RESEARCH OF PHYSICAL-MECHANICAL PROPERTIES OF SOIL RELATED TO EARTHWORMS ABUNDANCE IN AGRICULTURAL AND BACKGROUND AGROECOSYSTEMS AT DIDACTIC AND EXPERIMENTAL STATION "CHETROSU", REPUBLIC OF MOLDOVA

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Abstract

Within agroecological monitoring, an essential role is played by the biological monitoring, because surveillance of living organisms provides precious information regarding the vitality of agroecosystems and quality of environmental factors, essential for the quality of agricultural products and natural resources. The goal of earthworms' complex research is establishment of the high efficient agrocoenoses, ecologically balanced, stable, based on the rational usage of the nutritive substances of soil, vegetable rests, water, and finally the application of environment-friendly technologies. From this point of view, earthworms can be used within the agroecological monitoring, because they can be easily extracted from their environment without affecting the population assembly. Essential for earthworms' habitat is soil texture and soil humidity, physical-mechanical properties, organic debris, both quantitatively and qualitatively. The soil of the researched ecosystems was represented by calcic (carbonated) silt loamy chernozem. The limits of plasticity, resistance to penetration, and adherence of soil are influenced by humus content, fertilization type, and diversity of agrocoenoses. The forest strip and fallow farmland can contribute by providing with information the Database of background and agroecological (impact) monitoring. During the droughty seasons, earthworms were not found in soil, but a maximal number has been identified in forest strip (76 worms/m^2) at 0-30 cm depth, which represents a hiding habitat during the arid periods.

Key words: agroecosystem, chernozem, plasticity, adherence, penetration, earthworms, background monitoring

Within ecological security and integrated ecological monitoring, the biological monitoring has a great role, as a system of observations, interpretations, and prognoses of all constant changes appearing in the living world, but actually less applied in pedological studies. Research of pedofauna, of species with positive role for soil fertility; allow surveying the vitality and activity of soil, to avoid the critical levels of the anthropic impact on soil biota. Applying the integrated monitoring, pedoecological and of impact, through various approaches and activities, facilitate the permanent, complex observation of soils and agrocenoses, organisms with vital functions for soil.

According to present researches in the field [Godeanu S., 1997], earthworms can be used in the agroecological impact monitoring because these species live over 2 years, sizes of bodies are enough large, they can be easily extracted from soil, can live in laboratory conditions, are bio-accumulators, and their extraction out of habitat does not affect the population assembly.

Important for earthworms' habitat are soil texture, humidity, physical-mechanical conditions (bulk density, compaction degree), organic rests under quantitative and qualitative aspects, and selection of the most favourable living conditions for them must consider the technological elements of sustainable development.

Using earthworms in surveying agro-ecosystems with different anthropic impact allows the complex control of soil changes, including maintaining soil vitality and pedofauna habitat, control of seasonal changes on long and short term. Application of modern agricultural technologies, environment-friendly and pedofauna-friendly, also requires finding hiding habitats.

Earthworms research in various agroecosystems and buffer areas was performed in long term experiments at Didactic and Experimental Station (DES) „Chetrosu", State Agrarian University of Moldova (1990-2012), the present investigations representing a continuity of

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previous others [Fedotova L., 1993; Cojocaru O., 1998], which assessed the earthworm abundance in control variants and in variants with various types and doses of fertilizers, forest strips, fallow farmland.

MATERIAL AND METHODS

Within agroecosystems were investigated the influence of various types and doses of fertilizers (organic and mineral), crop rotations, permanent culture of maize (*Zea mays* L.), alfalfa (*Medicago sativa* L.), sun-flower (*Helianthus annuus* L.), winter wheat (*Triticum aestivum* L.), fallow farmland, including forest strips with different composition of plant species: 1 – predominantly autochthonous wild species, and 2 – predominantly forestry species, soils with different erosion degree.

There were established the presence and abundance of earthworms, soil humidity in the arable layer and sub-arable, bulk density, resistance to penetration, soil adherence and others.

Pedological researches were performed – morphological description of soil, physical-chemical analyses, which diagnosed a medium silt loamy chernozem, with surface carbonates with profile $Ap\text{-}Ah_k\text{-}Bh_k\text{-}BC_k\text{-}C_k$. There were investigated the agrophysical (texture, micro-aggregative composition, humidity) and physical-mechanical indices of soil (plasticity, adherence and resistance to penetration).

The research methods were those recommended and used in the pedological monitoring of Republic of Moldova [Cerbari V., 1997].

Plasticity and plasticity index have been determined according to method of A. Vasiliev, soil adherence (Kpa) according to method of N. Kacinski, on metallic surfaces by 10 cm^2, disc pressure - 0.005 Mpa, 30 seconds lasting, 10 repetitions.

The classical research method was performed for earthworm extraction from soil, using areas by 0.25 m^2 in 8 repetition, and soil sorting on layers of 10 cm until 40 cm depth, and afterwards the quantitative and qualitative analyse: abundance and weight.

RESULTS AND DISCUSSION

Analytical data regarding texture, micro-aggregative composition, dispersion index, and physical-chemical properties of researched soil are listed in *tables 1* and *2*. Detailed presentation of physical-chemical and agro-physical data of the investigated variants have been already published [Andriuca V. *et al.*, 2012].

Table 1

Granular composition (numerator) and micro-aggregative composition (denominator) of chernozem from DES „Chetrosu"

Depth, cm	Diameter of fractions (mm) / content (%)							Dispersion index (K), %
	1-0.25	0.25-0.05	0.05-0.01	0.01-0.005	0.005-0.005	<0.001	<0.01	
0-10	3.11	10.23	44.64	5.11	12.20	24.71	42.02	5.6
	24.07	29.30	36.90	3.80	4.55	1.38	9.73	
10-20	2.8	11.35	46.37	5.43	11.75	22.3	39.48	8.1
	25.21	28.03	36.50	4.13	4.33	1.8	10.26	
20-30	2.0	8.94	48.01	5.85	11.67	23.53	41.05	5.3
	27.65	28.26	35.14	4.14	3.55	1.26	8.95	
30-40	2.3	9.95	47.44	6.03	11.3	22.95	40.31	7.8
	25.24	30.01	33.10	4.66	5.10	1.8	11.56	
40-50	2.12	8.13	45.54	5.11	14.68	24.32	44.21	7.7
	21.4	30.45	35.15	5.13	6.0	1.87	13.0	

Table 2

Physical-mechanical indices of calcic chernozem from DES „Chetrosu"

Depth, cm	Humus, %	Carbonates, %	pH_{H2O}	Adsorbed cations, me/100g soil		
				Ca^{++}	Mg^{++}	$\sum Ca^{++}+Mg^{++}$
0-10	3.4	2.5	7.6	27.7	3.8	31.5
30-40	3.2	2.9	7.8	26.9	3.3	30.2
50-60	2.4	3.5	8.1	-	-	-
70-80	2.1	4.8	8.2	-	-	-
90-100	0.9	6.5	8.3	-	-	-
140-150	0.8	7.2	8.3	-	-	-

There were investigated agroecosystems unfertilised for 30 years and ecosystems with mineral ($N_{160}P_{90}K_{90}$) and organic-mineral (24 t cattle manure + P_{30}) fertilisation, and also their post-action, including ecosystems of fallow farmland and forest strip, where a series of indices have been determined: plasticity, adherence, resistance to penetration, and earthworm abundance. In *table 3* there are presented the superior limit of soil plasticity for different usages and various levels of anthropic impact. Plasticity ranges within the unfertilised agroecosystems between 30-31%, in fallow farmland between 30-33%, in forest strip between 25-30%. The lowest superior limit of plasticity (24.1%) was found in variants with chemical fertilisation ($N_{160}P_{90}K_{90}$) in the arable layer. The unfertilised variants are significantly different as compared with fertilised ones. In *table 4* are shown the values of inferior limit of plasticity, humidity which determines the optimal conditions for soil tillage and penetration. Data show that this parameter ranges in the unfertilised variant between 19-21%, and in the fertilised variants between 19-20%. Considering the inferior limit of plasticity, the researched variants insignificantly differ, except the forest strip. Difference between superior and inferior limit represents the plasticity index, shown in *table 5*. Data show that the researched coenoses are significantly different considering the plasticity index, especially the variant with mineral fertilisation with significant decrease of superior limit of plasticity (*table 3*).

Table 3

Superior limit of plasticity of the calcic chernozem in various coenoses

Depth, cm	Agrocoenoses			Fallow farmland	Forest strip
	Unfertilised (30 years)	Fertilised			
		$N_{160}P_{90}K_{90}$	24 t cattle manure + P_{30}		
0-10	31.0	24.9	28.0	30.0	30.0
10-20	31.2	23.8	27.6	29.7	28.1
20-30	31.0	23.7	27.4	33.4	25.2
30-40	30.0	24.5	28.9	33.2	24.6
40-50	30.0	25.0	34.0	33.0	25.8
50-60	29.7	24.5	33.7	32.5	27.8
0-30	31.0	24.1	27.6	27.7	27.7
30-60	29.9	24.6	32.2	32.9	26.0
DL_{05}=1.3					

Table 4

Inferior limit of plasticity of the calcic chernozem in various conenoses

Depth, cm	Agrocoenoses			Fallow farmland	Forest strip
	Unfertilised (30 years)	Fertilised			
		$N_{160}P_{90}K_{90}$	24 t cattle manure + P30		
0-10	19.4	18.3	19.3	19.2	21.6
10-20	18.6	19.8	20.2	19.0	17.8
20-30	20.3	19.1	20.4	19.5	17.0
30-40	20.3	18.9	20.4	20.4	15.0
40-50	20.5	20.9	21.0	21.0	17.0
50-60	20.5	20.1	18.9	20.5	16.6
0-30	19.4	19.0	19.9	19.2	18.8
30-60	20.4	19.9	20.1	20.6	16.2
DL_{05}=1.4					

Table 5

Plasticity index (%) of the calcic chernozem in various conenoses

Depth, cm	Agrocoenoses			Fallow land	Forest strip
	Unfertilised (30 years)	Fertilised			
		$N_{160}P_{90}K_{90}$	24 t cattle manure + P30		
0-10	11.6	6.6	8.7	10.8	8.4
10-20	12.6	4.0	7.4	10.7	10.3
20-30	10.7	4.6	7.0	13.9	8.2
30-40	9.7	5.6	8.5	12.8	9.6
40-50	9.5	4.1	13.0	12.0	8.8
50-60	9.2	4.4	14.8	12.0	11.2
0-30	11.6	5.1	7.7	8.5	8.9
30-60	9.5	4.7	12.1	12.3	9.8
DL_{05}=1.35					

In order to eliminate the influence of bulk density, structure, porosity and others on soil adherence, this physical-mechanical parameter has been studied in non-structured samples.

As compared with soils in natural arrangement, the adherence of the researched variants was higher.

Considering that adherence is directly influenced by soil humidity, researches have been carried out at a standard value of humidity – the superior limit of plasticity. Data are listed in *table* 6.

Results show a significant difference of the researched conenoses and depths by adherence. The values of adherence in the unfertilised variant range between 13 - 15 g/cm^2, between 7-8 g/cm^2 in the arable layer of the fertilised variants, and intermediary values in fallow farmland (*table 6*).

For all researched variants was observed a significant differentiation of parameter adherence in the arable and sub-arable layers of soil. In the soils with natural arrangement, the values of adherence ranges only between 3-4 g/cm^2 in the loamy varieties, for humidity values close to those found in non-structured soil (*table 7*).

It is obviously that degradation of soil structure will lead to adherence increase. Earthworms assessment under impact of fertilisers in background ecosystems (May, 1992) at DES „Chetrosu" is presented in *figure 1*.

Table 6

Adherence of calcic chernozem (numerator, g/cm^2) and humidity corresponding to the superior limit of plasticity (denominator, %) in various conenoses of DES „Chetrosu"

Depth, cm	Agrocoenoses			Fallow farmland	Forest strip
	Unfertilised (30 years)	Fertilised			
		$N_{160}P_{90}K_{90}$	24 t cattle manure + P_{30}		
0-10	15.0/31.0	9.2/24.9	9.3/28.0	15.1/30.0	16.6/30.0
10-20	17.9/31.2	7.3/23.8	8.4/27.6	7.9/29.7	19.7/28.1
20-30	15.3/31.0	3.6/23.7	6.8/27.4	17.4/33.4	11.0/25.2
30-40	14.2/30.0	10.9/24.5	7.5/28.9	11.0/33.2	8.2/24.6
40-50	12.8/30.0	12.5/25.0	8.1/34.0	8.4/33.0	16.5/25.8
50-60	13.5/29.7	7.9/24.7	7.1/33.7	12.3/32.5	14.2/27.8
0-30	16.0/31.0	6.7/24.1	8.1/27.6	13.4/31.0	15.7/27.7
30-60	13.5/29.9	10.4/24.6	7.5/32.2	10.5/32.9	12.9/26.0
DL_{05}=1.35					

Table 7

Relation between adherence (g/cm^2) and humidity (%) of arable and sub-arable layers of calcic chernozem in the agroecosystem of winter wheat (*Triticum aestivum* L.), May 2011

Depth, cm		Humidity, % (numerator) and adherence, g/cm^2 (denominator)				
Plowing, cattle manure						
0-10	Humidity, W, %	38.8	38.2	29.4	28.4	23.5
	Adherence, g/cm^2	9.1	10.2	4.6	2.6	0
10-20	Humidity, W, %	37.9	33.1	28.4	25.3	26.9
	Adherence, g/cm^2	6.0	5.3	4.3	2.9	0
20-30	Humidity, W, %	33.6	30.2	41.6	25.6	23.6
	Adherence, g/cm^2	6.0	5.7	1.7	3.6	0
30-40	Humidity, W, %	35.7	33.0	28.0	25.2	23.5
	Adherence, g/cm^2	7.3	4.9	2.2	2.5	0

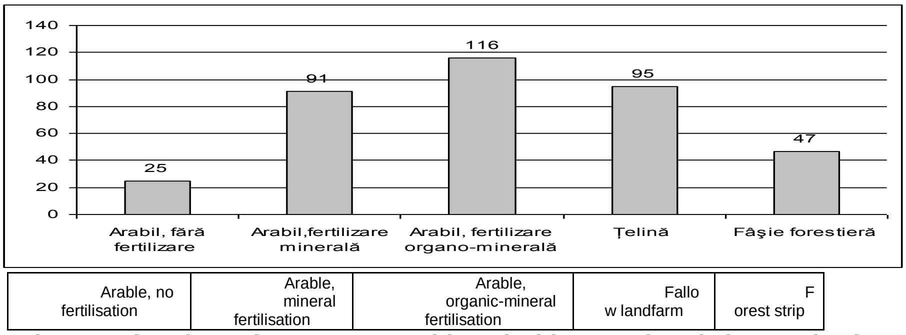

Figure 1. Earthworm abundance in conenoses with and without anthropic impact (Fedotova L., 1993)

Earthworms' research in 2012 in various agroecosystems and buffer areas of DES „Chetrosu" is presented in *table 8* and *9*. Results showed that earthworms were found in maize unfertilised and sun-flower with both types of fertilisation (post-action), and in the other research variants the earthworms lacked – alfalfa, winter wheat with and without fertilisation, fallow farmland. Earthworms' investigation (25 May 2012) has been made in alfalfa, maize, sun-flower, winter wheat with and without fertilisation, fallow farmland, and forest strip 1 and 2. Results showed that earthworms have been found only in alfalfa culture, with and without fertilisation, in forest strip 1 and 2 (*table 9*).

Researches performed in 2012 showed that maximal number of earthworms has been recorded in the forest strip 2 (72 worms/m^2), 0.204 t/ha; in the other variants, the earthworm number ranged between 1-16 worms/m^2, or 0.02-0.160 t/ha.

Table 8

Earthworms' abundance in various agroecosystems at DES „Chetrosu", 11 May 2012

Agroecosystem	Earthworms/m^2		Earthworms/ha	
	number of worms	weight (g)	number of worms, thousands	weight (t)
Maize, no fertilisers	4	1.2	40	0.120
Sun-flower, fertilised	16	1.6	160	0.160
Sun-flower, no fertilisers	4	0.8	40	0.080

Table 9

Earthworms' abundance in various agroecosystems at DES „Chetrosu", 24 May 2012

Agroecosystem		Earthworms/m^2		Earthworms/ha	
		number of worms	weight (g)	number of worms, thousands	weight (t)
Alfalfa	fertilised	4	0.4	40	0.040
	no fertilisers	1	0.2	10	0.020
Forest strip (1)		8	1.6	80	0.160
Forest strip (2)		72	20.4	720	0.204

There was observed that earthworm abundance and weight are directly influenced by the quantitative and qualitative vegetable debris, fertilisation type, tillage system. In parallel with earthworms abundance and weight, have been investigated several parameters as resistance to penetration, humidity, and soil adherence in natural arrangement in various agroecosystems.

The soil of the forest strips is characterised by homogeneity of resistance to penetration in the layer 20-40 cm (29-31 kgf/cm^2), and also the same aspect has been distinguished for alfalfa with and without fertilisation, exception being noticed only in weeding plats.

CONCLUSIONS

Mineral fertilisation of the researched agroecosystems influenced the plasticity indices of soil. Fertilisation with organic matter of soil decreased the soil adherence, and the degradation of soil structure determined increase of the adherence.More favourable for earthworms was the organic-mineral fertilisation, in moderate doses of mineral fertilisers.

During the droughty years, earthworms preferred the deep layers of soils.

The forest strips represented a refuge habitat for earthworms.

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