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IMPACT OF DIFFERENT SOIL TILLAGE SYSTEMS AND ORGANO-MINERAL FERTILIZATION ON PHYSICAL PROPERTIES OF THE SOIL AND ON CROPS YIELD IN PEDOCLIMATICAL CONDITIONS OF MOLDAVIAN PLATEAU

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ABSTRACT

Present preoccupations for the adaptation of sustainable agricultural systems are justified by the extension in alarming proportions of the degradation and deterioration of the soil resources. Maintaining or introduction of new technological systems must be in accordance with durable progress principles to ensure the possibility of progress and development. Research carried out aimed at developing fundamental knowledge through in-depth inquiries of soil quality indicators from Moldavian Plain, regarding integrated management of soil and water. The experiment was conducted at the Didactic Station of the University of Agricultural Sciences and Veterinary Medicine of Iasi, during 2008-2012. The site is located in the East part of Romania on a chambic chernozem. We investigated three variants of soil tillage systems – conventional tillage (CT), minimum tillage (MT) and no-till (NT) – in a winter wheat - oilseed rape crop rotation and with different fertilization levels. Tillage systems modified some of the physical properties of soil. All the tillage operations were significantly different in their effects on soil properties. The hydrophysical indicators of the soil were not influenced significantly by the tillage systems in short-term. Indicators of soil compaction had the lowest values in CT, intermediate values in MT and minimum values in NT variant. Analysis of mean values of quality indicators of soil structure showed that even if the water stability of soil aggregates and aggregation index indicates higher values in the CT systems, the quality of the structure and the ratio of aggregates were better in the MT system and especially in the NT system. Tillage system and the level of fertilization determined differences in crop yields, usually being higher in conventional treatment, but not always statistically significant. The results indicated that soil tillage systems must be adapted to plant requirements in accordance with crop rotation and to the pedoclimatic conditions of the area.

Key words: soil tillage, soil conservation, fertilization systems, crop yield.

INTRODUCTION

The global research regarding the unconventional technologies brings up some information about the implication of this kind of systems on the agricultural environment, the impact being different from an area to another, depending on the soil and climate conditions, management etc. Because the research from all over the world cannot offer a general valid solution, there is a necessity of zonal research on this subject. For these reasons, and due to demand to create a scientific data base to allow a complex analysis of the influence of unconventional tillage systems on environment, we initiated this research project. There are many practical and theoretical problems to analyse, to explore, to synthesize and communicate, for the beneficiaries of the new technologies, to be informed.

In Romania and abroad, the research towards the agricultural tillage systems have been orientated in the direction of finding ways to lead to the amelioration of the soil structure, to reduce the soil compaction, to ameliorate the hydrological and air regime, to improve the content in organic mater, to ameliorate the activity of micro and mezoorganisms in the soil, the knowledge of the changes that are caused by the chemical substances used, the critical limits of pollution

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(Sin, 2013; Jitareanu et al., 1999; Gus et al., 2003; Dumitru et al., 1999; Ailincai et al., 2004), the risks for human and animals health, and the energetically and economical advantages (Diaz-Zorita, 2002; Zentner, 2002).

The amplification of the degradation of soil resource phenomena has taken alarming dimensions, not only on local plan but also all over the world (Hamza et al., 2005, Garcia-Orens et al., 2005; Rusu et al., 2014). When we choose a tillage system we have to take a look at the climate condition, soils and crop, factors which can influence or can be influenced by the tillage system (Franzluelbers, 2002). The positive effect of the tillage system on one factor helps to keep the others factors on a satisfactory level, so that increasing of yield, decreasing the fuel consumption or the raising of the soil productivity could be possible by economical optimization solutions (Zentner, 2002; Czyż Ewa, 2004). Better soil tillage, besides the positive and novel effects for crop technologies, has also some permanent effects with influences on physical and mechanical properties of soil (Dexter, 2004; Munkholm et al., 2005).

The physical characteristics of soil structure, porosity, bulk density, hydrological regime, the regime of air and heat changes depends on soil tillage systems. Many different researches showed that changes of physical features in a certain direction occurs slowly, after a shorter period when values begin to stabilize (Fabrizzi et al., 2005; Ferreras et al., 2000; Reynolds et al., 2002; Gus et al., 2003; Osunbitan et al., 2005; Jitareanu et al., 2006). Soil physical properties have a major influence on how the soil functions within an ecosystem (Hamza et al., 2005; Dexter, 2004; Pagliai, 2005; Horn, 2005). Through various technical means, these characteristics can be improved, in a way that they would compete to develop the capacity of the soil, to ensure optimal conditions for plant growth (Wu et al., 2005, Topa et al., 2013).

This paper presents the results obtained in winter oilseed rape and winter wheat crops regarding the influence of the tillage methods on some soil physical characteristics of the soil and crops yield.

MATERIAL AND METHODS

The experiment was conducted at the Didactic Station of the „Ion Ionescu de la Brad” University of Agricultural Sciences and Veterinary Medicine of Iasi, Ezareni Farm (47°07´ N latitude, 27°30´ E longitude), during 2008-2012. The experimental site is located in the East part of Romania on a chambic chernozem (SRTS, 2003, or haplic chernozems after WRB-SR, 1998), with a clay-loamy texture, 6.8 pH units, 3.7% humus content and a medium level of fertility. The soil has high clay content (38-43%) and is difficult to till when soil moisture is close to the wilting point (12.2%). We investigated three variants of soil tillage systems – conventional tillage (CT), minimum tillage (MT) and no-till (NT) – in a winter wheat - winter oilseed rape crop rotation. In the same time, we investigated three variants of fertilization: chemical fertilization (CF), organic fertilization (OF) and organic and chemical fertilization (OCF), with three replications with plots covering a surface of 100 m^2.

In order to determine the main physical properties from the soil profiles, on each variant, soil samples were collected by 10 cm increments to 40 cm depth: 0-10, 10-20 20-30 and 30-40 cm. The bulk density (BD) of the soil was determined using 100 cm^3 cores, according to the ICPA methodology (Dumitru et al., 2009). Using the same samples, the capillary and total water capacity of the soil, total porosity (TP) and other category of soil pores were measured.

A number of physical and hydrophysical properties were estimated indirectly, based on calculation formulas and corresponding primary data - field capacity (FC) and available moisture holding capacity (AMHC) (Canarache, 1990). Calculation of total porosity of the three components - aeration porosity (AP), efficient porosity (EP) and inactive porosity - was performed using primary values of density, bulk density of soil and hydrophysical indices (Canarache, 1990).

Analysis of water distribution and stability of macro aggregates was performed according to the Tiulin-Erikson method (Onisie and Jităreanu, 1991). A number of indicators were determined by calculation - mean weight diameter (MWD) of structural aggregates and qualitative indices.

The yields were determined on each plot using a Wintersteiger Classic Plot Combine, equipped with Plot Harvest Data SystemTM with the Single Plot High Capacity GrainGage and HM800 electronics. The winter wheat yields are reported at 14% standardized moistures content.

The results of all determinations were statistically analysed by analysis of variance and LSD test.

The experimental site has an annual average temperature of 9.4°C and precipitation of 587 mm. In the years of the experiment the climatic conditions were characterized by the average annual temperature higher than the long term average, and the average annual precipitation below the long term average, which affected the results. Yields were higher in the system that succeeded to preserve more water in the soil.

RESULTS AND DISCUTIONS

a. Influence of tillage systems on the hydrophysical indicators of the soil.

The average values of the field capacity (FC) of the analysed crops were medium and had a small variation range. FC decreased during the growing season and in depth, no matter soil tillage was performed. The values increased in the same time with the increase of soil mobilization intensity. The highest average value for the entire growing season was reported in no-tillage variant (Table 1).

Table 1. Influence of soil tillage systems on hydrophysical indices

Tillage systems \ Crop	Winter wheat		Winter oilseed rape	
	FC (% g g^{-1})	AMHC (% g g^{-1})	FC (% g g^{-1})	AMHC (% g g^{-1})
Conventional tillage (CV)	25.3	14.8	25.7	15.3
Minimum tillage	25.2 ^{ns}	14.8 ^{ns}	25.5 ^{ns}	15.2 ^{ns}
No tillage	25.5 ^{ns}	14.9 ^{ns}	25.8 ^{ns}	15.4 ^{ns}
$LSD_{5\%}$=	0.4	0.8	0.2	0.7
$LSD_{1\%}$=	0.7	1.4	0.3	1.2
$LSD_{0.1\%}$ =	1.3	2.6	0.5	2.2

Note: CV – control variant; FC – field capacity; AMHC - available moisture holding capacity.
ns - not significant.

The values of available moisture holding capacity (AMHC) showed that the soil on which the research was carried out was not damaged over a short period of time by the tillage system used (Table 1). AMHC decreased during the growing season in ratio with the depth and with a different intensity depending on the tillage systems. The potential reserve of water available to plants was influenced to a small extent by the tillage system, the range of variation of the indicator being small from variant to variant, as well as by vegetation or depth. However, a higher average value was recorded in the no tillage variant, which created better conditions for retention of water available to plants. Statistical analysis revealed no statistical differences between variants (Table 1).

b. Influence of tillage systems on soil compaction indices

Bulk density is an indicator whose values change in restricted limits as average values on profile over a period of years (Czyz Ewa, 2004; Hamza and Anderson, 2005; Kay et al., 2002) influencing root growth (Scot et al., 2005; Czyz Ewa, 2004). Soil is generally able to repair its structure in time due to physical and biological processes that occur in its mass (Jitareanu and Raus, 2007; Jaiyeoba, 2003; Osunbitan et al., 2005; Chen, 2005). In determining and assessing the influence of tillage system or other agrotechnical measures on the bulk density, a multitude of factors should be considered. Researches in this direction are numerous and the results are often contradictory. A lot of researches registered a large increase in the values of these parameters under the depth of soil tillage influence, but the differences were not always significant (Etana et al., 1999).

Decreasing soil tillage intensity from conventional to direct sowing system has often resulted in an increase in bulk density in the upper layer. Also, in no-till system, very low values of bulk density in the 0-3 cm depth have been noticed, due to the organic matter layer from the soil surface. Compaction in no-till systems in all locations have been reported, especially in 0-10 cm depth and in depths of 25-30 cm. Compaction is higher in the conventional system (Scot et al., 2005; Motavalli et al., 2003; Chen, 2005). In the first years after the introduction of a no tillage system, usually BD significantly increases, both in the superficial layer and in concordance with depth, but over time values tend to balance, recording regularly similar results, which permit the normal development of roots (Fabrizzi et al., 2005; Ferreras et al., 2000; Rasmussen, 1997).

Following the bulk density (BD) values in winter wheat and winter oilseed rape it was revealed that it increased in both crops in all variants and depth, and the most compacted were the upper layers. The phenomenon of compaction decreased in depth. The lowest differences of values of the indicator between the two consecutive moments of sampling were determined at the NT variant.

Statistical processing of the data obtained, showed that the BD registered the highest values, with significant differences from control, in the MT variant. The NT variant and the MT variant had close values between themselves and higher then the control variant (CT).

Table 2. Influence of tillage systems on soil compaction indices

Crop / Tillage systems	Winter wheat		Winter oilseed rape	
	BD (g cm^{-3})	CD (% v v^{-1})	BD (g cm^{-3})	CD (% v v^{-1})
Conventional tillage (CV)	1.30	5.0	1.27	3.0
Minimum tillage	1.34*	5.2	1.31**	4.5
No tillage	1.33^{ns}	3.6	1.28*	2.6
$LSD_{5\%}$=	0.04		0.01	
$LSD_{1\%}$=	0.07		0.02	
$LSD_{0.1\%}$ =	0.13		0.04	

Note: CV – control variant; BD – bulk density; CD - degree of compaction.
Significance of differences from CV: ns - not significant; * significant; ** distinctly significant; ***very significant; **o** negative significant; **oo** negative distinctly significant; **ooo** negative very significant..

For the analyzed crops, the compaction degree (CD) showed that during the growing season, the most compacted variant was the one with inverting furrow, where the differences between the compaction degrees from sowing to vegetation and all the way to harvesting reached the highest values. Soil layers, which were not mobilized through tillage, were compacted with the lowest intensity, as results as an initial high values of this index. For the NT variant CD had the highest values, however, differences between sampling times were minimal.

Both crops registered the lowest average value of the indicator for the NT variant, because the amplitude of variation of the indicator over time was the lowest. The results confirm that compaction intensity varies depending on the system used. Our results showed that in a short-term interval, the compaction degree did not change significantly, no matter what tillage system has been used (Table 2).

c. The influence of tillage systems on soil porosity

Knowledge of soil porosity has a great importance because the entire dynamics of the soil largely depends on it (Hamza and Anderson, 2005). In soil as a dynamic system, porosity plays the same role as the solid phase, because the soil pores receive and release all mineral and organic components and microorganisms that circulate in one form or another in the mass of the soil.

Porosity variations induced at conventional tillage are not uniform on soil profile and do not affect all categories of pores. The increase of soil porosity is limited to the ploughed layer, while the layer immediately below registers a decrease in porosity due to compaction (Ishaq et al., 2001). Therefore, logically, to assess the impact and changes resulting from tillage on pores, identification and clarification of the depths where the changes were observed, and their duration in time, depending on the stress intensity factor, are necessary (Kay et al., 2002).

During the growing season total porosity (TP) decreased in all variants, but with different intensities on the profile depending on tillage system. Aeration porosity (AP) values decreased with depth in all phases of vegetation, regardless of tillage system. Efficient porosity (EP) did not undergo important changes in depth during the growing season or in accordance with tillage systems. With the increase of BD values, the AP decreased and some of the pores which retain water used by plants reduced their dimensions, with the inactive porosity increasing at the same time.

Table 3. The influence of tillage systems on soil porosity

Crop / Tillage systems	Winter wheat			Winter oilseed rape		
	TP (% v v^{-1})	AP (% v v^{-1})	EP (% v v^{-1})	TP (% v v^{-1})	AP (% v v^{-1})	EP (% v v^{-1})
Conventional tillage (CV)	50.2	17.3	11.7	52.1	17.5	11.7
Minimum tillage	49.4^{o}	16.0^{o}	11.7^{ns}	50.6^{ooo}	18.0*	11.7^{ns}
No tillage	49.5^{o}	17.1	11.8*	51.6^{o}	16.0^{o}	11.8^{ns}
LSD$_{5\%}$=	0.5	0.7	0.1	0.4	0.6	0.1
LSD$_{1\%}$=	1.5	1.2	0.1	0.6	1.4	0.3
LSD$_{0.1\%}$ =	4.7	2.1	0.3	1.2	2.8	0.5

Note: CV – control variant; TP – total porosity; AP - aeration porosity; EP - efficient porosity.
Significance of differences from CV: ns - not significant; * significant; ** distinctly significant, ***very significant;
o negative significant; **oo** negative distinctly significant; **ooo** negative very significant..

The processed data are presented in Table 3. It shows significant positive differences of EP between in the control variant and the NT variant. TP and AP had close average values, and there were no statistical differences found between variants for both crops.

d. Influence of tillage systems on soil structure

In modern conceptions, soil structure is one of the essential characteristics with direct influences on all physical, mechanical and biological processes, which take place in soil (Brown et al., 1996; Horn et al., 2005; Dexter, 1988). Vast investigations, carried out by many researchers, have reflected the multiple relations between soil structural characteristics and plant growth (Dexter, 1988; Beare et al., 1997). According to size, form and forming mode, the aggregates may have more or less characteristics favourable to the circulation of water and air, and root penetration.

Soil tillage systems have a profound and highly complex influence on the structure of the soil. There have been numerous data published in the world literature with reference to this subject. The results obtained on different soil types with different climatic conditions and agricultural systems were not homogenous, they differ depending on the actual conditions of locations where the studies were conducted.

Usually, research shows that conventional systems cause a significant increase in the number of units with reduced diameter, compared with the minimum tillage systems (Castro Filho et al., 2002; Raus et al., 2009). Aggregates larger than 2 mm prevailed in conservative systems due to the accumulation of large quantities of organic residues in the top layer of these systems. The interaction between climatic factors and organic residues resulted in an increase in microbial activity and determined an increased stability of aggregates and their diameter sizes (Pinheiro, 2004; Hajabbasi and Hemmat, 2000).

In our study, the mean weight diameter (MWD) of structural aggregates for autumn crops was differentiated easily between the variants and ways to formation of aggregates categories (Table 4). Unlike other variants, in the variant where the tillage was made with the chisel (MT), the aggregates with large diameter predominated, due to the accumulation and decomposition of organic matter at the surface of the soil. This contributed to the formation of aggregates with a larger diameter.

Statistical analysis showed that MWD for winter wheat registered the highest values in MT variant and minimum for the CT variant, but without significant differences between each variant and control variant (Table 4). For the oilseed rape crop, the highest value was registered for the NT variant, but the differences were not statistically significant.

The hydric stability of the soil aggregates (SH) is directly related to the amount of organic C and its location in the soil architecture (Eynard et al., 2005). Decreasing the content in this element as a result of intense tillage of the soil, causes a decrease in the size of aggregates and consequently in their hydric stability (Puget and Lal, 2000; Kushwaha et al., 2001; Lupwayi et al., 2001).

The water stability of the soil aggregates (SH), regardless of the stage of growth or variation of tillage system, increases with depth. This is explained by the fact that in the surface layer, the soil structure has pronounced degradation due to mechanical actions caused by the movements of the agricultural machineries, the direct and negative influence of raindrops and other factors. All these effects are attenuated in the deepness of the soil profile.

Basic seedbed preparation and sowing reduced the values of SH in upper layers. Until spring, under the influence of natural factors, the hydro stability of the structure improved. Until harvesting the process continued but with a lower intensity.

In the winter wheat crop, statistical analysis of mean values showed a better SH for the NT profile analyzed, but with a small difference. In the oilseed rape, the highest SH on the analyzed profile was determined at the MT variant, due to higher values of the indicator on 20-30 cm layer, in comparison with the same depth for all other treatments. In comparison with the control variant, in both conservative systems the SH values were higher.

The analysis of hydro stable aggregates to total percentage showed that on analyzed profile, the structural elements from MT variant were more stable to water. The values of aggregation index (AI) increased in depth and during vegetation period at all variants, excepting the CT variant (below the depth of 10 cm), because of the stress caused by soil continuous settling at this variant, which deteriorate the structure quality with time.

Qualitative indices determined for each variant and depth confirmed the aspects presented above. In the NT variant at sowing, the value of qualitative index determined for the superior layer of soil, fit the structure of the soil within "poor" to "bad" (I.C.P.A., 1987). On the other hand, analysing the average values of these indicators on 0-40 cm shows that whilst the stability of the soil and the rate of aggregation had greater values for the ploughed treatment (CT), the quality of the structure and the ratio of hydro stable aggregates were better for the variant tilled with the chisel (MT) and especially for the one with direct sowing (NT).

In the same time, analysis of hydro stable aggregates percentage to the total percentage of aggregates showed that on the profile analyzed structural aggregates formed in MT and NT variants were more stable to the action of water dispersion than the classic treatment (Table 4) for both crops.

Table 4. The influence of tillage systems on soil structure

Tillage systems \ Crop	Winter wheat			Winter oilseed rape		
	MVD (mm)	SH (%)	AI (mm)	MWD (mm)	SH (%)	AI (mm)
Conventional tillage (CV)	4.61	69.5	56.8	4.58	69.2	57.7
Minimum tillage	5.03^{o}	71.2^{ns}	56.8^{ns}	4.85^{ns}	70.7^{ns}	57.9^{ns}
No tillage	4.62^{ns}	73.2^{ns}	61.0^{ns}	4.91^{ns}	71.2^{ns}	59.2^{ns}
$LSD_{5\%}$=	0.6	5.7	6.4	0.7	5.5	7.5
$LSD_{1\%}$=	1.0	9.4	10.6	1.6	10.5	12.5
$LSD_{0.1\%}$ =	1.9	17.6	19.8	2.3	19.3	23.3

Note: CV – control variant; MWD – mean weight diameter; SH – hydric stability of the soil aggregates.
AI – aggregation index.
Significance of differences from CV: ns - not significant, * significant; ** distinctly significant;
***very significant; **o** negative significant; **oo** negative distinctly significant; **ooo** negative very significant.

e. The influence of tillage systems on crops yield

Modern, intensive, high yield agriculture places great demand on soil and insufficient knowledge of the way in which soil reacts to this sort of solicitations may have negative consequences, reflected by degradation processes that tend to destroy the yielding capacity. The elaboration of any tillage system must consider the soil conditions, crop and climate, which can influence or can be influenced by that system. Tillage system and level of fertilizer determined difference in crop production, usually being higher in conventional variants, but not always statistically significant.

In the last decade, one of the current agricultural priorities was to sustain and maintain fertility levels of soils without damaging the natural ecosystem. Various alternatives, including no tillage management systems and organic byproducts application, such as sewage sludge, compost, crop residues, etc. to soil is a current environmental and agricultural practice for maintaining soil organic matter, reclaim degraded soils and supplying plants nutrients (Bayer et al., 2002; Tejada and Gonzales, 2004; García-Orenes et al., 2005; Gonzáles-Pérez et al., 2006; Paramasivan et al., 2006; Alcantara et al., 2009). Due to its high organic matter content, sewage sludge can improve physical, chemical, and biological properties of soil (Aggelides, 2000; McBride, 2003; Sanchéz-Monedero et al., 2004; Zhang et al., 2007; Gonzáles-Pérez et al., 2006; Alcantara et al., 2009).

The highest yield of winter wheat (5210 kg ha^{-1}) was recorded in the MT variant. Lower yield with significant difference from the control was registered for the variant sown directly (Table 5). Compared to the unfertilized variant in all other variants the yield was evidently higher with significand statistical differences (Table 6). In the interaction between tillage system and fertilization, the fact that the highest yields were reported in MT variant for all variants of fertilization compared to the other variants, was observed (Table 7).

Fertilization with different doses of sewage sludge, with or without mineral fertilizers, increased the yield. The increase was 1381 kg ha^{-1} when 30 t ha^{-1} were applied. Significant yield increases were obtained when organic fertilization associated with mineral fertilization was applied.

Table 5. The influence of tillage systems on winter wheat yield

Tillage systems	Yield (kg ha^{-1})	%	Difference (kg ha^{-1})	Significance
Minimum tillage	5210	104.6	226.7	xxx
Conventional tillage	4983	100.0	0.0	control variant
No tillage	4560	91.51	-423.3	ooo

$LSD_{5\%}$= 65.6 kg ha^{-1} $LSD_{1\%}$= 108.8 kg ha^{-1} $LSD_{0,1\%}$ = 203.3 kg ha^{-1}

Table 6. The influence of fertilization systems on winter wheat yield

Fertilization systems	Yield (kg ha^{-1})	%	Difference (kg ha^{-1})	Significance
$N_{64}P_{64}$ + 30 t ha^{-1}	5455	148.8	1789	xxx
$N_{96}P_{96}$ + 20 t ha^{-1}	5241	142.9	1575	xxx
$N_{64}P_{64}$	5158	140.7	1491	xxx
$N_{32}P_{32}$	5115	139.5	1448	xxx
30 t ha^{-1}	5058	137.9	1391	xxx
20 t ha^{-1}	4730	129.0	1063	xxx
Unfertilized	3666	100.0	-	control variant

LSD $_{5\%}$= 380.5 kg ha^{-1} LSD $_{1\%}$ = 534.1 kg ha^{-1} LSD $_{0.1\%}$ = 754.1 kg ha^{-1}

The results of the experiment showed that fertilization with organic fertilizers only does not increase the yield significantly, whilst mineral fertilization leads to yield increases, higher than those achieved in organically fertilized plots. The administration of chemical fertilizers associated with organic fertilizers determined a yield increase in correlation with the doses used (Table 7).

Table 7. The influence of tillage systems and fertilization systems on winter wheat yield

Tillage systems	Fertilization systems	Yield		Difference	Significance
		kg ha^{-1}	%	kg ha^{-1}	
Minimum tillage	$N_{64}P_{64}$+30 t ha^{-1}	5706	155.3	2031	xxx
Minimum tillage	$N_{64}P_{64}$	5647	153.7	1972	xxx
Minimum tillage	$N_{96}P_{96}$ +20 t ha^{-1}	5614	152.8	1939	xxx
Conventional tillage	$N_{64}P_{64}$ + 30 t ha^{-1}	5525	150.3	1850	xxx
Minimum tillage	30 t ha^{-1}	5455	148.4	1780	xxx
Minimum tillage	$N_{32}P_{32}$	5420	147.5	1745	xxx
Conventional tillage	$N_{96}P_{96}$ + 20 t ha^{-1}	5396	146.8	1721	xxx
Conventional tillage	$N_{64}P_{64}$	5159	140.4	1484	xxx
No tillage	$N_{64}P_{64}$ + 30 t ha^{-1}	5136	139.8	1461	xxx
Conventional tillage	30 t ha^{-1}	5126	139.5	1451	xxx
Conventional tillage	$N_{32}P_{32}$	5115	139.2	1440	xxx
Minimum tillage	20 t ha^{-1}	4952	134.7	1277	xxx
No tillage	$N_{64}P_{64}$	4942	134.5	1267	xxx
Conventional tillage	20 t ha^{-1}	4887	133.0	1212	xxx
No tillage	$N_{96}P_{96}$ + 20 t ha^{-1}	4715	128.3	1040	xxx
No tillage	30 t ha^{-1}	4594	125.0	919	xxx
No tillage	$N_{32}P_{32}$	4532	123.3	857	xx
No tillage	20 t ha^{-1}	4352	118.4	677	xx
Minimum tillage	Unfertilized	3676	100.0	1	
Conventional tillage	Unfertilized	3675	100.0	0	control
No tillage	Unfertilized	3650	99.3	-25	

LSD $_{5\%}$= 445.6 kg ha^{-1} LSD $_{1\%}$ = 646.8 kg ha^{-1} LSD $_{0.1\%}$ = 985.2 kg ha^{-1}

The efficiency of crop yield production is a result of the analysis of the seed yield based on the interaction between factors. The results are more plausible than when studying each factor separately. Interaction between soil tillage and the influence of the fertilization system revealed that the association of minimum tillage system (MT) with different doses of fertilizer leads to an increased wheat yield. Highest yield was obtained for MT variant associated with 30t ha^{-1} sewage sludge and $N_{64}P_{64}$.

Tillage system and fertilization are considered by most as the decisive technological links on yield, quality and efficiency in oilseed rape yield. Of the three soil tillage systems analyzed, the classic system proved to be more favourable giving the highest yield (Table 8). Scientific studies have shown that oilseed rape is a crop that responds very well to fertilization, both organic or mineral, or only mineral, or combined (Table 9).

Table 8. The influence of tillage systems on oilseed rape yield

Tillage systems	Yield ($kg\ ha^{-1}$)	%	Difference ($kg\ ha^{-1}$)	Signification
Conventional tillage	3757	100.0	0.0	control variant
No tillage	3522	93.74	-235.0	ooo
Minimum tillage	3319	88.35	-437.7	ooo

$LSD_{5\%}$= 65.6 $kg\ ha^{-1}$ $LSD_{1\%}$= 108.8 $kg\ ha^{-1}$ $LSD_{0.1\%}$ = 203.3 $kg\ ha^{-1}$

Table 9. The influence of fertilization systems on oilseed rape yield

Fertilization systems	Yield ($kg\ ha^{-1}$)	%	Difference ($kg\ ha^{-1}$)	Signification
$N_{96}P_{80}K_{60}$ + 20 t ha^{-1}	3698	118.6	581.0	xx
$N_{64}P_{50}K_{40}$ + 30 t ha^{-1}	3689	118.4	572.6	xx
30 t ha^{-1}	3644	116.9	527.3	xx
$N_{96}P_{80}K_{60}$	3517	112.8	400.0	x
20 t ha^{-1}	3413	109.5	296.3	
$N_{64}P_{50}K_{40}$	3322	106.6	205.0	
Unfertilized	3117	100.0	-	control variant

$LSD_{5\%}$= 324.3 $kg\ ha^{-1}$ $LSD_{1\%}$= 455.2 $kg\ ha^{-1}$ $LSD_{0.1\%}$ = 642.6 $kg\ ha^{-1}$

Table 10 presents the data yields obtained in rapeseed crop under the influence of fertilization with different doses of sewage sludge in combination with chemical fertilizers or applied alone, as well as with various doses of chemical fertilizers.

The lowest yield with significantly negative value was obtained for the unfertilized variant. Yield increases, as a result of application of sewage sludge, were obtained in the organic- chemical fertilized variants $N_{96}P_{80}K_{60}$ + 20 t ha^{-1} and $N_{64}P_{50}K_{40}$ + 30 t sewage sludge (Table 10).

Based on the results we concluded that oilseed rape fertilization with sewage, alone or associated with chemical fertilizers applied, is likely to lead to obtaining high yields. Higher doses administered with mineral nutrients increased the crop yield massively (Table 10).

Table 10. The influence of tillage systems and fertilization systems on oilseed rape yield

Tillage systems	Fertilization systems	Yield		Difference	Signification
		kg ha^{-1}	%	kg ha^{-1}	
Conventional tillage	$N_{96}P_{96}$ + 20 t ha^{-1}	4501	144.5	1387	xxx
Conventional tillage	$N_{64}P_{64}$ + 30 t ha^{-1}	4005	128.6	891	xxx
No tillage	$N_{96}P_{96}$ + 20 t ha^{-1}	3954	127.0	840	xxx
Conventional tillage	30 t ha^{-1}	3868	124.2	754	xx
Conventional tillage	$N_{64}P_{64}$	3757	120.6	643	xx
No tillage	30 t ha^{-1}	3687	118.4	573	xx
Minimum tillage	$N_{96}P_{96}$ + 20 t ha^{-1}	3634	116.7	520	x
No tillage	$N_{64}P_{64}$ + 30 t ha^{-1}	3633	116.7	519	x
Conventional tillage	$N_{32}P_{32}$	3600	115.6	486	x
No tillage	20 t ha^{-1}	3561	114.4	447	x
No tillage	$N_{64}P_{64}$	3552	114.1	438	x
Conventional tillage	20 t ha^{-1}	3454	110.9	340	
Minimum tillage	$N_{64}P_{64}$ + 30 t ha^{-1}	3427	110.1	313	
Minimum tillage	30 t ha^{-1}	3375	108.4	261	
Minimum tillage	$N_{64}P_{64}$	3239	104.0	125	
Minimum tillage	20 t ha^{-1}	3223	103.5	109	
Minimum tillage	$N_{32}P_{32}$	3200	102.8	86	
No tillage	$N_{32}P_{32}$	3163	101.6	49	
Minimum tillage	Unfertilized	3131	100.5	17	
Conventional tillage	Unfertilized	3114	100.0	0	ctrl. variant
No tillage	Unfertilized	3105	99.7	-9	

$LSD_{5\%}$ = 390.6 kg ha^{-1} $LSD_{1\%}$= 548.2 kg ha^{-1} $LSD_{0.1\%}$= 803.0 kg ha^{-1}

CONCLUSION

Tillage systems modified some of the physical properties of soil. All the tillage operation was significantly different in their effects on soil properties.

The hydrophysical indicators of the soil were not influenced by the tillage systems in short-term significantly. Indicators of soil compaction had the lowest values in the variant tiled with plough (CT), intermediate values in the variant tiled without turning the furrow (MT) and minimum values for the NT variant. The method of mobilization of the soil by plowing (CT) resulted in obtaining higher values of the total porosity (TP) than in the unconventional variants (MT and NT) but the proportion between all categories of pores were more favourable for plants in conservation tillage systems.

The conservative system favoured the intensification of soil structure formation. In this variant we found aggregates with agronomic value, as effect of accumulation of organic matter at soil surface. The mean weight diameter (MWD) increased in all systems with the highest intensity in the surface layer and less on depth during the growing season. Till the harvesting, MWD tended towards equilibrium, on depth and between the tillage systems, but NT system determined the improvement of the soil quality on a faster rate. Depending on tillage system, the water stability of the aggregates (SH) varied according with depth and vegetation stages. The best SH was recorded in the NT system, followed by that obtained in MT. Analysis of mean values of quality indicators of soil structure showed that even if the hydro stability of soil aggregates and aggregation index had higher values in the CT systems, the quality of the structure and the ratio of aggregates were best in the MT system and especially in the NT system. The analysis of the percentage of water-stable aggregates to the total percentage of aggregates showed that the structural aggregates formed in MT and NT variants were more stable to the action of water dispersion than in CT system.

The highest winter wheat yield was recorded in MT system. In the conditions of a high content of clay in soil, NT treatment led to a negative effect on crop yields, showing that after four years of experimentation the a chambic chernozem form Ezareni Farm did not reach the desired equilibrium. The interaction between the tillage and fertilization systems revealed that the combination of MT system with different levels of fertilizer, determined increased yield for winter wheat.

The yield of oilseed rape registered in CT system was superior to those obtained from the variant tilled without turning furrow - NT and MT systems. The result showed that in the study region, the classical methods of tillage and seed bed preparation led to superior cropping conditions and higher emergency degree of rape seeds, with direct influences on yield, proving that this crop is less responsive to conservation tillage treatment in the conditions of University Didactical Station – Ezareni. Fertilization of oilseed rape with sewage sludge lead to higher yields, but higher doses administered with mineral nutrients caused the highest yield increases.

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