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Effect of traditional agriculture technology on communities of soil invertebrates

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The study of peculiarities specific for the spatial organization of communities of living organisms allows to develop principles of the rational and effective use of the biosphere natural resources and optimal adaptation of mankind to the natural environment. The aim of the research was to study communities of the soil mesofauna as an integral indicator of the state of soils under conditions of applying the traditional farming technology, to carry out the quantitative accounting of the soil mesofauna, and assessment of morphometric parameters of sunflower plants in places of selecting soil and zoological samples, to determine the species composition and abundance, as well as to analyze the ecological structure of the soil mesofauna community. Rheophilous species predominate on black steam, and mesophilic species predominate under sunflower. This can be explained by the fact that in the periodic cultivation of black steam, the evaporation from the soil surface is much higher. Ultra-mega-coenotrophs are dominant on black steam, and megacoenotrophs are dominant under sunflower. Since both demonstration trails are laid on one field, but have strategically been divided into a plot under black steam and a plot under sunflower, one can assume a different degree of saturation of the soil solution, as during the growth the crop being cultivated uses soil nutrients. Among topomorphs of soil animals, exactly soil animals are dominant, which is characteristic for both demonstration trails being studied. In the composition of trophomorphs of soil animals, phytophages are dominant in soil of the test demonstration trail on black steam, and in soil of the test demonstration trail, where sunflower was cultivated, phyto- and saprophages predominate in equal proportions. As a result of the correlation analysis, statistically reliable dependences are obtained: – numbers of soil animals in soil of the demonstration trail on black steam – on the distance from forest belt areas (-0.23) and length and width of sunflower leaves - on the distance from forest belt areas (0.53 and 0.53 respectively). The species composition, abundance and distribution in space of soil invertebrates are an informative indicator, which reflects the ecological state of soils, intensity in development of soil horizons as well as intensity of processes occurring in them.
Key words: agrocoenosis; trophomorphs; soil animals

Introduction

Human activities have caused a depletion of the biodiversity at all levels of the organization. The loss of the biological diversity is largely a result of traditional, extensive and mixed practices of the agriculture (Rubtsov, Vinogradov, 1950; Klemina, 2008; Lykholat et al., 2016; Yermishev et al., 2017). The crop sector production is an outcome of the purposeful functioning of the artificial (cultural) ecological system (Owen, 1977). Such an ecological system was named Agro-Ecosystem (Chernyshev, 2001; Kuleshov, Gadzhieva, 2008; Sumarokov, 2009).

The tillage with agricultural implements and use of chemicals significantly change the habitat of soil animals (Ovsiannikov, 2000). Ecosystems with the rich biological diversity of living organisms have a higher resistance to the anthropogenic influence (Sidorenko, 2007). Under conditions of agrobiogeocoenoses, total energy losses sharply increase. The last fact is conditioned by both the imperfection of agro-technical methods and the relatively low ecological stability of the production process due to their homogeneity (Zhuchenko, 2012).

Agricultural ecosystems or agro-ecosystems are related to the number of anthropogenic ecosystems that are the closest ones to natural ecosystems (Mirkin, 1997). The main difference consists in replacement of multi-species plant community with field crops. The structure of the heterotrophic link is simplified, and the ability to self-regulation and maintenance of the stability is reduced. In the presence of a limited set of ecological niches, only the most adapted species and groups of soil animals reaching a high abundance remain. However, even in mono-cultural agrocoenoses the regular structure of communities being repeated under similar conditions is formed (Striganova, 2003).

The soil fauna of agro-ecosystems has been well studied, but up to now the mechanisms of the dynamics of mesopedobionts communities have not been disclosed yet in the changing agro-landscape, and the factors of their functioning have not been determined (Altieri, 1999; Burel, Baudry, 2005). This is explained by the fact that the studies mainly consider elements of the biodiversity without taking into account structural and functional features of the soil coenosis (Tillage ..., 2010; Khabbibulina et al., 2012). The soil population is a convenient model that reflects changes in environmental conditions and acts as the integral indicator of the dynamics of terrestrial ecosystems (Nagumanova, Ni, 2005). The functional structure of soil invertebrate communities can be an effective indicator of the depth of the impact on the ecosystem (Quantitative ..., 1987; Striganova, 2000; Bragina, 2004). The functional structure of communities can be quantified on the basis of the principles of Akimov-Belgard eco-morphic analysis. The spectra of ecomorphs enable to make diagnosis of essential properties of natural and transformed biogeocoenoses (Zhukov, 2009). Ecomorphs of animals as the ecological classification are a context-dependent generalization of information about their relationship with the environment (Belgard, 1971). The ratio of ecomorphs in the community characterizes its eco-morphic structure. Ecomorphs are in certain relationship between themselves, which creates the eco-morphic organization (Zhukov, 2007; Zhukov, 2009).
The importance of studying the population of soil invertebrates is conditioned by their role in the life of soil, where they not only inhabit, but also actively form the structure of soil horizons. Representatives of the soil mesofauna participate in many soil-forming processes and are important ecosystem engineers (Lavelle, Bignell, Lepage, 1997; Methodical ..., 2010). Earthworms are important edificators; they perform a number of functions that support the soil-forming process (Methodical..., 2010). One of them is to maintain the aeration of soil. The need in intensive «ventilation» of the earth cover is caused by the fact that as a result of life-sustaining activities of the biota, as well as biochemical processes taking place in soil, various gases enter into it (Ovsiannikov, 2000).
The study of peculiarities specific for the spatial organization of communities of living organisms allows to develop principles of the rational and effective use of the biosphere natural resources and optimal adaptation of mankind to the natural environment (Ravkin, Lukianova, 1976; Vtorov, Drozdov, 2001; Voronov et al., 2003; Abdurakhmanov and al., 2003).
The aim of the research was to study communities of the soil mesofauna as an integral indicator of the state of soils under conditions of applying the traditional farming technology, to carry out the quantitative accounting of the soil mesofauna, and assessment of morphometric parameters of sunflower plants in places of selecting soil and zoological samples, to determine the species composition and abundance, as well as to analyze the ecological structure of the soil mesofauna community.

Material and methods

The material was selected in the spring-summer period of 2016 in soils for agricultural purposes (Znamenovka village, Novomoskovskyi district of Dnipropetrovsk region). Soil and zoological samples were selected on two plots – a plot with black steam and a plot, where the medium-ripened SI Bacardi sunflower hybrid was farmed. Corn was a preceding crop on both plots.
The material was selected according to the regular grid – 5 transects by 15 samples in each, in total - 75 samples. The lag between transects and samples is 2 m. Accounting of soil invertebrates was carried out by the method of soil open test pits and manual disassembly of soil samples. The sample size as per standard methods of soil and zoological researches (Spatial..., 2007) amounted to 0.25×0.25 m. In totality, 150 soil and zoological samples were selected. Ecomorphs of the soil mesofauna are given according to A.V. Zhukov (Zhukov, 2009).
Within the limits of each plot, where soil and zoological samples were selected on the demonstration trail with sunflower, 3 plants were being randomly selected and subjected to measurements. The coordinates of these plants were fixed relatively the local system of coordinates. The height of the plant's stem and the length and width of its leaf were measured. The accuracy of measuring the height of plants was 1 cm, the diameter of the stem, as well as the length and width of the leaf – 1 mm. In totality, 225 sunflower plants were measured and 1125 morphometric measurements were performed.

Results and discussion

Table 1 presents the average number of invertebrates in soil and zoological samples on two demonstration trails – 1.2 specimens/sample on black steam and 0.8 specimens/sample on the demonstration trail, where sunflower has been cultivated. Minimal (0.0 specimens/sample for both demonstration trails) and maximal values (13.0 and 10.0 respectively) are also specified.
We studied the species composition and population density of each species of the soil mesofauna community on the agricultural field, being under black steam (table 2).

Table 1. Descriptive statistics of the number of soil animals on demonstration trails being studied

Indicators	Mean	Minimum	Maximum	Standard deviation
Numbers of soil animals (black steam), specimen/sample	1.20	0.00	13.00	1.86
Numbers of soil animals (sunflower), specimen/sample	0.80	0.00	10.00	1.52

We fixed 10 species of soil invertebrates related to 9 families, 4 classes and 2 types, with the total density of 18.6 specimens/m² on black steam. Under the sowing of sunflower there are also 10 species of soil invertebrates that are attributable to 10 families, 4 classes and 2 types, with the total density of 13.0 specimens /sq².

Table 2. Species composition of the soil mesofauna on the agricultural field

Type	Class	Family	Genus	Species	Phase of development	Density, specimen/m² (black steam)	Density, specimen/m² (sunflower)
Annelidae	Oligohaeta	Enchytraeidae	Enchytraeidae sp.	*Enchytraeidae sp.*	imago	1.3	3.8
		Lumbricidae	Aporrectodea	*Aporrectodea rosea rosea* (Savigny, 1826)	imago	2.6	3.4
Arthropoda	Chilopoda	Geophilidae	Geophilus	*Geophilus proximus* C.L.Koch 1847	imago	2,1	1.3
		Lithobiidae	Lithobius	*Lithobius (Lithobius) forficatus* (Linnaeus 1758)	imago	0.6	0.2
				Lithobius (Monotarsobius) curtipes C.L. Koch 1847	imago	0.2	0.0
	Diplopoda	Julidae	Rossiulus	*Rossiulus kessleri* (Lohmander, 1927)	imago	1.1	0.2
	Insecta	Elateridae	Agriotes	*Agriotes sputator* (Linnaeus 1758)	larvae	4.7	2.0
		Noctuidae	Noctuidae	*Noctuidae sp.*	larvae	0.6	0.0
		Scarabaeidae	Pentodon	*Pentodon idiota* Herbst, 1789	larvae	4.7	0.9
		Tenebrionidae	Cylindronotus	*Cylindronotus brevicollis* Kuster, 1850	larvae	0.6	0.64
		Carabidae	Zabrus	*Zabrus (Zabrus) tenebrioides* (Goeze 1777)	larvae	0.0	0.2
		Gryllidae	Gryllidae sp.	*Gryllidae sp.*	imago	0.0	0.2
Result						18.6	13.0

In the studied soils, the family Lumbricidae is represented by 1 species – *Aporrectodea rosea*. This species is actually a soil middle-tiered earthworm feeding on soil black mold humus. This is the only species of Lumbricidae, which can be called a permanent inhabitant of steppe zonal communities (Zhukov, 2004; Zhukov, Pakhomov, Kunakh, 2007). The density of *A. rosea* population on black steam amounts to 2.6 specimens /m², and on the demonstration trail, where sunflower was cultivated – 3.4.

Perhaps, the density of the population in soil under sunflower is higher due to the minor factor of alarm, since earthworms are sensitive to the tillage operations.

Two-legged millipedes (Diplopoda, Myriapoda) are herpetobion invertebrates. This group is represented, within the limits of the demonstration trails being studied, by the species *Rossiulus kessleri* (Lohmander, 1927), which is able to exist in the wide range of moisture domain, that is why it is met just as in steppe communities, so in artificial forest plantations and meadows. This species is a saprophage and plays the important part in the soil-forming process as an active destructor of the litter, in this case, plant remains of the preceding crop - corn. On black steam *R. kessleri* is fixed with the density of 1,1 specimens/m², and in soil, where sunflower was cultivated – 0,2 specimens/m². The difference in the population density can presumably be explained by weather conditions, as soil-zoological samples were selected on different dates.

Chilopoda Myriapods (Chilopoda, Myriapoda) are represented by orders of Lithoboimorpha millipedes and Geophilomorpha millipedes.

Lithoboimorpha millipedes are entomophages that feed on small invertebrates (insects, oligochaetes, spiders, springtails). They are markers of the intensity in development of the litter block and lead the hidden lifestyle.

In soils under black steam there are fixed 2 species - *Lithobius forficatus* and *Lithobius curtipes*, with the population density of 0.6 and 0.2 specimens/m² respectively. In soil, where sunflower was cultivated, 1 species – *L. forficatus* (0,2 specimens /m²) is registered.

Geophilous-morphic millipedes are inhabitants of mineral soil horizons and are also entomophages. Only 1 species - *Geophilus proximus* is fixed on the demonstration trails being studied. In soils under black steam the density of *G. proximus* population amounts to 2.1 specimens/m²; in soil, where sunflower was cultivated, the density amounts to 1.3 specimens/m².
Chafers are one of the most numerical groups of invertebrates, which plays an important role in the functioning of ecosystems. We registered only the larval phase of the development.
4 species are registered on black steam, and 5 species from three orders - Coleoptera, Lepidoptera and Orthoptera – in soil under sunflower. All the fixed species are more or less pests.
The type of spatial distribution for soil invertebrates was established using Lexis formula (Giliarov, 1975):

$$\lambda = \sigma / M,$$

where λ – aggregation coefficient, σ – mean-square deviation, and M – mean value. The aggregated distribution of individuals corresponds to values of the index being more than 1, random one – the index being close to 1, and uniform – the index being close to 0 (Giliarov, 1975).

Table 3. Lexis aggregation index (λ)

Option	Mean	Standard deviation	Lexis index
Black steam	18.6	1,9	0.09
Sunflower	13.0	1.5	0.12

On the demonstration trails being studied, the Lexis index highlights the uniform distribution of individuals. Table 4 shows ecomorphs of soil animals.

Table 4. Ecomorphic characteristics of the soil mesofauna

Species	Hygromorph	Trophocoenomorph	Topomorph	Trophomorph
Aporrectodea rosea rosea (Savigny, 1826)	Ms	MgTr	End	SF
Geophilus proximus C.L.Koch 1847	Hg	MsTr	Anec	ZF
Lithobius (Lithobius) forficatus (Linnaeus 1758)	Ms	MsTr	Ep	ZF
Lithobius (Monotarsobius) curtipes C.L. Koch 1847	Hg	MsTr	Ep	ZF
Rossiulus kessleri (Lohmander, 1927)	Ms	MgTr	Ep	SF
Agriotes sputator (Linnaeus 1758)	Ks	UMgTr	End	FF
Pentodon idiota Herbst, 1789	Ms	MsTr	End	FF
Cylindronotus brevicollis Kuster, 1850	Ks	UMgTr	End	FF

Notes: Coenomorphs: St – stepants, Pr – pratants, Pal – palludants, Sil – silvants. Hygromorphs: Ks – xerophiles, Ms – mesophiles, Hg – hygrophiles, UHg – ultrahygrophiles. Coenotrophomorphs: MsTr – mesotrophs; MgTr – megatrophs; UMgTr – ultramegatrophs. Topomorphs: End – endogeic. Ep – epigene, Anec – cubs. Trophomorphs: SF – saprophages; FF – phytophages; ZF – zoophages.

Figs 1-8 show the spectra of ecomorphs of soil animals taking into account the abundance.

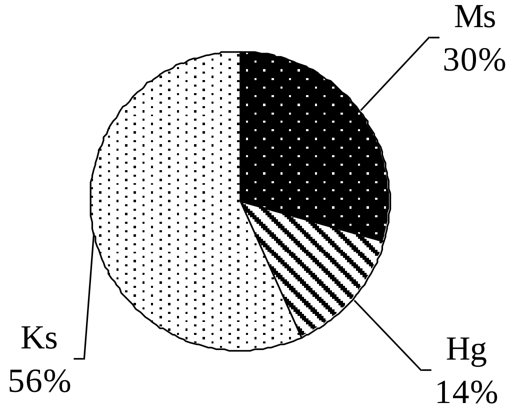

Figure 1. Hygromorph spectrum of soil animals (black steam)

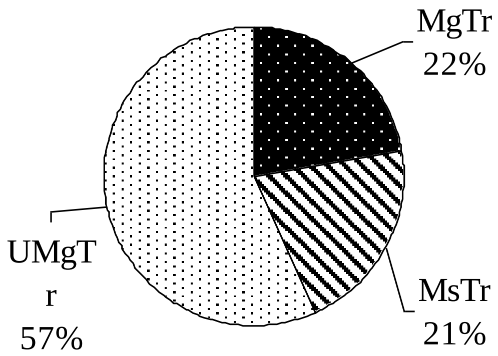

Figure 2. Trophocoenomorph spectrum of soil animals (black steam)

In the context of the species richness of the animal population from the studied demonstration trail (black steam), the biomorphic-ecomorphic structure looks as follows: among hygromorphs, xerophilous species (56%) are predominantly represented, mesophilic species are comparatively less – 30 %, hygrophilic ones – 14 %. In the composition of coenotrophomorphs, ultramegacoenotrophs predominate (57 %), mesocoeno- (21%) and megacoenotrophs (22%) are not so much. Topomorphs are represented by endogeic species (76 %), epigene (11 %) and cubs (13 %).

The trophomorph spectrum is represented by such distribution: phytophages – 73 %, zoophages – 21 % and saprophages – 6 %.

The animal population of the studied demonstration trail under sunflower has the following biomorphic-ecomorphic appearance: among hygromorphs, xerophilous species (56 %) are predominantly represented, mesophilic species are comparatively less – 30 %, hygrophilic ones – 14 %. In the composition of coenotrophomorphs, ultramegacoenotrophs predominate (57 %), mesocoeno- (21%) and megacoenotrophs (22%) are not so much. Topomorphs are represented by endogeic species (76 %), epigene (11 %) and cubs (13 %). The trophomorph spectrum is represented by such distribution: phytophages – 73 %, zoophages – 21 % and saprophages – 6 %.

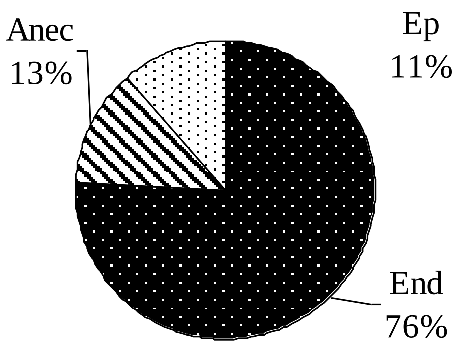

Figure 3. Topomorph spectrum of soil animals (black steam)

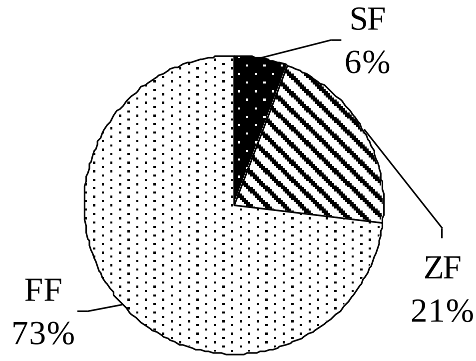

Figure 4. Trophomorph spectrum of soil animals (black steam)

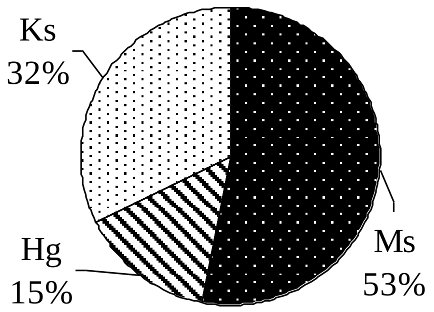

Figure 5. Hygromorph spectrum of soil animals (sunflower)

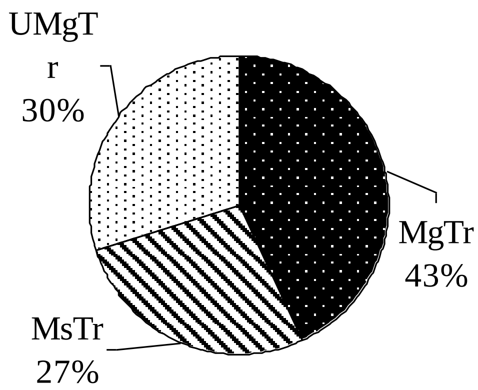

Figure 6. Trophocoenomorph spectrum of soil animals (sunflower)

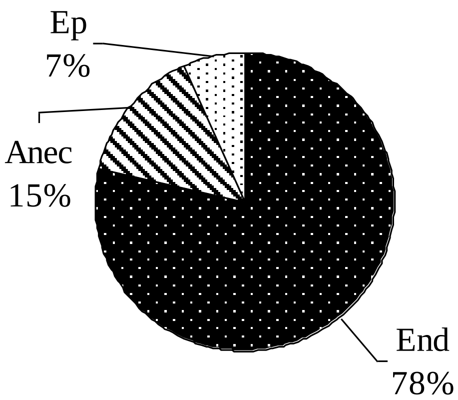

Figure 7. Topomorph spectrum of soil animals (sunflower)

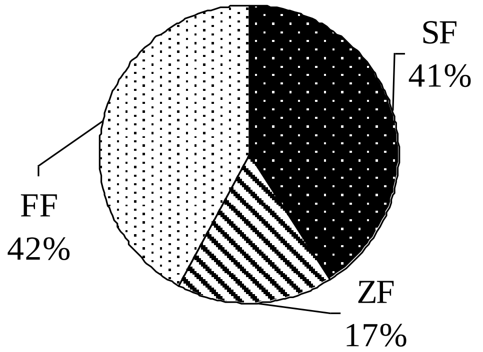

Figure 8. Trophomorph spectrum of soil animals (sunflower)

Ecomorphic structures of the studied demonstration trails have both a number of common features and a number of differences. In accordance with the type of the biological cycle, coenotic groups that have functional features are formed. A.L. Belgard (1950) determined coenomorphs as an adaptation of species in general to phytocoenosis (see also Zhukov, 2009).

The water regime of soils is an important environmental factor that determines the features of the life-sustaining activities of the mesofauna and properties of soil animal communities. Hygromorph is a collection of living organisms, which prefer a certain moisture regime (Zhukov, 2009). The hygromorphic structure of the soil animal population gradually varies in the gradient of the humidity conditions (Zhukov, 2007). Rheophilous species dominate on black steam, and mesophilic species dominate under sunflower. This can be explained by the fact that during periodic cultivation of black steam, the evaporation from the soil surface is much higher.

Trophocoenomorphs are an ecological group of soil animals that prefer a type of biogeocoenosis with a certain level of mineralization of the soil solution. The properties of trophotop form the properties of the soil mesofauna communities (Zhukov, 2009). Ultramegacoenotrophs are dominant on black steam, and megacoenotrophs are dominant under sunflower. Since both demonstration trails are laid on the same field, but have strategically been divided into a plot under black steam and a plot under sunflower, one can assume a different degree of saturation of the soil solution, as during the growth the crop being cultivated uses soil nutrients.

The mineralization of the soil solution affects the trophic and topic structure of the animal soil population. Topomorph is an ecological group of soil animals, which is distinguished on the basis of the preference of the specific soil horizon. In more fertile or poor soils the role of cubs decreases, and the role of endogeic forms increases (Zhukov, 2009). Such a distribution among topomorphs of soil animals is characteristic for two demonstration trails being studied.

Trophomorphs are ecological groups of animals that are distinguished by their specific feeding habits (Zhukov, 2009). The nature of the participation of soil invertebrates in the ecosystem cycle of substances and flow of energy depends on food relations, the presence in the composition of the soil population of some or other trophic groups, which, in its turn, depends on the structure of the vegetation cover and type of soil (Zhukov, 1996).

The important biogeocoenotic role of soil invertebrates consists in processing of plant remains, which determines the intensity and direction of the process of soil formation and level of fertility (Striganova, 1980). In the composition of trophomorphs of soil animals in soil of the test demonstration trail on black steam, phytophages predominate, and in soil of the test demonstration trail, where sunflower was cultivated, phyto- and saprophages predominate in equal proportions.

Tables 5-6 provide with the descriptive statistics of the density in standing of sunflower plants, the height of plants, length and width of leaves.

Table 5. Descriptive statistics of the density and phytometric characteristics of SI Bacardi sunflower plants

Indicators	Mean	Minimum	Maximum	Standard deviation
Density in standing of sunflower plants per 1 m	4.48	3.00	7.00	0.86
Height of sunflower plants, cm	5.53	3.20	8.23	1.00
Leaf length	6.34	2.37	9.70	1.72
Leaf width	3.17	1.20	4.82	0.86

Table 6. Pearson's correlation code (valid codes are highlighted p <0,05)

Indicators	Distance from forest belts, m	Density in standing of sunflower plants per 1 m	Height of sunflower plants, cm	Leaf length	Leaf width
Numbers of soil animals (black steam), specimens	**-0.23**	-	-	-	-
Numbers of soil animals (sunflower), specimens	-0.19	-0.08	0.22	0.0	0.1
Density in standing of sunflower plants per 1 m	-0.17	-	-	-	-
Height of sunflower plants, cm	-0.21	-	-	-	-
Leaf length	**0.53**	-	-	-	-
Leas width	**0.53**	-	-	-	-

Also, in Table 6 there are given results of the correlation analysis, following on from which statistically reliable dependences are obtained: – numbers of soil animals in soil of the demonstration trail on black steam – on the distance from forest belt areas (-0.23, p <0.05); length and width of sunflower leaves - on the distance from forest belt areas (0.53 and 0.53 respectively, p <0.05).

Conclusions

Therefore, the average number of invertebrates in soil-zoological samples on two demonstration trails is 1.2 specimens/sample on black steam and 0.8 specimens/sample on the demonstration trail, where sunflower was cultivated. 10 species of soil invertebrates were recorded, which belong to 9 families, 4 classes and 2 types, with the total density of 18.6 specimens/m² on black steam. Under the sowing of sunflower there are also 10 species of soil invertebrates, that belong to 10 families, 4 classes and 2 types, with the total density of 13.0 specimens/m². On the demonstration trails being studied, the aggregation index of the soil invertebrates' community highlights a uniform distribution of individuals in space.
Rheophilous species predominate on black steam, and mesophilic species predominate under sunflower. This can be explained by the fact that in the periodic cultivation of black steam, the evaporation from the soil surface is much higher. Ultramegacoenotrophs are dominant on black steam, and megacoenotrophs are dominant under sunflower. Since both demonstration trails are laid on one field, but have strategically been divided into a plot under black steam and a plot under sunflower, one can assume a different degree of saturation of the soil solution, as during the growth the crop being cultivated uses soil nutrients.
Among topomorphs of soil animals, exactly soil animals are dominant, which is characteristic for both demonstration trails being studied. In the composition of trophomorphs of soil animals, phytophages are dominant in soil of the test demonstration trail on black steam, and in soil of the test demonstration trail, where sunflower was cultivated, phyto- and saprophages predominate in equal proportions. As a result of the correlation analysis, statistically reliable dependences are obtained: – numbers of soil animals in soil of the demonstration trail on black steam – on the distance from forest belt areas (-0.23, $p < 0.05$) and length and width of sunflower leaves - on the distance from forest belt areas (0.53 and 0.53 respectively, $p < 0.05$).
The species composition, abundance and distribution in space of soil invertebrates are an informative indicator, which reflects the ecological state of soils, intensity in development of soil horizons as well as intensity of processes occurring in them. These studies are prospective for assessment of the degree of influence and transformation of edaphotope as a component of agrocoenosis.

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