	6	8	16	70	42
Diptera	4	2	7	2	31	48	153	55
Formicoidea	5	3		13	300	222	459	323
Heteroptera					19	21	119	33
Hymenoptera	4	5	6	5	15	20	18	9
Chilopoda	1	3			10	8	16	13
Isopoda				2	6	1	36	5
Lacertidae								
Larvae	3		52	6	76	56	152	64
Lepidoptera					2			
Lumbricidae		1		2	7	6	5	1
Opilionida	25	37	20	35	77	47	231	98
Siphonaptera					4	1	1	
Stylommatophora							1	
Thysanoptera							2	
Σ	**1379**	**842**	**487**	**411**	**2058**	**2859**	**5395**	**2642**

Table 3
Abundance of epigeic groups in the integrated farming on the locality Nitra-Dolná Malanta, in the years 2017 to 2020

Years	**2017**		**2018**		**2019**		**2020**	
crop / epigeic groups	***Vicia faba* & *Medicago sativa***	***Zea mays***	***Vicia faba* & *Medicago sativa***	***Zea mays***	***Vicia faba* & *Medicago sativa***	***Zea mays***	***Vicia faba* & *Medicago sativa***	***Zea mays***
Acarina	128	116	80	90	369	349	281	323
Araneida	43	68	33	55	132	93	156	96
Auchenorrhyncha	4							
Caelifera	2				60	9	33	17
Cicadoidea		2		5				
Coleoptera	214	351	242	191	461	306	196	276
Collembola	15				496	533	496	681
Dermaptera	30	35	56	35	6	7	28	20
Diplopoda	5	10	1	5	11	10	24	21
Diptera	2	5	6	7	36	28	37	15
Ensifera							13	
Formicoidea	9	23	7	4	329	289	295	185
Heteroptera	2				12	10	50	16
Hymenoptera	3	8	7	4	13	12	7	11
Chilopoda	2	1			14	10	10	10
Isopoda		5		3		7	2	6
Larvae		1	8		41	51	140	27
Lepidoptera								2
Lumbricidae	2			3	5		3	3
Opilionida	30	54	19	11	86	82	147	88
Siphonaptera	12							
Σ	**503**	**679**	**459**	**413**	**2071**	**1796**	**1918**	**1797**

The highly dominant populations in both management systems were the Coleoptera and Collembola groups. After evaluating the correlation dependencies, it can be stated that their occurrence in relation to most of the

present populations was inconclusive, which means that their occurrence was not influenced or. conditioned by the presence of other populations. Their highly evident correlation relationship was recorded within the integrated management to Auchenorrhyncha, Hymenoptera, Diptera, Larvae and Opilionida. The ecological management system showed a highly evident correlation between Coleoptera and Collembola with the populations of Araneida, Isopoda, Larvea, Lumbricidae, Diplopoda, Diptera, Caelifera, Formicoidea and Heteroptera. The ongoing correlation relationships within both management systems were also shared between the present communities by participating in trophic, climatic, topical and ecological factors.

The dependence of the occurrence of the present epigeic groups on the individual factors of the management system, the cultivated crop, temperature and precipitation were evaluated using the non-parametric Kruskal-Walli's test.

Based on the results, it can be stated that in no case was a high degree of evidence of $P < 0.01$ from the monitored factors found.

Within the integrated management system, the dependence of the occurrence of most communities on the factors of the management system, the cultivated crop, temperature and precipitation can be assessed as inconclusive ($P > 0.05$). The factors of the management system and climatic conditions of the environment in the form of temperatures and precipitation had a significant effect ($P = 0.05 – 0.01$) on the occurrence of the communities of Acarina, Araneida, Auchenorrhyncha Dermaptera, Lumbricidae and Opilionida. In the case of the influence of the crop, significant dependence ($P = 0.05 – 0.01$) was found in Caelifera, Collembola, Diptera, Formicoidea and Chilopoda.

Within the organic farming system, the dependence of the occurrence of most communities on the farming system, cultivated crops, temperature and precipitation can again be assessed as inconclusive ($P > 0.05$). The factors farming system, temperature and precipitation had a significant influence ($P = 0.05 – 0.01$) on the occurrence of communities of Acarina, Aphidoidea, Araneida, Auchenorrhyncha, Collembola, Diplopoda, Hymenoptera. A significant dependence ($P = 0.05 – 0.01$) of the influence of the cultivated crop on the occurrence of epigeic communities was found in Caelifera, Dermaptera and Lumbricidae.

In addition to the monitored factors, the occurrence of populations is also largely influenced by the application of pesticides. During the research period, no insecticides were applied that could contribute to the reduction of the epigeic component of animals in the soil. Within the integrated management system, herbicides and fungicides were applied, i.e. plant protection was targeted, the use of preparations permitted in integrated production was "economical". Within organic management, plant protection was based on preventive, indirect and mechanical principles, in wide row crops also with the use of physical methods. In both systems, soil cultivation was based only on plowing, with elements of minimization. It can be stated that the management system itself did not contribute to a significant increase in the number of employees. decrease in the epigeic groups present. Both systems are relatively close in essence and philosophy, i.e. they did not significantly affect the results obtained.

It can be stated that organic farming is more suitable in the conditions of the Zittau Uplands, because the absence of agrochemicals protects sensitive predatory arthropods, thereby increasing biodiversity in the soil. Synergy with crops such as Vicia faba and Medicago sativa naturally fix nitrogen, improve soil structure

and, in combination with organic management of Zea mays, mitigate the risk of erosion and degradation while maintaining ecosystem stability.

Discussion

In response to the intensification of agriculture, the concept of sustainable agriculture is emphasized, which aims to balance economic, environmental and social aspects and subsequently create a resilient agricultural system. The expansion of populations of epigeic groups represents a key aspect of biodiversity and the functioning of agroecosystems from the point of view of agricultural prosperity. Also based on our results, it can be stated that biodiversity loss currently represents a serious global problem, since most of the biodiversity is found in the soil (Porhajašová et al. 2015; Ivanič Porhajašová et al. 2018). Epigeic Arthropoda of agricultural landscapes are characterized by greater tolerance than epigeic arthropods of natural habitats, which is also confirmed by our findings. Dominant communities of Coleoptera, Collembola, Araneae and others were recorded, which affect the maintenance of natural balance, the cycle of elements in ecosystems such as carbon, nitrogen, sulfur and phosphorus (Bote and Romero 2012).

The obtained relatively numerous abundances reflect the processes taking place in these complex systems, of course, with the application of other factors, such as the cultivated crop and its associated agrotechnical management and local climatic fluctuations of the environment. Based on our results, it can be stated that in the event of a decrease in the species composition and abundance of epigeic groups, many ecosystem functions would be reduced, including biodiversity, which implies that biodiversity is a key resource in terms of ecosystem functioning (Wagg et al. 2014).

Maintaining the complex structure and diversity of these ecosystems represents a fundamental strategy for stabilizing populations within integrated communities (Rainio and Niemelä 2003).

It is likely that the above populations respond positively to the implemented agronomic practices, the present fauna, microclimatic conditions and trophic preferences of the habitat. In the above context, (Mhlanga et al. 2022) identify correlations between the above factors and the biodiversity of epigeic groups, which is a prerequisite for their further development or. changes. From the point of view of monitoring epigeic groups, Collembola, Coleloptera, Acarina almost always dominated, whose high abundance, according to Lenoir and Lennartsson (2010), positively affects the maintenance of the natural balance, the substance cycle of biogenic elements in ecosystems or agroecosystems. The dominant occurrence is also typical for the Formicoidea (Hymenoptera) population, the abundant occurrence of which is characteristic of epigeic communities with many functions, such as accelerating the decomposition of plant residues, aerating the soil, improving the structure and quality of the soil. Morris and Winter (1999) state that integrated management systems are not evaluated only by yields and profits, but mainly by ecological aspects and natural regulation in agroecosystems. Unlike conventional agriculture, sustainability is at its core, similar to organic farming. However, in contrast to organic farming, it still uses inorganic inputs, although to a lesser extent than conventional practice. Our results confirm biodiversity in favor of organic farming, where up to 16,073 individuals were collected, which greatly exceeds the integrated management system, where 9,636 individuals were obtained. Following the above Bhagat et al. (2024) argue that the integrated farming system mechanism offers various ecosystem services that make the farming system

environmentally friendly, sustainable and resilient to climate change, characterized by the systematic allocation of different agricultural components that work synergistically, making the system more productive, healthier, greener and more biodiverse.

The integrated farming system approach has gained wide recognition and acceptance in the agricultural community to promote sustainable development. The integration of natural resources and regulatory mechanisms into agricultural activities aims to minimize the use of external inputs, ensure the sustainable production of high-quality food and other products through sustainable ecological practices, and reduce the sources of current environmental pollution caused by agriculture (Fatima et al. 2023).

Currently, there is a need to protect soil to maintain productivity, achieve efficient agriculture and ensure the availability of water (Bardgett and van der Putten 2014). In this context, there has been an increased awareness of the importance of soil biota, which significantly contributes to the above-ground functioning of terrestrial ecosystems and their ability to withstand and respond to environmental changes (Simoni et al. 2018). Soil microarthropods play a key role in many fundamental processes, such as decomposition and cycling of nutrients and carbon, regulation of microflora and bioturbation (Lakshmi et al. 2020; Menta and Remelli 2020).

Soil functionality and the ecosystem service it provides largely depend on biological activity in it, therefore biodiversity reflects the ability of soil to provide ecosystem services

It can be stated that bioindication is a key tool for monitoring habitat quality and ecosystem dynamics under increasing anthropogenic pressure. Among model organisms, Coleoptera of the family Carabidae play a particularly important role, and one of the widely used functional indicators describing their community structure is their qualitative and quantitative representation (Szyszko-Podgórska 2025).

The summary results obtained of the collected epigeic groups indicate a mixed trend. The ecological management system had a clearly positive effect on the occurrence of epigeic groups, when 16,073 ex were collected, compared to the integrated 9,636 ex. The influence of the cultivated crop is also significant, where Vicia faba with Medicago sativa clearly confirmed a positive impact on the biodiversity of epigeic groups. The results show that the dominant populations of Coleoptera (Ecol. farm. 35.20%, Int. farm. 23.22%), Collembola (Ecol. farm. 23.31%, Int. farm. 23.02%), Acarina (Ecol. farm. 12.51%, Int. farm. 18.01%) and Formicoidae (Ecol. farm. 8.22%, Int. farm. 11.84%) were recorded in the occurrence. The mentioned differences in the abundance of epigeic groups were influenced primarily by the climatic conditions of the environment during the seasons and individual months, with individual taxa showing different seasonal dynamics related to the life cycle of the captured groups (Brygadyrenko 2015).

Conclusion for future biology

Research conducted between 2017 and 2020 confirmed that organic farming, compared to an integrated system, significantly contributes to higher species diversity and stability of epigeic macrofauna. The above findings point to the preferential behavior of epigeic arthropods within the compared farming systems, organic and integrated farming systems, within the cultivation of model crops Vicia faba with Medicago

sativa and Zea mays, in the conditions of the southwestern part of the Slovak Republic. The positive trend of the impact of organic farming on qualitative and quantitative indicators has been confirmed. Their presence in ecosystems remains irreplaceable, they represent a driving force of ecosystem functions, and their occurrence is clearly conditioned by the microclimatic conditions of the environment. It is necessary to support farming systems that are gentle in terms of the strategy for the protection of arthropoda in the agricultural landscape. The support of ecological, or rather integrated management systems is crucial for the preservation of biodiversity in agroecosystems, as these systems create optimal conditions for the occurrence of organisms and the implementation of their ecological, environmental and zoological functions.

In addition to the management system, the key factors influencing the structure of arthropod communities are also the type of crop, with dense stands providing better conditions than wide-row crops and their species composition serving as a sensitive bioindicator of soil quality and health in the Danube Uplands.

Based on the results, it is appropriate for practice to prioritize ecological practices, introduce crop rotation with forage crops and use bioindication through epigeic arthropods. For further research, it is proposed to focus on the long-term effects of climate extremes on the seasonal dynamics of communities, a detailed analysis of trophic networks and the economic valuation of ecosystem services.

Declarations

Conflict of interest:

The authors confirm that they have no conflict of interest.

Author Contribution

Authors' contribution: Both authors participated in the collection, analysis, processing of samples, and writing of the article. The authors approved the final version for publication and agreed to bear responsibility for the work. Data availability: The data for this paper are available from the authors.Conflict of interest: The authors confirm that they have no conflict of interest.

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