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ORGANIC CROPS AS RESERVOIR FOR BENEFICIAL EPIGEAL ARTHROPODS

Summary

The aim of the study was to conduct quantitative and qualitative analysis of epigeic arthropods (Carabidae, Staphylinidae, Arachnida) occurring in crops within "Norfolk" rotation in organic farming. Arthropods' collecting was carried out in 2014 at the Experimental Research Station Swojec of the Wrocław University of Environmental and Life Sciences and at the organic farm located at Kamieniec Wrocławski. In both locations ground beetles, rove beetles and arachnids were the most numerous arthropods. The highest number of ground beetles was found within oat treatment, while rove beetles and arachnids within fodder peas. The greatest diversity of ground beetles species was calculated in Kamieniec Wrocławski, in case of pea crops. It may be assumed that these crops, provided by organic farming method, are optimal habitat for beneficial epigeal arthropods development.
***Key words**: organic agriculture, organic crops, epigeal arthropods, ground beetles, rove beetles, arachnids*

UPRAWY EKOLOGICZNE REZERWUAREM POŻYTECZNYCH STAWONOGÓW NAZIEMNYCH

Streszczenie

Celem pracy była analiza ilościowa i jakościowa zgrupowań stawonogów epigeicznych (Carabidae, Staphylinidae, Arachnida) występujących w uprawach płodozmianu norfolskiego, prowadzonych metodą ekologiczną. Odłowy stawonogów do pułapek glebowych prowadzono w 2014 roku, w Rolniczym Zakładzie Doświadczalnym Swojec, należącym do Uniwersytetu Przyrodniczego we Wrocławiu oraz w gospodarstwie ekologicznym w Kamieńcu Wrocławskim. W obu miejscowościach najliczniejszą grupą stawonogów były chrząszcze z rodzin biegaczowatych i kusakowatych oraz pajęczaki. Liczebność biegaczy najwyższa była w uprawie owsa, natomiast kusaków i pajęczaków najwięcej odłowiono w uprawie grochu pastewnego. Największe zróżnicowanie gatunkowe biegaczowatych odnotowano w Kamieńcu Wrocławskim w uprawie peluszki. Można przypuszczać, że wymienione uprawy prowadzone metodą ekologiczną stanowią optymalne siedlisko dla rozwoju pożytecznych stawonogów naziemnych.
***Słowa kluczowe**: rolnictwo ekologiczne, uprawy ekologiczne, stawonogi epigeiczne, biegaczowate, kusakowate, pajęczaki*

1. Introduction

All management practices used in organic crop production should influence the environment as little as possible. For this reason, organic farming seems environmentally friendly, helps in maintaining biodiversity and consequently ensuring the stability of the agro-ecosystem [1, 2, 3]. A diversified crop rotation is one of the basic principles of organic farming. Proper selection of plants for cultivation may even increase the diversity of beneficial organisms and thus limit the incidence of crop pests and prevent crop loss [4].

Non-specialized arthropods such as ground beetles, rove beetles and arachnids [5, 6, 7] are among the most important natural pests enemies. The biggest impacts on their occurrence Physical and chemical soil properties [8] have the biggest impacts on their occurrence. Undoubtedly omission of pesticides is also a key factor determining their survival [9]. Through a diversified crop rotation and as a result increasing the amount of organic matter in the soil, it is possible to affect positively the abundance and species diversity of these organisms [10, 11]. Carabidae and Staphylinidae are among the most numerous beetles family in Polish agricultural landscape [12]. Most are predatory and feed at ground level, but some will climb plants to feed on aphids, small caterpillars and other animals. Majority are mandatory or optional carnivorous (eg. *Poecilus* spp., *Pterostichus* spp., *Carabus* spp.), less numerous group are hemicarnivorous, such as common in Poland *Pseudoophonus rufipes* and few herbivores (*Amara* spp.), feeding mainly with seed of various plants, including segetal weeds [13, 14, 15]. These last two trophic groups of Carabidae may have a significant impact on the regulation of some weeds presence [5, 16]. Beetles, rove beetles and arachnids are considered to be valuable bioindicators of changes in the environment [5, 12, 17, 18] because these arthropods easily respond to agricultural practices carried out in arable fields.

The aim of the study was to conduct quantitative and qualitative analysis of epigeic arthropods (Carabidae, Staphylinidae, Arachnida) collected in crops within "Norfolk" rotation in organic farming.

2. Material and methods

The studies were conducted at the Experiment Station at Swojec belonging to the Wrocław University of Environmental and Life Sciences, and on organic farm in the Kamieniec Wrocławski town located 10 km from Wrocław. The geographical coordinates of these two sites are: 51°07'02.4"N, 17°08'25.2"E (Swojec) and 51°05'37.7"N, 17°10'21.3"E (Kamieniec Wrocławski). Organic farming in

both locations lasted for 10 years. In both sites the experiment was established on sandy soil. Four different crops were cultivated in an organic way: potato (Vineta cultivar), oat (Rajtar cultivar), fodder peas (Roch cultivar) and rye (Dańkowskie Złote cultivar). Those crops were cultivated on plots of area 36 m^2 (8 x 4 m) each, arranged randomly in three replicates. Agricultural practices carried out at different sites and treatments are presented in Table 1. In both of the localities treatments were performed on similar dates. Most of the practices were carried out in potato production. Within this crop biological insecticide against Colorado potato beetle was applied, i.e. Novodor SC (based on *Bacillus thuringiensis* var. *tenebrionis)*, approved for application in organic farming. In other crops number of treatments done during the growing season ranged from 7 to 9.

Epigeic arthropods were collected by using pitfall traps in the period from 12 May to 27 July 2014. The traps were emptied weekly. These were inserted into the ground so that the lip was flush with the soil surface. Each trap was a plastic container with a 9 cm diameter and 12 cm deep, filled with 100% ethylene glycol used as a preservative, and was sunk into another plastic tube. A square plastic, transparent lid protected the trap against precipitation. In each of the locations 12 traps were placed (4 in each crop in 3 replicates). In the laboratory material was taxonomically selected in three groups: Carabidae, Staphylinidae, Arachnida. All Carabidae were identified to the species level, and nomenclature was taken from Hůrka key (1996). Only adult individuals were considered for analysis [19].

The differences between arthropods assemblages collected from different treatments through whole of each sampling period were checked by ANOVA variance analyses with repeated measures and consequently Tukey's honest significant difference test (post-hoc). The significant level of $p \leq 0.05$ was considered for all tests. For this statistical analysis Statistica version 12.5 was chosen. To avoid seasonal trends influence, statistical analyses were calculated separately for each date. To compare the diversity aspects of ground beetle assemblages and to assess their similarities, the following ecological indices were applied: Shannon-Weaver index ($H' = -\Sigma p_i \ln(p_i)$, where p_i = the decimal fraction of individuals belonging to the i^{th} species) with the evenness index ($E=H'/\ln S$, where H' is the Shannon index and S is the number of species). Also species diversity by Simpson index was calculated: $D = \frac{\sum_{i=1}^{S} n_i(n_i-1)}{N(N-1)}$.

3. Results and discussion

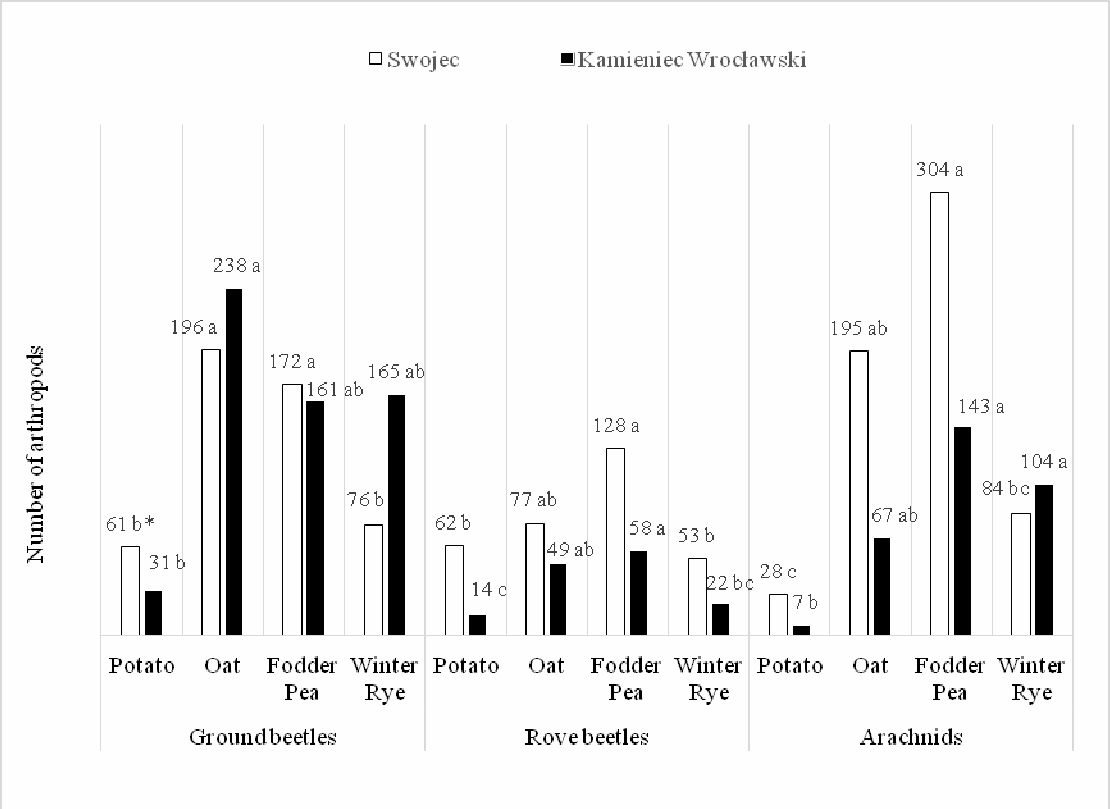
In total, 1100 ground beetles, 462 rove beetles and 932 arachnids were collected in both localities during whole experiment (Fig. 1). The highest number of Carabidae was found in oat, both in Swojec (196 individuals), and in Kamieniec Wrocławski (238 individuals). Less numerous beetles were recorded in fodder peas (respectively 172 individuals in Swojec and 161 in Kamieniec) and in winter rye (respectively 76 and 165 individuals). The least numerous ground beetles were noted in potato treatments (respectively 61 and 31 individuals). The probable reason of the lowest number of beneficial beetles Carabidae in the potato was lying in the largest number of agrotechnical practices performed in this crop. In a research carried out at Swojec ground beetles were significantly more numerous in oats and pea cultivation in comparison to potato and rye. In the second site - Kamieniec Wrocławski, Carabidae were significantly more numerous in organic cultivation of oat as compared to potato.

Table 1. The dates of agrotechnical treatments made in the field experiment in 2014
Tab. 1. Terminy wykonania zabiegów agrotechnicznych w doświadczeniu polowym w 2014

Treatment	Potato		Oat		Pea		Winter Rye	
	I*	II**	I	II	I	II	I	II
Harrowing (heavy harrow)	27.02		27.02		27.02			
Sowing			14.03	20.03	18.03	20.03	28.09 (2013)	30.09(2013)
Seedbed	12.03	20.03 29.09	12.03	20.03 27.08 29.09	12.03	20.03 27.08 29.09	12.03	27.08 29.09
Planting	28.04	28.04						
Harrowing (weeder)	21.05		28.03 06.05	28.04	28.03 06.05	28.04	28.03	31.03
Ridging	07.05 23.05 09.06	23.05 09.06 02.07						
Cultivating	05.06 27.06	21.05 05.06 27.06			07.08		07.08	
Spraying (Cuproflow 375 SC, Novodor SC)	13.06 24.06	13.06 24.06						
Skimming (10-12 cm)			18.08	20.08	05.08	20.08	05.08	20.08
Harrowing (medium harrow)			19.08		07.08		07.08	
Collecting	10.09	16.09	10.08	09.08	28.07	23.07	21.07	22.07
Liming (3t/ha)		19.09		19.09		19.09		19.09
Tillage (20-22 cm)		23.09		23.09		23.09		23.09

I* – organic fields in ERS Swojec / *uprawy ekologiczne w RZD Swojec*
II** – organic fields in Kamieniec Wrocławski / *uprawy ekologiczne w Kamieńcu Wrocławskim*

Source: Authors' own research / Źródło: opracowanie własne



**significant differences, separately for each locality(p≤0.05) /* istotne różnice, oddzielnie dla każdej miejscowości (p≤0,05)

Source: Authors' own research / Źródło: opracowanie własne

Fig. 1. The number of epigeic arthropods caught in experiment
Rys. 1. Liczebność stawonogów epigeicznych odłowionych w doświadczeniu

Beetles of the family Staphylinidae were the most numerous in the cultivation of fodder peas (Fig. 1). In this case, in total 186 rove beetles were collected in both studied locations (128 individuals in Swojec and 58 in Kamieniec). Less numerous they were recorded within oat cultivation (126 individuals). The least numerous rove beetles were noted in cultivation of potato and rye (respectively 76 and 75 individuals). Rove beetles caught in crops in Swojec and Kamieniec Wrocławski, occurred in significantly greater number on fodder peas compared to potato and winter rye. Arthropods belonging to Arachnida, similarly to Staphylinidae, were the most numerous in fodder peas. In both sites total number of collected arachnids was 447 (304 individuals in Swojec and 143 in Kamieniec). They were less numerous within oat cultivation (total 262 individuals), and the least numerous in potato (35 individuals). Epigeic arachnids, which were caught in an experiment carried out in Swojec, occurred significantly in greater number in the oat cultivation as compared to potato. In Kamieniec Wrocławski, Arachnida were significantly more numerous in fodder peas and winter rye cultivation than in potato.

Carabidae caught in both localities were identified to 44 species (Tables 2 and 3). In organic farming in Swojec only 24 species of ground beetles were observed, while in Kamieniec Wrocławski 40 species. In both sites the most numerous species was *Pseudoophonus rufipes* (116 individuals in Swojec and 226 in Kamieniec). It is a species commonly recorded within agricultural area in Poland, which prefers light, airy and dry soils [25]. Less numerous in the first location was species belonging to genus *Poecilus*, ie. *P. cupreus* (87) and *P. lepidus* (69), while in the second locality *Agonum sexpunctatum* (85) and *Harpalus affinis*(58).

Taking into account Carabidae noted in Swojec, the highest number of species was found in organically cultivated fodder peas (20 species), less in rye (16) and oat (13), and the least in potato (11) (Table 2). Nevertheless, in the ecological analysis of the results was noted that the highest ground beetles species diversity was recorded on the winter rye field. Shannon-Weaver index value of 2.58 was calculated for this crop, while in fodder peas H'=2.45. Oat field (H'=2.05) and potato (H'=2.17) were the highest species richness habitat. Similarly, the highest Pielou index was noted in rye (0.41) and the lowest in oat (0.27).

In Kamieniec Wrocławski the highest number of Carabidae species also was found in fodder pea'streatment (27 species). Both in case of oat and rye 25 species were identified. The least number of ground beetles were found in potato cultivation (7). Obtained values of species diversity calculated with Shannon-Weaver and Simpson index clearly confirmed that pea crop was the most attractive habitat for ground beetles in this location. Pielou index was the highest in the cultivation of field peas and potato (0.31).

Organic farming influence positively through increasing biotic diversity in comparison to conventional farming [1]. For crop rotation within organic farms this positive effect should be taken into account. Beneficial organisms supported with a proper crop rotation may have a huge importance in reducing pest populations and help in maintaining the ecological stability of the agroecosystem. A properly selected crop for rotation is a key issue for whole environment and undoubtedly has a positive effect on the soil quality. It results in the presence of numerous soil beneficial arthropods such as ground beetles, rove beetles and arachnids. In the present study rotation consisted of four plant

species, i.e. potato, oat, fodder peas and rye. O'Rourke et al. (2008) argue that greater diversity and abundance of Carabidae occurs in simplified two-year crop rotation compared to four-year crop within 'Norfolk' crop rotation. Research conducted in Swojec and Kamieniec denies this thesis by a higher number of beetles than reported in cited work [20]. In another study there was formulated a thesis that greater diversity of Carabidae was determined by crops rapidly covering with plants [21, 23]. These results confirm the dependence due to the most numerous abundance of arthropods in oat and fodder peas cultivation. Kosewska and Nijak [24] in their study showed that a greater diversity of species occurred in cereals. In other studies it was found that the density of plants per unit area [25] may be one of the factors determining the activity and presence of Carabidae. These authors suggest that some species may be closely related to habitat. *Bembidion quadrimaculatum* preferring light and well sunlit soil [15] is good example. This species is very common in potato crops and our results confirm this thesis. In both locations *Pseudoophonus rufipes* was the dominant species. It is an eurytopic species occurring frequently in different habitats [12, 24]. *P. rufipes* is also hemicarnivorous, which may have impact on reducing the numerous of pests. Similar beneficial influences have other dominant species of Carabidae in organic farming [5, 12, 18].

Table 2. Species composition and number of ground beetles caughtin organic fields at swojec
Tab. 2. skład gatunkowy i liczebność biegaczowatych odłowionych w uprawach ekologicznych na Swojcu

Species	*Potato*		*Oat*		*Pea*		*Winter Rye*	
	N*	%	N	%	N	%	N	%
Pseudoophonus rufipes (De Geer)	18	29,4	52	26,5	35	20,3	11	14,6
Poecilus cupreus(Linnaeus)	9	14,8	40	20,4	28	16,2	10	13,2
Poecilus lepidus (Leske)	1	1,6	37	18,9	22	12,7	9	11,8
Agonum sexpunctatum (Linnaeus)			5	2,6			2	2,6
Harpalus affinis (Schrank)	3	4,9	9	4,6	11	6,4	6	7,9
Bembidion properans (Stephens)	7	11,5	20	10,2	24	14	6	7,9
Bembidion quadrimaculatum (Linnaeus)	4	6,6	6	3,1	7	4,1	5	6,6
Anchomenus dorsalis (Pontoppidan)			10	5,1	8	4,7	8	10,5
Broscus cephalotes (Linnaeus)	4	6,6	3	1,5	8	4,7	2	2,6
Poecilus versicolor (Sturm)			3	1,5	3	1,7	2	2,6
Bembidion femoratum (Sturm)	4	6,6			4	2,3		
Microlestes minutulus (Goeze)	5	8,2	1	0,5			2	2,6
Calathus ambiguus (Paykull)					3	1,7		0
Calathus fuscipes (Goeze)			1	0,5	1	0,6	2	2,6
Bembidion lampros (Herbst)					4	2,3	3	4
Amara similata (Gyllenhal)	1	1,6			2	1,2		
Calathus erratus (Sahlberg)					2	1,2	1	1,3
Amara aenea (De Geer)						0	1	1,3
Clivina fossor (Linnaeus)	2	3,3			1	0,6		
Ophonus brevicollis (Audinet-Serville)					1	0,6	2	2,6
Carabus nemoralis (Müller)					1	0,6		
Cicindela hybrida (Linnaeus)					2	1,2		
Stenolophus teutonus (Schrank)			1	0,5				
Calosoma inquisitor (Linnaeus)					1	0,6		
Unidentified	3	4,9	8	4,1	4	2,3	4	5,3
Total	61	100	196	100	172	100	76	100
No. species	11		13		20		16	
Simpson's Index D	0,13		0,16		0,11		0,07	
Shannon - Weaver Index H'	2,17		2,05		2,45		2,58	
Pielou Index J'	0,36		0,27		0,32		0,41	

* number of Carabidae / *liczebność Carabidae*

Source: Authors' own research / Źródło: opracowanie własne

Table 3. Species composition and number of ground beetles caught in organic fields at Kamieniec Wrocławski
Tab. 3. Skład gatunkowy i liczebność biegaczowatych odłowionych w czterech uprawach ekologicznych w Kamieńcu Wrocławskim

Species	Potato		Oat		Pea		Winter Rye	
	N*	%	N	%	N	%	N	%
Pseudoophonus rufipes (De Geer)	8	25,8	105	44,1	63	39,1	50	30,3
Poecillus cupreus (Linnaeus)			6	2,5	24	14,9	3	1,8
Poecillus lepidus (Leske)			29	12,2	10	6,2	2	1,2
Agonum sexpunctatum (Linnaeus)			26	10,9	3	1,9	56	33,9
Harpalus affinis (Schrank)			39	16,4	14	8,7	5	3
Bembidion properans (Stephens)	3	9,7	5	2,1	8	5	5	3
Bembidion quadrimaculatum (Linnaeus)	13	41,9	2	0,8	2	1,2	1	0,6
Anchomenus dorsalis (Pontoppidan)	1	3,2	3	1,3	4	2,5	1	0,6
Amara communis (Panzer)			2	0,8	1	0,6	20	12,1
Broscus cephalotes (Linnaeus)					2	1,2		
Poecillus versicolor (Sturm)			3	1,3	1	0,6	2	1,2
Bembidion femoratum (Sturm)	2	6,5	1	0,4	2	1,2		
Microlestes minutulus (Goeze)	2	6,5			1	0,6		
Calathus ambiguus (Paykull)	2	6,5	1	0,4	3	1,9	1	0,6
Calathus fuscipes (Goeze)			1	0,4	4	2,5	1	0,6
Bembidion lampros (Herbst)					2	1,2	1	0,6
Amara similata (Gyllenhal)			1	0,4	4	2,5	1	0,6
Calathus erratus (Sahlberg)			4	1,7				
Dolichus halensis (Schaller)					2	1,2	3	1,8
Amara aenea (De Geer)			1	0,4	2	1,2	1	0,6
Clivina fossor (Linnaeus)					1	0,6		
Carabus granulatus (Linnaeus)			1	0,4	1	0,6	1	0,6
Amara apricaria (Paykull)					2	1,2	1	0,6
Anisodactylus binotatus (Fabricius)			1	0,4			1	0,6
Dyschirius globosus (Herbst)			1	0,4	1	0,6		
Cylindera germanica(Linnaeus)			1	0,4			1	0,6
Dyschirius intermedius (Putzeys)							2	1,2
Amara equestris (Duftschmid)							2	1,2
Carabus nemoralis (Müller)			1	0,4				
Amara bifrons (Gyllenhal)			1	0,4				
Amara aulica (Panzer)			1	0,4				
Loricera pillicornis (Fabricius)			1	0,4				
Amara plebeja (Gyllenhal)			1	0,4				
Calathus melanocephalus (Linnaeus)					1	0,6		
Pterostichus vernalis (Panzer)							1	0,6
Pterostichus niger (Schaller)					1	0,6		
Badister bullatus (Schrank)					1	0,6		
Agonum muelleri (Herbst)							1	0,6
Harpalus rubripes (Duftschmid)							1	0,6
Trechus quadristiatus (Schrank)					1	0,6		
Nieoznaczone Unidentified							1	0,6
Total	31	100	238	100	161	100	165	100
No. species	7		25		27		25	
Simpson Index D	0,24		0,24		0,18		0,22	
Shannon - Weaver Index H'	1,58		1,91		2,3		2,02	
Pielou Index J'	0,31		0,25		0,31		0,27	

*number of Carabidae / *liczebność Carabidae*

Source: Authors' own research / Źródło: opracowanie własne

4. Conclusions

1. Beneficial ground beetles arthropods were the most numerous in organic farming in oat, while rove and arachnids in the fodder pea crop. Potato cultivation was the least attractive for epigeic arthropods
2. The greatest species diversity of ground beetles was found in cultivation of fodder peas. Organic potato cultivation had negative influence on diversity of these arthropods.

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