Bulgarian Journal of Agricultural Science, 29 (No 1) 2023, 117–123

The dispersion of Coleoptera in ecological and conventional farming conditions

Vladimír Langraf [1*], Kornélia Petrovičová[2*] and Janka Schlarmannová[1]

[1] *Constantine the Philosopher University in Nitra, Department of Zoology and Anthropology, 94901 Nitra, Slovakia*
[2] *University of Agriculture in Nitra, Institute of Plant and Environmental Sciences, 94901 Nitra, Slovakia*
[*]*Corresponding author:* langrafvladimir@gmail.com, kornelia.petrovicova@gmail.com

Abstract

Langraf, V., Petrovičová, K. & Schlarmannová, J. (2023). The dispersion of Coleoptera in ecological and conventional farming conditions. *Bulg. J. Agric. Sci., 29 (1)*, 117–123

Changes in the structures of abundance of Coleoptera reflect changes in the ecological status of their habitats. The aim of this research was to assess the dispersion of individual Coleoptera in ecological and conventional farming conditions and the influence of environmental variables (pH soil, potassium, phosphorus and nitrogen) on the abundance of Coleoptera. Between the years 2018 to 2021, we collected 18 207 individual Coleoptera in ecological farming conditions (*Pisum sativum*, *Grass mixture*, *Triticum spelta* and T. *aestivum*) and conventional farming conditions (*Brassica napus*, *Hordeum vulgare* and *Zea mays*). We used the pitfall trap method for sampling. The dispersion of individual Coleoptera was highest around Zea mays crops (integrated farming) and Grass mixture (ecological farming). We confirmed an increasing number of individuals where there were increasing values of potassium, phosphorus and nitrogen in ecological farming. In contrast, we found a declining number of individuals with declining values of potassium, phosphorus and nitrogen in conventional farming. Our results suggest that agricultural intensification affects the abundance of Coleoptera in ecological and conventional farming conditions. An abundance of Coleoptera and soil structure stability are important for the production of biomass and also affect crop yields.

Keywords: Agrosystems; central Europe; crop; diversity; soil management

Introduction

Ecological farming is one of the most intensively contested topics in recent times, it is being proposed as an alternative way of farming to achieve sustainability in agricultural production. It represents a modern system of management which is receiving more attention all over the world. In comparison to conventional methods of farming, ecological farming has a more positive effect on the protection of natural features, landscapes and biodiversity (Kalivoda et al. 2010; Ubrežiová et al., 2012; Hazarika et al., 2013). Biodiversity of flora and fauna is greater in areas of arable land, permanent grassland and surrounding habitats. Ecological farming avoids synthetic fertilizers, pesticides, growth regulators and livestock feed additives. An ecological farming system depends on the use of crop residues, green manure, animal manure, off-farm organic waste, crop rotation incorporating legumes and biological pest control to maintain soil productivity. The land is characterized by higher microbial activity, higher organic matter content and there is not a risk of contamination to water resources by pesticides (Scialabba & Hattam, 2002; Scialabba & Müller-Lindenlauf 2010; Wollni & Andersson, 2014; Faly et al., 2017).

Conventional farming relies on chemical products to fight weeds or pests. In conventional agriculture, with the use of chemical fertilizers, productivity is faster and takes less time. That is exactly why farmers are tempted to use them, but the toxic elements used in the manufacturing of fertilizers and pesticides ultimately accumulates in the crops themslves and may lead to severe ailments to the consumer. These chemicals are also a heavy load on the environment as they create a residual effect in the soil and air. Modern techniques have revolutionized the agricultural sector; they are also replacing human resources with machines and chemicals and ultimately creating an unemployment problem (Mijangos & Garbisu, 2010; Briones & Schmidt, 2017; Simão et al., 2015).

Soil is a complex and important component of the environment, it undergoes different processes during organic and inorganic phases. Epigeic and soil biodiversity is an important indicator of soil health. The dominant proportion of the epigeic component is Coleoptera, which plays an irreplaceable role in the decomposition of organic matter, in the cycle of biogenic elements such as carbon, nitrogen, sulfur and phosphorus, and in the transformation and degradation of waste and toxic substances. In general, it directly influences the main property of soil, which is soil fertility (Fazekašová & Bobuľovská, 2012; Zazharskyi et al., 2019). Coleoptera are an important group of beneficial insects contributing to restricting pest activity. Their prey includes insects feeding on both the aerial and the subterranean parts of the plants (Kalushkov et al., 2009; Symondson et al., 2002). Diversity of Coleoptera cenoses contributes to enhanced stability and productivity ecosystems, the greater amount found in the soil, the better the soil fertility (Wall et al., 2015; Langraf et al., 2021). The abundance of coeloptera is declining significantly. This is as a result of a number of causes such as intensification of agricultural production, use of pesticides, ploughing field boundaries and the cultivation of monocultures over large areas. Pesticides have a negative effect on Coleoptera cenoses. Many biochemical reactions in this environment are dependent on the presence of soil enzymes (Porhajašová et al., 2018; Dobrovodská et al. 2019; Kozak et al., 2020; González et al., 2021).

The objective of this study was tracking the dispersion of individual Coleoptera in ecological and conventional farming conditions. It was also intended to discover the influence of environmental variables (soil pH and levels of potassium, phosphorus and nitrogen) on individual Coleoptera.

Materials and Methods

Research took place between the years 2018-2020. Over this period of time, we collected individual Coleoptera from seven types of agricultural crops. Coleoptera were harvested in crops with ecological (*Pisum sativum*, *Grass mixture*, *Triticum spelta* and *Triticum aestivum*) and conventional farming (*Brassica napus*, *Hordeum vulgare* and *Zea mays*) methods. These types of agricultural crops were examined throughout each year, as the position of crops in the fields changed every year. In winter-planted crops (*Brassica napus*, *Pisum sativum*, *Triticum aestivum* and *T. spelta*), Coleoptera were collected from November to July. In the spring-planted crop (*Hordeum vulgare* and *Zea mays*), Coleoptera were trapped from April to October. In the *grass mixture*, Coleoptera were collected all year round. We used five pitfall traps (750 mL) for each site, which were placed in a line at distances of 10 m. A formaldehyde solution (4%) for material fixation during regular collection at two-week intervals was used. Pitfall traps were always in the fields and were collected at two-week intervals. The nomenclature of epigeic arthropods was established according to the work of Schierwater & DeSalle (2021). The study area was located in the Podunajská pahorkatina - the Danubian upland geomorphological unit (in the south-western part of Slovakia) in the cadastral territory of Nitra. The altitude of the monitored area was approximately 130 m above sea level with a brown soil type. The study area is considered a warm arid climate with mild winters. The mean temperature ranges during each month were as follows: January −5–5°C, February −3–6°C, March 0–12°C, April 10–20°C, May 15–22°C, June 18–27°C, July 22–29°C, August 20–29°C, September 15–23°C, October 8–15°C, November −3–7°C, December −5–5°C. The average precipitation for each month was as follows: January 30 mm, February 26 mm, March 35 mm, April 12 mm, May 65 mm, June 77 mm, July 41 mm, August 57 mm, September 64 mm, October 54 mm, November 40 mm and December 55 mm.

Tillage was based on annual tillage ploughing, incorporating crop residues and weeds into the soil. The soil was ploughed three times and turned. Pre-sowing preparation and sowing were combined. Machines with driven working tools were used in conjunction with a seed drill. When sowing, it was possible to use seed coulters with an obtuse angle of penetration into the soil.

The FORCE insecticide (Syngenta, Basel, Switzerland), a granular insecticide intended for soil application to control soil pests, was applied to the crops in conventional farming (*Brassica napus*, *Hordeum vulgare*, *Zea mays*). Insects were killed through respiratory and tactile poison ingestion. The preparation had a fast effect and a strong residual (repellent) action against a wide range of soil pests from the orders of Coleoptera, Aranea, and Hymenoptera. The applied dose was administered uniformly at a concentration of 12–15 kg per ha each year for the duration of the research. Solinure FX fertilizer (Medilco Hellas S.A., Athens, Greece) containing chlorides and urea, was applied to the crops and was intended for field fertility. Due to its acidifying effect, it contributed to lowering the soil pH.

At each pitfall trap location, we removed stones and fallen leaves from crops and sampled the soil to a depth of 15 cm for analysis. Five samples (one from each of the five sites) were taken from each field every two weeks over the three years of the study period. Subsequently, environmental variables (N, P, K, pH and moisture) were analysed using a soil moisture meter (Rapitest 3 1835, Luster Leaf, Illinois, IL, USA) and a pH meter (Dexxer PH-03, Luboň, Poland). We thoroughly wetted the broken-up soil with water (ideally distilled or deionised water) to make a muddy consistency. We wiped the meter probe clean with a tissue or paper towel and inserted it into the soil up to the probe base (7–10 cm). We waited one minute and wrote down the value. We converted the measured values into units of mg/kg. The average values of environmental variables of crops between the years 2018–2020 are shown in Table 1.

Table 1. Average values of environmental variables between the years 2018–2020 for the studied crops

Crops	pH	Potassium	Phosphorus	Nitrogen
Grass mixture	6.908	10.425	1.033	10.917
Pisum sativum	6.914	10.286	0.823	10.991
Hordeum vulgare	6.856	17.991	1.444	18.049
Zea mays	6.951	14.121	1.518	14.727
Triticum aestivum	7.035	11.923	1.154	11.899
Brassica napus	7.072	17.141	1.434	17.931
Triticum spelta	6.986	10.984	0.886	11.071

Database Quality

The data obtained was saved in the Microsoft SQL Server 2017 database program (Express Edition) (Microsoft Corporation, Washington, United States), consisting of frequency tables for collections and measured environmental variables (pH, soil moisture, potassium, phosphorus, nitrogen and soil temperature (°C)). The database also contained code tables for study sites and their variables (crops, habitat, locality name, cadastral area, altitude and coordinates of localities). Matrices for statistical calculations using Microsoft SQL Server Management (SSMS, 2017) were programmed.

Statistical Analyses

Multivariate analysis (detrended correspondence analysis, DCA) was employed to determine the dispersion and number of individual Coleoptera between the crops in the Canoco5 program (Ter Braak & Šmilauer, 2012). The number of individual Coleoptera at each crop was used as a matrix.

Analysis in the statistical program Statistica Cz. Ver. 7.0 (StatSoft, Inc., 2004) focused on linear regression, expressing the relationship between the number of beetles and the values of potassium, phosphorus, nitrogen and pH.

Results and Discussion

Over the three year research period, we found a total of 18,207 individual Coleoptera. The highest number of individuals was recorded in the *Zea mays* (7519 (41.3%)), *Grass mixture* (4050 (22.24%)) and *Hordeum vulgare* crops (3911 (21.48%)). The lowest number of individuals was in the *Triticum spelta* (573 (3.15%)), *Triticum aestivum* (662 (3.64%)), *Pisum sativum* (722 (3.97%)), *Brassica napus* crops (770 (4.23%)).

Multivariate analysis of Coleoptera abundance over the study period was determined using detrended correspondence analysis (DCA, SD (length of gradient) = 4.13 on the first ordination axis). We observed dispersion of Coleoptera in crops with ecological (*Pisum sativum, Grass mixture, Triticum spelta* and *Triticum aestivum*) and conventional farming (*Brassica napus, Hordeum vulgare* and *Zea mays*). The values of the explained data variability of individual Coleoptera were 44.9% on the first ordination axis and 57.2% on the second cumulative ordination axis. The ordination graph (biplot) shows that the type of dispersion of individual Coleoptera is clustered. The predominance of individual Coleoptera is ordered around *Zea mays* (integrated farming) and *Grass mixture* crops (ecological farming).

The structure, scale, management and use of land affects the composition of fields, which may be a source of weeds, pests and disease. Also plant diversity is an important factor for the abundance of Coleoptera beneficial for agriculture (Haddaway et al., 2016). The beneficial effects of botanical diversity, particularly wild flowers, has an effect on Coleoptera abundance. Their activities accelerated the decomposition of plant residues, aerated the soil and improved soil structure and quality (Diehl et al., 2012; 2013). Bote & Romero (2012) and Attwood et al. (2008) observed a decline in arthropods with increasing land use. Coleoptera use in a biological control could improve ecosystem conservation and sustainable development Teofilova (2021) (Figure 1).

Using the regression model, we expressed the relationship (correlation) between the number of individual Coleoptera in ecological farming conditions (*Pisum sativum*, *Grass mixture*, *Triticum spelta* and *Triticum aestivum*) and potassium (mg/kg), phosphorus (mg/kg), nitrogen (mg/kg) and pH. The correlation coefficient value was high for the number of individuals and pH ($r = 0.8999$) (Figure 2A), potassium ($r = 0.7405$) (Figure 2B), phosphorus ($r = 0.8405$) (Figure 2C), nitrogen ($r = 0.7905$) (Figure 2D), which indicated a strong relationship. The reliability coefficient for the pH $r^2 = 0.7154$ indicated the capture of 72% variability, potassium $r^2 = 0.7597$ (76% variability), phosphorus

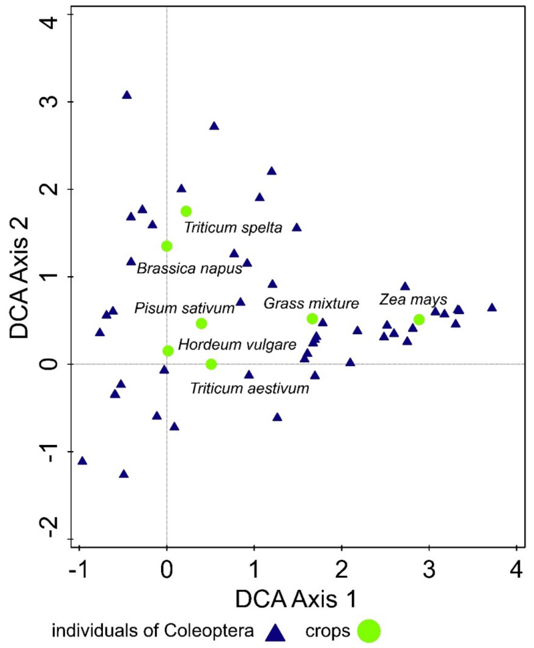

Fig. 1. DCA analysis dispersion of Coleoptera of individuals of in crops

$r^2 = 0.8197$ (82% variability) and nitrogen $r^2 = 0.8111$ (81% variability). The overall suitability of the regression model is statistically significant in all cases: pH ($p = 0.0418$), potassium ($p = 0.0212$), phosphorus ($p = 0.0112$) and nitrogen ($p = 0.0142$).

The results showed that increasing values of potassium, phosphorus, nitrogen, also increased the number of individual Coleoptera. The ideal values for Coleoptera in ecological farming conditions were 5-15 mg/kg potassium, 0.5-1.25 mg/kg P, 5-15 mg/kg nitrogen and pH 7. Coleoptera living in agricultural landscapes have a wider tolerance than the Coleoptera of natural habitats. They achieve high local density due to the influence of agriculture (Porhajašová et al., 2015; Alberti et al., 2017; Magura et al., 2020). The great abundance of Coleoptera influenced the maintenance of the natural balance and substance cycle of the biogenic elements in ecosystems such as carbon, nitrogen, sulfur and phosphorus. The dominance of Coleoptera has been indicated as a general trait of ground-dwelling assemblages; their activities accelerated the decomposition of plant residues, aerated the soil and improved soil structure and quality (Varvara, 2010; Curell et al., 2012; Bažok et al., 2015).

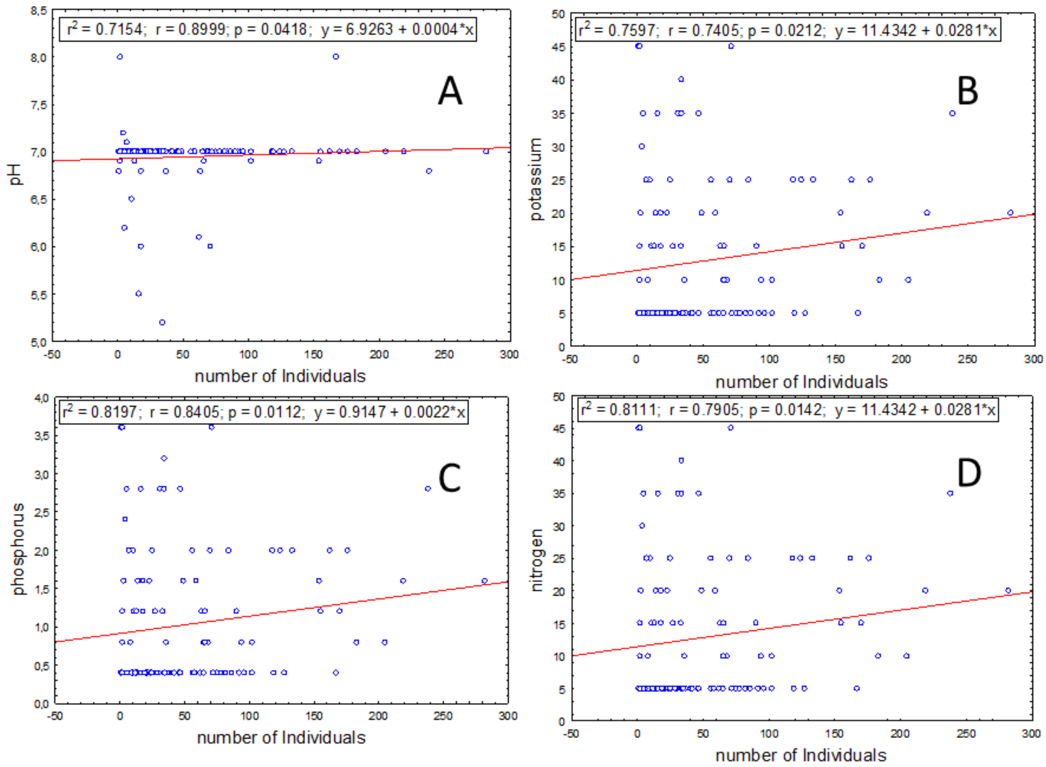

Fig. 2. Linear regression model of potassium, phosphorus, nitrogen, pH and number of individual Coleoptera in ecological farming conditions

Using the regression model, we expressed the relationship (correlation) between the number of individual Coleoptera in the integration of conventional farming (*Brassica napus*, *Hordeum vulgare* and *Zea mays*) and potassium (mg/kg), phosphorus (mg/kg), nitrogen (mg/kg) and pH. The correlation coefficient value was high for the number of individuals and pH (r = 0.8999) (Figure 3A). A medium - strong negative correlation coefficient, we recorded at potassium (r = -0.539) (Figure 3B), phosphorus (r = -0.4904) (Figure 3C) and nitrogen (r = -0.5421) (Figure 3D) which indicated negative impact of environmental variables (potassium, phosphorus, nitrogen) on the number of individuals in integrated farming conditions.

The reliability coefficient for the pH r^2 = 0.8108 indicated the capture of 81% variability, potassium r^2 = 0.6571 (65% variability), phosphorus r^2 = 0.7741(77% variability), nitrogen r^2 = 0.6999 (70% variability). The overall suitability of the regression model is statistically significant in all cases: pH (p = 0.0248), potassium (p = 0.0073), phosphorus (p = 0.0173) and nitrogen (p = 0.0324). The results showed that increasing values of potassium, phosphorus and nitrogen reduce the number of individual Coleoptera. The results showed that declining values of potassium, phosphorus and nitrogen reduce the number of individual Coleoptera. The ideal values for Coleoptera in integrated farming conditions were 5-20 mg/kg potassium, 0.5-2 mg/kg P, 5-20 mg/kg nitrogen and pH 7. Higher values cause a decrease in the number of individual Coleoptera. Schuster et al. (2019) discovered that soil disturbance during manure injection may mitigate the impacts on arthropod populations and may cause reductions in arthropod abundance. Boháč & Jahnová (2015) found that Coleoptera is a dominant group of soil macrofauna, which react sensitively to human activity. The order Coleoptera is sensitive to insecticides, pesticides, pH, soil moisture, phosphorus, potassium, nitrogen, and the excessive use of artificial fertilizers. Another factor influencing the order Coleoptera is vegetation structure in connection with various human interventions, while their effects are stronger in agriculturally used ecosystems (Vician et al., 2015; 2018; Tiemann et al., 2015).

Conclusion

Our results provided new knowledge regarding the dispersion of Coleoptera in crops in ecological farming conditions (*Pisum sativum, Grass mixture, Triticum spelta*, *Triticum aestivum*) and conventional farming (*Brassica napus,*

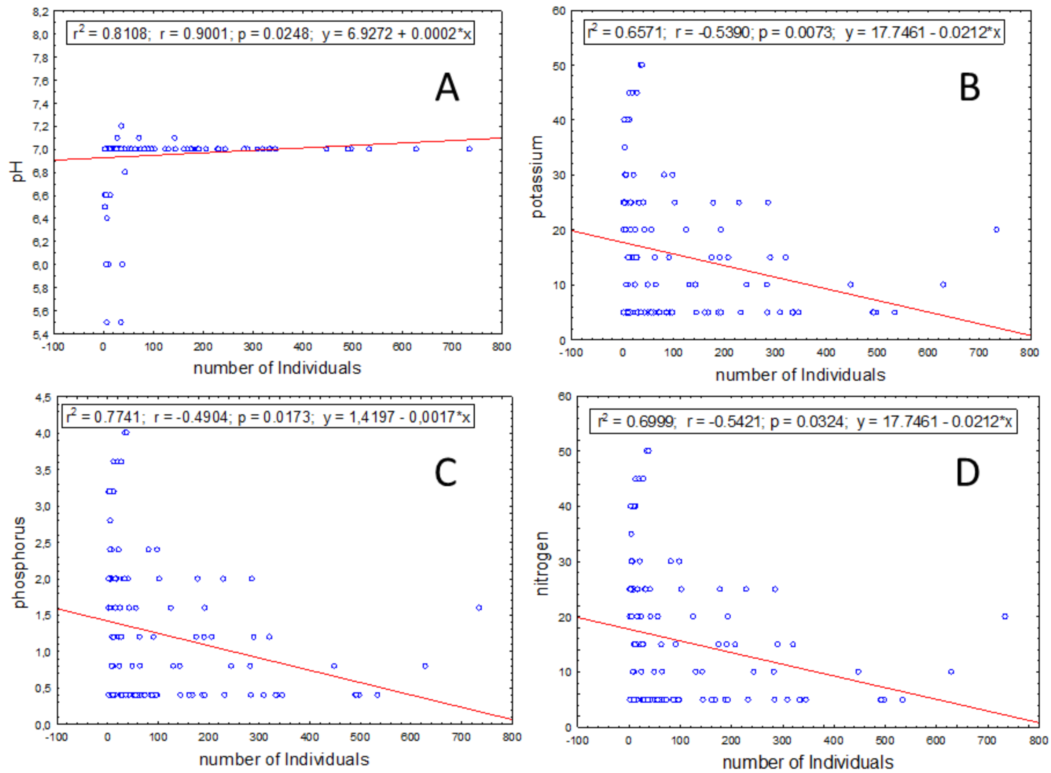

Fig. 3. Linear regression model of potassium, phosphorus, nitrogen, pH and number of individual Coleoptera in integrated farming conditions

Hordeum vulgare, *Zea mays*). The dispersion of individual Coleoptera has a predominance around Zea mays (integrated farming) and Grass mixture crops (ecological farming). In ecological farming, we found a positive correlation between the number of Coleoptera and phosphorus (mg/kg), potassium (mg/kg) and nitrogen (mg/kg). With increasing values of potassium, phosphorus and nitrogen, the number of individuals also increased. In contrast, in conventional farming we found a negative correlation between the number of Coleoptera and phosphorus (mg/kg), potassium (mg/kg) and nitrogen (mg/kg). The results showed that declining values of potassium, phosphorus and nitrogen reduce the number of individual Coleoptera. This is affected by higher values of phosphorus, potassium and nitrogen in conventional farming conditions. The pH had a positive effect on the number of Coleoptera in both types of farming. Coleoptera is an important part of the ecosystem for processes such as nutrient cycling and pest control. Good agricultural practices contribute to the increase of abundance of Coleoptera. A combination of soil structure and abundance of Coleoptera can be used as an indicator when evaluating the sustainability of soil use, influence of cultivation practices on fertile soil and crop yield.

Acknowledgments

This research was supported by the grants VEGA 1/0604/20 Environmental assessment of specific habitats in the Danube Plain and KEGA No. 002UKF-4/2022 Metaanalyzes in Biology and Ecology (Databases and Statistical Data Analysis).

References

Alberti, M., Marzluff, J. & Hunt, V. M. (2017). Urban driven phenotypic changes: empirical observations and theoretical implications for eco-evolutionary feedback. *Philosophical Transactions of the Royal Society B*, *372(1712),* 1-9.

Attwood, S. J., Maron, M., House, A. P. N. & Zammit, C. (2008). Do arthropod assemblages display globally consistent responses to intensified agricultural land use and management? *Global Ecology and Biogeography*, *17(5),* 585-599.

Bažok, R., Kos, T. & Drmić, Z. (2015). Importance of ground beetles (Coleoptera: Carabidae) for biological stability of agricultural habitat focus on cultivation of sugar beet. *Glasilo biljne zaštite*, *15*, 264-276 (Pl).

Boháč, J. & Jahnová, Z. (2015). Land use changes and landscape degradation in central and eastern Europe in the last decades: Epigeic invertebrates as bioindicators of landscape changes. In: *Environmental Indicators*, Armon, R. & Hanninen, O. (eds.), *Springer,* Dordrecht, 395-420.

Bote, P. J. & Romero, A. (2012). Epigeic soil arthropod abundance under different agricultural land uses. *Spanish Journal of Agricultural Research*, *10(1),* 55-61.

Briones, M. J. I. & Schmidt, O. (2017). Conventional Tillage Decreases the Abundance and Biomass of Earthworms and Alters Their Community Structure in a Global Meta-Analysis. *Global Change Biology*, *23*(10), 4396-4419.

Curell, C., Gross, P. & Steinke, K. (2012). Soil Health and Soil Quality: Understanding the Differences between Soil Health and Soil Quality. Michigan State University Extension, East Lansing, MI.

Diehl, E., Wolters, V. & Birkhofer, K. (2012). Arable weeds in organically managed wheat fields foster carabid beetles by resource- and structure-mediated effects. *Arthropod-Plant Interactions*, *6(1),*75-82.

Diehl, E., Mader, V. L., Wolters, V. & Birkhofer, K. (2013). Management intensity and vegetation complexity affect web-building spiders and their prey. *Oecologia*, *173(2),* 579-589.

Faly, L. I., Kolombar, T. M., Prokopenko, E. V., Pakhomov, O. Y. & Brygadyrenko, V. V. (2017). Structure of litter macrofauna communities in poplar plantations in an urban ecosystem in Ukraine. *Biosystems Diversity*, *25(1),* 29-38.

Fazekašová, D. & Bobuľovská, L. (2012). Soil organisms as an Indicator of Quality and Environmental Stress in the Soil Ecosystem. *Environment*, *46(2),*103-106 (Sk).

González, I. M., Vidal, K. & Peñaloza, P. (2021). Comparing nitrate leaching in lettuce crops cultivated under agroecological, transition, and conventional agricultural management in central Chile. *Chilean Journal of Agricultural Research*, *81(2),* 210-219.

Haddaway, N. R., Brown, C., Eggers, S., Josefsson, J., Kronvang, B., Randall, N. & Uusi-Kämppä, J. (2016). The multifunctional roles of vegetated strips around and within agricultural fields. A systematic map protocol. *Environmental Evidence*, *5(18),* 1-27.

Hazarika, S., Kumar, M., Thakuria, D. & Bordoloi, L. J. (2013). Organic Farming: Reality and Concerns. *Indian Journal of Hill Farming*, *26(2),* 88-97.

Simão, F. C. P., Carretero, M. A., Amaral, M. J. A., Soares, A. M. V. M. & Mateos, E. (2015) Composition and seasonal ariation of epigeic arthropods in field margins of NW Portugal. *Turk. J. Zool.*, *39,* 404-411.

Langraf, V., Petrovičová, K. & Schlarmannová, J. (2021). The Composition and Seasonal Variation of Epigeic Arthropods in Different Types of Agricultural Crops and Their Ecotones. *Agronomy*, *11(11),* 2276.

Kalushkov, P., Guéorguiev, B., Spitzer, L. & Nedved, O. (2009). Biodiversity of ground beetles (Coleoptera: Carabidae) in genetically modified (Bt) and conventional (non-Bt) potato fields in Bulgaria. *Biotechnology & Biotechnological Equipment*, *23(3),* 1346-1350.

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.

Magura, T., Ferrante, M. & Lövei, L. G. (2020). Only habitat specialists become smaller with advancing urbanization. *Global Ecology and Biogeography*, *29(11),* 1978-1987.

Microsoft SQL Server. (2017). Microsoft Corporation, Redmond,

WA, USA.
Mijangos, I. & Garbisu, C. (2010). Consequences of Soil Sampling Depth during the Assessment of the Effects of Tillage and Fertilization on Soil Quality: A Common Oversight. *Soil & Tillage Research*, *109(2),* 169-173.
Porhajašová, J., Noskovič, J., Rakovská, A., Babošová, M. & Čeryová, T. (2015). Biodiversity and dynamics of occurence of epigeic groups in different types of farming. *Acta Horticulturae et Regiotecturae*, *18(1),* 5-10.
Porhajašová, J., Babošová, M., Noskovič, J. & Ondrišík, P. (2018). Long-term developments and biodiversity in Carabid and Staphylinid (Coleoptera: Carabidae and Staphylinidae) fauna during the application of organic fertilizers under agroecosystem conditions. *Polish Journal Environmental Studies*, *27(5),* 2229-2235.
Schierwater, B. & DeSalle, R. (2021). Invertebrate Zoology: A Tree of Life Approach. *CRC Press.*
Scialabba, E. N. & Hattam, C. (2002). Organic agriculture, environment and food security. Food and Agriculture Organization of the United Nations, Rome.
Scialabba, E. N. & Müller-Lindenlauf, M. (2010). Organic agriculture and climate change. *Renewable Agriculture and Food Systems*, *25(2),* 158-169.
Statistica Cz (Softwarový Systém na Analýzu Dat); Statsoft, Inc: Tulsa, OK, USA, 2004. Available online: www.StatSoft.Cz (accessed 1.6.2010).
Schuster, N. R., Peterson, J. A., Gilley, J. E., Schott, L. R. & Schmidt, A. M. (2019). Soil Arthropod Abundance and Diversity Following Land Application of Swine Slurry. *Agricultural Sciences*, *10(2),* 150-163.
Symondson, W. O. C., Sunderland, K. D. & Geenstone, M. H. (2002). Can generalist predators be effective biocontrol agents? *Annual Review of Entomology*, *47(1),* 561-594.
Ter Braak, C. J. F. & Šmilauer, P. (2012). Canoco reference manual and user's guide: software for ordination, vers 5.0. Microcomputer Power, Ithaca, USA.
Teofilova, T. (2021). Ground beetles in Bulgarian oilseed rape fields and adjacent actively grazed pastures (Coleoptera: Carabidae). *Bulg. J. Agric. Sci.*, *27(6),* 1153-1167.
Tiemann, L. K., Grandy, A. S., Atkinson, E. E, Marin-Spiotta, E. & McDaniel, M. D. (2015). Crop rotational diversity enhances belowground communities and functions in an agroecosystem. *Ecology Letters*, *18(8),* 761-771.
Ubrežiová, I., Kapsdorferová, Z. & Sedliaková, I. (2012). Competitiveness of Slovak agri-food commodities in third country markets. *Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis*, *60(4),* 379-384.
Varvara, M. (2010). The genus Carabus (Coleoptera, Carabidae) in some poteto crops from Romania, 1978-1999. *Oltenia. Studii şi comunicări Ştiinţele Naturii*, *26(2),* 137-146.
Wall, D. H., Nielsen, U. N. & Six, J. (2015). Soil Biodiversity and Human Health. *Nature*, *528*, 69-76.
Wollni, M. & Andersson, C. (2014). Spatial patterns of organic agriculture adoption: Evidence from Honduras. *Ecological Economics*, *97*, 120–128.
Zazharskyi, V. V., Davydenko, P. O., Kulishenko, O. M., Borovik, I. V. & Brygadyrenko, V. V. (2019). Antimicrobial activity of 50 plant extracts. *Biosystems Diversity*, *27(2),* 163-169.
Vician, V., Svitok, M., Kočík, K. & Stašiov, S. (2015). The influence of agricultural management on the structure of ground beetle (Coleoptera: Carabidae) assemblages. *Biologia*, *70(2),* 240-251.
Vician, V., Svitok, M., Michalková, E., Lukáčik, I. & Stašiov, S. (2018). Influence of tree species and soil properties on ground beetle (Coleoptera: Carabidae) communities. *Acta Oecologica*, *91*, 120-126.

Received: **August, 06, 2021**; *Accepted*: **November, 04, 2021**; *Published*: **February, 2023**