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IMPACT OF DIFFERENT SOIL TILLAGE PRACTICES ON BIOTA OF CHERNOZEMS IN THE NORTHERN ZONE OF THE REPUBLIC OF MOLDOVA

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Abstract

The effect of different tillage practices on soil biota' state of chernozems has been investigated. Two experimental sites located in the northern zone of the Republic of Moldova have been tested with application of soil biological indicators in June and October, 2014. Land management practices with application of no-tillage on the leached chernozem (2 years of use) and mini-tillage on the slightly eroded typical chernozem (10 years of use) have been compared with the long-term conventional tillage of 25-27 cm. The application of no-tillage has created conditions for the improvement of the biota's vital activity in the leached chernozem. The effect of no-tillage was manifested in the increase of number and biomass of Lumbricidae family by 4.1 and 14.1 times respectively. Worms were concentrated in the 0-40 cm soil layer. Chernozem with no-tillage application is characterized by greater stability in comparison with the conventional tillage due to higher number of saprophages. No-tillage system has increased the microbial biomass carbon compared to the traditional tillage system. Dehydrogenase and polyphenoloxidase activities were significantly higher in conditions of no-tillage treatment. A positive impact of mini-tillage practice on soil was less pronounced. It was shown that biota's abundance increased and the humus content in the slightly eroded typical chernozem grew by 0.44-0.51%. The application of conservation management practices led to the soil compaction. Bulk density in the 0-40 cm soil layer increased on average from 1.36 to 1.41 g cm^{-3} in the leached chernozem and from 1.15 to 1.30 g cm^{-3} in the slightly eroded typical chernozem.

Key words*: biota, no-tillage, mini-tillage, conventional tillage, chernozem.*

INTRODUCTION

Soil tillage system is important for the regulation of the formation of humus and nutrients in the root zone, for the soil biota's ensuring access to plant residues in the upper layers of the soil, and the crop yield formation as a whole (Miura et al., 2008; Soane, 2012). As a result of the mixing of soil layers the water-air and thermal regimes have been changed, thus affecting on the composition and activity of soil invertebrates and microorganisms. The periodic tillage favors the air admission into the soil, thereby adjusting the ratio between air and water in it, creates optimal conditions for growth of agricultural plants and multiplication of aerobic microorganisms. The use of different types of tillage can modify the direction and intensity of the processes of humification - mineralization in the soil.

Soil conventional tillage or traditional intensive tillage by plowing besides the positive effects, such as reduction of compaction and increase the water permeability, is the reason of the evolution of soil towards the development of degradation processes in conditions of the Republic of Moldova. This concerns primarily with the intensified mineralization of organic matter, restructuring of the arable layer, its spraying, reducing of the aggregate stability and soil biota's degradation (Andriesh et al., 2004; Senicovscaia, 2012). On the other hand, the usual tillage of land is expensive process and depends on the prices of fuel and lubricants.

The negative effects of conventional tillage have led to necessity of application of alternative soil management practices. These techniques are known as *"conserving/preserving tillage"*. It should be noted that the concept of conservation processing includes many processes from direct

seeding and *no-tillage* to the deep cultivation without turning of soil layers. The implementation of soil tillage technologies should be based on the detailed knowledge of characteristics of soil. Necessarily should be taken into account such important factor as soil biological properties in cases when soil conservation tillage is applied.

The importance of monitoring researches of the biota increases in case of the application of soil conservation technologies on degraded soils.

The purpose of research was to determine the impact of conventional and conservation soil tillage technologies on biota of chernozems in the northern zone of the Republic of Moldova.

MATERIALS AND METHODS

Experimental sites and soils. Two experimental sites located in the northern zone of the Republic of Moldova in the forest steppe region of northern upland have been tested in June and October, 2014. Land management practices with application of *mini-tillage* and *no-tillage* have been compared with the long-term conventional tillage on 25-27 cm.

The first site was located in "Gospodarul Rediu" SRL in the Rediu de Sus village, Falesti region. The experimental site was on the slope with a gradient of 2-3º. Soil conservation technique *mini-tillage* was applied in the area of 60 ha over 10 years. Field with *mini-tillage* was compared with conventional tillage (plowing to a depth of 25-27 cm). The soil of plot is the slightly eroded heavy loamy typical chernozem with humus content of 3.52% and pH = 6.97 in the 0-40 cm layer.

The second site was located on the territory of "SoroAgro" SRL in the Rediu Mare village, Dondusheni region. Technology of *no-tillage* has been implemented for 2 years at the demonstration plot with the area of 106 ha. The area of control plot with conventional tillage (plowing to a depth of 25-27 cm) consists of 109 ha. The soil was presented by the deep heavy loamy leached chernozem with humus content of 3.71 % and pH = 6.66 in the 0-40 cm layer.

Status of invertebrates. The state of invertebrates was identified from test cuts by manually sampling the soil layers to the depth of soil fauna occurrence. The identification of invertebrate's diversity at the level of families and their classification according to nutrition were conducted by Gilyarov and Striganova's method (1987).

Microbiological properties. The microbial biomass C was measured by the rehydratation method based on the difference between C extracted with 0.5 M K_2SO_4 from dried soil at 65-70^oC within 24 h and fresh soil samples with K_c coefficient of 0.25 (Blagodatsky et al., 1987). K_2SO_4 – extractable organic C concentrations in the dried and fresh soil samples were simultaneously measured by dichromate oxidation. The quantity of K_2SO_4 – extractable C was determined at 590 nm with "СФ-103" spectrophotometer. Reserves of MB have been calculated taking into account the carbon content of the microbial cell and the bulk density of soils.

Enzymatic activity. The (potential) dehydrogenase activity was determined by the colorimetric technique on the basis of triphenylformazan (TPF) presence from TTC (2, 3, 5-triphenyltetrazolium chloride) added to air-dry basis of soil (Haziev, 2005). The (potential) polyphenoloxidase activity was determined by the colorimetric technique with the use of hydroquinone as a substrate (Karyagina and Mikhailovskaya, 1986).

RESULTS AND DISCUSSIONS

Invertebrates. Conservation tillage has an ambiguous effect on the biota of investigated chernozems. Number of invertebrates and *Lumbricidae* family under the soil conservation tillage technology *mini-tillage* is characterized by slightly increase compared to indicators in soil in the plot with conventional tillage to a depth of 25-27 cm. Number of invertebrates in the slightly eroded typical chernozem under *mini-tillage* increases from 50.7 to 86.7 ex m^{-2} and earthworms – from 41.4 to 78.7 ex m^{-2} (Table 1). The biomass of invertebrates and *Lumbricidae* family contrary reduces from 12.3 to 5.6 g m^{-2} and from 6.7 to 5.3 g m^{-2} in the initial sampling period. On the whole the number of invertebrates in the plot with *mini-tillage* on average is higher by 1.7 times than in the plot with plowing of 25-27 cm but the total biomass is lower by 1.2 times.

The application of *no-tillage* technology has a positive effect on the biota in the leached

chernozem. The rise of the total number of invertebrates and earthworms from 33.3 to 136.0 ex m^{-2} and their biomass from 1.7 to 23.9 g m^{-2} in conditions of *no-tillage* has been observed.

The dominant position in the composition of soil fauna occupies *Lumbricidae* family in all technologies of tillage. Their share in the total number of invertebrates increases from 84.9% in the plot with conventional tillage to 90.8% under *mini-tillage* and 92.2% in conditions of *no-tillage* technology. A similar tendency has been established in the indicators of biomass. Their share in the total biomass of invertebrates rises from 71.8% in the plot with plowing to 74.3% under *mini-tillage* and 93.3% in conditions of *no-tillage* technology.

Table 1. Number and biomass of invertebrates and *Lumbricidae* family in chernozems under different soil tillage (average values, n = 6, P ≤ 0.05)

Soil	Soil tillage	Number, ex m^{-2}		Biomass, g m^{-2}	
		total	*Lumbricidae* family	total	*Lumbricidae* family
Slightly eroded typical chernozem	Arable 25-27 cm	50.7	41.4	8.5	5.2
	Mini-tillage	86.7	78.7	7.0	5.2
Leached chernozem	Arable 25-27 cm	33.3	29.3	1.7	1.4
	No-tillage	136.0	125.4	23.9	22.3

In the slightly eroded typical chernozem under arable the base mass of invertebrates (72.3 - 75.1%) and *Lumbricidae* family (66.8-68.9%) is concentrated in the 0-30 cm layer, while in the soil under *mini-tillage* the most animals (76.3-92.6%) and earthworms (79.4-92.0%) are accumulated in the layer of 10-40 cm. Chernozem in conditions of *mini-tillage* techniques is characterized by a thick active layer of soil.

In the leached chernozem in conditions of conventional tillage earthworms are concentrated in the layer of 30-50 cm. On the contrary in the soil under *no-tillage* a major amount of invertebrates (92.6-100.0%) is located in the layer of 0-40 cm. The number of *Lumbricidae* family decreases gradually in the soil profile to a depth of 50 cm.

Slightly eroded typical chernozem under arable is characterized by a high diversity of invertebrates in comparison with the soil in conditions of *mini-tillage* technique (Table 2).

Table 2. Diversity of soil invertebrates (on the family's level) in the slightly eroded typical chernozem under different soil tillage, ex m^{-2}

No	Family	Arable 25-27 cm	Mini-tillage
17-18.06.2014			
1	*Lumbricidae*	42.7	66.6
2	*Glomeridae*	0	2.7
3	*Scarabaeidae (larva)*	2.7	0
4	*Gryllidae*	2.6	0
5	*Geophilidae (larva)*	0	2.7
6	*Pyralidae (larva)*	2.7	0
7	*Carabidae*	2.6	0
8	*Formicidae*	+	0
Total		**53.3**	**72.0**
13-14.10.2014			
1	*Lumbricidae*	40.0	90.7
2	*Scarabaeidae*	0	2.7
3	*Geophilidae*	2.7	0
4	*Carabidae*	2.7	5.3
5	*Lucanidae*	0	2.6
6	*Tenebrionidae*	2.6	0
Total		**48.0**	**101.3**

This soil contains 4-6 families of invertebrates, whereas under *mini-tillage* conditions only 3-4 families. In addition to *Lumbricidae* family, other species of the *Formicidae, Scarabaeidae, Gryllidae, Pyralidae, Geophilidae, Tenebrionidae* and *Carabidae* families in faunal samples have been identified. *Lumbricidae* family is prevalent in soils with both types of tillage. Species of *Glomeridae, Scarabaeidae, Lucanidae, Carabidae and Geophilidae* families have been reported in the chernozem under soil conservation tillage.

In the fauna of the leached chernozem *Lumbricidae* family occupies a dominant position also, their numbers amounts to 85.0-100.0% (Table 3). The average weight of *Lumbricidae* family's representatives increased from 0.05 g on the plot with arable to 0.18 g on the plot with *no-tillage*. *Lumbricus terrestris* is the most typical specie of earthworms in the leached chernozem. *Allolobophora rosea* has been encountered in single copies.

Besides *Lumbricidae* family, species of invertebrates from ants which are spread in enormous quantities have been identified in faunal samples. *Lasius niger* was a typical representative of *Formicidae* family.

Soil fauna was represented by only two families in summer, the plot with conventional tillage contained 4 families, and plot with *no-tillage* – 6 families in autumn.

Table 3. Diversity of soil invertebrates (on the family's level) in the leached chernozem under different soil tillage, ex m^{-2}

No	Family	Arable 25-27 cm	No-tillage
19.06.2014			
1	*Lumbricidae*	13,3	72,0
2	*Formicidae*	++	++++
Total		**13,3**	**72,0**
15-16.10.2014			
1	*Lumbricidae*	45,3	178,7
2	*Glomeridae*	0	8,0
3	*Geophilidae*	0	5,3
4	*Araneidae*	2,7	2,7
5	*Elateridae*	2,6	0
6	*Tenebrionidae*	2,7	2,6
7	*Pieridae*	0	2,7
Total		**53,3**	**200,0**

Saprophages predominated in both methods of tillage in investigated chernozems.

The share of saprophages in the complex of soil fauna in the slightly eroded typical chernozem under arable is 80.1-83.3%, under *mini-tillage*– 89.5-92.4% (Figure 1). The contribution of phytophages in the total number of invertebrates is significantly lower and has been reduced to zero in the plot with *mini-tillage*. The content of invertebrates with mixed type of nutrition amounts to 2.7-9.8% in the arable chernozem and 0-3.8% with *mini-tillage*. Zoophages constitute 0-2.7% in the arable soil and 3.8-5.3% in the soil with *mini-tillage*. Ecological pyramids in the chernozem with *mini-tillage* application are characterized by higher stability compared to the application of the conventional tillage on 25-27 cm depth. Necrophages have been found only in the arable soil and constitute 2.6%.

The contribution of saprophages to the total number of invertebrates in the leached chernozem is significant and constitutes 85.0-100.0% for both types of soil tillage. Invertebrates with mixed type of nutrition (*Formicidae* family) are significant in the plot with *no-tillage*. Ecological pyramids are incomplete, but the soil under *no-tillage* is characterized by greater stability compared to the conventional tillage due to larger number of saprophages.

Microorganisms. The application of *mini-tillage* and *no-tillage* technologies stimulates the restoration of microorganisms in investigated chernozems in the demonstration sites.

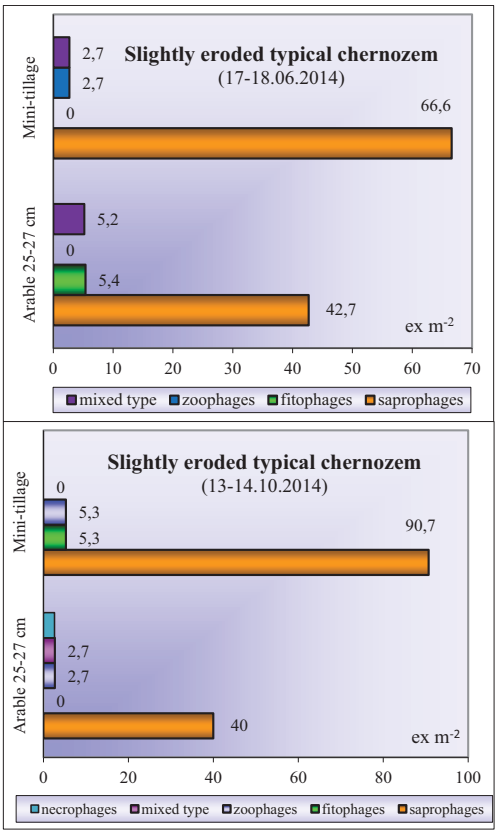

Figure 1. The composition of invertebrates depending on the mode of nutrition in the slightly eroded typical chernozem in conditions of the different tillage methods application (average, without *Formicidae* family in the arable plot)

The microbial biomass in the slightly eroded typical chernozem increases in average from 283.2-514.7 to 398.5-524.0 μg C g^{-1} soil in the 0-20 cm layer and from 227.2-440.9 to 469.0-588.0 μg C g^{-1} soil in the 20-40 cm layer (Table 4). The share in the total microbial carbon in the 0-40 cm layer in the plot under arable is 1.24-2.37% and in the plot with *mini-tillage* – 1.87-2.40%. The application of *mini-tillage* contributes to the increase of microbial biomass stocks by 1.3-1.9 times in the 0-40 cm layer.

Enzymatic activity. The tendency to activate the polyphenoloxidase in conditions of *mini-tillage* in the slightly eroded typical chernozem in autumn has been registered (Table 6). Dehydrogenase activity has not changed statistically significant with the exception of the layer of 20-40 cm.

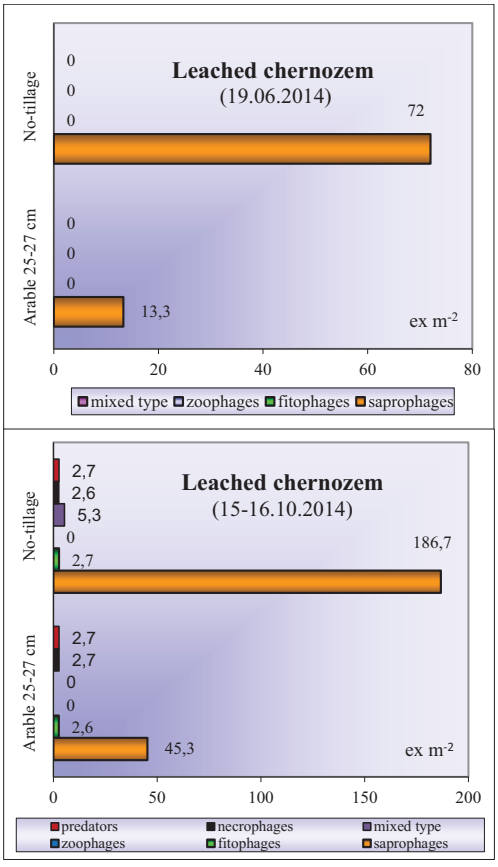

Figure 2. The composition of invertebrates depending on the mode of nutrition in the leached chernozem in conditions of the different tillage methods application (average, without *Formicidae* family)

Table 4. Microbial biomass content and reserves in the slightly eroded typical chernozem in conditions of different tillage systems

Soil tillage	Depth, cm	MB, µg C g^{-1} soil	C_{MB}/C_{org}, %	Reserves of MB, kg ha^{-1}	
				in layers	in 0-40 cm layer
17-18.06.2014					
Arable 25-27 cm	0-20	283.2	1.34	1246.1	2300.3
	20-40	227.2	1.14	1054.2	
Mini-tillage	0-20	398.5	1.73	2131.9	4383.1
	20-40	469.0	2.00	2251.2	
LSD 5%		98.5			
13-14.10.2014					
Arable 25-27 cm	0-20	514.7	2.43	2285.3	4436.9
	20-40	440.9	2.30	2151.6	
Mini-tillage	0-20	524.0	2.30	2661.9	5884.1
	20-40	588.0	2.50	3222.2	
LSD 5%		67.6			

MB – microbial biomass; C_{org} – organic C

The humus content in the slightly eroded typical chernozem grew from 3.48-3.56% in arable soil to 3.99-4.00% in the 0-40 cm layer of soil under *mini-tillage*.

The increasing trend of microbial carbon content and the ratio between microbial and total carbon content have been recorded in the leached chernozem in conditions of *no-tillage* technology. There has also been indicated the increase of microbial biomass reserves under the application of *no-tillage* (Table 5). Reserves of microorganisms' biomass in the 0-40 cm layer are 4796.6-6449.9 kg ha^{-1} in the plot with plowing and 5649.4-6563.9 kg ha^{-1} in the plot with *no-tillage*.

Favorable conditions for the functioning of enzymes in soil under conditions of *no-tillage* have been found (Table 7). The most powerful impact of the conservation technology on soil enzymes was recorded in the 20-40 cm layer.

Table 5. Microbial biomass content and reserves in the leached chernozem in conditions of different tillage systems

Soil tillage	Depth, cm	MB, µg C g^{-1} soil	C_{MB}/C_{org}, %	Reserves of MB, kg ha^{-1}	
				in layers	in layers
19.06.2014					
Arable 25-27 cm	0-20	403.3	1.90	2097.2	4796.6
	20-40	485.5	2.26	2699.4	
No-tillage	0-20	441.6	2.02	2773.3	5649.4
	20-40	528.7	2.37	2876.1	
LSD 5%		48.9			
15-16.10.2014					
Arable 25-27 cm	0-20	597.1	2.76	3319.9	6449.9
	20-40	592.8	2.71	3130.9	
No-tillage	0-20	469.2	2.13	2665.1	6563.9
	20-40	667.6	2.95	3898.8	
LSD 5%		72.5			

MB – microbial biomass; C_{org} – organic C

Table 6. Influence of different tillage systems on the enzymatic activity of the slightly eroded typical chernozem

Soil tillage	Depth, cm	Dehydrogenase, mg TPF 10g^{-1} soil 24h^{-1}	Polyphenoloxidase, mg 1,4-p-benzoquinone 10 g^{-1} soil 30 min^{-1}
17-18.06.2014			
Arable 25-27 cm	0-20	2.58	64
	20-40	1.10	6.5
Mini-tillage	0-20	2.54	9.0
	20-40	2.54	7.3
LSD 5%		0.60	1.0
13-14.10.2014			
Arable 25-27 cm	0-20	3.90	6.5
	20-40	0.13	5.8
Mini-tillage	0-20	1.65	4.0
	20-40	1.58	5.0
LSD 5%		1.27	1.0

Table 7. Influence of different tillage systems on the enzymatic activity of the leached chernozem

Soil tillage	Depth, cm	Dehydrogenase, mg TPF $10g^{-1}$ soil $24h^{-1}$	Polyphenoloxidase, mg 1,4-p-benzoquinone $10\ g^{-1}$ soil 30 min^{-1}
19.06.2014			
Arable 25-27 cm	0-20	2.65	6.5
	20-40	0.79	3,3
No-tillage	0-20	3.29	10.0
	20-40	2.04	10.3
LSD 5%		0.88	2.7
15-16.10.2014			
Arable 25-27 cm	0-20	2.50	6.8
	20-40	0.13	4.5
No-tillage	0-20	2.73	10.5
	20-40	1.33	9.8
LSD 5%		0.97	2.7

The application of conservation management practices led to the soil compaction. Bulk density in the 0-20 cm soil layer increased from 1.11 under arable to 1.31 g cm^{-3} under *mini-tillage* in the slightly eroded typical chernozem and from 1.35 in the plot with arable to 1.40 g cm^{-3} in conditions of *no-tillage* in the leached chernozem. A similar regularity has also been observed in the 20-40 cm soil layer. Bulk density increased from 1.19 to 1.29 g cm^{-3} in the slightly eroded typical chernozem and from 1.36 to 1.41 g cm^{-3} in the leached chernozem respectively.

CONCLUSIONS

The application of conservation tillage practices in conditions of the northern zone of the Republic of Moldova has different effects on soil biota. The common characteristic of *mini-tillage* and *no-tillage* is the growth of the number of invertebrates, reserves of microbial biomass, the multiplication and development of the *Lumbricidae* family, increase enzymatic activity.

The effect of *mini-tillage* on the soil biota manifests by the increase of the total number of invertebrates by 1.7 times, *Lumbricidae* family – by 1.9 times, growth of the microbial biomass and reserves. The slightly eroded typical chernozem at the plot with *mini-tillage* is characterized by the lower diversity of invertebrates compared to arable chernozem. Ecological pyramids in conditions of *mini-tillage* application are characterized by the greater stability compared to the arable soil by the reason of increasing numbers of saprophages and the lack of phytophages.

More pronounced effect is the use of *no-tillage* technology though this method has been used for 2 years. The number of *Lumbricidae* family in the leached chernozem in average was 4.1 times higher compared with the arable plot, the biomass – 14.1 times respectively. The weight of one exemplar of earthworms in chernozems was 3.6 times higher and constituted 0.18 g. The characteristic feature of the chernozem with *no-tillage* application is concentration of earthworms in the layer of 0-40 cm and the higher share of saprophages in the total population of soil invertebrates.

Negative consequences of the conservation practices application are soil compaction.

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