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Impact of arable farming management on the biodiversity of Carabidae (Coleoptera)



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ABSTRACT

The Carabidae (Coleoptera) are a useful tool for monitoring the effects of different types of control and therefore it is important to highlight about their role as possible ecological indicators. We studied the composition of carabids in ecological and integrated farming, in three different crops in southern Slovakia. The ground beetles were caught using pitfall traps during a period of three years, from 2018 to 2020. 7 801 adult carabids belonging to 26 species were collected and recorded altogether. The number of species varied from 11 to 15 between traps. The distribution and number of individuals were positively influenced by ecological management with the amount of 4784 individuals, compared to integrated management, where 3017 individuals were obtained. The influence of the crops was in the following order: *Triticum aestivum*, *Pisum sativum* and *Medicago sativa*. In both farming systems, representatives of the Carabidae family were almost the same species. The most abundant species of the pooled number was *Harpalus rufipes* (from 61.16 to 88.08%). *Brachinus crepitans* also dominated (from 5.98 to 16.47%). Other species were *Poecilus cupreus*, *Anchomenus dorsalis*, *Brachinus expulso*. The species identity index according to Jaccard when comparing both farming types for the observed period reached 60.00%. The average comparison of the identity of dominance for the observed period of ecological vs integrated management represents 90.39%. The Shannon-Weaver diversity index for ecological farming was 0.9957 and 1.0184 for integrated farming.

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1. Introduction

The protection of biodiversity and ecosystems is an important and key task in maintaining nature conservation. By stabilizing agricultural conditions, it can contribute to the protection of ecosystems. The occurrence of zoofauna is significantly influenced by the structure of vegetation in connection with various agrotechnical interventions and inputs into the soil (Ivanič Porhajašová et al., 2019). Sustainable agroecosystems must be biologically and ecologically balanced, technically manageable, economically efficient and socially acceptable. The aim should be to reach a com-

promise between environmental needs and economic efficiency (Ivanič Porhajašová et al., 2019; Černý et al., 2019).

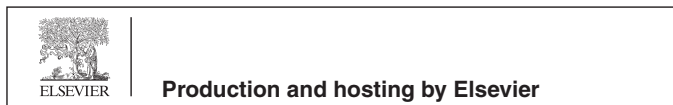
One of the main goals of sustainable agriculture is to reduce the risk of diseases and pests in crop systems, thus contributing to the protection of the environment. When applying agrochemicals in different types of farming (conventional, integrated and ecological), we must first understand the ecological processes taking place in these types of agroecosystems. Usually, the management of low-input agroecosystems is more environmentally friendly and sustainable compared to classical conventional types. Carabidae (Coleoptera) are a useful tool for monitoring the effects of different types of control (Legrand et al., 2011).

The structure of communities, with emphasis on the abundance and dominance of the Carabidae population within agroecosystems (wheat, potatoes, sugar beet, maize, alphaalpha, clover, etc.) are influenced by many synergistically acting factors such as pedological and hydrological conditions, microclimatic conditions specific to each stand, agrotechnical measures, presence of diseases and pests. Knowledge of trends in the communities of Carabidae agroecosystems is essential for assessing their condition and understanding the processes taking place in nature and in a chang-

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ing climate, which is manifested by frequent fluctuations in climatic events (Varvara and Šustek, 2011).

Highly specialized agroecosystems are exposed to excessive pressure during the entire growing season, e.g. in the form of an increased number of pests. In addition to anthropogenic factors, Carabidae are one of the main groups that significantly contribute to their regulation. Therefore, their roles and function in environmental services cannot be underestimated (Bianchi et al., 2006). The dominance structure of the Carabidae communities clearly reflects the conditions of the given habitat and their trophic structure changes depending on the state of the environment (Allegrò and Sciaky, 2003). Species of the Carabidae family act as effective bioindicators within agroecosystems, they are extremely adaptable, able to colonize almost all terrestrial habitats and geographical locations, with a stable taxonomy. They are useful organisms in agroecosystems due to their role as predators of cultivated plant pests, thereby reducing pest populations. An important role also belongs to the granivorous species that consume weed seeds, which can only be welcomed in agroecosystems. From the functioning view of the agroecosystems, dominant species play an important role, the spectrum of prey and the degree of trophic specialization also depend on the individual seasons (Ivanič Porhajašová et al., 2016; Pizzolotto et al., 2018).

In addition to the basic factors influencing agroecosystems, two important aspects are currently crucial. In the first place, there are negative anthropogenic factors acting on a local scale, whilst their effects are unpredictable. In addition, there is the phenomenon of global warming, the causes of which are related to human activities (Kirichenko-Babko et al., 2020). Whether species can survive in agroecosystems depends on many integrating factors, most of the research focuses on the requirements of adult individuals, and on abiotic and biotic factors influencing their survival, larval research is problematic due to the practicality of the research (Holland, 2002).

Agroecosystems include a myriad of species from the Carabidae family, which increase the biodiversity of agroecosystems with their presence, examples are presence of the abundant species *Harpalus rufipes*, *Poecilus cupreus*, *Pterostichus melanarius*, etc. They are so adapted to the anthropogenic influences that their occurrence in agroecosystems affected by human activity is highly dominant. Species richness and abundance of organisms increase with the intensity of habitat disturbances, but if the intensity exceeds certain limits, biodiversity decreases and leads to the overall imbalance of the community. Such disturbances are usually caused by management, which is a decisive factor influencing the populations present, including Carabidae (Ivanič Porhajašová, 2018).

The aim of the presented study is to evaluate and compare the impact of ecological and integrated arable farming systems on the species composition, spatial structure and biodiversity of Carabidae (Coleoptera) populations, within selected cultivated crops. Prediction of the richness of Carabidae populations and homeostasis of agroecosystems was also evaluated. Monitored species indicate topical and trophic environmental conditions and serve as part of complex mechanisms.

2. Materials and methods

2.1. Characteristics of the monitored area

Collection of biological material was carried out on an Experimental basis of the Slovak University of Agriculture in Nitra, on a location in Nitra – Dolná Malá (48°31'67"N, 18°15'00"E, 178 m a.s.l.). The area is located in the western part of the Žitava uplands, its triangular shape defines the Tribeč Mountains and Nitra and Žitava rivers. The site has a character of a plain, with a slight incli-

nation to the south. The area belongs to a warm, dry, lowland climate region. The average long-term (1961–1990) annual precipitation is 532.5 mm and the average annual temperature is 9.6 °C, the average temperature of the growing season is 16.4 °C (Linkeš et al., 1996; Špánik et al., 2002). The soil is of brown earth type, Cutani-Haplic luvisols subtype. The main soil unit is Stagni-Haplic luvisols on loess loams and polygenetic loams. The humus content of the humate-fulvate type is medium (1.95–2.28%) in the A1 horizon, the soil reaction is acidic to weak acidic (pH_{KCl} is 4.76–5.56) (Hanes et al., 1993).

Two management systems were implemented at the monitored site, ecological and integrated (Ecological farming = Ecol.farm., Integrated farming = Int.farm.), consisting of a group of rotating crops, suitable for local soil - climatic conditions, which are in mutual interactions, accompanied by flora and fauna with the desired positive benefits. The main goal of implementing sowing procedures is to replace chemical inputs with biological ones. Identical varieties of cultivated crops were used in both management systems, in accordance with good agrotechnical practices, the differences were only in the methods of regulation of harmful factors and in the application of industrial fertilizers within the integrated management system. The size of the monitored area of one crop was 50 m². The crops used, in which earth traps were exposed in both farming systems, were: *Medicago sativa*, *Triticum aestivum*, *Pisum sativum*. The density of the stand in the crops *Medicago sativa* was 450 pcs m⁻², *Triticum aestivum* 350 pcs m⁻² and *Pisum sativum* 90 pcs m⁻². The crop rotation in the organic farming system was as follows: *Vicia faba* with *Medicago sativa*, *Medicago sativa*, *Triticum aestivum*, *Pisum sativum*, *Zea mays* and *Hordeum vulgare*. And in the integrated system: *Triticum aestivum*, *Pisum sativum*, *Triticum aestivum*, *Zea mays*, *Hordeum vulgare* and *Medicago sativa* (Ivanič Porhajašová et al., 2019).

The differences between management were in the applied nutrition, fertilization and plant protection. The integrated management system used fertilization with manure with corn silage in a dose of 40 t ha⁻¹ and industrial fertilizers. Doses were determined by the balance method of the average yield of cultivated crops based on the nutrient content of the soil. Plant protection has been targeted, with the economical use of products authorized in integrated production. In the ecological system fertilization with manure with corn silage was used in a dose of 40 t ha⁻¹, and extra fertilization with permitted preparations in organic agricultural production as needed. Plant protection was based on preventive, indirect and mechanical principles, in broadleaf crops also using physical methods. Tillage in both systems was based on plowing, with elements of minimization.

2.2. Methods

The method of ground traps, which were exposed in the field during the vegetation period (April to October), was used. Collected biological material was gathered at monthly intervals, earth traps were then restored and the material was determined in an environment of the Institute of Plant and Environmental Studies (FAFR - SAU) (Hůrka, 1996) and statistically evaluated.

The specific weight of the soil is 2.6 t m⁻³, porosity 45–48%. Capillary soil absorption is 36–40%, maximum water capacity is 30–34%, wilting point 8–9% and water retention capacity is 27–30%. Humus content is 1.95–2.28%, pH is 4.76–5.56 (Hanes et al., 1993). Measurements of canopy density, plant distribution and soil chemical composition were not carried out during the research.

The ground trap method (Stašiov, 2015) consists of exposing 1 l glass bottles (with a hole diameter of 10 cm), sunk at a ground level, which were filled with a concentrated 4% formaldehyde fixing solution and covered with a metal sheet roof, which protects against precipitation and partially from small rodents. Within

two types of farming and three monitored crops, 2 earth traps were placed (at the beginning and in the middle of the stand), which means that a total of 12 earth traps were placed in each monitored year.

2.3. Data analysis

In the population of Carabidae species we evaluated the quantitative and qualitative indicators, abundance, dominance, calculation of species identity according to Jaccard (I_j), identity of dominance according to Renkonen (I_D), degree of diversity according to Shannon-Weaver (d), overall assessment of Carabidae population and their biodiversity (Losos et al., 1984).

Gathered results were statistically evaluated in the STATISTICA 10 application and due to the fact that the file did not have an even distribution, even after the use of transformations, the nonparametric Kruskal-Wallis test was used (Vrábelová and Markechová, 2001). Index calculations we made using Past 3.05 (Hammer, 2015).

The database of collection and environment variables was created in Microsoft SQL Server 2017 (Express Edition). Matrices for statistical calculations were made in Microsoft SQL Server Management Studio (SSMS).

3. Results

It was recorded during the period considered 7 801 adult carabids belonging to 26 different species were recorded. The number of species during individual years varied between the types of farming and cultivated crops from 11 to 15. The number of registered species tended to decrease, but increased for some species. The values of the total epigeic activity, their abundance and dom-

inance of ground beetles captured at individual sites during this research are shown in Tables 1, 2, 3.

Based on the abundance of the results presented in Tables 1, 2, 3 when comparing the implemented farming methods for the observed period for Carabidae biodiversity, the results are in favor of the ecological type of farming (4 784 individuals), compared to the integrated type (3 017 individuals). *Triticum aestivum* dominated in the assessment of the impact of the crop type (Ecol. Farm. – 2 086 individuals, Int. Farm. – 1 344 individuals), *Pisum sativum* (Ecol. Farm. – 1 656 individuals, Int. Farm. – 863 individuals), *Medicago sativa* (Ecol. farm. – 1 042 individuals, Int. farm. – 770 individuals). We found that the highest biodiversity of the monitored species was usually in crops with denser growth.

In terms of management and based on the number, 2019 can be evaluated as the most suitable year. 3 610 individuals were obtained (1 923 individuals from Ecol. Farm., 1 687 individuals from Int. Farm.). In 2020, 3 156 individuals were obtained (2 252 individuals from Ecol. Farm., 904 individuals from Int. Farm.). The lowest abundance was recorded in the first year of the study, when 1 035 individuals were collected (609 individuals from Ecol. Farm., 426 individuals from Int. Farm.). According to our findings, the integrated management system has a positive effect on the number of dominant groups, especially Coleoptera. Their population varies in abundance and species representation depending on the type of vegetation and soil conditions. The impact of crop harvesting, the application of insecticides and herbicides in integrated farming has had a significant negative effect on biodiversity, but organic fertilizers have contributed to increasing their abundance. 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.

In both farming systems over a three-year period representatives of the Carabidae family had almost mirror occurrence, and

Table 1
Abundance and dominance of species of the family Carabidae in the ecological and integrated farming, on the locality Nitra-Dolná Malanta, in the year 2018.

Ecological farming system – 2018 crop / species	<i>Medicago sativa</i>	<i>Triticum aestivum</i>	<i>Pisum sativum</i>	Σ	%
<i>Amara aenea</i> (De Geer, 1774)	4	15	10	29	4,76
<i>Amara familiaris</i> (Duftschmid, 1812)	12	8	3	23	3,77
<i>Bembidion lampros</i> (Herbst, 1784)	6	5	8	19	3,12
<i>Brachinus crepitans</i> (Linnaeus, 1758)	4	10	7	21	3,45
<i>Brachinus explodens</i> Duftschmid, 1812	6	8	7	21	3,45
<i>Calathus fuscipes</i> (Goeze, 1777)	8	7	9	24	3,94
<i>Carabus scheidleri</i> Panzer, 1799	3			3	0,49
<i>Harpalus affinis</i> (Schränk, 1781)		4	2	6	0,99
<i>Harpalus rufipes</i> (De Geer, 1774)	115	122	170	407	66,83
<i>Microlestes minutulus</i> (Goeze, 1777)	8	10	2	20	3,28
<i>Nebria brevicolis</i> (Fabricius, 1792)	4			4	0,66
<i>Poecilus cupreus</i> (Linnaeus, 1758)		11	15	26	4,27
<i>Zabrus tenebrioides</i> (Goeze, 1777)	1	5		6	0,99
Σ	171	205	233	609	100
Integrated farming system – 2018 crop / species	<i>Medicago sativa</i>	<i>Triticum aestivum</i>	<i>Pisum sativum</i>	Σ	%
<i>Amara familiaris</i> (Duftschmid, 1812)	4	2	3	9	2,11
<i>Anchomenus dorsalis</i> (Pont., 1763)	6	3	5	14	3,29
<i>Anisodactylus poeciloides</i> (Stephens, 1828)			4	4	0,94
<i>Bembidion lampros</i> (Herbst, 1784)		2	2	4	0,94
<i>Brachinus crepitans</i> (Linnaeus, 1758)	5	4	8	17	3,99
<i>Brachinus explodens</i> Duftschmid, 1812	5	3	6	14	3,28
<i>Calathus fuscipes</i> (Goeze, 1777)	5	3	4	12	2,82
<i>Carabus scheidleri</i> Panzer, 1799	3			3	0,71
<i>Drypta dentata</i> (Rossi, 1790)	2			2	0,47
<i>Harpalus affinis</i> (Schränk, 1781)	4	1	2	7	1,64
<i>Harpalus rufipes</i> (De Geer, 1774)	166	109	35	310	72,77
<i>Microlestes minutulus</i> (Goeze, 1777)	6	3	3	12	2,82
<i>Nebria brevicolis</i> (Fabricius, 1792)		2		2	0,47
<i>Poecilus cupreus</i> (Linnaeus, 1758)	4	6		10	2,34
<i>Zabrus tenebrioides</i> (Goeze, 1777)	3	2	1	6	1,41
Σ	213	140	73	426	100

Table 2

Abundance and dominance of species of the family Carabidae in the ecological and integrated farming, on the locality Nitra-Dolná Malanta, in the year 2019.

Ecological farming system – 2019					
crop / species	<i>Medicago sativa</i>	<i>Triticum aestivum</i>	<i>Pisum sativum</i>	Σ	%
<i>Amara bifrons</i> (Gyllenhal, 1810)	3	–	–	3	0,15
<i>Anchomenus dorsalis</i> (Pont., 1763)	20	12	54	86	4,47
<i>Anisodactylus poeciloides</i> (Steph., 1828)	11	7	5	23	1,19
<i>Brachinus crepitans</i> (Linnaeus, 1758)	34	7	19	60	3,12
<i>Brachinus explodens</i> Duftschmid, 1812	3	–	5	8	0,42
<i>Carabus scheidleri</i> Panzer, 1799	–	–	3	3	0,16
<i>Harpalus affinis</i> (Schrank, 1781)	–	–	4	4	0,21
<i>Harpalus rufipes</i> (De Geer, 1774)	133	663	832	1 628	84,66
<i>Nebria brevicolis</i> (Fabricius, 1792)	–	4	–	4	0,21
<i>Poecilus cupreus</i> (Linnaeus, 1758)	56	8	14	78	4,06
<i>Zabrus tenebrioides</i> (Goeze, 1777)	11	10	5	26	1,35
Σ	271	711	941	1 923	100
Integrated farming system – 2019					
crop / species	<i>Medicago sativa</i>	<i>Triticum aestivum</i>	<i>Pisum sativum</i>	Σ	%
<i>Anchomenus dorsalis</i> (Pont., 1763)	14	8	13	35	2,07
<i>Brachinus crepitans</i> (Linnaeus, 1758)	36	47	18	101	5,98
<i>Brachinus explodens</i> Duftschmid, 1812	–	–	5	5	0,29
<i>Calathus fuscipes</i> (Goeze, 1777)	–	–	3	3	0,18
<i>Carabus scheidleri</i> Panzer, 1799	–	–	5	5	0,29
<i>Drypta dentata</i> (Rossi, 1790)	–	2	–	2	0,12
<i>Harpalus rufipes</i> (De Geer, 1774)	352	780	354	1 486	88,08
<i>Harpalus signaticornis</i> (Duftschmid, 1812)	–	–	3	3	0,18
<i>Chlaenius nigricornis</i> (Fabricius, 1787)	–	7	–	7	0,44
<i>Microlestes minutulus</i> (Goeze, 1777)	2	–	–	2	0,12
<i>Poecilus cupreus</i> (Linnaeus, 1758)	10	12	8	30	1,78
<i>Zabrus tenebrioides</i> (Goeze, 1777)	3	5	–	8	0,47
Σ	417	861	409	1 687	100

Table 3

Abundance and dominance of species of the family Carabidae in the ecological and integrated farming, on the locality Nitra-Dolná Malanta, in the year 2020.

Ecological farming system – 2020					
crop / species	<i>Medicago sativa</i>	<i>Triticum aestivum</i>	<i>Pisum sativum</i>	Σ	%
<i>Anchomenus dorsalis</i> (Pont., 1763)	25	47	6	78	3,46
<i>Anisodactylus poeciloides</i> (Steph., 1828)	81	–	9	90	3,99
<i>Brachinus crepitans</i> (Linnaeus, 1758)	156	195	20	371	16,47
<i>Brachinus explodens</i> Duftschmid, 1812	39	–	22	61	2,71
<i>Calosoma auro-punctatum</i> (Herbst, 1784)	2	–	2	4	0,18
<i>Carabus scheidleri</i> Panzer, 1799	–	3	–	3	0,15
<i>Dolichus halensis</i> (Schaller, 1783)	4	3	–	7	0,31
<i>Harpalus affinis</i> (Schrank, 1781)	24	11	–	35	1,55
<i>Harpalus rufipes</i> (De Geer, 1774)	186	781	410	1 377	61,16
<i>Microlestes minutulus</i> (Goeze, 1777)	7	–	3	10	0,44
<i>Poecilus versicolor</i> (Sturm, 1824)	–	9	–	9	0,39
<i>Poecilus cupreus</i> (Linnaeus, 1758)	72	121	9	202	8,97
<i>Tachyta nana</i> (Gyllenhal, 1810)	–	–	1	1	0,04
<i>Zabrus tenebrioides</i> (Goeze, 1777)	4	–	–	4	0,18
Σ	600	1 170	482	2 252	100,00
Integrated farming system – 2020					
crop / species	<i>Medicago sativa</i>	<i>Triticum aestivum</i>	<i>Pisum sativum</i>	Σ	%
<i>Amara aulica</i> (Panzer, 1796)	–	2	–	2	0,22
<i>Amara bifrons</i> (Gyllenhal, 1810)	5	12	–	17	1,88
<i>Anthraxus consputus</i> Duftschmid, 1812	–	1	–	1	0,11
<i>Anchomenus dorsalis</i> (Pont., 1763)	10	15	42	67	7,44
<i>Anisodactylus poeciloides</i> (Steph., 1828)	19	–	–	19	2,11
<i>Brachinus crepitans</i> (Linnaeus, 1758)	19	44	26	89	9,84
<i>Brachinus explodens</i> Duftschmid, 1812	2	10	35	47	5,19
<i>Carabus hortensis</i> (Linnaeus, 1758)	–	–	6	6	0,66
<i>Carabus scheidleri</i> Panzer, 1799	–	5	–	5	0,55
<i>Dolichus halensis</i> (Schaller, 1783)	–	–	2	2	0,22
<i>Harpalus affinis</i> (Schrank, 1781)	6	6	13	25	2,76
<i>Harpalus rufipes</i> (De Geer, 1774)	62	288	249	599	66,26
<i>Poecilus cupreus</i> (Linnaeus, 1758)	17	–	8	25	2,76
Σ	140	383	381	904	100,00

their presence was relatively stable. The most abundant of the species was the regularly present, autodominant, farmland, eurytopic *Harpalus rufipes*, an expansive representative of the farmland fauna, its eudominant occurrence was recorded each year, within

all variants, in 2018 (Ecol. Farm. – 66.83%; Int. Farm. – 72.77%), in 2019 (Ecol. Farm. – 84.66%; Int. Farm. – 88.08%), and in the year 2020 (Ecol. Farm. – 61.16%; Int. Farm. – 66.26%). The results show the suitability of an integrated management system, where this

species always recorded a higher dominance. None of the other species was as prominent as *Harpalus rufipes*. In relation to climatic factors and the year, its occurrence recorded a high level of significance. This macropterous, highly expansive species confirmed the suitability of the environmental conditions, which are suitable for moist to semi-moist, slightly shaded habitats of fields and meadows. Its presence in agroecosystems in relation to other species confirmed insignificance. Based on our findings, the average dominance of *Harpalus rufipes* in organic farming was 70.88% and in integrated 75.70%.

The open land species *Brachinus crepitans* was also dominant. Its dominant occurrence was limited to 2019 within the integrated management system (5.98%) and to 2020 in the ecological system (16.47%) and the integrated management (9.84%). The impact of the year, temperature, precipitation and type of farming was not significant. Its occurrence is not affected by the presence of another species. It is a species characterized by a strong link to the environment.

In 2020, *Poecilus cupreus* species also showed a dominance in ecological management (8.97%), which together with *Harpalus rufipes* act as evidence of adaptation to anthropogenic influences, as their occurrence is higher in agroecosystems affected by human activity, with potential to reduce the populations Limacidae and Agriolimacidae, both adults and their eggs, but also the elimination of an increasing number of aphids. *Anchomenus dorsalis* (7.44%) and *Brachinus explodens* were also dominant in the integrated system (5.19%).

Within the range of values from 2 to 5%, i.e. the species *Anisodactylus poeciloides*, *Anchomenus dorsalis*, *Calathus fuscipes*, *Microlestes minutulus*, *Poecilus cupreus* confirmed their subdominant occurrence in both farming systems. The species spectrum in ecological management was also supplemented by subdominance of *Amara aenea*, *Amara bifrons*, *Bembidion lampros* - synonym of *Metalina lampros*, *Zabrus tenebrioides*, *Amara familiaris*, *Brachinus explodens*, *Harpalus affinis* also had a subdominant occurrence in the integrated system.

Recent occurrence in the ecological system has been reported in the species *Anisodactylus poeciloides* and *Harpalus affinis*. Within the integrated system, these were *Harpalus affinis*, *Poecilus cupreus* and *Zabrus tenebrioides*.

Minor occurrence, i.e. subprecedent occurrence was recorded in e.g. *Drypta dentata*, *Amara bifrons*, *Nebria brevicolis*, *Chlaenius nigricornis*, *Carabus scheidleri*, *Tachyta nana*.

The indices of specific identity according to Jaccard were also calculated, expressing the concordance of the species composition of the zoocenoses compared to each other. Within the evaluation of individual years, types of management systems and crops, in 2018 the value was 75.00%, in 2019 their value represented 44.00% and in 2020 it was 50.00%. The total value with the comparison of both types of management for the observed period reached the value of 60.00%.

Calculated values of dominance identity according to Renkonen, when comparing ecological vs integrated management for 2018 were 87.53%, in 2019 they were 92.55% and in 2020 they were 83.96%. The average comparison summary of the identity of dominance for the observed period of ecological vs integrated management represents 90.39%.

No significant differences were observed when comparing values of diversity index according to Shannon-Weaver. The value for the ecological type was 0.9957 and for the integrated 1.0184, which is realistic when comparing farming in both types of agroecosystems.

In terms of the ecological demands of individual species, the communities consisted mainly of species typical to lowland farmland ecosystems, where these species occur mainly in close coexistence of their reproductive cycle, the presence of the

relevant crop and management. Subsequently, their occurrence is also influenced by local soil and moisture conditions, but it can be stated that the presence of the monitored Carabidae family is a reflection of relatively complex relationships taking place in agroecosystems.

It is typical for species of the Carabidae family that they either have fully developed wings, resp. wings are completely or partially reduced. This is associated with restriction or complete loss of movement, which plays an important role in the migration of individuals to the environment. 85% of macropterous and only 15% of brachypteran species were present in the monitored group, which is evidence of a relatively large migration of individuals.

When evaluating ecological valence and their association with the environment, 19 species can be classified as eurytopic, 4 for xerophilic, 3 for hygrophilic and 1 species acts as a halobiont.

Based on a graphical comparison (Fig. 1 A,B,C) of ecological vs integrated farming system, using the f-test shows that the ecological type of farming recorded a higher number of Carabidae individuals on the monitored crops, with the exception of *Harpalus rufipes* on *Medica sativa*. It can be stated that on the basis of the f-test, which shows zero hypothesis results, the ecological impact of farming within the monitored crops was significant.

Based on the analysis of variance (Fig. 2), which expresses a graphical comparison of both types of farming, the results were in favor of the ecological type, which represents a higher abundance in all crops.

4. Discussion

Based on the results obtained, it can be stated that loss of biodiversity has now become a global problem. Much of the biodiversity of terrestrial ecosystems is "hidden" in the soil. Using an experimental system to change soil levels of biodiversity and community composition has shown that declining numbers of soil organisms cause a reduction in multiple ecosystem functions, including biodiversity, suggesting that biodiversity is a key resource for ecosystem functioning (Wagg et al., 2014). Carabids are efficient bioindicators in terrestrial ecosystems because of their adaptability and ability to colonize almost all terrestrial habitats and geographical locations, their quick response to environmental changes, the ease in collecting them, and their relatively stable taxonomy. They are also useful organisms in agroecosystems due to their role as predators of crop insect pests and slugs, thus reducing their populations (Rossi et al., 2019). Preserving high biodiversity in agroecosystems makes agricultural production more sustainable and economically viable. Which is also confirmed by the results we found, when during the monitored period 7 801 adult carabids belonging to 26 species were recorded. Intensified production, increased use of pesticides and fertilizers are under constant criticism. Agriculture is looking for other biological and agrotechnical methods to meet the requirements of global food production (Feledyn-Szewczyk et al., 2016). Agricultural ecosystems are exposed to heavy burden during the year, however the composition of epigeic groups shows significant stability and homogeneity. The species richness of agroecosystems almost always exceeds the species richness of natural, resp. semi-natural landscape (Ivanič Porhajašová et al., 2018).

Carabidae, with their abundance and functionality, represent a dominant group involved in reducing the number of pests in agroecosystems (Boháč and Jahnová, 2015). Carabidae are a taxonomically stable and well studied family, because of their specific life strategies and ecological preferences in terms of humidity, temperature, shading, soil and vegetation (Vician et al., 2018; Litavský et al., 2021). They are efficient bioindicators in terrestrial ecosystems because of their adaptability and ability to colonize almost

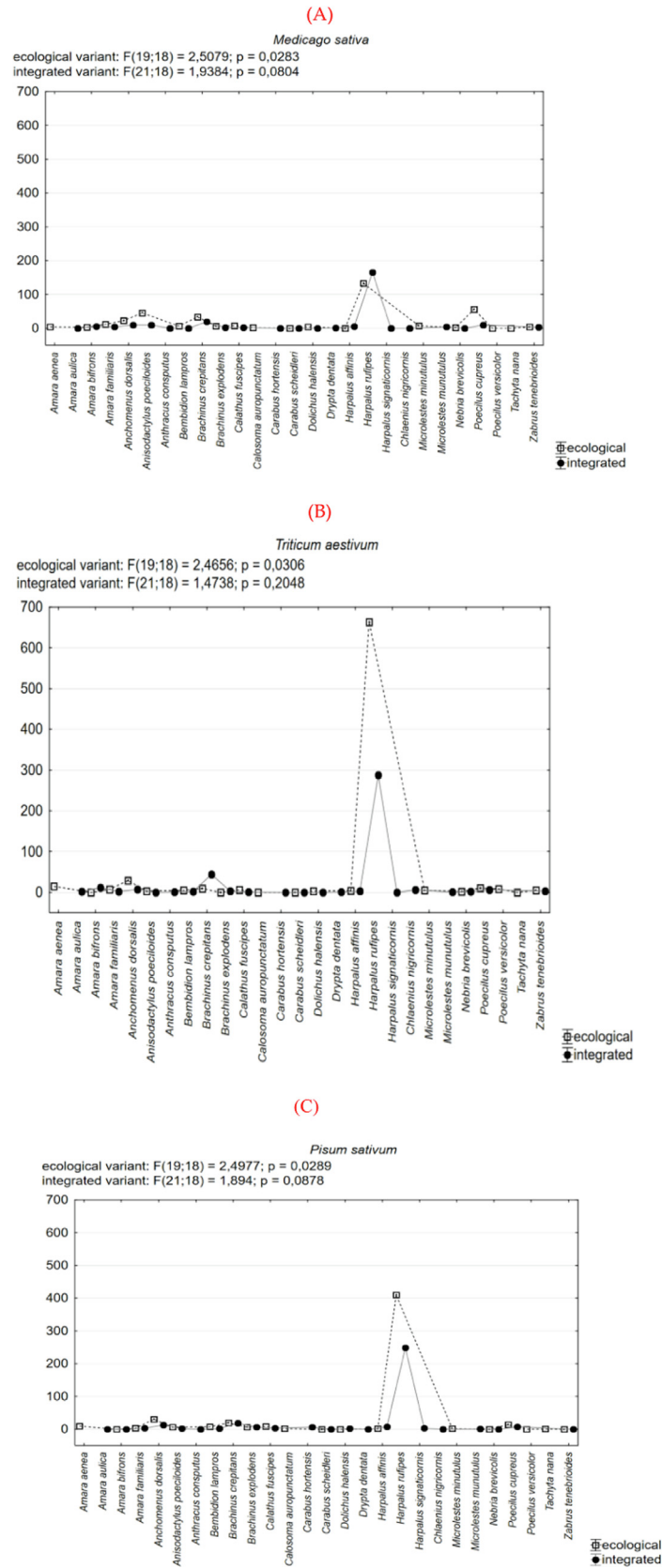


Fig. 1. Comparison of ecological and integrated farming system using f-test on *Medicago sativa* (A), *Triticum aestivum* (B), *Pisum sativum* (C).

all terrestrial habitats and geographical locations, their quick response to environmental changes, the ease of collecting them, and their relatively stable taxonomy (Bennewicz and Barczak,

2020). The total number of Carabidae in both types of farming is also 7 801 individuals, of which 4 784 were in organic and 3 017 in integrated farming.

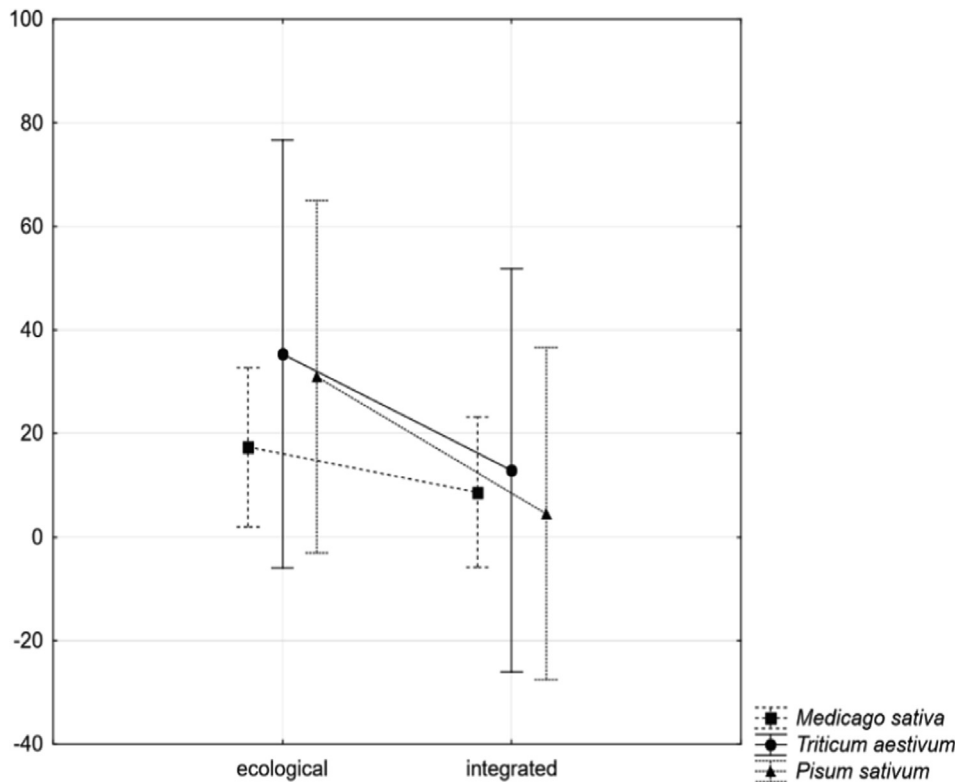


Fig. 2. Analysis of variance of ecological and integrated types of farming, within individual crops. Explanations: the x-axis shows the species representation and the y-axis indicates the number of species.

The Carabidae, Staphylinidae, Coccinellidae families are natural enemies of aphids and play an important role in agroecosystems. Predatory beetles play their role primarily in ecologically grown crops (Feledyn-Szewczyk et al., 2016). By their presence, Carabidae species reflect the current topical, environmental and trophic conditions of agroecosystems, at the same time they act as part of the transport mechanisms of substances and energy and react sensitively to changes in agroecosystems and are a proven model group. Thanks to their biodiversity, they are suitable for detecting the effects of natural and anthropogenic disturbances (Ivanič Porhajašová et al., 2016). There are seventy-nine species of ground beetles recorded at the study sites of Slovakia according to authors (Litavský et al., 2021; Majzlan and Litavský, 2017).

Ecological management systems are characterized by a larger floristic area and consequently faunistic biodiversity, compared to integrated systems, which provide suitable conditions especially for shade-loving species. However, it can not be excluded that if integrated systems are managed properly, they can increase biodiversity (Bavec and Bavec, 2015).

The level of biodiversity of agroecosystems depends on vegetation cover, sowing process, management intensity, and also on factors that contributed to the influence of biodiversity within the monitored types of management, which is confirmed by our findings (Ivask et al., 2008). Most Carabidae species belong to the group of predatory generalists or polyphagous, but are also narrow within this family specialists who prefer specific prey or plant food (Ivanič Porhajašová et al., 2016). The distribution of present species is applied by the temperature, soil type, humidity, trophic relationships, sufficient food, mutual competition and all of it varies depending on the nature of the biotope. In addition to natural factors, an anthropogenic factor is also applied in agroecosystems, e.g. in the form of tillage, crop structure, cultivated crop, and applied inputs (Varvara et al., 2012). It is necessary to highlight the rich network of their trophic relationships and ties, which is the main

mechanism that ensures the balance of monitored agroecosystems. In terms of the ecological demands of individual species, their communities consisted mainly of species typical of lowland field ecosystems, where these species occur mainly in close coincidence of their reproductive cycle, the presence of the relevant crops and management. Subsequently, their presence is also influenced by local soil and moisture conditions, but it can be stated that the presence of the monitored Carabidae family is a reflection of relatively complex ongoing relationships in agroecosystems. It can be stated that Carabidae species are effective bioindicators within agroecosystems, they are adaptable, able to colonize all terrestrial habitats and at the same time they are useful organisms in agroecosystems, also due to their role as predators of cultivated plant pests, thus reducing their populations. An important role also belongs to the other granivorous, consuming weed seeds. They perform ecosystem services in the form of pest control and weed seed destruction (Ivanič Porhajašová, 2017).

Harpalus rufipes was the eudominant species in all variants. It can migrate both by ground and by air, enabling large aggregations to form in areas with optimal hydrothermal regime and high aggregations of food (plants and animals) (Brygadyrenko and Reshetniak, 2014). *Harpalus rufipes* is a trans-palaearctic, polyzonal, habitat generalist, and is usually the most numerous ground beetle species in agricultural ecosystems and forest plantations (Reshetniak et al., 2017). Due to the complex of adaptations and migratory abilities, it achieves the mentioned high values of abundance. It can be found in an extremely wide range of terrestrial ecosystems, with a particularly high population inhabiting an anthropogenically transformed environment. It is distinctive by the consumption of a wide range of foods, it is distributed in Central and Eastern Europe and was introduced to North America. Under the influence of various factors, this species of ground beetles can form aggregations up to tens and hundreds of individuals per square meter (Reshetniak, 2015; Birthisel et al., 2014). The

abundance of carabids was not significantly different under the two management systems. *Harpalus rufipes* and *Poecilus cupreus* were the most captured species. These results coincide with the data collected across Europe by other authors (Rossi et al., 2019).

Despite the disruptions of agricultural operations, the populations of carabids in arable crops have been found to be relatively constant. Pitfall trapping conducted from 1973 to 1981 in an arable field showed that the peak capture of *H. rufipes*, *H. aeneus*, *P. madidus*, *P. melanarius* and *N. brevicollis* remained relatively constant (Luff, 1982).

The majority of species inhabiting agricultural fields have greater dispersal ability, often by flight, are generally eurytopic, and are thus better adapted to living in unstable or temporary habitats. Species typical to arable fields are included in this group (e.g. from the *Amara*, *Pterostichus*, *Agonum* genera and also include species such as *Loricera pilicornis*, *Nebria brevicollis*, *Harpalus rufipes*) (Den Boer et al., 1987).

Agricultural practices such as the application of insecticides that remove prey, or habitat destruction, may have a sufficient impact to create unfavourable conditions for Carabidae, but these impacts may not be long lasting, due to reinvasion or relatively quick dispersal distribution. In recent years the declining value of arable crops, combined with pressure from environmental organisations and consumer groups, has driven farmers to look more closely at integrated crop management and integrated farming techniques. Lower insecticide usage and choice of selective insecticides, non-inversion tillage and augmenting non-crop habitat are likely to have the greatest impact on Carabidae (Ivanič Porhajašová, 2016).

Carabids have frequently been used to compare biodiversity in ecological and integrated management systems. Much evidence shows how agroecological practices can mean that ecological systems have less of an impact on carabid habitats than integrated ones. Some soil management practices such as reduced tillage or cover cropping can considerably influence the effects of organic management on carabid biodiversity (Rossi et al., 2019; Legrand et al., 2011). The Shannon-Weaver index, which we consider sufficient, was used to evaluate species diversity. However, species diversity can also be assessed using the Hill index (Chao et al., 2014). The susceptibility of some carabid species to insecticides, herbicide use through modification of plant cover and microclimate, and soil cultivation, has ensured that they are also frequently monitored in farming system studies. Studies have frequently found that differences between farming systems are relatively small compared to results between multiple years, fields and farms systems. This is because carabids exhibit considerable natural temporal and spatial variation (Holland, 2002). Some soil management practices such as reduced tillage or cover cropping can considerably influence the effects of organic management on carabid biodiversity. Normally, low-input practices make organic systems overall more eco-friendly and sustainable than conventional ones, although sustainability is important, not only from a short-term perspective, but also taking into account a long timeline. Carabids can be a useful tool to monitor the effects of different management systems in long-term trials (Legrand et al., 2011; Langraf et al., 2017). Ground beetles living in anthropogenic environments have a wider environmental tolerance than species in natural habitats. They achieve high local density due to anthropogenic activities such as agriculture, urbanization or forestry (Ivanič Porhajašová, 2016; Macák et al., 2020; Langraf et al., 2020).

5. Conclusion

The occurrence and abundance of beetles of the Carabidae family were positively influenced by the ecological type of farming

compared to the integrated one. The impact of the crop was significant, the abundance of beetles decreased depending on the crop as follows: *Triticum aestivum*, *Pisum sativum*, *Medicago sativa*. In addition to the above factors, the abundance of beetles is also influenced by the microclimatic conditions of the studied site and by the intraspecies and interspecies relationships. These are also characteristic of agroecosystem homeostasis. The self-dominance was confirmed by the strongly expansive, field, eurytopic, macropterous beetle species *Harpalus rufipes*, which can be considered as evidence of beetles adaptation to anthropogenic influences. This beetle is very common in agroecosystems affected by human activities.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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