INFLUENCE OF THE MANAGEMENT SYSTEM OF SOIL AND PLANT CULTURE ON EARTHWORMS (OLIGOCHAETA: LUMBRICIDAE) IN CONDITIONS OF BANAT PLAIN

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Abstract: *In this paper there are exposed the results of the researches aiming to establish the effect of some different systems of soil tillage on earthworms, in this case considering the classic system and the no-till system, in maize (Zea mays L.) and soybean (Glycine hispida (Mnch)) cultures. The research has as goal to study the earthworms under aspect of numerical and biomass dynamics in field experiments, in a cambic chernozem soil. Within the same research were made physical-chemical analysis of soil for a series of indices, like pH, total nitrogen, phosphorous and potassium, in order to study their influence on earthworms as numerical abundance and weight. The registered data showed that earthworm number (individuals/m^2) identified in the experimental variants cultivated in classic system is lower than earthworm number found in the no-till system, and the earthworm biomass (g/m^2) generally had the same tendency. It was found that earthworm number was higher in the soybean culture than in the maize culture for both cultivation systems. The research methodology that was used respects the actual legislation and protocols in force. The statistic connections between the researched factors were realized by statistical methods, consisting of dispersion analysis ANOVA (Analysis of Variance). For statistical calculation, the SPSS software (Statistical Package for the Social Sciences) was used. This type of research was required because the Romanian scientific research in the field of soil fertility in the last decades was predominantly orientated in direction of usage of chemical fertilizers, irrigations, pesticides and other agricultural technologies as methods for fast increasing of the crops. Generally, the tendency was the same in the worldwide plain. It can be concluded that, in great measure, the scientific research from agriculture was not ready to offer solutions in order to accede from the concept of intensive agriculture to the ecological sustainable concept.*

Key words: *earthworms, classic tillage, no-till system, maize, soybean, soil characteristics*

INTRODUCTION

Earthworms are not favoured by tillage (system of agricultural workings of soil) and, generally, the higher is the intensity and the frequency of soil disturbance, the lower is earthworm density or biomass [BARNES AND ELLIS, 1979; EDUARDS, 1983; GERARD AND HAY, 1979; MACKAY AND KLADIVKO, 1985]. The agricultural lands are generally dominated by species adapted to disturbance, to a low content of organic matter and to the absence of the surface litter.

Earthworms depend on moderate humidity o soil, and the cultivation workings tend to have a negative effect on earthworms by reducing the soil humidity [GUNADI ET AL., 2003]. Some common species of agricultural earthworms are *Allolobophora chlorotica*, the complex of species *Aporrectodea caliginosa (A. trapezoides, A. turgida, A tuberculata)* and *L. terrestris*. Common species in the habitats rich in organic matter, like *Eisenia foetida*, are rarely present [CLAPPERTON ET AL., 1997; DIDDEN, 2001].

The results of a study realised in USA in long-time experiments (over 30 years) in a Mediterranean climate in the year of 2000 revealed reduced effectives of earthworms in the conventional tillage systems and an increase of the earthworm number in the minimum tillage systems. The research comprised four types of tillage in a simple crop rotation *Pisum sativum/Triticum aestivum* [WUEST, 2001]. Thus, there were found approximately 15 times less earthworms in the soil worked with disc plough and chisel than in the soil with minimum tillage.

Earthworm populations usually are poorly represented in the cultivated lands than in the pastures or in the undisturbed soils, at a level by approximately 1/3 from the usual amount. *Aporrectodea trapezoides* is less affected than *Eisenia rosea,* fact possible because it is able to dig much deeper canals in the soil and to escape from the disturbed area [REINECKE AND VISSER, 1980].

GERARD AND HAY (1979) reported a number of 93 earthworms /m^2 in the lands normally ploughed, inclusive *A. caliginosa, A. chlorotica, A. longa* and *L. Terrestris* [GERARD AND HAY, 1979]. Earthworm abundance increased in the soils aerated with disk or in the lands with no-till treatments, and doubled in soybean crops in no-till system comparing to the ploughed soils [MACKAY AND KLADIVKO, 1985].

The tillage system has a great importance regarding the numerical dynamics of earthworms, but beside this, a great importance too is attributed to the culture plant [JOHNSON-MAYNARD ET AL., 2007; SIX ET AL., 2002]. The results of a study realised in USA, Indiana State, on earthworm abundance, in different systems of soil management, respectively different types of plant cultures, showed a number of 400 earthworms/m^2 in the clover culture in free growth, and 340 earthworms/m^2 in a pasture organically fertilised with cattle manure, and only 10 earthworms/m^2 in maize monoculture in ploughing system, 20 earthworms /m^2 in maize monoculture in no-till system, 60 earthworms /m^2 in soybean monoculture in ploughing system and 140 earthworms /m^2 in soybean monoculture in no-till system [22].

There was demonstrated that the no-till systems of soil management are favourable to earthworm development, especially on the background of the appropriate crop rotations [CURRY ET AL., 2002]. Some studies concerning the earthworm abundance and prolificacy (in Havana, 1995) showed for three types of crop rotations (wheat-maize, maize-soybean and wheat-soybean) that the largest number of earthworms was found in the wheat-soybean rotation (443 individuals/yd^2), and the largest cocoon number in the maize-soybean rotation (71 cocoon/yd^2) [DEIBERT AND UTTER, 1994].

Similar studies were realised for different systems of soil management lasting on 5 years in Hungary, in maize monoculture, being monitored both the earthworm number *(Lumbricus terrestris)* and the digging intensity into the soil. The study results showed a double number of canals in direct seeding system with vegetal rests on the surface comparative to the ploughing system without vegetal rest, and the absence of canals in the compacted soil. Within the same study there was also demonstrated that the management system of soil influences the earthworm weight too, as well as their growth (length). Thus, in the case of direct seeding (without disturbance) there were identified 99 de earthworms/m^2 weighing 26 g, and in the disking system there were identified 41 earthworms/m^2 weighting only 5,5 g [BIRKAS ET AL., 2004].

Although the major function of tillage is to aerate the soil and to increase its porosity, what is reached is only the increase of the microporosity [GORES ET AL., 2001]. The macropores, which can have physical or biological origin and which play an important role in the rapid conduction of water through the soil, are destroyed by tillage. As example, a decrease of the infiltration rate with 67% after a forest soil was ploughed was attributed to earthworm canals destruction. The infiltration rate of an adjacent arable soil, which initially was much lower than in the forest soil, increased with 23% after ploughing, because the surface crust was destroyed [AINA, 1984]. The infiltration rate increases in the cultivated soils if organic mulch is added, because of the intense activity of earthworms in these soils and macropores formation [SLATER AND HOPP, 1947]. The soil compaction caused by the traffic with agricultural machines may, as well, to determine the decrease of the earthworm populations [BOSTROM, 1986].

MATERIAL AND METHODS

The experiments aiming to establish the earthworm abundance and biomass under different tillage systems (classic and no-till) were developed in a temperate-continental climate with Mediterranean influences, the multiannual mean temperature being 10,3°C, and the multiannual precipitations being 596,2 mm.

The experimental soil was classified as Chernozem according to the Romanian System of Soils Taxonomy (SRTS 2003) and correlated to the FAO System.

The experimental device represents experiments in the following plant cultures: *Glycine hispida* (Mnch) (soybean) and *Zea mays* L. (maize).

Earthworm extraction from soil was realized using the formaldehyde solution 2%, according to specific methodology enounced by the standard ISO 23611-1/2006: Soil quality-Sampling of soil invertebrates, part 1-Hand-sorting and formaldehyde extraction of earthworms. It must be mentioned that this method can expel from soil only the earthworms located in the first 40 cm of soil.

The pedological conditions and soil profile were described according to the FAO System. The physical and chemical analyses of soil were realized according to the following methodologies: the soil reaction (pH values) was established by the potentiometric method in aqueous suspension (pH_2O), ratio soil: solution 1:2.5; total nitrogen content of soil: by the Kjeldahl method, digested with H_2SO_4 at 350°C, catalytic agents potassium sulphate and copper sulphate; plant-available phosphorus and potassium from soil were determined by the spectrophotometry and flame spectrometry methods, respectively, in acetate-lactate ammonium solution (AL) at 3.7 pH, by the Egner-Riehm-Domingo method (table 1). In parallel with numerical and biomass study of earthworms, were recorded data on several chemical indices of soil such as pH, total nitrogen, phosphorous, and potassium to establish their influence on earthworm dynamics, in conditions of classic tillage and no-till system. The study of the statistic connections between the studied variables was made in the basis of statistical methods, which consisted of: dispersion analysis ANOVA (Analysis of Variance) (using ANOVA method it can be tested hypothesizes regarding the parameters of a model, and can be estimated the components of dispersion; regression method (the concept of regression expresses a statistical connection, namely the mean regression regarding the behaviour of some variables); correlation method (the concept of correlation expresses reciprocal reports between certain characteristics). For statistical calculus was used the soft SPSS (Statistical Package for the Social Sciences), which assures the covering for all the methods already exposed.

RESULTS AND DISCUSSIONS

Within the experimental device was monitored the earthworm dynamics (numerical abundance and weight) in two types of agricultural cultures, maize and soybean, in two types of soil working systems, classic and respectively no-till. Also, there were realised statistical analyses to put in evidence the way how earthworm abundance and weight are influenced by some chemical parameters of soil like: pH, nitrogen index (NI), phosphorus (P) and potassium (K). In the table 2 there are presented the mean values of the earthworm number and weight and the mean values of the studied chemical indices of soil, for the two plant cultures and for each management system of soil: classic and no-till.

Table 1

Main physical, hydro-physical and chemical characteristics of the cambic chernozem, medium loam-clayish/medium loam clayish

PEDOLOGICAL HORIZONS	Ap	Atp	Am	A/B	Bv	B/C	Cca	Ck	Ck	Ck
Depth of pedological horizon (cm)	21	33	45	59	80	96	125	155	175	200
Rough sand (2.0–0.2 mm) (%)	0.8	0.7	0.4	0.2	0.3	0.2	0.2	0.5	0.8	0.7
Fine sand (international system) (0.2–0.02 mm) (%)	30.3	26.9	29.2	37.4	32.8	29.9	28.1	31.4	31.4	27.6
Dust (international system) (0.02–0.002 mm) (%)	29.5	33.5	28.0	23.5	27.5	29.5	34.1	25.8	24.9	29.8
Clay (< 0.002 mm) (%)	39.4	38.9	42.4	38.9	39.4	40.4	37.5	42.3	42.9	42.0
Physical clay (< 0.01 mm) (%)	52.4	52.9	56.9	49.9	53.9	51.4	55.1	55.7	54.8	55.9
TEXTURE	TT	TT	TT	TT	TT	TT	TT	TT	TT	TT
Specific density (g/cm3)	2.63	2.63	2.65	2.64	2.66	2.65	2.65	-	-	-
Apparent density (g/cm3)	1.48	1.48	1.42	1.44	1.46	1.48	1.34	-	-	-
Total porosity (%)	43.7	43.7	46.7	45.5	45.1	44.2	49.4	-	-	-
Aeration porosity (%)	5.0	5.1	8.9	7.9	7.0	5.3	14.6	-	-	-
Compaction degree (%)	15.0	14.8	10.6	11.5	12.3	14.4	3.3	-	-	-
Hygroscopic coefficient (%)	9.2	9.1	9.9	9.1	9.2	9.5	8.8	-	-	-
Wilting coefficient (%)	13.8	13.7	14.9	13.7	13.8	14.2	13.2	-	-	-
Water field capacity (%)	26.1	26.1	26.4	26.1	26.1	26.2	26.0	-	-	-
Water total capacity (%)	29.5	29.5	32.7	31.6	30.9	29.8	36.9	-	-	-
Useful water capacity (%)	12.3	12.4	11.5	12.4	12.3	12.0	12.8	-	-	-
pH in water (pH units)	5.95	6.10	6.20	6.55	6.70	7.10	7.70	8.20	8.25	8.15
$CaCO_3$ (%)	-	-	-	-	-	-	12.10	6.85	3.55	2.60
Total organic carbon (%)	3.40	2.10	2.10	1.70	1.60	1.25	1.20	1.00	0.90	0.70
N total (%)	3.06	1.91	1.95	-	-	-	-	-	-	-
Total organic carbon reserve (50)	191.0	-	-	-	-	-	-	-	-	-
P mobile (mg/kg)	35.0	23.0	5.0	4.0	4.0	7.0	11.0	7.0	5.0	4.0
K mobile (mg/kg)	153	128	128	123	113	136	113	98	113	113
Exchangeable bases (meq/100 g soil)	35.6	31.2	26.8	-	-	-	-	-	-	-
H^+ exchangeable (meq/100 g soil)	12.0	10.0	7.9	-	-	-	-	-	-	-
Base saturation (% of total)	90	91	93	-	-	-	-	-	-	-
Al mobile (meq/100 g soil)	0.10	0.05	0.05	-	-	-	-	-	-	-

Table 2.

Mean values of the chemical indices of soil pH, nitrogen index (IN), phosphorous (P) and potassium (K) related to the earthworm number and weight in different systems of soil management

Culture plant/ Soil management	Earthworm number (individuals/m^2)	Earthworm weight (g/m^2)	pH (%)	Nitrogen index (NI) (%)	Phosphorus (P) (ppm)	Potassium (K) (ppm)
Maize classic	17,33	6,27	5,55	2,05	36	228
Maize no-till	18,67	13,47	5,75	2,23	33	257
Soybean classic	14,67	4,00	5,45	2,40	47	275
Soybean no-till	21,33	6,53	5,60	2,82	60	260

Basing on the means values, there were made comparisons between the plant cultures and soil management systems concerning the earthworm abundance and weight (table 3).

Table 3

Statistical results regarding the earthworm number and weight in classic tillage and no-till system

Culture plant/ Soil management	Earthworm number (individuals/m^2)	Earthworm weight (g/m^2)
Maize classic / Maize no-till	92,82	46,54
Soybean classic / Soybean no-till	68,77	61,25

It can be observed that the earthworm number is lower in the variants with classic soil tillage for both plant cultures (figure 1). Earthworm number was higher in soybean culture in both soil management systems. This fact is attributed to earthworm preference for soils with low degree of tillage disturbance and because soybean is a plant which let the soil more aerated, situation pleasant for earthworms, which prefer high aerated soils and well oxygenated [KLADIVKO, 1990; LOFS-HOLMIN, 1983].

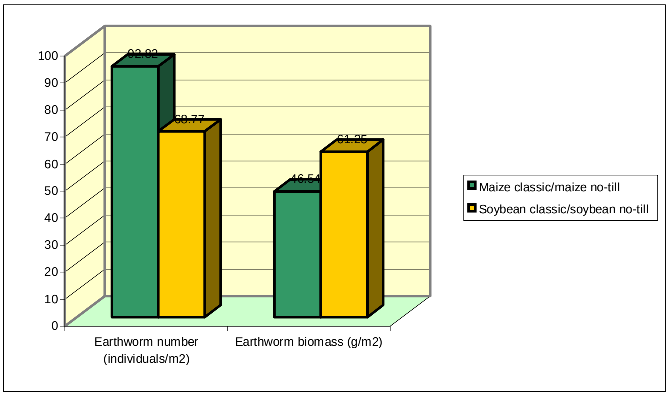

Figure 1. Comparisons between earthworm number and weight in the classic system of soil tillage and in no-till system

In the figures 2-5 there are presented the values of the studied chemical indices of soil (pH, NI, P, K) related to earthworm number and weight in the two systems of soil management and plant cultures.

Statistical analysis regarding the influence of chemical indices of soil on earthworm dynamics in no-till soil management

In the following there are presented only those results and interpretations referring to those chemical indices of soil for which the analyses showed a significant influence. For both systems of soil management there was found a high degree of data homogeneity for the indices pH and potassium (K), namely 2,02% and respectively 6,97% (table 4). The most non- homogeneous data were found for the index phosphorus (P), the homogeneity coefficient for this factor being 25,18% (table 4, column 3).

Statistical analysis regarding the influence of chemical indices of soil on earthworm numerical abundance in no-till soil management

Because $F_{calculated} < F_{table}$ (table 5), the conclusion is that the analyzed chemical factors (taken together) don't influence the earthworm number in great measure, but this thing does not mean that they don't influence it separately, fact ulterior confirmed by other statistical interpretations of data.

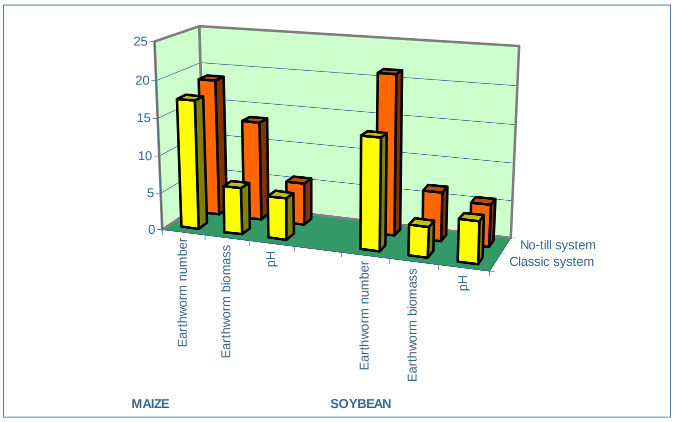

Figure 2. Values of soil *pH* related to the earthworm dynamics in different plant cultures and soil management systems

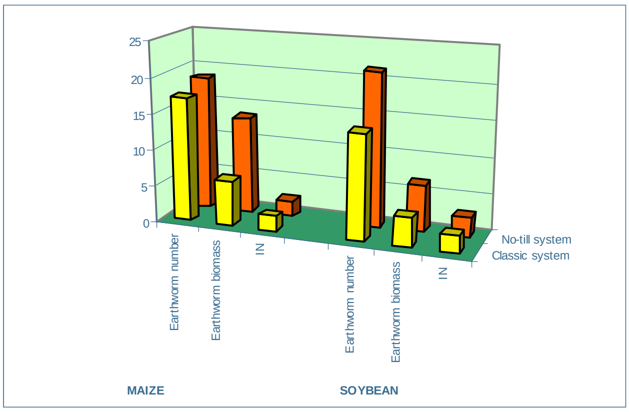

Figure 3. Values of *nitrogen index* of soil related to the earthworm dynamics in different plant cultures and soil management systems

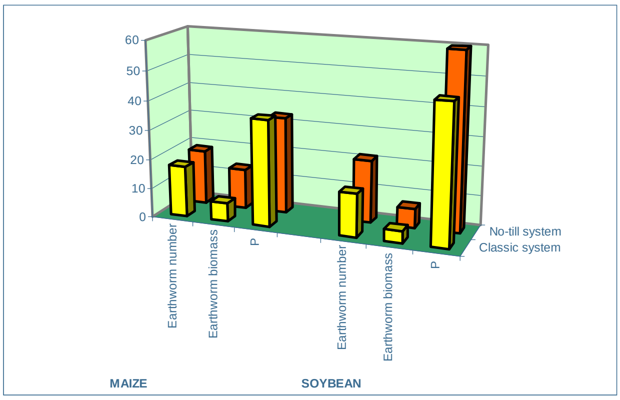

Figure 4. Values of soil content in *phosphorous* related to the earthworm dynamics in different plant cultures and soil management systems

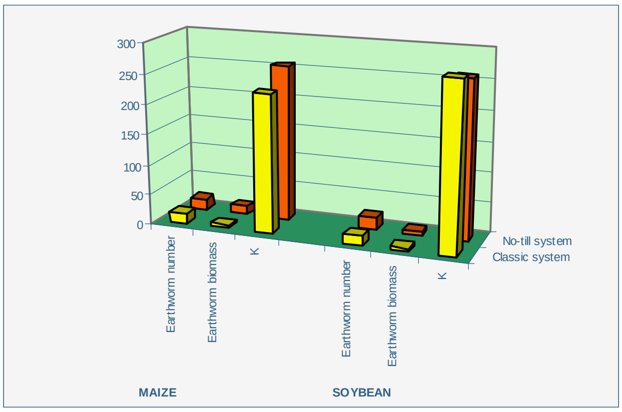

Figure 5. Values of soil content in *potassium* related to the earthworm dynamics in different plant cultures and soil management systems

Table 4.

Mean, standard deviation and homogeneity degree for the analyzed indices

Analyzed factor	Mean	Std. Deviation	Homogeneity degree (%)
A	1	2	3
Earthworm weight	7,5667	6,51813	86,14
pH	5,5875	,11307	2,02
NI	2,3750	,29786	12,54
P	44,0000	11,07823	25,18
K	255,00	17,77127	6.97
Earthworm number	17,3333	5,14045	29.66

Table 5

Analysis of variance (ANOVA) on the influence of chemical indices of soil on earthworm number

Model		Sum of Squares	Df	Mean Square	$F_{calculated}$	F_{table}	Sig. $F_{calculated}$
1	Regression	98,667	3	32,889	1,370	3,86*	,320[a]
	Residual	192,000	8	24,000	-	-	-
	Total	290,667	11	-	-	-	-
2	Regression	88,673	2	44,337	1,975	4,26*	,194[b]
	Residual	201,993	9	22,444	-	-	-
	Total	290,667	11	-	-	-	-

**Signification degree is 5%*
a. Predictors: (Constant): K, pH, P
b. Predictors: (Constant): K, P
c. Dependent Variable: Earthworm number

Correlation coefficient *(R)* and determination coefficient *(R Square)* ulterior calculated for both models showed that between studied factors exists a medium connection, the correlation coefficient for the first model is 0,583, and for the second model is 0,552, with standard deviations presented in the table 6.

Analyzing the partial correlation coefficients (table 7) there was found that a single factor exert a negative influence on earthworm number, namely the potassium (K) content of soil, which determinates the decrease of earthworm number by 0,259 times for each increase of it with a unit, with a signification by 0,208. The other factors included into analysis positively influence the increase of earthworm number. The largest influence in this case is attributed to the phosphorus (P), so that its increasing with a unit determines the increase of earthworm number by 0,313 times, the guaranty degree of results being 16,1%.

Table 6

The influence of chemical indices of soil on the earthworm numerical dynamics

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	,583[a]	,339	,092	4,89898	,339	1,370	3	8	,320
2	,552[b]	,305	,151	4,73748	-,034	,416	1	8	,537

a. Predictors: (Constant): K, pH, P
b. Predictors: (Constant): K, P
c. Dependent Variable: Earthworm number

Table 7

The matrix of partial correlations and results signification for the factor earthworm number

Correlation coefficients		Earthworm number	pH	Nitrogen index (NI)	Phosphorus (P)	Potassium (K)
Pearson Correlation	Earthworm number	1,000	,063	,277	,313	-,259
Sig. (1-tailed)	Earthworm number	1,000	,423	,192	,161	,208

Statistical analysis regarding the influence of chemical indices of soil on earthworm weight in no-till soil management

Using the statistical methods of regression and correlation, there were identified three models of possible influence as can be observed in the table 8.

The values of regression coefficients *(R)* and determination coefficients *(R Square)* (table 8, column 1-2) demonstrated a moderate connection between the studied factors.

Table 8

The influence of chemical indices of soil on earthworm weight

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
A	1	2	3	4	5	6	7	8	9	10
1	,568[a]	,323	,069	6,28967	,323	1,271	3	8	,348	-
2	,568[b]	,323	,172	5,93028	,000	,001	1	8	,977	-
3	,561[c]	,315	,247	5,65780	-,008	,102	1	9	,757	1,931

a. Predictors: (Constant): K, pH, P
b. Predictors: (Constant): K, pH
c. Predictors: (Constant): K
d. Dependent Variable: Earthworm weight

The relation $F_{calculated} < F_{table}$ (table 9, column 6) shows that the studied chemical indices of soil influence the earthworm weight with a medium signification. This result can be explained by other factors which significantly influence the dependent (earthworm weight), but they were not studied within this research, remaining thus unknown. It can be certainly mentioned that one of these factors is earthworm age, because not all individuals extracted from soil were adults, so that the young earthworms weigh less than those adults.

Table 9

Analysis of variance (ANOVA) on the influence of chemical indices of soil on earthworm weight

Model		Sum of Squares	df	Mean Square	$F_{calculated}$	F_{table}	Sig. $F_{calculated}$
A		1	2	3	4	5	6
1	Regression	150,867	3	50,289	1,271	3,71*	,348[a]
	Residual	316,480	8	39,560	-	-	-
	Total	467,347	11	-	-	-	-
2	Regression	150,833	2	75,416	2,144	4,10*	,173[b]
	Residual	316,514	9	35,168	-	-	-
	Total	467,347	11	-	-	-	-
3	Regression	147,240	1	147,240	4,600	4,96*	,058[c]
	Residual	320,107	10	32,011	-	-	-
	Total	467,347	11	-	-	-	-

** Signification degree is 5%*
a. Predictors: (Constant): K, pH, P
b. Predictors: (Constant): K, pH
c. Predictors: (Constant): K
d. Dependent Variable: Earthworm weight

In the table 10 it can be observed that a single factor positively influences the earthworm weight, although is a moderate one, by 0,017 with a signification by 0,48. In the case of this factor the homogeneity degree of data is quite large, by 2,02% (table 4, column 3). The other analyzed factors determine the decrease of the earthworm weight, the greatest influence in this case is manifested by potassium (*r*=-0,561, signification degree 2,9%).

Table 10

Matrix of partial correlations and results signification regarding the influence of chemical indices of soil on earthworm weight

Correlation coefficients		Analyzed factors				
		Earthworm weight	pH	Nitrogen index (NI)	Phosphorus (P)	Potassium (K)
Pearson Correlation	Earthworm weight	1,000	,017	-,320	-,227	-,561
Sig. (1-tailed)	Earthworm weight	.	,480	,155	,239	,029

CONCLUSIONS

The obtained results showed in both plant cultures (maize and soybean) an increase of the earthworm number in the no-till system of soil management, as well as an increase of the earthworm number in the soybean culture.

Analyzing the registered data it was observed that earthworm number (individuals/m^2) in the experimental variants cultivated with maize in classic system is lower with 7,18% than earthworm number obtained in the same culture but in no-till system, and the earthworm weight in classic system is lower with 53,46% than that recorded in the no-till system in the same plant culture. The same tendency was also observed for the soybean culture.

These results are attributed to the fact that earthworms prefer the soils with a reduce degree of tillage disturbance, as well as to the fact that soybean is a plant which let the soil more aerated, fact appreciated by earthworms, organisms which prefer the aerated and very well oxygenated soils.

Finally, there was found that earthworm number considerably increase in the no-tillage systems and in the undisturbed systems.

The achieved results and conclusions contribute to adjustment and strengthening of some principles concerning the sustainable restoration of soil fertility under aspect of physical and chemical features improvement using the biological component of soil, applying those agricultural technologies which positively influence the biological activity in soil.

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