

THE EFFECT OF DIFFERENT SOIL TILLAGE SYSTEMS ON SOIL PHYSICAL CHARACTERISTICS AND CROP YIELD IN MAIZE AND WINTER WHEAT CROPS FROM THE MOLDAVIAN PLAIN, ROMANIA

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Optimal crop rooting soil physical conditions are a result of complex interactions between soil strength and oxygen and water supply to plant roots. Spatial/temporal variability in soil properties can be critical in the evaluation of the effects of tillage management practice on soil and crop parameters. In this paper tillage were evaluated for theirs effects on soil physical properties. Tillage treatments were plough to 20 cm, plough to 30 cm, chisel and disc harrow applied to wheat in to been/ wheat/ maize rotation. The experiments have been conducted in the Didactic Station of the University of Agricultural Sciences and Veterinary Medicine – Iasi, Ezăreni Farm, during the period between 2002-2006, on a cambic chernozem with 3,7 % humus and pH 6.8. 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. 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.

Soil tillage, besides new and direct effects, good for plant growing technologies, induces in soil long-term residual effects, which act on its physical and physico-mechanical characteristics, by modifying them [6]. Soil physical characteristics have a major influence on the way of soil functioning within an ecosystem [2]. Plant growth and development, water regime and soil solution are tightly connected to soil physical characteristics [8]. According to size, form and forming mode, the soil aggregates may have more or less characteristics favorable to the circulation of water and air, and root penetration [5]. Therefore, the implementation of a certain tillage system must be done in concordance with all the aspects that may be influenced or may influence this system [4, 7]. This requires the detailed knowledge of all elements contributing to soil fertility increase or diminution [1, 3].

MATERIAL AND METHOD

The experiment was conducted at the Didactic Station of the „Ion Ionescu de la Brad” University of Agricultural Sciences and Veterinary Medicine of Iași, Ezareni Farm, during farming years 2002-2006. The experimental site is located in the East part of Romania (47°07' N latitude, 27°30' E longitude) on a cambic 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 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%). The experimental site has an annual average temperature of 9.40°C and precipitation of 587 mm. The experimental design was in a “divided plots design” with three replications. We have investigated two variants of the classical soil tillage system – plough at depths of 20 cm and 30 cm– and two variants of minimum tillage – Chisel variant and disk harrow variant – in the crop rotation made of beans/wheat/maize. This paper presents the results obtained in winter wheat and maize growing as concerns the influence of the tillage method on some soil physical characteristics. Soil samples were taken from the fields just after the sowing of each crop, during the vegetation season and right after the harvesting, in order to determine soil bulk density (BD) and total porosity (TP) and efficient porosity (EP). We have also calculated degree of compaction (CD) [1]. For the determination of penetration resistance (PR) we have used the dynamic penetrometer. The analysis of distribution and structure hydrostability (SH) of structural macroaggregates was carried out according to Tiulin-Ericson method and certain indicators as mean weight diameter (MWD), were determined by calculation [1]. Determinations were carried out 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 DISCUSSION

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. Studying the evolution of mean values of bulk density after four years of experiencing in winter wheat and maize, we found out that at sowing (layer 0-10 cm), they were between 1.10 and 1.17 g/cm³. The bulk density has increased in layer 10-20 cm, reaching values comprised between 1.23 and 1.28 g/cm³ in ploughed and disk harrow-tilled variants. In the next depth degree (20-30 cm), the differences between variants were very high, minimum values being registered in the case of variant ploughed at 30 cm (1.24 g/cm³) and maxima ones in the case of disk harrow-tilled variant (1.41 g/cm³). The 20 cm ploughed variant had higher values on this depth scale, in comparison with the chisel variant (1.38 g/cm³ respectively, 1.31 g/cm³ in winter wheat crop) (*fig. 1 and 2*).

During the vegetation period, the bulk density has increased in all variants and at all depths (*fig. 1 and 2*). In all variants, the most settled layers were upper layers, and this phenomenon diminished at depth; the lowest differences of values of the indicator between the two consecutive moments of sampling were signaled at the disk harrow-tilled variant. In maize crop, after cultivation tillage has been created a compacted layer with values between 1.36 and 1.44 g/cm³, as result as machinery passing for cultivation tillage. At harvesting, the bulk density on

analyzed profile had the lowest mean values at the variant plough at 30 cm (1.39 g/cm^3), followed by the variant plough at 20 cm (1.42 g/cm^3), and chisel and disk harrow variants (1.44 g/cm^3) (fig. 1 and 2).

Statistical processing of obtained data, as an average of analyzed profile (0-30 cm) and during the vegetation period, in the four years of experiment, has shown that bulk density had the highest values, with significant differences, compared to the control variant (+3.6 %), at the disk harrow variant in both crops. The variant plough at 20 cm depth and chisel variant had close values between them and also close to the control variant; the variant plough at 30 cm has statistically demonstrated that it decreasing settling degree (tab. 1).

Studying the average results of penetration resistance (PR) registered in winter wheat and maize crops, we found out that at sowing, the lowest values were at 0-10 cm layer. At the depth interval of 10-20 cm, because of settling produced by equipments used for seedbed preparation, the values of penetration resistance were high, close to the values shown at the depth of 20-30 cm (fig. 1 and 2).

The both ploughed variants have generally shown lower mean values on profile (17.08 daN/cm^2 at plough at 20 cm and 15.38 daN/cm^2 at plough at 30 cm in winter wheat crop) than the variants tilled without furrow inverting (18.11 daN/cm^2 in Chisel variant and 19.90 daN/cm^2 in disk harrow variant). By comparing the values of 20 cm ploughed and Chisel variants on the layer 10-20 cm, we found out that the chisel variant was more loosened, the values of penetration resistance being of 20.97 daN/cm^2 compared to 21.90 daN/cm^2 at 20 cm ploughed variant in winter wheat crop. In maize crop it was found similar values like in winter wheat crop.

Because of natural processes from the interval sowing-straw elongation, soil was settled and the values of penetration resistance have increased in all the layers until harvesting; this increase was higher at depth of 20-30 cm in the winter wheat crop. In maize crop it was found a compacted layer on 10 cm depth, as results of machinery passing for cultivation tillage (fig. 1 and 2).

During the vegetation period, the penetration resistance has increased in all the variants at the depth of 0-30 cm, this increase being higher at the interval sowing-straw elongation in winter wheat crop and at the depth of 0-20 cm. The lowest values of this index were registered at 30 cm ploughed variant, at all stages and depths, and the highest one, at disk harrow variant. In chisel and 20 cm ploughed variants, the values were intermediary compared to 30 cm ploughed and disk harrow-tilled variants for both crops (fig. 1 and 2).

The statistical analysis of mean values has shown that soil tilled only with disk harrow determined a higher soil settling, with 14% statistically insured difference to the control variant in winter wheat and 16 % in maize crop (tab. 1). The treatment plough at 30 cm maintained soil more loosened on studied profile, the difference to the control variant being statistically significant. The chisel tillage led to a higher soil compaction, compared to 20 cm ploughing, but the differences to the control were not statistically insured.

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 its texture [1], a complex indicator was calculated, which included bulk density, total porosity, and texture, respectively, degree of compaction (CD) [1].

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 in both crops. 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 higher than 10 % v/v, which were found at harvesting in the variant plough at 20 cm, chisel and disk harrow variants, at the depth of 20-30 cm, have shown that soil was moderately compacted (according I.C.P.A., 1987). The values between 1 and 10 indicate a weakly compacted soil, which needs loosening of third emergency [1]. Our results have shown that in a short-term interval, the compaction degree did not change significantly, no matter what tillage system has been used (*tab. 1*). A progressive increase of this parameter was registered from sowing to harvesting and according to depth, in all soil tillage variants.

The values of total porosity (TP) decrease from sowing to harvesting in all tillage systems variants for both crops. The statistical interpretation of mean values has shown that 30 cm ploughed variant determined an increase of total porosity at 0-30 cm layer, with a statistically insured difference of almost three percentages, compared to the control variant (*tab. 1*). Aeration porosity 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 (*tab. 1*).

Table 1

Influence of tillage systems on some indicators of soil compaction condition

Crop	Winter wheat					Maize				
	BD (g/cm ³)	PR (daN/cm ²)	CD (% v/v)	TP (% v/v)	EP (% v/v)	BD (g/cm ³)	PR (daN/cm ²)	CD (% v/v)	TP (% v/v)	EP (% v/v)
Disk harrow	1.38 ^x	25.3 ^{xx}	5.29	47.7 ^o	13,8	1.38 ^{xxx}	25.1 ^{xxx}	5.15	47.8 ^{ooo}	13,7
Chisel	1.35	22.7	2.43	49.2	13,9	1.34	22.2	1.88	49.5	13,9
Plough to 20 cm	1.34	21.2	1.72	49.6	13,9	1.33	20.9	0.89	50.0	13,8
Plough to 30 cm	1.29 ^o	19.0 ^{oo}	-1.69	51.3 ^x	14.0	1.29 ^{oo}	18.2 ^{ooo}	-1.85	51.4 ^{xx}	14,0
Control variant (C.V.) – mean value for all variants										
LSD 5% =	0.04	1.5		1.5	1,0	0.02	1.1		0.8	0,1
LSD 1% =	0.06	2.2		2.2	1,5	0.03	1.7		1.2	0,2
LSD 0.1% =	0.09	3.6		3.6	2,4	0.05	2.7		1.9	0,3

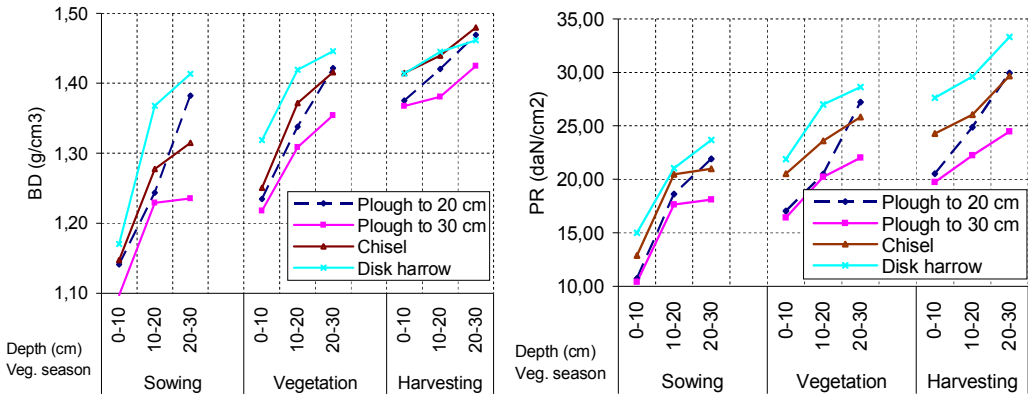


Figure 1 The dynamic of BD and PR on winter wheat crop

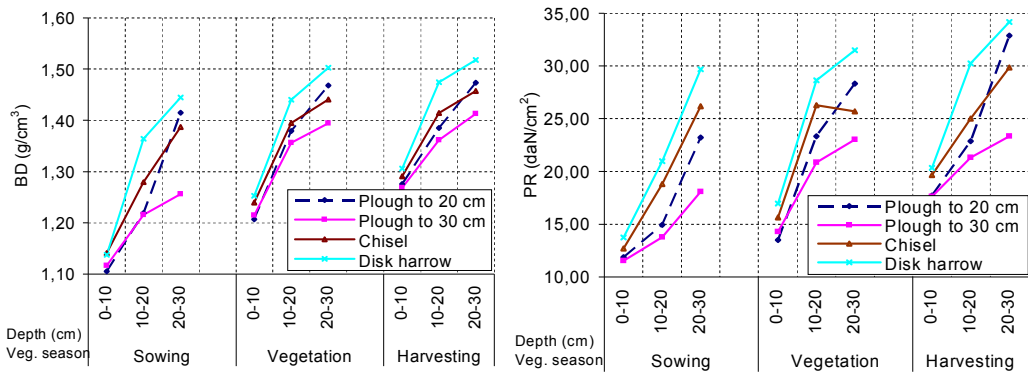


Figure 2 The dynamic of BD and PR on maize crop

The statistical analysis of mean values has shown that the chisel treatment 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 (*tab. 2*). Disk harrow tillage and the cultivation treatment lead to mechanical destruction of soil aggregates, this assessment being supported by statistically insured differences.

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 Chisel variant it has been recorded the best structure hydrostability, at depth of 20-30 cm (*fig. 3, a, b*).

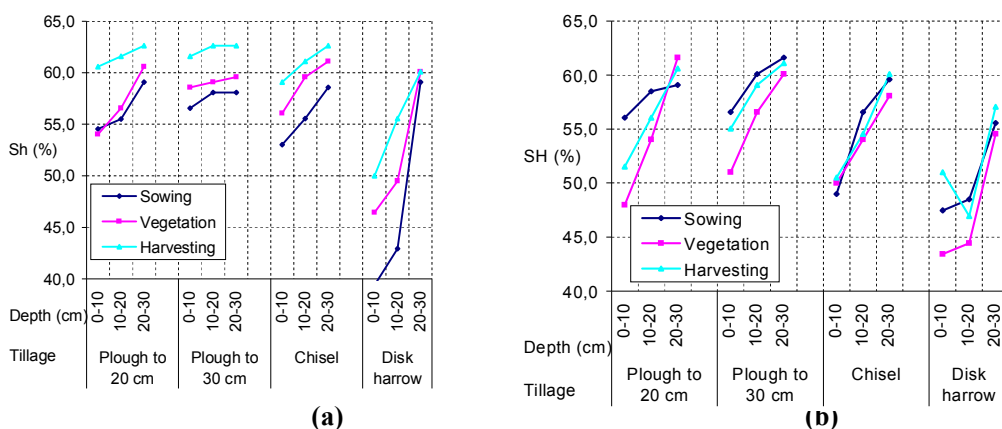
The statistical analysis of mean values on profile and for the entire vegetation period has classified the variants according to data presented in table 2, the differences between variants being greater, and the differences compared to the control variant is statistically significant. The greatest structure hydrostability on the analyzed profile was determined at the plough at 30 cm 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, the statistically insured negative differences were found only at the disk harrow variant. These tendencies are relevant for the both crops.

Table 2

Influence of tillage systems on some indicators of soil structure

Crop	Winter wheat		Maize	
	SH (% v/v)	MWD (% v/v)	SH (% v/v)	MWD (% v/v)
Tillage systems				
Plough to 30 cm	59.6	6.16	57.9xx	5.69
Plough to 20 cm	58.4	6.52	56.2	5.75
Chisel	58.5	6.81	54.7	6.30xxx
Disk harrow	51.5	5.54	49.9ooo	4.28ooo
Control variant (C.V.)– mean value for all variants				
LSD 5% =	2.5	0.6	1.8	0.3
LSD 1% =	3.7	0.9	2.7	0.5
LSD 0.1% =	6.0	1.4	4.4	0.8

**Figure 3 The dynamic of SH on winter whet (a) and maize crop (b)**

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 tend to destroy their yielding capacity [1]. 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.

It was the tillage system and level of fertilizer that determined the difference between wheat and maize crop production, usually was being higher in conventional variants but not always statistically significant (*tab. 3*).

The mean wheat yield during 2002-2006 using 20 cm ploughing was 3666 kg/ha, and in the case of chisel ploughing and disk and also by repeated diking yields were lower by 10.1% (-370 kg/ha) and 15.0% (-915 kg/ha) respectively (*tab. 3*). In the same period, 30 cm ploughing resulted in higher wheat yields, compared to 20 cm ploughing, by 1.6% (57 kg/ha) but the difference is not statistical insured.

Table 3

The influence of tillage system on winter wheat and maize yield

Crop Tillage systems	Winter wheat		Maize	
	Yield (kg/ha)	Difference (kg/ha)	Yield (kg/ha)	Difference (kg/ha)
Plough to 30 cm	3723	57	8729	809
Plough to 20 cm	3666	-	7920	-
Chisel	3296	-370 ⁰⁰	7050	-870 ⁰
Disk harrow	2751	-915 ⁰⁰⁰	6337	-1583 ⁰⁰
	LSD _{5%} = 218 kg/ha LSD _{1%} = 330 kg/ha LSD _{0,1%} = 530 kg/ha		LSD _{5%} = 829 kg/ha LSD _{1%} = 1255 kg/ha LSD _{0,1%} = 2016 kg/ha	

In maize, 30 cm ploughing resulted in higher yields by 10.2% (809 kg/ha) compared to 20 cm ploughing and disk tillage reduced yield by 20% (1583 kg/ha) (tab. 3). In the case of chisel plowing resulted in a yield reduction of 11.0% (870 kg/ha) compared to 20 cm ploughing.

CONCLUSIONS

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.

During vegetation period, as a result of natural processes from the interval sowing-straw elongation, soil was settled; therefore, the values of penetration resistance have increased in all the layers. Until harvesting, the values of penetration resistance have increased in all the layers, this increase being higher at the depth of 20-30 cm.

The compactation degree had lower values at sowing and in tilled layer; for each variant, it has increased at depth and once with vegetation development. During the vegetation period, the highest compactation was found in ploughed variants with furrow inverting; the differences between the values of compactation degree at sowing, in vegetation and until harvesting were the highest, especially at depth 10-20 cm.

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 mean weighed diameter has registered a diminution in vegetation period on layers 0-10 and 10-20 cm, and a slight increase until harvesting. Unlike the other variants, aggregates with great diameter were prevalent in the Chisel-tilled variant, because of accumulation and decay of organic matter at soil surface; this favored the intensification of structure formation.

The tilled variants without furrow inverting had high values of structure hydrostability in upper layers (0-10 and 10-20 cm). The Chisel-tilled variant had, on the average, the best structure hydrostability, at depth of 20-30 cm.

The tillage system that determined the difference between wheat, maize or beans crop production, usually was being higher in conventional variants but not always statistically significant.

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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