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Effect of organic farming on the ladybird beetle diversity (Coleoptera: Coccinellidae)

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Coccinellidae perform the function of biological control of pests in nature, they eat aphids and other insects, which is important in organic agriculture. The aim of the work was to establish the distribution and species composition of the family Coccinellidae in the organic agro-landscape. The research was conducted at the Skvyra research station of organic production (Kyiv region, Ukraine). Insects were collected by entomological mowing with a net in four stages of plant development. The organic agro-landscape included crops of buckwheat, oats, soybeans and winter wheat. Data from neighbor conventional soybean and winter wheat ecosystems were used for comparison. The agroecosystems of these crops, which included fields, ecotones"field – field protective forest shelter belt", field protective forest shelter belts, were studied. The study identified 10 species of the family Coccinellidae, the number of species ranged from 1 to 89/100 waves, the largest in the ecosystem of organic winter wheat. *H. axiridis* belonged to the recedents and was found in five agroecosystems in the amount of 1-7 individuals / 100 waves. The most common species were *C. septempunctata*, *T. sedecimpunctata* and larvae of Coccinellidae, which were eudominant in the organic agro-landscape. Species *Vibidia sp.* was found only in organic agroecosystems of buckwheat and oats. The variety of ladybugs in organic winter wheat was higher than in conventional. Organic soybeans, in contrast, had less variety of Coccinellidae than conventional soybeans, as confirmed by cluster analysis. Species richness in crop ecosystems ranged from 3 to 8 in different study periods. High correlations of insect numbers were found between fields, ecotones and forest shelter belts, as well as between neighbor ecotones and neighbor forest belts, which indicates the migration of insects between these areas. Thus, the diversity and prevalence of Coccinellidae in the organic agro-landscape, compared to the traditional one, has been established.

Key words: ladybugs, organic farming, agrolandscape, agroecosystem, crops, species.

Problem statement and analysis of recent research. Coccinellidae (also referred to as ladybird beetle or ladybugs) are one of the most diverse beetles family of about 4,200–6,000 species distributed throughout the world [1, 2], inhabiting all types of terrestrial ecosystems [3]. The family Coccinellidae is divided into eight subfamilies: Sticholotidinae, Chilocorinae, Scymninae, Coccidulinae, Coccinellinae, Epilachninae, Hyperaspidinae and Microweiseinae. Many of the species are characterized by a specific appearance of yellow, orange, and red and dark spots or stripes on wings covers. The size of adults varies between 0.8 and 18 mm long. The body is mostly elliptical, dome-shaped with six short legs. Due to their scientific and economic importance, coccinellids are the subject of many studies of the last decades [1, 3].

About 90 % of coccinellids are carnivores [2], their preferred prey are small soft bodied insects such as aphids (Aphididae), mealy bugs (Pseudococcidae), whiteflies (Aleyrodidae), thrips (Thripidae), jassids (Cicadellidae) and psyllids (Psyllidae) [3, 4]. The insect-eating coccinellids play an important role as major predators of pests and in biological control strategies [5]. The preferred diet of larval and adult stages is generally the same [2], though larvae show lower consumption rates than adults [6]. Most of the species lay eggs in the nearby location of their prey, to provide better access of larvae to nutrients.

Some species of Coccinellidae are phytophagous, feeding on plant tissue and pollen; or mycophagous, feeding on fungal spores. Phytophagous species can become a significant pest of fruit and wine production [7].

Many species of Coccinellidae are aphidophagous, feeding as larvae and adults on aphids, but some species also feed on other hemipterous insects (i.e., heteropterans, psyllids, whiteflies), beetle and moth larvae, pollen, fungal spores, and even plant tissue [8, 9]. The coccinellid has been introduced into at least 64 countries/territories to control more than 16 pest species [10].

Coccinellid beetles are effective natural enemies for biological control of pests, which are injurious to agricultural and forest plantations. These are environmentally friendly bugs and more effective without any harmful effects on non-target organisms. They can be used in classical, augmentative and conservation biological control programmes, and possesses a tremendous potential in these regards [10].

Intensive use of natural resources, construction, agricultural and other activities have significantly changed the vegetation of natural landscapes. This has led to disruption of the habitats of many biota species, including the number of Coccinellidae. In the temperate zone, dominant species are most often associated with large populations of prey on crops, weeds and trees as a result of human activity [11].

A variety of plant protection products and other agrochemicals are used in agro-ecosystems. Products approved for integrated pest management or organic farming should have minimal negative side effects on beneficial insects [12]. Coccinellidae are of high priority in organic cropping and integrated pest management systems. They are nature's own pest controllers and more effective than poisonous chemicals [10].

Insecticides used in crop production, such as dimethoate, lambda-cyhalothrin, deltamethrin, bifenthrin and, to a lesser degree, imidacloprid and acetamiprid, can be harmful to ladybugs, which are natural enemies of pests [12–15]. Thus, there are more these beetles in ecosystems untreated with pesticides [10].

Invasive species of coccinellides can threaten natural species through intra-guild predation or competition for resources, but their expected serious adverse effects on native species can vary widely [11]. Several species are biological control agents or widespread invasive species [8]. *Harmonia axyridis* Pallas, 1773 (Coleoptera, Coccinellidae) is a globally invasive ladybird. It has been intentionally introduced in many countries as a biological control agent. As a predatory insect, *H. axyridis* plays a major role in natural pest control by regulating the population of their density [16]. However, the introduction of this species into unexplored ecosystems can cause unpredictable and undesirable effects. *H. axyridis* competes with native predators and parasitoids for common food resources and is effective in the predatory domestic guild. This has become a problem because with increasing population density of *H. axyridis*, local diversity is under pressure [17]. Nowadays its spread still poses a threat for the native Coccinellidae species in different regions, including Latvia, western and central Ukraine [18, 19]. Unlike other alien ladybirds, *H. axyridis* had higher potential dispersal ability [16].

The aim of the research was to establish the distribution and species composition of Coccinellidae family in the organic agro-landscape.

Material and methods of research. The research was carried out on organic and conventional fields of Skvyra research station of organic production (Kyiv region, Ukraine) in 2020 in the phases of plant development during the growing season: I – 24.05, II – 14.06, III – 29.06, IV – 17.07. The structural components of the crops agroecosystem were considered to be the field, the field protective forest shelter belts surrounding it, and the adjacent ecotones "field – forest shelter belt". Insects were counted by entomological mowing per 100 waves of the net with a standard net diameter of 35 cm. The counts were carried out at equidistant sections in fields, adjacent ecotones "field – forest shelter belt", field protective forest shelter belts. The area of organic fields was 5.30–8.62, the area of conventional fields – 2.0 hectares. The organic agro-landscape included agroecosystems of buckwheat, oats, soybeans, winter wheat, and the conventional agro-ecosystems included soybeans and winter wheat (they were used for comparison). The predecessor of soybeans was winter wheat, oats – buckwheat, winter wheat – milk thistle, buckwheat – oats.

Vegetation of field protective forest shelter belts is presented in the literature [20]. Weather conditions during the study period were arid. Technology used in organic fields included peeling stubble, autumn plowing, harrowing, disking area, pre-sowing plowing, spring harrow treatment once before sowing, once after sowing before germination, 3–4 times during the growing season with an interval of 4-5 days. Conventional technology: peeling stubble, autumn plowing, harrowing, disking area, application of mineral fertilizers nitroammophoska 100 kg/ha before sowing, pre-sowing plowing, application of herbicides in the phase of 1–3 trifoliate leaves against dicotyledonous annual weeds with "bazagran "2.0–2.5 l/ha, application of herbicides at the height of cereal weeds 10–15 cm with" fusilade forte "1.0–2.0 l/ha.

Statistical data processing was performed using Excell and IBM SPSS Statistics 26. The probability level was taken as 95 % (p> 0.05). Domination coefficient was calculated by the formula from Kasprzak & Niedbała [21]:

$$Di\ (\%) = (n_i \times 100)/N, \qquad (1)$$

where Di – domination coefficient of particular species in percent; ni – number of particular species; N − total number of all species collected.

There were five classes of domination coefficient: eudominants (EU) – more than 30 % of the total number of individuals recorded; dominants (D) – 20-30%; subdominants (SD) – 10–20 %; recedents (R) – 1–10 %; subrecedents (SR) – less than 1 %.

The frequency (F) provided information about the distribution of one species in the sampled area and was calculated according to Mühlenberg et al. [22]:

$$F = (Gi \times 100)/S, \qquad (2)$$

where Gi = number of site records for a species i; S = number of all sites surveyed.

The correlation coefficient was calculated by Pearson and the dendrogram using the method of Between-groups linkage by squared Euclidean distance.

Research results and discussion. Species of the family Coccinellidae, order Coleoptera, such as *Adonia (Hippodamia) variegata* Goeze, 1777; *Coccinella septempunctata* L., 1758; *Propylea quatuordecimpunctata* L., 1758; *Thea vigintiduoctopunctata* L., 1758; *Tytthaspis sedecimpunctata* L., 1758; *Scymnus sp.*; *Harmonia axyridis* Pallas, 1773; *Vibidia sp.* were found in organic and conventional agrolandscapes. The largest number of individuals in the agroecosystem of buckwheat during the growing season had species *C. septempunctata* (31.7 % – EU), *P. quatuordecimpunctata* (21.7 % – D), as well as larvae of Coccinellidae (Table 1). In the agroecosystem of oats eudominants were larvae of the family Coccinellidae (40 %), other species were 0.8–20.8 %. In the agroecosystem of organic soybeans species *Scymnus sp.*, *H. axiridis*, *Vibidia sp.* were absent; sixteen-spot ladybird was eudominant – 39.7 %. There were no eudominants in organic winter wheat, but seven-spotted and 14-spotted ladybirds and family larvae were dominant. In conventional winter wheat, *C. septempunctata* and larvae Coccinellidae occupied a dominant position. According to Soares et al. (2018) [23], *C. septempunctata* are generally abundant in agricultural habitats. Makwela (2019) [24] considers the species *A. variegata* and *C. septempunctata* as the most common. The invasive species *H. axiridis* in the presented ecosystems occupied 2.1–3.9 %.

On average, in the field of buckwheat there were 18 individuals of ladybugs (Fig. 1), the maximum value – 57 individuals of the species *C. septempunctata*. In the agroecosystem of oats, the median was 5.5, the average value of individuals of species – 12. In agroecosystems of soybeans, the median in both cases was 3, the average value for organic soybeans – 6.3, for conventional – 9.5 individuals. In the ecosystem of organic winter wheat the largest number

Table 1 – **Dominance of insect species in crops agroecosystems,** %

Species	Buckwheat (organic)	Oats (organic)	Soybean (organic)	Soybean (conventional)	Winter wheat (organic)	Winter wheat (conventional)
Adonia variegata	R	R	R	R	R	SD
Coccinella septempunctata	EU	SD	SD	SD	D	D
Propylea quatuordecimpunctata	D	D	SD	EU	D	SD
Thea vigintiduoctopunctata	R	R	R	R	R	SR
Tytthaspis sedecimpunctata	R	R	EU	R	R	R
Scymnus sp.	R	SR	–	R	R	R
Harmonia axiridis	R	R	–	R	R	R
Vibidia sp.	SR	R	–	–	–	–
Other Coccinellidae	R	SR	–	–	SR	SD
Larvae Coccinellidae	D	EU	SD	EU	D	D

of individuals of ladybugs (306) was recorded; *C. septempunctata* and *P. quatuordecimpunctata* had 88 and 89 individuals, respectively. These data are confirmed by Makwela (2019), who indicates that the adult *C. septempunctata* prefers aphids feeding on wheat [24]. Pushnya et al. (2020) [25] proved that the abundance of this species on wheat is sufficient to control aphids, even without pesticide tillage. On average, in our studies, 30.6 individuals of species were found in this agroecosystem. In the ecosystem of conventional winter wheat, an average of 10.9 individuals were recorded, a total 109. As a result of studies conducted by Grinko (2018) [26], such species of ladybugs as *C. septempunctata*, *A. variegata*, *P. quatuordecimpunctata* are stable present in crops wheat. In the early spring there is a mycetophage *T. vigintiduopunctata*.

According to the frequency of occurrence, *A. variegata*, *C. septempunctata*, *P. quatuordecimpunctata*, *T. vigintiduoctopunctata*, *T. sedecimpunctata* and larvae were found during the growing season in all (6) agroecosystems – in organic and conventional landscapes (Table 2). *Vibidia sp.* was recorded only in the organic agro-landscape in the I (buckwheat, oats) and II (oats) study period in single specimens. Therefore, according to Makwela (2019) [24] it can be considered as an indicator species. *H. axiridis* gradually occupied a smaller area with the development of plant vegetation, its frequency decreased from 66.7 % in the first period of the study to 0 % in the fourth period, although it was recorded in five agroecosystems (1–7 individuals/100 waves). As in the Medvid (2017) studies [27], the peak in the number of Coccinellidae larvae was observed in the second decade of June.

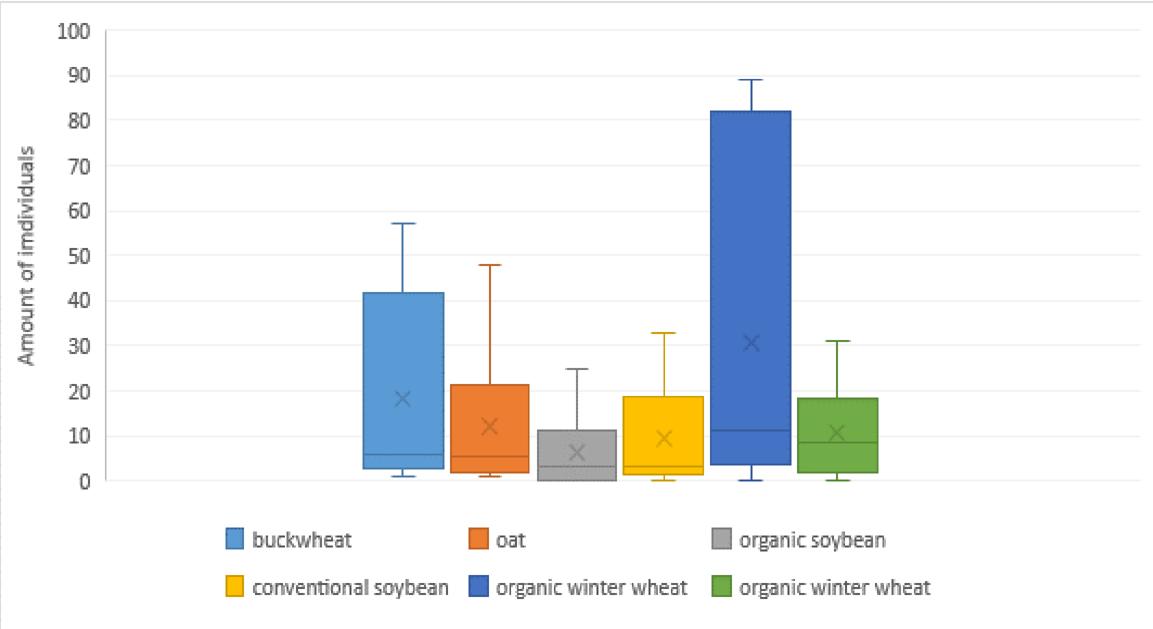


Fig. 1. **The number of species individuals during the growing season in crops**

Table 2 – **Frequency of Coccinellidae species recorded during the vegetation study period in the crops agroecosystems, %**

Species	I	II	III	IV	Total for the growing season
Adonia variegata	16.7	66.7	66.7	50.0	100.0
Coccinella septempunctata	66.7	100.0	100.0	83.3	100.0
Propylea quatuordecimpunctata	100.0	100.0	100.0	100.0	100.0
Thea vigintiduoctopunctata	16.7	66.7	83.3	50.0	100.0
Tytthaspis sedecimpunctata	33.3	16.7	50.0	83.3	100.0
Scymnus sp.	50.0	50.0	33.3	66.7	83.3
Harmonia axiridis	66.7	50.0	33.3	0.0	83.3
Vibidia sp.	0.0	0.0	66.7	16.7	66.7
Other Coccinellidae	33.3	16.7	0.0	0.0	33.3
Larvae Coccinellidae	16.7	100.0	0.0	0.0	100.0

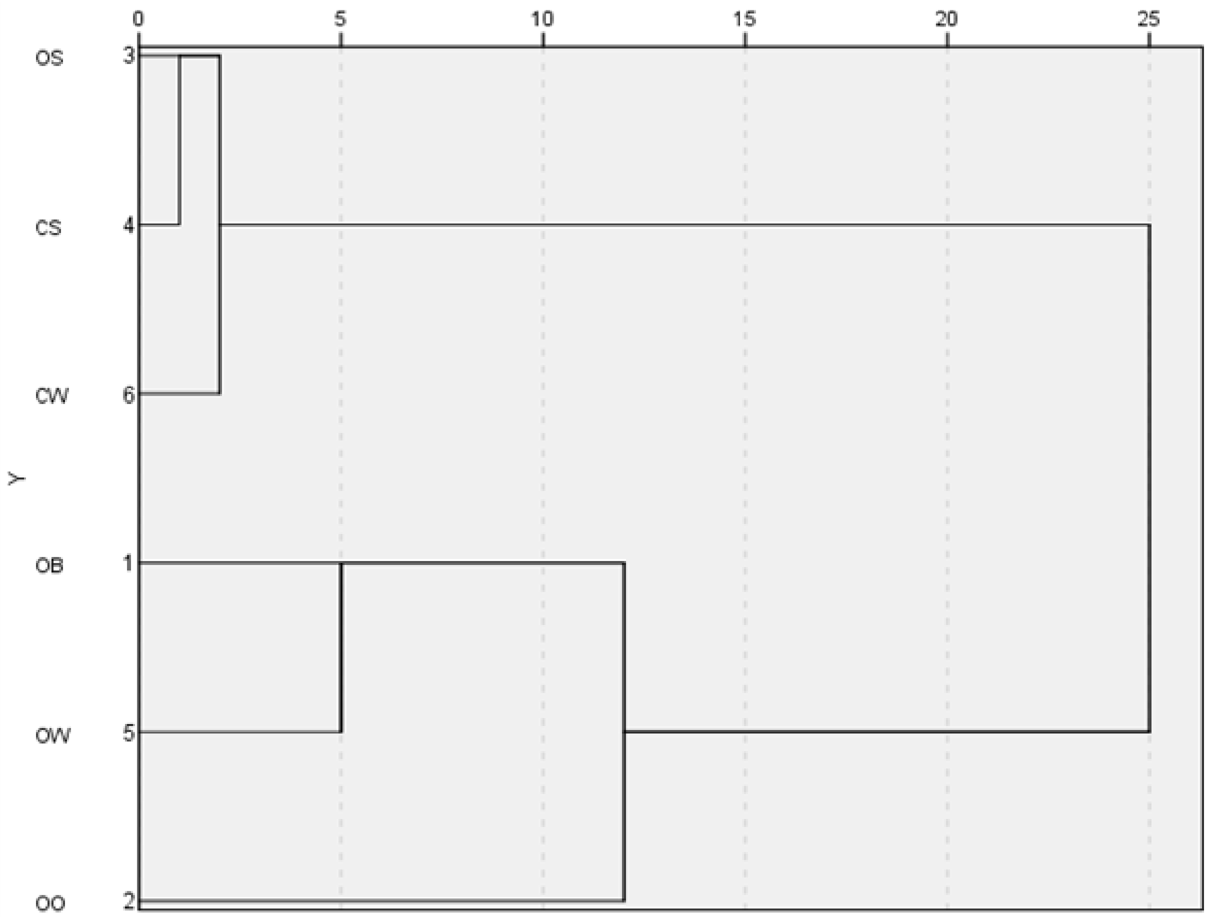
The number of species in agroecosystems varied during the growing season from 2 to 8 (Table 3). The greatest species richness and peaks in the number of Coccinellidae insects were observed in the second and third periods of the study. During the entire study period, the largest species richness was in agroecosystems of buckwheat and oats (10 species each), as well as winter wheat (9 species in organic and conventional).

These data are confirmed by cluster analysis (Fig. 2), because in both agroecosystems of soybean there was the lowest number of species, as well as in conventional winter wheat during the growing season. Organic winter wheat, buckwheat and oats are allocated to a separate group. This indicates a significant species diversity of these agroecosystems.

Table 3 – **Species richness of ladybugs in crops agroecosystems***

Research period	Buckwheat (organic)	Oats (organic)	Soybean (organic)	Soybean (conventional)	Winter wheat (organic)	Winter wheat (conventional)
I	6	6	2	3	4	3
II	5	6	5	5	7	6
III	8	6	3	3	7	5
IV	6	3	3	5	6	4
Total for the growing season	10	10	6	8	9	9

***Note:** For calculations, larvae and other Coccinellidae were taken as separate species.



OB – buckwheat, OO – oats, OS – organic soybeans, CS – conventional soybeans, OW – organic winter wheat, CW – conventional winter wheat.

Fig. 2. **Dendrogram of the cluster analysis results by the number of species of the family Coccinellidae.**

For each agroecosystem, the correlations between the experimental plots were characterized. In the organic agroecosystem of buckwheat, the highest correlation (r = 0.85) was found between the ecotones adjacent to the field (Table 4). In the oat agroecosystem, the most significant correlations were between field and ecotone 2 (r = 0.98), and a negative correlation between ecotone 1 and forest shelter belt 1, which may indicate that insects moved to different areas, reducing there its number. Organic soybeans had only one forest shelter belt nearby, so no significant correlations were observed there, only the average between the field and the ecotone (r = 0.59). However, in the agroecosystem of conventional soybeans, a correlation between field and ecotone 1 (r = 0.96), field and forest shelter belt 1 (r = 0.97), forest shelter belt 2 (r = 0.93), ecotone 1 and forest shelter belt 1 (r = 0.94), slightly smaller between ecotone 1 and forest shelter belt 2 (r = 0.80) and forest shelter belts between them (r = 0.88) was revealed. This indicates the migration of insects and growth of their number in these parts of the ecosystem. Also significant correlations were found in the agroecosystem of organic winter wheat – between field and ecotone 1 (r = 0.76), field and forest shelter belt 1 (r = 0.82,) field and forest shelter belt 2 (r = 0.88), ecotone 1 and forest shelter belt 1 (r = 0.96), ecotone 2 and forest shel-

Table 4 – **Correlation between the studied areas of the agro-landscape**

Buckwheat					
Plot	field	ecotone 1	forest shelter belt 1	ecotone 2	forest shelter belt 2
Field	1.00				
Ecotone 1	0.19	1.00			
Forest shelter belt 1	-0.35	0.69	1.00		
Ecotone 2	0.56	0.85	0.57	1.00	
Forest shelter belt 2	-0.39	-0.48	0.26	-0.26	1.00
Oat					
Plot	field	ecotone 1	forest shelter belt 1	ecotone 2	forest shelter belt 2
Field	1.00				
Ecotone 1	-0.30	1.00			
Forest shelter belt 1	-0.27	-0.71	1.00		
Ecotone 2	0.98	-0.42	-0.10	1.00	
Forest shelter belt 2	-0.67	0.30	0.45	-0.58	1.00
Organic soybean					
Plot	field	ecotone 1	forest shelter belt 1	–	–
Field	1.00				
Ecotone 1	0.59	1.00			
Forest shelter belt 1	-0.03	-0.41	1.00		
Conventional soybean					
Plot	field	ecotone 1	forest shelter belt 1	ecotone 2	forest shelter belt 2
Field	1.00				
Ecotone 1	0.96	1.00			
Forest shelter belt 1	0.97	0.94	1.00		
Ecotone 2	-0.42	-0.49	-0.22	1.00	
Forest shelter belt 2	0.93	0.80	0.88	-0.34	1.00
Organic winter wheat					
Plot	field	ecotone 1	forest shelter belt 1	ecotone 2	forest shelter belt 2
Field	1.00				
Ecotone 1	0.76	1.00			
Forest shelter belt 1	0.82	0.96	1.00		
Ecotone 2	0.56	-0.09	0.12	1.00	
Forest shelter belt 2	0.88	0.37	0.45	0.81	1.00
Conventional winter wheat					
Plot	field	ecotone 1	forest shelter belt 1	ecotone 2	forest shelter belt 2
Field	1.00				
Ecotone 1	0.91	1.00			
Forest shelter belt 1	0.78	0.46	1.00		
Ecotone 2	0.87	0.89	0.45	1.00	
Forest shelter belt 2	0.36	0.00	0.85	-0.08	1.00

ter belt 2 (r = 0.81). There is a dependence of the number of insects in the field and neighboring areas of the agroecosystem. A similar correlation was observed in the agroecosystem of conventional winter wheat – a positive significant correlation between field and ecotone 1 (r = 0.91), forest shelter belt 1 (r = 0.78) and ecotone 2 (r = 0.87). In addition, there is a relationship between ecotones (r = 0.89) and forest shelter belts (r = 0.85).

Conclusions. 10 species of the family Coccinellidae insects were found on the experimental organic landscape, the number of individuals within the species ranged from 1 to 89. The invasive species *H. axiridis* belonged to the recedents in all agroecosystems where it was recorded. Eudominants of organic agrolandscape included species of *C. septempunctata*, *T. sedecimpunctata* and Coccinellidae larvae. Compared to conventional ecosystems, organic winter wheat was more diverse, but soybeans – less diverse. Significant correlations were found between the fields and adjacent areas of agroecosystems – ecotones "field – forest belt" and forest shelter belts.

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LIST OF REFERENCES

1. Bieńkowski A.O. Key for identification of the ladybirds (Coleoptera: Coccinellidae) of European Russia and the Russian Caucasus (native and alien species). Zootaxa, 4472(2), 2018. P. 233–260. DOI: https://doi.org/10.11646/zootaxa.4472.2.2.

2. Roy H., Migeon A. Ladybeetles (Coccinellidae). Chapter 8.4. BioRisk, 4(July), 2010. P. 293–313. DOI: https://doi.org/10.3897/biorisk.4.49.

3. Kundoo A.A., Khan A.A. Coccinellids as biological control agents of soft bodied insects: A review. Journal of Entomology and Zoology Studies, 5(5 R), 2017. P. 1362–1373.

4. Honěk A. Distribution and Habitats. Ecology and Behaviour of the Ladybird Beetles (Coccinellidae), Chapter 4, 2012. P. 110–140. DOI: https://doi.org/10.1002/9781118223208.ch4.

5. Ponnusamy N., Biwash G., Suprakash P. Faunistics and diagnostics of predaceous Coccinellids in Terai region of West Bengal. 81(4), 2019. P. 896–899.

6. Spatial and temporal changes in the abundance and compostion of ladybird (Coleoptera: Coccinellidae) communities, Current Opinion in Insect Science. / Honek A. et al. Volume 20, 2017. P. 61–67. DOI: https://doi.org/10.1016/j.cois.2017.04.001.

7. Koch R.L., Galvan T.L. Bad side of a good beetle: The North American experience with Harmonia axyridis. BioControl, 53(1), 2008. P. 23–35. DOI: https://doi.org/10.1007/s10526-007-9121-1.

8. Molecular phylogeny reveals food plasticity in the evolution of true ladybird beetles (Coleoptera: Coccinellidae: Coccinellini) / Escalona H.E. et al. BMC Evol Biol. 17, 151. 2017. DOI: https://doi.org/10.1186/s12862-017-1002-3

9. Evaluation of Scymnus nubilus (Coleoptera: Coccinellidae) as a biological control agent against Aphis spiraecola and Cinara juniperi (Hemiptera: Aphididae) / Rosagro R.M. et al. Pest. Manag. Sci., 76, 2020. P. 818–826. DOI: https://doi.org/10.1002/ps.5585.

10. Kundoo A.A., Khan A.A. Coccinellids as biological control agents of soft bodied insects: A review. Journal of Entomology and Zoology Studies. 5(5), 2017. P. 1362–1373.

11. Lumbierres B., Madeira F., Pons Prey X. Acceptability and Preference of Oenopia conglobata (Coleoptera: Coccinellidae), a Candidate for Biological Control in Urban Green Areas. Insects. 9(1), 2018. 7. DOI: https://doi.org/10.3390/insects9010007.

12. Effects of so-called "environmentally friendly" agrochemicals on the harlequin ladybird Harmonia axyridis (Coleoptera: Coccinelidae) Eur. J. Entomol / Niedobová J. et al. 116, 2019. P. 173–177. DOI: https://doi.org/10.14411/eje.2019.018.

13. Toxicity of selected insecticides to the two-spot ladybird Adalia bipunctata / Jalali M.A. et al. Phytoparasitica, 37(4), 2009. P. 323–326. DOI: https://doi.org/10.1007/s12600-009-0051-6.

14. Effect of synthetic insecticides on the larvae of Coccinella septempunctata from Greek populations / Skouras P.J. et al. Phytoparasitica 45(2), 2017. P. 165–173. DOI: https://doi.org/10.1007/s12600-017-0577-y.

15. Effect of intra-guild predation and sub lethal concentrations of insecticides on the predation of coccinellids / Afza R. et al. Pakistan Journal of Zoology 51(2), 2019. P. 611–617. DOI: https://doi.org/10.17582/journal.pjz/2019.51.2.611.617.

16. Koch R.L., Costamagna A.C. Reaping benefits from an invasive species: role of Harmonia axyridis in natural biological control of Aphis glycines in North America. BioControl 62, 2017. P. 331–340. DOI: https://doi.org/10.1007/s10526-016-9749-9.

17. Hiller T., Haelewaters D. A case of silent invasion: Citizen science confirms the presence of *Harmonia axyridis* (Coleoptera, Coccinellidae) in Central America. PLoS ONE 14(7), 2019. e0220082. DOI: https://doi.org/10.1371/journal.pone.0220082.

18. Ukrainsky A.S., Orlova-Bienkowskaja M.J. Expansion of Harmonia axyridis Pallas (Coleoptera: Coccinellidae) to European Russia and adjacent regions. Biological Invasions, 16(5), 2014. P. 1003–1008. DOI: https://doi.org/10.1007/s10530-013-0571-3.

19. Viktor M., Gabor P. Aharlekinkatica (Harmonia Axyridis Pallas, 1773) (Coleoptera, Coccinellidae) Elterjedése Magyarországon És Megjelenése Romániában, Ukrajnában. Növényvédelem. 45 (9), 2009. P. 481–490.

20. Порівняльний аналіз екологічної структури фіторізноманіття полезахисних лісосмуг на полях органічного та традиційного виробництва / Мірошник Н.В. та ін. Екологічні науки. Випуск 3 (30), 2020. P. 64–72.

21. Kasprzak K., Niedbała W. Wskaźniki biocenotyczne stosowane przy porządkowaniu i analizie danych w badaniach ilościowych. In: Górny M., Grüm L., eds. Metody Stosowane w Zoologii Gleby. PWN, Warszawa, 1981. P. 379–416.

22. Mühlenberg M., Behre G.F., Bogenrieder A. Freilandökologie. 3rd ed. UTB Quelle & Meyer Verlag; Heidelberg, Germany: 1993.

23. Can Native Geographical Range, Dispersal Ability and Development Rates Predict the Successful Establishment of Alien Ladybird (Coleoptera: Coccinellidae) Species in Europe, Front. Ecol. Evol. / Soares A.O. et al. 6:57. 2018. DOI: https://doi.org/10.3389/fevo.2018.00057.

24. Makwela M.M. Biodiversity of predatory beetle groups, carabidae and coccinellidae and their role as bioindicators in wheat agroecosystems. 2019 Dissertation. Master of science in the subject agriculture at the University of South Africa. 99 p. URL: http://hdl.handle.net/10500/26902.

25. Регулирующая роль энтомофагов доминантных вредителей озимой пшеницы в системах органического земледелия / Пушня М.В. и др. Достижения науки и техники АПК. 2020. № 7. С. 49–55. URL: https://cyberleninka.ru/article/n/reguliruyuschaya-rol-entomofagov-dominantnyh-vrediteley-ozimoy-pshenitsy-v-sistemah-organicheskogo-zemledeliya.

26. Гринько А.В. Энтомофаги вредителей озимой пшеницы в условиях Нижнего Дона. Научно-практический электронный журнал Аллея Науки. № 3(19). 2018. URL: https://alley-science.ru/domains_data/files/12March18/ENTOMOFAGI%20VREDITELEY%20OZIMOY%20PShENICY%20V%20USLOVIYaH%20NIZhNEGO%20DONA.pdf.

27. Medvid Y. Fauna and Station Distribution of Coccinellids (Coleoptera: Coccinellidae) in the Right-Bank Forest Steppe. Interdepartmental Thematic Scientific Collection of Plant Protection and Quarantine. (63), 2017. P. 123–128. DOI: https://doi.org/10.36495/1606-9773.2017.63

REFERENCES

1. Bieńkowski, A.O. (2018). Key for identification of the ladybirds (Coleoptera: Coccinellidae) of European Russia and the Russian Caucasus (native and alien species). Zootaxa, 4472(2), pp. 233–260. Available at: https://doi.org/10.11646/zootaxa.4472.2.2.

2. Roy, H., Migeon, A. (2010). Ladybeetles (Coccinellidae). Chapter 8.4. BioRisk, 4(July). pp. 293–313. Available at: https://doi.org/10.3897/biorisk.4.49.

3. Kundoo, A.A., Khan, A.A. (2017). Coccinellids as biological control agents of soft bodied insects: A review. Journal of Entomology and Zoology Studies. 5(5 R), pp. 1362–1373.

4. Honěk, A. (2012). Distribution and Habitats. Ecology and Behaviour of the Ladybird Beetles (Coccinellidae), Chapter 4, pp. 110–140. Available at: https://doi.org/10.1002/9781118223208.ch4.

5. Ponnusamy, N., Biwash, G., Suprakash, P. (2019). Faunistics and diagnostics of predaceous Coccinellids in Terai region of West Bengal. 81(4), pp. 896–899.

6. Honek, A., Dixon, A.FG., Soares, A., Skuhrovec, J., Martinkova, Z. (2017). Spatial and temporal changes in the abundance and compostion of ladybird (Coleoptera: Coccinellidae) communities, Current Opinion in Insect Science. Vol. 20, pp. 61–67. Available at: https://doi.org/10.1016/j.cois.2017.04.001.

7. Koch, R.L., Galvan, T.L. (2008). Bad side of a good beetle: The North American experience with Harmonia axyridis. BioControl. 53(1), pp. 23–35. Available at: https://doi.org/10.1007/s10526-007-9121-1.

8. Escalona, H.E., Zwick, A., Li, H.S. (2017). Molecular phylogeny reveals food plasticity in the evolution of true ladybird beetles (Coleoptera: Coccinellidae: Coccinellini). BMC Evol Biol. 17, 151. Available at: https://doi.org/10.1186/s12862-017-1002-3

9. Rosagro, R.M., Borges, I., Vieira, V., Solé, G.P., Soares, A.O. (2020). Evaluation of Scymnus nubilus (Coleoptera: Coccinellidae) as a biological control agent against Aphis spiraecola and Cinara juniperi (Hemiptera: Aphididae). Pest. Manag. Sci. 76, pp. 818–826. Available at: https://doi.org/10.1002/ps.5585.

10. Kundoo, A.A., Khan, A.A. (2017). Coccinellids as biological control agents of soft bodied insects: A review. Journal of Entomology and Zoology Studies. 5(5), pp. 1362–1373.

11. Lumbierres, B., Madeira, F., Pons Prey, X. (2018). Acceptability and Preference of Oenopia conglobata (Coleoptera: Coccinellidae), a Candidate for Biological Control in Urban Green Areas. Insects. 9(1), 7. Available at: https://doi.org/10.3390/insects9010007.

12. Niedobová, J., Skalský, M., Fric, Z.F., Hula, V., Brtnický, M. (2019). Effects of so-called “environmentally friendly” agrochemicals on the harlequin ladybird Harmonia axyridis (Coleoptera: Coccinelidae) Eur. J. Entomol. 116, pp. 173–177. Available at: https://doi.org/10.14411/eje.2019.018.

13. Jalali, M.A., Van Leeuwen, T., Tirry, L., De Clercq, P. (2009). Toxicity of selected insecticides to the two-spot ladybird Adalia bipunctata. Phytoparasitica. 37(4), pp. 323–326. Available at: https://doi.org/10.1007/s12600-009-0051-6.

14. Skouras, P.J., Stathas, G.J., Voudouris, C.C., Darras, A.I., Tsitsipis, J.A., Margaritopoulos, J.T. (2017). Effect of synthetic insecticides on the larvae of Coccinella septempunctata from Greek populations. Phytoparasitica 45(2), pp. 165–173. Available at: https://doi.org/10.1007/s12600-017-0577-y.

15. Afza, R., Afzal, M., Majeed, M.Z., Riaz, M.A. (2019). Effect of intra-guild predation and sub lethal concentrations of insecticides on the predation of coccinellids. Pakistan Journal of Zoology 51(2), pp. 611–617. Available at: https://doi.org/10.17582/journal.pjz/2019.51.2.611.617.

16. Koch, R.L., Costamagna, A.C. (2017). Reaping benefits from an invasive species: role of Harmonia axyridis in natural biological control of Aphis glycines in North America. BioControl 62, pp. 331–340. Available at: https://doi.org/10.1007/s10526-016-9749-9.

17. Hiller, T., Haelewaters, D. A case of silent invasion: Citizen science confirms the presence of *Harmonia axyridis* (Coleoptera, Coccinellidae) in Central America. PLoS ONE 14(7), 2019. e0220082. Available at: https://doi.org/10.1371/journal.pone.0220082.

18. Ukrainsky, A.S., Orlova-Bienkowskaja, M.J. (2014). Expansion of Harmonia axyridis Pallas (Coleoptera: Coccinellidae) to European Russia and adjacent regions. Biological Invasions, 16(5), pp. 1003–1008. Available at: https://doi.org/10.1007/s10530-013-0571-3.

19. Viktor, M., Gabor, P. (2009). Aharlekinkatica (Harmonia Axyridis Pallas, 1773) (Coleoptera, Coccinellidae) Elterjedése Magyarországon És Megjelenése Romániában, Ukrajnában. Növényvédelem. 45 (9), pp. 481–490.

20. Miroshnyk, N.V., Lavrov, V.V., Grabovsky, M.B., Grabovskaya, T.O., Teslenko, I.K. (2020). Porivnjal'nyj analiz ekologichnoi' struktury fitoriznomanittja polezahysnyh lisosmug na poljah organichnogo ta tradycijnogo vyrobnyctva [Comparative analysis of the ecological structure of phytodiversity of field protective forest belts in fields of organic and

traditional production]. Ekologichni nauky [Environmental sciences]. Issue 3 (30), pp. 64–72.

21. Kasprzak, K., Niedbała, W. (1981). Wskaźniki biocenotyczne stosowane przy porządkowaniu i analizie danych w badaniach ilościowych. In: Górny M., Grüm L., eds. Metody Stosowane w Zoologii Gleby. PWN, Warszawa. pp. 379–416.

22. Mühlenberg, M., Behre, G.F., Bogenrieder, A. (1993). Freilandökologie. 3rd ed. UTB Quelle & Meyer Verlag; Heidelberg, Germany.

23. Soares, A.O., Honěk, A., Martinkova, Z., Brown, P.M.J., Borges, I. (2018). Can Native Geographical Range, Dispersal Ability and Development Rates Predict the Successful Establishment of Alien Ladybird (Coleoptera: Coccinellidae) Species in Europe, Front. Ecol. Evol. 6:57. Available at: https://doi.org/10.3389/fevo.2018.00057.

24. Makwela, M.M. (2019). Biodiversity of predatory beetle groups, carabidae and coccinellidae and their role as bioindicators in wheat agroecosystems. Dissertation. Master of science in the subject agriculture at the University of South Africa. 99 p. Available at: http://hdl.handle.net/10500/26902.

25. Pushnya, M.V., Rodionova, E.Yu., Snesareva, E.G., Ismailov, V.Ya. (2020). Regulirujushhaja rol' jentomofagov dominantnyh vreditelej ozimoj pshenicy v sistemah organicheskogo zemledelija [Regulatory role of entomophages of dominant pests of winter wheat in organic farming systems]. Dostizhenija nauki i tehniki APK [Achievements of science and technology of the agro-industrial complex], no. 7, pp. 49–55. Available at: https://cyberleninka.ru/article/n/reguliruyuschaya-rol-entomofagov-dominantnyh-vrediteley-ozimoy-pshenitsy-v-sistemah-organicheskogo-zemledeliya.

26. Grin'ko, A.V. (2018). Jentomofagi vreditelej ozimoj pshenicy v uslovijah Nizhnego Dona [Entomophagous pests of winter wheat in the conditions of the Lower Don]. Nauchno-prakticheskij jelektronnyj zhurnal Alleja Nauki [Scientific and practical electronic journal Alley of Science], no. 3(19). Available at: https://alley-science.ru/domains_data/files/12March18/ENTOMOFAGI%20VREDITELEY%20OZIMOY%20PShENICY%20V%20USLOVIYaH%20NIZhNEGO%20DONA.pdf.

27. Medvid, Y. (2017). Fauna and Station Distribution of Coccinellids (Coleoptera: Coccinellidae) in the Right-Bank Forest Steppe. Interdepartmental Thematic Scientific Collection of Plant Protection and Quarantine. (63), pp. 123–128. Available at: https://doi.org/10.36495/1606-9773.2017.63

Вплив органічного землеробства на різноманітність жуків-сонечок (Coleoptera: Coccinellidae)

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Coccinellidae у природі виконують функцію біологічного контролю шкідників, вони поїдають попелиць та інших комах, що важливо в органічному сільському господарстві. Метою роботи було встановити поширення та видовий склад родини Coccinellidae в органічному агроландшафті. Дослідження проводили на Сквирській дослідній станції органічного виробництва (Київська область, Україна). Комах збирали методом ентомологічного косіння сачком у чотирьох фазах розвитку рослин. Органічний агроландшафт містив сільськогосподарські культури: гречку, овес, сою та пшеницю озиму. Для порівняння використовували дані з сусідніми традиційними екосистемами сої та пшениці озимої. Досліджували агроекосистеми зазначених культур, які включали поля, екотони «поле – полезахисна лісосмуга», полезахисні лісосмуги. В результаті дослідження було виявлено 10 видів родини Coccinellidae, чисельність видів становила від 1 до 89/100 п.с., найбільше в екосистемі органічної пшениці озимої. *H. axiridis* належав до рецедентів і був знайдений у п'яти агроекосистемах у кількості 1–7 особин/100 п.с. Найчастіше зустрічалися види *C. septempunctata*, *T. sedecimpunctata* та личинки Coccinellidae, які були еудомінантами в органічному агроландшафті. Вид *Vibidia sp.* зустрічався лише в органічних агроекосистемах гречки та вівса. Різноманіття сонечок в органічній пшениці озимій було вище, ніж у традиційній. Органічна соя, навпаки, мала менше різноманіття Coccinellidae, ніж традиційна, що підтверджено кластерним аналізом. Кількість видів у екосистемах культур варіювала від 3 до 8 у різних періодах дослідження. Знайдено високі кореляційні залежності чисельності комах між полями, екотонами та лісосмугами, а також між сусідніми екотонами та сусідніми лісосмугами, що вказує на міграцію комах між цими ділянками. Отже, встановлено різноманіття та поширеність сонечок в органічному агроландшафті порівняно з традиційним.

Ключові слова: сонечки, органічне сільське господарство, агроландшафт, агроекосистема, сільськогосподарські культури, вид.

Влияние органического земледелия на разнообразие божьих коровок (Coleoptera: Coccinellidae)

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Coccinellidae в природе выполняют функцию биологического контроля вредителей, они поедают тлей и других насекомых, что важно в органическом сельском хозяйстве. Целью работы было установить распространение и видовой состав семьи Coccinellidae в органическом агроландшафте. Исследования проводили на Сквырский опытной станции органического производства (Киевская область, Украина). Насекомых собирали методом энтомологического кошения сачком в четырех фазах развития растений. Органический агроландшафт включал сельскохозяйственные культуры: гречку, овес, сою и пшеницу озимую. Для сравнения использовали данные с соседними традиционными экосистемами сои и пшеницы озимой. Исследовали агроэкосистемы указанных культур, которые включали поля, экотон «поле – полезащитная лесополоса», полезащитные лесополосы. В результате исследования было выявлено 10 видов семейства Coccinellidae, численность видов составляла от 1 до 89/100 в.с., больше всего в экосистеме органической пшеницы озимой. *H. axiridis* принадлежал к рецедентам и был найден в пяти агроэкосистемах в количестве 1–7 особей/100 в.с. Чаще всего встречались виды *C. septempunctata*, *T. sedecimpunctata* и личинки Coccinellidae, которые были эудоминантами в органическом агроландшафте. Вид *Vibidia sp.* встречался только в органических агроэкосистемах гречки и овса. Многообразие божьих коровок в органической пшенице озимой было выше, чем в традиционной. Органическая соя, наоборот, имела меньше разнообразия Coccinellidae, чем традиционная, что подтверждается кластерным анализом. Количество видов в экосистемах культур варьировало от 3 до 8 в разных периодах исследования. Найдены

высокие корреляционные зависимости численности насекомых между полями, экотонами и лесополосами, а также между соседними экотонами и соседними лесополосами, что указывает на миграцию насекомых между этими участками. Таким образом, установлено многообразие и распространенность божьих коровок в органическом агроландшафте в сравнении с традиционным.

Ключевые слова: божьи коровки, органическое сельское хозяйство, агроландшафт, агроэкосистема, сельскохозяйственные культуры, вид.

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