THE UNCONVENTIONAL TILLAGE SYSTEM ON SOIL PROPERTIES AND WINTER WHEAT CROP PRODUCTION IN THE MOLDAVIAN PLATEAU, ROMANIA

Lucian RÃUS[1], Gerard JITĂREANU[1], Costica AILINCĂI[1]
E-mail: rauslucian@uaiasi.ro

Abstract

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, during farming years 2007-2009. The experimental site is located in the East part of Romania on a chambic chernozem, with a clay-loamy texture, 6.8 pH units, 3.7 % humus content and a medium level of fertilization. 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 have investigated three variants of soil tillage system – conventional tillage, minimum tillage and no-till – in the crop rotation made of wheat and raps. This paper presents the results obtained in winter rape growing as concerns the influence of the tillage method on some soil physical characteristics and yield.
Research carried out aimed at developing fundamental knowledge through in-depth inquiries of soil quality indicators of Moldavian Plain, regarding integrated management of soil and water. Research carried out also aimed to quantify the influence of agricultural technologies on physic, hydric, thermic, nutrient and biological soil regime, and ecological impact of these changes on ecological, energetically, hydrological, biogeochemical and breathing soil function, in specific areas of Moldavian Plain.
Tillage system modify, at least temporarily, some of the physical properties of soil, such as soil bulk density, penetration resistance, soil porosity and soil structural stability. All the tillage operation was significantly different in their effects on soil properties. The results indicate that soil tillage systems must be adjusted to plant requirements for crop rotation and to the pedoclimatic conditions of the area.

Key words: soil tillage, bulk density, penetration resistance, compactation degree, soil structure, structural, yields

At present, the soil research is aimed at the turnover and sequestration of carbon in environmental development of functional models for chemical, physical and biological properties of soil. The soil organic matter (SOM) concentration plays a major role in forming and stabilizing aggregates and optimal physical properties (Tisdall and Oades, 1982; Dutartre et al., 1993; Beare et al., 1994; Martens, 2000; Lal and Shukla, 2004). The soil tillage can affect the amount and turnover of SOM (Lal and Shukla, 2004). Tillage disrupts soil aggregates, compacts soil and disturbs plant and animal communities that contribute to the aggregation and decreasing of SOM (Plante and McGill, 2002). Six et al. (2000a) observed that the rate of macro-aggregate formation and degradation was reduced under no-tillage (NT), compared with conventional tillage (CT), and led to the formation of stable micro-aggregates that favoured a longterm carbon (C) sequestration. The addition of mulch (in crop residues form) on soil surface decreases the erosive effect, reduces evaporation, protects from the rain impact and increases the aggregate stability (Layton et al., 1993) and the amount of soil organic carbon (SOC) pool (Duiker and Lal, 1999; Sharma and Acharya, 2000). The determination of carbon (C) pools in aggregates provides important information on soil C sequestration and mineralization in aggregate size fractions that could be protected by using appropriate soil and crop management practices (Whalen and Chang, 2002). The share of macroaggregates in size from 5x10-4 to 3x 10-3 m is important from the agronomical point of view (Demo et al., 1995). Beare et al. (1994) described physical protection of aggregate associated with SOM. In macro-aggregates, the protected C was more labile than non-protected on the surface; it means that labile fractions of SOM are physically protected in front of the decomposition in inside of aggregates. SOM in inside of aggregates is decomposed slowly, which leads to aggregate stability.

MATERIAL AND METHOD

The experiment was conducted at the Didactic Station of the „Ion Ionescu de la Brad"

[1]University of Agricultural Sciences and Veterinary Medicine, Iasi

University of Agricultural Sciences and Veterinary Medicine of Iasi, Ezareni Farm, during farming years 2007-2009. The experimental site is located in the East part of Romania on a chambic chernozem, with a clay-loamy texture, 6.8 pH units, 3.7 % humus content and a medium level of fertilization. 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 have investigated three variants of soil tillage system – conventional tillage, minimum tillage and no-till – in the crop rotation made of wheat and raps. This paper presents the results obtained in winter rape growing as concerns the influence of the tillage method on some soil physical characteristics.

Table 1

Influence of soil tillage systems on hydrophysical indices

Soil tillage systems	FC		Available moisture holding capacity	
	% g/g	%	% g/g	%
NT	25.6	100.4	15.3	100.7
CT (M)	25.5	100,0	15.2	100,0
MT	25.4	99.2^{o}	15.0	98.7o

FC	Available moisture holding capacity
$LSD_{5\%}$ = 0.2 (% g/g)	$LSD_{5\%}$ = 0.2 (% g/g)
$LSD_{1\%}$ = 0.3 (% g/g)	$LSD_{1\%}$ = 0.3 (% g/g)
$LSD_{0,1\%}$= 0.5 (% g/g)	$LSD_{0,1\%}$= 0.5 (% g/g)

Tillage system modify, at least temporarily, some of the physical properties of soil, such as soil bulk density, penetration resistance, soil porosity and soil structural stability. All the tillage operation was significantly different in heir effects on soil properties.

Table 2

Influence of tillage systems on bulk density and compactation degree

Soil tillage systems	BD		CD	
	g/cm^3	%	% v/v	%
MT	1,33	101,5*	4.3	146.9
NT	1,30	99,47	2.7	85.6
CT (M)	1,31	100,0	3.0	100.0

$LSD_{5\%}$ = 0,02 g/cm^3
$LSD_{1\%}$ = 0,03 g/cm^3
$LSD_{0,1\%}$ = 0,05 g/cm^3

This paper presents the results obtained in winter wheat growing as concerns the influence of the tillage method on some soil physical and hydrophysical characteristics. We have taken samples at sowing, emergence and on phenological phases typical of each crop, in order to determine soil moisture, bulk density and total aeration, utile and inactive porosity. We have also calculated wilting coefficient, field capacity, available moisture holding capacity, and settling degree. The analysis of distribution and structure hydrostability (SH) of structural macroaggregates was carried out according to Tiulin-Ericson method and certain indicators as mean weigh diameter (MWD) were determined by calculation.

Determinations were carried out at sowing, on vegetation and at harvesting, at three depths (0-10, 10-20 and 20-30 cm). Statistical processing of data was done by means of the analysis of variance.

RESULTS AND DISCUSSIONS

In winter wheat crop, the range of values of field capacity was reduced. High values of field capacity (> 25 % g/g, according to ICPA scale, 1987) were registered only at sowing, at all tillage systems, in the surface layer.

We remarked that the values of field capacity diminished during vegetation period and according to depth, indifferently of tillage system; the values were higher as soil mobilization was more intense. Highest average value for the whole growing season has been reported in NT variant.

The potential water stock allowable to plants was slightly influenced by tillage system, the variation interval being diminished both from system to system and in vegetation or at depth.

Studying the mean values of available moisture holding capacity (AMHC) in winter wheat crop, we found out that it diminished during vegetation period and at depth, with different intensity, according to base tillage (*tab. 1*).

As the values of the available moisture holding capacity of over 16% , registered especially at sowing, in upper layers, were considered to be “very high” (according to ICPA, 1987), and the ones over 13 % g/g as “high”, it resulted that the tillage system did not worsen this parameter on the soil on which the experiment was conducted.

The statistical interpretation of mean values has shown that NT variant determined an increase in available moisture holding capacity and field capacity at depth of 0-30 cm, but without a statistically insured difference, compared to the control, respectively CT (table 1).

Table 3

Influence of tillage systems on soil porosity

Soil tillage systems	TP		EP		AP	
	(% v/v)	%	(% v/v)	%	(% v/v)	%
NT	50.8	100.6	17.3	101.2	11.8	100.9*
CT (M)	50.5	100.0	17.1	100.0	11.7	100.0
MT	49.8^{o}	98.6	16.0	93.6 ^{o}	11.7	100.0

	TP	EP	AP
	$LSD_{5\%}$= 0.6 (% v/v)	$LSD_{5\%}$= 0.7 (% v/v)	$LSD_{5\%}$= 0.1 (% v/v)
	$LSD_{1\%}$= 0.9 (% v/v)	$LSD_{1\%}$= 1.2 (% v/v)	$LSD_{1\%}$= 0.1 (% v/v)
	$LSD_{0.1\%}$ = 1.8 (% v/v)	$LSD_{0.1\%}$ = 2.1 (% v/v)	$LSD_{0.1\%}$ = 0.3 (% v/v)

The influence of soil tillage on bulk density (BD) and on layers had a special importance; we could therefore, estimate more accurately how loosening or settling degree has influenced plant development and yield level.

Statistical processing of obtained data, as an average of analyzed profile (0-30 cm) and during the vegetation period, in three years of experiment, has shown that bulk density had the highest values, with significant differences, compared to the control variant (+1.5%), at the MT variant. In NT system indicator values were lowest (table 2).

Table 4

Influence of tillage systems on some indicators of soil structure

Soil tillage systems	MWD		SH		AI	
	mm	%	%	%	mm	%
NT	4,72	100,2	72,6	104,2	60,07	108,1
MT	5,12	108,9	70,8	101,6	56,09	100,9
CT (M)	4,70	100,0	69,7	100,0	55,59	100,0

	MWD	SH	AI
	$LSD_{5\%}$= 0.8 mm	$LSD_{5\%}$= 7.5 (% v/v)	$LSD_{5\%}$= 10.0 (% v/v)
	$LSD_{1\%}$= 1.4 mm	$LSD_{1\%}$= 12.5 (% v/v)	$LSD_{1\%}$= 16.5 (% v/v)
	$LSD_{0.1\%}$ = 2.5 mm	$LSD_{0.1\%}$ = 23.3 (% v/v)	$LSD_{0.1\%}$ = 30.8 (% v/v)

As the absolute values of bulk density or total porosity could not be adequately interpreted, in order to assess the soil settling condition, because their practical significance was different from a type of soil to another, according to it’s texture, a complex indicator was calculated, which included bulk density, total porosity, and texture, respectively, degree of compaction (CD).

Studying data obtained in winter wheat crop, we have noticed that the compaction degree had lower values at sowing and in ploughed layer, for each variant increasing according to depth and in same time with vegetation development. Till harvesting, the values of compaction degree are increasing. The ploughed variants with furrow inverting are becoming intensely compacted at depth of 10-20 cm, where differences were the biggest. Soil layers, which were not mobilized through soil tillage, were compacted with the lowest intensity, as results as a initial high values of this index. The values between 1 and 10 indicate a weakly compacted soil, which needs loosening of third emergency (tab. 2). Our results have shown that in a short-term interval, the compactation degree did not change significantly; no matter what tillage system has bean used (*table 2*).

The values of total porosity (TP) decrease from sowing to harvesting in all tillage systems variants. The statistical interpretation of mean values has shown that NT system determined an increase of total porosity at 0-30 cm layer, but without a statistically insured difference compared to the control variant (table 3). Aeration porosity (AP) becomes smaller at the same time with depth increasing, in all vegetation stages, in all soil tillage systems. Efficient porosity (EP) was not significantly influenced by depth, growing stages or tillage systems (table 3).

The mean weigh diameter (WMD) of structural aggregates has recorded a decreasing in vegetation period on layers 0-10 and 10-20 cm, and a slight increase till harvesting. At the depth of 20-30 cm, where the effect of conservation practices was not felt, the diameter of aggregates has increased constantly till harvesting.

The statistical analysis of mean values has shown that the MT system has favored the intensification of structure formation, finding on this variant aggregates with agronomic value, as effect of accumulation of organic matter at soil surface (*table 4*). Statistical analysis showed that the MWD had the highest values in the MT system and minimum in CT system, but no statistically differences was calculated between each variant and control.

The structure hydrostability (SH), indifferently of the vegetation stage or tillage variant, has increased with depth, having a peak value in the 20-30 cm layer. The tilled variants without furrow inverting had high values of structure hydrostability in upper layers (0-10 and 10-20 cm). In the NT variant it has bean recorded the best structure hydrostability, at depth of 0-30 cm (*table 4*).

The statistical analysis of mean values on profile and for the entire vegetation period has classified the variants according to data presented in table 2, the differences between variants being greater, and the differences compared to the control variant is not statistically significant. The greatest structure hydrostability (SH) on the analyzed profile was determined at the NT 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 unconventional systems the SH values were higher.

The analysis of hydrostable aggregates to total percentage has shown that on studied profile, the structural elements from NT variants were more stable at spreading action of water. The values of aggregation index (AI) have increased at depth and during vegetation period at all the 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.

Modern, intensive, high yielded 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 tent to destroy their yielding capacity. The elaboration of certain tillage system must have in view the soil conditions, plant 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 bigger in conventional variants but not always significant statistically (table 5).

Table 5

The influence of tillage system on winter wheat yield

Tillage systems	Yield (kg/ha)	%	Difference (kg/ha)	Signification
NT	5210	104,6	226,7	xxx
CT (M)	4983	100,0	-	-
MT	4560	91,51	-423,3	ooo

$LSD_{5\%}$= 76,6 kg/ha
$LSD_{1\%}$= 117,2 kg/ha
$LSD_{0,1\%}$ = 214,4 kg/ha

CONCLUSIONS

Field capacity diminished during vegetation period and according to depth, indifferently of tillage system. The values were higher as soil mobilization was more intense.

The potential moisture capacity available to plants was slightly influenced by soil tillage system, the variation interval of the indicator being diminished both from system to system and on vegetation or depth. Because the values of available moisture holding capacity over 16%, registered at sowing in the upper layers, were very high (ICPA, 1987) and the values over 13 % g/g were high, the tillage system did not worsen this parameter in short term on the soil on which the investigations were carried out.

The bulk density has increased in all variants and according to depth; the highest settling degree was found in upper layers, at all variants; the phenomenon was reduced with depth. Bulk density had the highest values, with significant differences, compared to the control variant (+1.5%), at the MT variant. In NT system indicator values were lowest.

The mean values on the studied profile, between 1 and 10 %v/v, determined at crop harvesting, show that soil was weakly compacted (according to value classes of settling degree I.C.P.A., 1987) and requires loosening of the third emergence; therefore, in a short time interval, the compactation degree is not significantly changed, indifferently of tillage system. A progressive increase in this parameter was registered from sowing to harvesting and according to depth, in all soil tillage variants. The values of total porosity decrease from sowing to harvesting in all tillage systems variants. The statistical interpretation of mean values has shown that NT system determined an increase of total porosity at 0-30 cm layer, but without a statistically insured difference compared to the control variant. Aeration porosity becomes smaller at the same time with depth increasing, in all vegetation stages, in all soil tillage systems. Efficient porosity was not significantly influenced by depth, growing stages or tillage systems

The MT system has favored the intensification of structure formation, finding on this variant aggregates with agronomic value, as effect of accumulation of organic matter at soil surface. Statistical analysis showed that the mean weigh diameter had the highest values in the MT system and minimum in CT system, but no statistically differences was calculated between each variant and control.

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The results indicate that soil tillage systems must be adjusted to plant requirements for crop rotation and to the pedoclimatic conditions of the area. Establishing systems of soil tillage for all components of the crop rotation sequence resulted in a better utilization of the other technological factors, soil water conservation, maintaining soil physical conditions and reduction in fuel consumption.

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