THE INFLUENCE OF SOME CHEMICAL INDICES OF SOILS ON EARTHWORM ABUNDANCE (OLIGOCHAETA: LUMBRICIDAE) IN CONDITIONS OF ORGANIC AND MINERAL FERTILIZATION

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Abstract

This paper presents data obtained by researching the influence of organic fertilizers (bovine manure in dose of 20 t/ha) and chemical fertilizers ($N_{120}P_{120}$) on earthworm dynamics in soil, under aspect of individuals number and biomass, within the wheat and maize cultures, on a luvic phaeozem soil (FAO System). It was observed that in wheat culture was identified an earthworm number and a biomass larger than in the maize culture, regardless the fertilization type. The chemical fertilization negatively influenced both the earthworm number and their biomass, in both plant cultures. The organic fertilization positively influenced the earthworm activity, their number and biomass significantly increasing. In this case there was noticed a superior activity of earthworms in the wheat culture against the maize. The statistical study made by regression and correlation methods for the data recorded in the control variant showed that the chemical parameters of soil nitrogen index, potassium and pH manifest by the recorded values in the experimental variants a positive influence on earthworms' number and biomass. For the variant with chemical fertilization ($N_{120}P_{120}$), the same factors have positive influences on the earthworms' number, the same tendency being observed regarding the biomass too. In the case of organic fertilization it was observed both for the earthworm number and biomass a positive influence of the analyzed factors pH, nitrogen index and potassium. The factor phosphorous manifested a negative influence on earthworms' dynamics.

Key words: earthworms, organic fertilizers, inorganic fertilizers, wheat, maize.

The organisms living in the soil must be considered as an integrant part of the soil. If there are approached the processes that are developing into the soil, for example those concerning its geneses and evolution, as well as the physical and the purely chemical transformation, it can be found that a part of these processes are purely biological. On the other hand, the soil plays a decisive role in the circuit of the chemical elements in the nature. If the transformation and the decomposing activity exerted by the organisms living in the soil is stopped or disturbed in their development, then there will appear stagnations in this circuit, which will affect, among others, the supplying of the human society with food and clothes (Eliade, Gh. et. al., 1983).

Taking into account the advantages that the organisms from the soil bring to it, increasing its fertility, became very actual the promotion of an ecological agriculture, having as main objectives to maintain the diversity of the agricultural ecosystems, the quality of life, to promote agricultural ecosystems based on the general laws that are governing the structure and the functions of the biosphere, to reduce the agricultural pollution.

The most representative organisms for the soil quality which are living into the soil are the earthworms. The studies of numerous researchers demonstrated this fact since a long time ago. Charles Darwin wrote in 1881, in his work "The formation of the vegetable mould through the action of worms" said that is doubtable whether there are other animals playing a more important role than earthworms in the history of the earth, as did these little creatures.

The major benefits of the earthworm activity in the soil fertility can be resumed as biological, chemical and physical.

The earthworms play a variety of important roles in agroecosystems. Their feeding activities and the digging of the canals determine the incorporation of the organic rests and of the amendments into the soil, intensify the decomposing of the organic matter, the humus formation, the circulation of the nutritive elements and the structural development of the soil (Kladivko, E.J. et al., 1986).

The earthworm canals persist as macropores, offering spaces with low resistance for roots growth, for water infiltration and for gases exchanges (Kladivko, E.J., Timmenga, H.J., 1990).

The quality, quantity and the localization of the organic matter are main determinants of the earthworm abundance and of their activity in the agricultural soils (Edwards, C.A., 1983), as well as the soil disturbances by agricultural workings (tillage), cultivation, and use of the pesticide (Doran, J.D., Werner, M.R., 1990).

The species digging deep canals, like *Lumbricus terrestris,* can penetrate the compacted soils, even the hardpan, creating canals for drainage, aeration and for the plant (Joschko, M. et al., 1989).

The earthworms are essential in the composting processes and in the conversion of the dead organic matter in humus, which is vital for the growing of healthy plants, assuring in this way the continuity of the fertility cycle. Beside the dead organic matter, the earthworms also ingest soil particles enough small in their „crop" where they are milling all the material in very small particles, resulting a fine paste, that are ulterior digested in their stomach. When the earthworms excrete this mixture as coprolites and deposit them on the soil surface or deep into the soil, in fact they put at the plant availability, in a more accessible form, a perfectly equilibrated palette of minerals and nutritive elements necessary for their nutrition. When the humus abundantly exists in an accessible form, the weight of the excreted coprolites can exceed 4,5 kg/earthworm/year, being an indicator that explains why the gardeners and farmers are so interested to maintain the populations of these worms at a high level.

The earthworms are species with a large substrate adaptation capacity, being demonstrated in several times the high adaptability of these organisms to the various material types where they are obligated to live at a certain (Thang, M.C., 2003). The studies on the species *Perionyx excavatus* (Manna, M.C. et al., 1997) showed that this species is able to consume a large range of materials, as straws of wheat, maize, stalks of maize, house garbage, chicken feathers etc.

In order to elaborate durable models able to maintain the soil fertility it is necessary to be promoted the mechanisms of the natural regulation of this feature of the soil. This is the reason why the responsibility in front of the present and future generations regarding the soil health, its fertility state, and especially the prevention of its degradation, is a duty not only of the political and administrative forums and of the whole society, but moreover is a duty of the science (Hera, C., 2005).

MATERIAL AND METHOD

The researchers concerning the effect of the organic fertilizers (bovine manure 20t/ha) and of the mineral fertilizers (chemical fertilizers in the dose of $N_{120}P_{120}$) on earthworms in the soil, under the aspects of number and weight were realized within two experiments with wheat and maize on a luvic phaeozem soil (FAO System). The experimental variants were placed on the land belonging to S.C. Agroindustriala S.A. Fântânele from Arad County. The surface of each experimental plot was 100 m^2. in the *table 1* there are presented the chemical and physical indices describing this type of soil.

The earthworms' extraction out of the soil was realized using solution of formaldehyde 2%, according to the methodology stipulated by the standard ISO 23611-1/2006 (Soil quality – Sampling of soil invertebrates, part 1: Hand-sorting and formalin extraction of earthworms).

The pedological conditions and the descriptions of the soil profiles were realized according to the "Romanian System of Soil Taxonomy (SRTS)", elaborated by INCDPAPM Bucharest in 2003. the classification of the soils at type category was realized according to the same methodology.

The physical and chemical analyses of soil were realized in the laboratories of OSPA Timiş and Arad, according to the specific working methodologies and protocols.

RESULTS AND DISCUSSIONS

At the level of the experimental placement was monitored the earthworm dynamics (number and weight) using the method of formaldehyde 2%, in experimental variants cultivated with wheat and maize and organically (bovine manure 20 t/ha) and chemically ($N_{120}P_{120}$) fertilized.

In the table 2 there are presented the mean values of the indicators number and weight in order to distinguish the differences which occur in the two plant cultures, respectively for the two types of the tested fertilizers (*table 2*).

Examining the data recorded in the table 2 can be observed that in the wheat culture there was found an earthworm number much higher and larger weights comparing to the maize culture, regardless the fertilization type.

The chemical fertilization negatively influenced both the number and the weight of the earthworms in both cultures. The organic fertilization favored the earthworm activity, their number and weight significantly increasing. It can be also observed that in this case the earthworm activity is more intense in the wheat culture comparing to the maize.

Table 1

The characteristics of the luvic phaeozem (FAO System), medium loamy clayey/ medium loamy clayey

A. Chemical indicators								
Depth (cm)	Pedogenetical horizon	pH in H_2O	$CaCO_3$ (%)	V (%)	Humus	Nitrogen index (IN)	Mobile phosphorous (ppm)	Mobile potassium (ppm)
0-13	Ap	5,85	-	76	2,75	2,37	82	192
13-26	Atp	5,50	-	65	2,85	1,72	48	185
26-37	Am	5,90	-	91	2,40	2,18	9	152
37-58	AB	6,25	-	94	1,60	1,50	3,5	158
58-70	Bt_1	6,35	-	95	1,30	1,24	3,5	148
70-100	Bt_2	6,40	-	97	1,20	1,16	3,5	144
100-150	BC	6,30	-	96	1,00	0,96	3,5	138
150-200	C	6,45	-	98	0,90	0,88	4,8	152
B. Physical indicators								
Pedogenetical horozon	Ap	Atp	Am	AB	Bt1	Bt2	BC	C
Depth (cm)	0-13	13-26	26-37	37-58	58-70	70-100	100-150	150-200
Skeleton % (over 2 mm)	-	-	-	-	-	-	-	-
Thick sand % (2-0,2 mm)	1,6	1,6	0,9	1,1	0,8	0,8	1,3	2,4
Fine sand % (0,2-0,02 mm)	32,7	39,9	26,7	25,0	28,1	26,0	29,1	25,3
Dust I and II % (0,02-0,002 mm)	32,0	25,6	32,6	32,4	31,4	34,1	28,2	29,0
Clay % (under 0,002 mm)	33,7	32,9	39,8	41,5	39,7	39,1	41,4	43,3
Texture	TT	TT	TT	TT	TT	TP	TT	TT

Table 2

Mean values regarding the earthworm number and weight in wheat and maize cultures under chemical ($N_{120}P_{120}$) and organic fertilization (bovine manure 20 t/ha)

Culture plant/ Experimental variant		Earthworm abundance (individuals/m^2)	Weight (g/m^2)
Wheat	Control	22	6,70
	Chemical fertilization ($N_{120}P_{120}$)	5,67	3,26
	Organic fertilization (bovine manure 20 t/ha)	35,33	10,58
Maize	Control	12,33	3,71
	Chemical fertilization ($N_{120}P_{120}$)	2,67	1,81
	Organic fertilization (bovine manure 20 t/ha)	17,67	5,42

Comparing the data regarding the earthworm dynamics registered in wheat and maize with the data obtained in the control variant it can be found the situation presented in the *table 3*.

In the *table 4* there are presented the values of the agrochemical indices of the soil which had been monitored in parallel with the earthworm dynamics in wheat and maize cultures, in different variants of fertilization.

Table 3

Comparisons regarding the earthworm dynamics (abundance and weight) in wheat and maize cultures under chemical ($N_{120}P_{120}$) and organic (bovine manure 20 t/ha) fertilization related to the control variant

Experimental variant	Wheat / Maize		Wheat		Maize	
	Earthworm abundance (%)	Weight (%)	Earthworm abundance (%)	Weight (%)	Earthworm abundance (%)	Weight (%)
Control	178,43	51,58	100,00	100,00	100,00	100,00
$N_{120}P_{120}$	212,36	180,11	25,77	48,66	21,65	13,93
Bovine manure 20 t/ha	199,94	195,20	160,59	157,91	143,31	41,72

Table 4

The values of the chemical indices of the soil for each experimental variant

Culture plant/ Experimental variant		pH	Humus (%)	Nitrogen index (IN) (%)	Mobile phosphorous (ppm)	Mobile potassium (ppm)
Wheat	Control	5,31	2,69	1,70	65	143
	Chemical fertilization ($N_{120}P_{120}$)	5,20	2,56	1,76	70	158
	Organic fertilization (bovine manure 20 t/ha)	5,39	2,80	1,82	59	165
Maize	Control	5,65	2,45	1,87	42	162
	Chemical fertilization ($N_{120}P_{120}$)	5,55	2,30	1,91	65	175
	Organic fertilization (bovine manure 20 t/ha)	5,95	2,90	2,04	48	173

The *pH* value decreases slightly in the variants where the chemical fertilizer was applied. As well, it can be observed that the earthworm abundance is decreasing both in the wheat and in the maize culture. The increasing of the pH value in the organically fertilized variants was accompanied by a significant increasing of earthworm number in both cultures. This increasing can not be attributed only to the pH increasing values, and it is also considered to be a consequence of the large quantity of organic matter which represents the main food source of the earthworms (Cook, S.M.F., Linden, D.R., 1996; Cortez, J., Bouche, M.B., 1998; Curry, J. P., 2004; Gunadi, B., Edwards, C. A., 2003).

The soil content in *humus* registered a significant increasing in the variants organically fertilized with bovine manure comparing to the control variant and to the chemically fertilized variant with $N_{20}P_{120}$. It was found lower humus content of the soil in the variant with chemical fertilization, with approximately 5% against the control and with approximately 9% against the organically fertilized variant. The experimental variants with a high content of humus (organic fertilization), for both of the plant cultures, register also an increasing of the earthworm abundance. In wheat culture, the earthworm abundance is much superior to the maize culture, for all the experimental variants, fact that can be explained by a reduced tillage of the wheat comparing to the maize and therefore a lower disturbance degree of the soil and also by the larger quantity of organic vegetal rests on the soil surface which remain in wheat culture comparing to the maize culture.

The influence exerted by the *nitrogen* content of the soil on earthworms was established by analyzing the values of the nitrogen index (IN). The earthworm number//m^2 is lower in the case of chemical fertilization ($N_{120}P_{120}$) comparing to the variant with organic fertilization for the both plant cultures, the same tendency being observed too for earthworm weight.

Referring to the organically fertilized variant, the analysis results showed that both earthworm abundance and weight are strongly influenced by the nitrogen content of the soil with a probability of 95%.

Related to the *phosphorous* content of the soil, there was found that in the experimental variants chemically fertilized where the phosphorous content of the soil was high, the earthworm abundance and weight were fewer comparative to the organically fertilized variants where the phosphorous content of the soil was lower than in the control, and the earthworm number/m^2 as well as their biomass (g/m^2) registered a significant increasing comparative to the control.

As for the influence of the *potassium* content of the soil on earthworm dynamics there was found that under chemical fertilization the potassium content of the soil increased comparative to the control, and the earthworm abundance and biomass decreased. In the wheat culture organically fertilized there was registered a significant increasing of the potassium content with 15,38% comparative to the control and in the same time an increasing of the earthworm number/m^2. In maize culture, in condition of organic fertilization, there was found an increasing of the potassium content of the soil, with 6,79% comparative to the control and the earthworm abundance and biomass increased as well.

Statistical analysis of the influence of chemical and organic fertilization on the chemical indices of soil and on earthworms. According to the values that indicates the homogeneity degree (table 5), the most homogeneous data were found for humus (5,11%), nitrogen index (5,22%) and potassium (6,82%). As a consequence of this fact there was analyzed the influence of these factors on earthworms abundance and weight. The analysis of data was made using the correlation method.

Table 5

Mean, standard deviation and homogeneity degree of the data regarding the earthworm abundance and biomass in control variants

Analyzed factor	Mean	Std. Deviation	Homogeneity degree (%)
Earthworm number	17,1667	5,98052	34,83
Earthworm weight	9,845	10,42235	-
pH	5,4800	,18623	15,75
P	53,5000	12,59762	23,54
K	1,5250E2	10,40673	6,82
Humus	2,5700	,13145	5,11
IN	1,7850	,09311	5,22

Analysis of the influence of chemical indices of soil on earthworm abundance under chemical fertilization. The partial correlation coefficients and the signification degrees for each coefficient are presented in the *table 6*. There was found that a positive and relevant influence on the earthworm number is manifested by the factor *pH* (r=0,492), followed by the factor humus (r=0,297). A great direct negative influence on earthworm number under chemical fertilization with ($N_{120}P_{120}$) is exerted by the factor phosphorous (P) (r=-0,902).

Table 6

The matrix of the partial correlation and of results signification for the factor earthworm abundance under chemical fertilization

Correlation coefficient		Earthworm abundance	pH	Phosphorous (P)	Potassium (K)	Humus	Nitrogen index (IN)
Pearson Correlation	Earthworm abundance	1,000	,492	-,902	-,185	,297	,154
Sig. (1-tailed)	Earthworm abundance	.	,052	,000	,283	,175	,316

Analysis of the influence of chemical indices of soil on earthworm weight under chemical fertilization. The single factor which exerts a direct influence is the humus (r=0,309). The other factors – pH, phosphorous (P), potassium (K) and even the nitrogen index (IN) registered a negative influence. Potassium is that factor which determines in great measure the decreasing of the earthworm weight (r=-0,44), but it be noticed that the signification degree is small for all partial correlation coefficients (*table 7*), which indicates the possibility of another influence factors untaken into consideration for this study (as example, the earthworm individuals were found in different development stages, which means that their weight significantly varied from an organism to another).

Table 7

The matrix of the partial correlation and of results signification for the factor earthworm biomass under chemical fertilization

Correlation coefficient		Earthworm biomass	pH	Phosphorous (P)	Potassium (K)	Humus	Nitrogen index (IN)
Pearson Correlation	Earthworm biomass	1,000	-,130	-,059	-,440	,309	-,347
Sig. (1-tailed)	Earthworm biomass	.	,351	,431	,088	,177	,148

Analysis of the influence of chemical indices of soil on earthworm abundance under organic fertilization. The greatest positive influence on earthworm number is exerted by the pH, (r=0,428) and respectively by the humus (r=0,369) (*table 8*).

Table 8

The matrix of the partial correlation and of results signification for the factor earthworm abundance under organic fertilization

Correlation coefficient		Earthworm abundance	pH	Phosphorous (P)	Potassium (K)	Humus	Nitrogen index (IN)
Pearson Correlation	Earthworm abundance	1,000	,428	-,894	-,207	,369	,107
Sig. (1-tailed)	Earthworm abundance	.	,095	,000	,271	,132	,378

Analysis of the influence of chemical indices of soil on earthworm weight under organic fertilization. In the *table 9* it can be observed that the greatest positive influence on earthworm biomass is exerted by the factor nitrogen index (IN) (r=0,939). Another factor with positive influence is the pH (r=0,896). The homogeneity degree of the recorded data related to the mean value is enough relevant for the factor nitrogen index, by 5,22%, and for pH is 15,75% (*table 5*, column 3). The greatest negative influence on earthworm weight is manifested by the factor phosphorous (P), (r=-0,651), with a signification of the results by 1,1%.

Table 9

The matrix of the partial correlation and of results signification for earthworm biomass under organic fertilization

Correlation coefficient		Earthworm biomass	pH	Phosphorous (P)	Potassium (K)	Humus
Pearson Correlation	Earthworm biomass	1,000	,896	-,651	-,219	,939
Sig. (1-tailed)	Earthworm biomass	.	,000	,011	,247	,000

CONCLUSIONS

The researchers regarding the influence of some chemical indices of soil on earthworm activity on a luvic phaeozem under chemical and organic fertilization show that a part of these indices, natural or modified by the performed agricultural technologies, are positively correlated with the presence of the earthworms into the soil.

The earthworms' behavior under organic and chemical fertilization was different. The bovine manure led to an increasing of the earthworm abundance, with approx. 60% in wheat and 40% in maize. The chemical fertilizers diminished the earthworm number with approx. 75% in wheat and 79% in maize.

The performed researchers prove that earthworm number in soil depends on the nature of the substances introduced into the soil (organic matter, chemical fertilizers) and implicitly on the values reached by certain physical and chemical indices of the soil which were modified or not by performing the agricultural technological links.

In order to maintain an healthy equilibrium of the earthworms in the soils, it is recommended to assure an appropriate supplying of organic matter at soil level, to use with high precaution the different chemical substances (in this case the chemical fertilizers), so that the activity of these fragile organisms living into the soil, with such a major role in soil fertility, not be disturbed, and their abundance into the soil be optimal.

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