SOIL COMPACTION INFLUENCE ON WINTER WHEAT YIELD AND SOIL PHYSICAL PROPERTIES

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Abstract

Soil compaction is widespread and with current trends, its incidence is likely to increase. Tillage effects on soil properties are usually site specific and depend upon the interaction of soil and climatic conditions, with soil and crop management practices. Soil compaction is not a recent phenomenon. It was encountered in the form of plough-pans long before the advent of mechanized agriculture but in these days, current farming techniques exacerbate the risks. Field experiment were carried out in 2010-2011 at Ezareni – The Experimental Farm of the Agricultural University of Iasi, in the East side of Romania (47°07' N latitude, 27°30'E longitude), on a cambic chernozem (SRTS-2003, or haplic chernozems WRB-SR, 1998), with a clay-loamy texture, 6.8 pH, 2.7% humus content and a medium level of fertilization. Long-term amount of precipitation at this site is 517.8 mm at an average air temperature of 9.4°C. Wheat variety Fundulea 4 was grown at a sowing rate of 280 kg ha^{-1}. The experimental soil tillage systems were as follows: V_1 – disc harrow , V_2 – paraplow, V_3 – chisel plow + rotary harrow, V_4 – plough at 20 cm (control variant) and V_5 – plough at 30 cm. The purpose of this study was to evaluate the influence of conventional and minimum tillage systems on winter wheat yield and soil physical properties in the pedoclimatic conditions of the Moldavian Plain. The mean of grain yield was significantly lower on all five tillage systems under unfertilized variant compared with the control treatment. Analyzing the fertilized variant ($N_{80}P_{80}$) the yield was significantly lower only in disk harrow (4830 kg ha^{-1}). As regards soil bulk density, this indicator had the lowest value of the seeding time at 0-10 cm depth (1.13-1.21 g/cm^3). The values increased on 10-20 cm layer, recording the greatest intensity in the disk harrow variant (1.39 g/cm^3). Analyzing the annual average the biggest value has been recorded in disk harrow variant (1.34 g/cm^3).

Key words: soil compaction, reduced tillage, yield

Tillage effects on soil properties are usually site specific and depend upon the interaction of soil and climatic conditions, with soil and crop management practices.

Soil tillage is an important agricultural activity because of its impact on crop production and soil properties (*Chatterjee and Lal, 2009, Chivenge et al., 2007*).

Soil compaction is not a recent phenomenon. It was encountered in the form of plough-pans long before the advent of mechanized agriculture but in these days, current farming techniques exacerbate the risks.

Soil compaction is the physical consolidation of the soil by an applied force that destroys structure, reduce porosity, limits water and air infiltration, increases resistance to root penetration, and often results in reduce crop yield.

The effect of soil compaction depends on the compaction effort, soil type, water content, landscape position, cropping system involved and its effects on crops and soil properties are complex (Kirkegaard et al., 1993; Radford et al., 2000; Miller et al., 2002; Green et al., 2003). Soil compaction is widespread and with current trends, its incidence is likely to increase.

The principal causes of compaction are compressive forces applied to compressible soil from wheels under tractors, trailers and harvesters, during the passage of tillage implements through the soil (particularly powered rotary equipment) and from pressure under the hooves of livestock or other animals.

Compaction causes deterioration of soil physical properties, evidenced by increasing the bulk density, penetration resistance, high specific resistance to soil tillage operations and reduced porosity, soil structure stability, with direct impact on fuel consumption and production costs (Jităreanu G., 2005, Rusu T. et al., 2006, Dexter A.R. 2004, Botta et al., 2007, 2008).

MATERIAL AND METHOD

The study was carried out in 2010-2011 in an agroecosystem located at Ezareni – The Experimental Farm of the Agricultural University of Iasi, in the East side of Romania (47°07' N latitude,

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27°30'E longitude), on a cambic chernozem (SRTS-2003, or haplic chernozems WRB-SR, 1998), 6.8 pH, 2.7% humus content and a medium level of fertilization. The texture of the surface soil is clay-loamy (0–30 cm).

Treatments were arranged in a "split plot" design with three replicates. All subplots were separated by a 1-m buffer zone. Plots covered an area of 60 m^2 with a rotation of soybean - winter wheat – maize, with the current experiment in winter wheat *(Triticum aestivum)*.

Long-term amount of precipitation at this site is 517.8 mm at an average air temperature of 9.4°C.

Wheat variety Fundulea 4 was grown at a sowing rate of 280 kg ha^{-1}. All crop management techniques followed the regional recommended practices.

The experimental soil tillage systems were as follows: V_1 – disc harrow , V_2 – paraplow, V_3 – chisel plow + rotary harrow, V_4 – plough at 20 cm (control variant) and V_5 – plough at 30 cm.

Table 1

The influence of tillage systems on Bulk density at winter wheat crop (2010/2011)

Variant	Deapth (cm)	Bulk density (g/cm^3)		
		Sowing	Growing period	Harvesting
Disk harrow	0-10	1.21	1.31	1.39
	10-20	1.39	1.46	1.46
	20-30	1.43	1.52	1.54
Average on 0-30 cm deapth		**1.34**	**1.43**	**1.46**
Annual average		**1.41 xxx**		
Paraplow	0-10	1.13	1.28	1.33
	10-20	1.28	1.41	1.43
	20-30	1.44	1.47	1.49
Average on 0-30 cm deapth		**1.28**	**1.39**	**1.42**
Annual average		**1.36**		
Chisel	0-10	1.10	1.23	1.29
	10-20	1.24	1.35	1.40
	20-30	1.36	1.43	1.47
Average on 0-30 cm deapth		**1.23**	**1.34**	**1.39**
Annual average		**1.32 o**		
Plough 20 cm	0-10	1.13	1.25	1.32
	10-20	1.22	1.35	1.42
	20-30	1.41	1.47	1.53
Average on 0-30 cm deapth		**1.25**	**1.36**	**1.42**
Annual average		**1.34 control variant**		
Plough 30 cm	0-10	1.14	1.25	1.31
	10-20	1.21	1.31	1.39
	20-30	1.26	1.38	1.42
Average on 0-30 cm deapth		**1.20**	**1.31**	**1.37**
Annual average		**1.30 ooo**		

LSD 5% = 0.022 g/cm^3 LSD 1% = 0.031 g/cm^3 LSD0.1%= 0.047 g/cm^3

Soil bulk density was determined on an oven-dry basis by the core method (*Blake and Hartge, 1986*). To determine bulk density at a soil depth of 0-10, 10-20, 20-30 cm, undisturbed 100 cm^3 core samples of 5 cm diameter were taken from all the five variants after sowing, during the growing period, and at harvesting. The penetration resistance of the soils was determined using a digital penetrologger *(Eijkelkamp Equipment, Model 0615-01 Eijkelkamp, Giesbeek, The Netherlands*) which had a cone angle of 30^0 and a base area of 1 cm^2. It was carefully inserted into the soil profiles in 1 cm increments from the surface to a depth of 50 cm by the same person following a rain event that satisfied the field capacity of the soils and avoiding wheel tracks. 10 parallel records were made in each plot and averaged for statistical analysis. Cone index data were digitized into the computer at 5-cm-depth intervals. Yield was measured using 1m x 1m quadrate sampling with 3 replications per plot.

The ANOVA procedure was used to evaluate the significance for the split plot design in three replicates. Treatment means were separated by the least significance difference (LSD) test and all significant differences were reported at 5%, 1% and 0.1% levels.

RESULTS AND DISCUSSIONS

Cultivation can alter the physical, chemical, and biological properties of the soil, whereby plant growth, development, and yield are influenced.

The purpose of this study was to evaluate the influence of conventional and minimum tillage systems on winter wheat yield and soil physical properties in the pedoclimatic conditions of the Moldavian Plain.

The physical properties of soil are extremely vital for plant growth. Tillage systems have significant effect on the physical properties of soil.

Analyzing soil bulk density (BD) in winter wheat (*Triticum aestivum L.),* this indicator had the lowest value of the seeding time at 0-10 cm depth (1.10-1.21 g/cm^3). The values increased on 10-20 cm layer, recording the greatest intensity in the disk harrow variant (1.39 g/cm^3). Analyzing the 20-30 cm layer we observed that the biggest values have been provided by paraplow and disc harrow (1.44-1.43 g/cm^3) (tab. 1).

At the end of the season, at harvesting, the mean values on 0-30 cm layer had the highest value on disk harrow treatment (1.46 g/cm^3).

Bulk density becomes higher once with the increasing of depth for all treatments and from sowing to harvesting. Statistically analyze as annual mean values indicate negative significant differences for chisel and plough at 30 cm variants. Significant differences were also detected for disk harrow variant, this time positively, indicating a slightly compaction degree. No significant differences were detected between paraplow and control variant, plough at 20 cm.

Table 2

The influence of tillage systems on Penetration resistance (Pr) at winter wheat crop

Variant	Pr - sowing (Mpa)									
	Depth (cm)									
	0-5	5-10	10-15	15-20	20-25	25-30	30-35	35-40	40-45	45-50
Disk harrow	0.33	0.68	0.89	1.38	1.53	1.51	1.41	1.39	1.37	1.37
Paraplow	0.35	0.51	0.75	0.93	1.11	1.29	1.34	1.39	1.37	1.34
Chisel	0.30	0.47	0.68	0.88	1.03	1.24	1.30	1.37	1.35	1.30
Plough 20 cm	0.34	0.53	0.71	0.81	1.38	1.49	1.46	1.38	1.35	1.32
Plough 30 cm	0.33	0.52	0.73	0.83	0.93	1.15	1.44	1.52	1.37	1.33
	Pr growing period (Mpa)									
Disk harrow	0.72	1.18	1.47	1.72	2.25	2.34	2.42	2.40	2.12	2.10
Paraplow	0.62	0.89	1.19	1.29	1.56	2.08	2.30	2.28	2.15	2.01
Chisel	0.55	0.82	1.10	1.27	1.53	2.00	2.24	2.26	2.10	1.97
Plough 20 cm	0.61	0.86	0.94	1.22	1.95	2.34	2.36	2.29	2.13	2.05
Plough 30 cm	0.62	0.86	0.96	1.24	1.48	1.59	2.30	2.31	2.18	2.08
	Pr -harvest. (Mpa)									
Disk harrow	0.83	1.27	1.63	1.88	2.36	2.50	2.57	2.48	2.41	2.34
Paraplow	0.69	1.06	1.28	1.40	1.75	2.32	2.41	2.37	2.26	2.21
Chisel	0.65	0.98	1.21	1.37	1.67	2.25	2.34	2.33	2.28	2.19
Plough 20 cm	0.71	1.04	1.25	1.36	2.15	2.52	2.47	2.41	2.33	2.21
Plough 30 cm	0.73	1.04	1.23	1.35	1.60	1.91	2.56	2.58	2.35	2.24

Penetrometer resistance is widely measured because it provides an easy and rapid method of assessing soil strength. The penetration resistance (Pr) of the soil varied with the method of tillage operations. Pr in the soil for all the five tillage treatments increased with depth and from sowing to harvesting. Several researchers have reported that Pr is reduced in conventional tillage compared to reduced tillage (Sidiras et al., 2000). Right after sowing penetration resistance was lower in the 0–5 and 5–15-cm depths under chisel than all other four treatments, coinciding with the tilled depth under rotary harrow (about 15 cm), used for seed bed preparation only in chisel variant. Tillage created a loose soil structure in the affected soil depth. As a consequence, these lower values of Pr were observed only in the tilled zone (*table 2*). On 15-20 cm depth the highest value was observed under disk harrow treatment (1.38 MPa), indicating a compacted layer under the tilled zone.

Analyzing the growing period we observed high values of Pr for Plough 20 cm and Plough 30 cm variants under the tilled zone, indicating the existence of hardpan on conventional tillage systems. On Disk harrow treatment was recorded a pick value on 30-35 cm depth at harvesting (2.57 MPa) indicating a subsoil compaction pan.

Table 3

The influence of "tillage systems x nutrients level" interaction on winter wheat yield (2010/2011)

Variant		Yield		Differences to the control variant (kg/ha)	Statistical significations
Tillage system	Nutrient level	kg/ha	Comparison with control variant (%)		
Disc harrow	$N_{80}P_{80}$	4830	74.57	-1647	**ooo**
	N_0P_0	2645	40.84	-3832	**ooo**
Paraplow	$N_{80}P_{80}$	6847	105.71	370	
	N_0P_0	3348	51.69	-3129	**ooo**
Chisel	$N_{80}P_{80}$	6129	94.63	-348	
	N_0P_0	3451	53.28	-3026	**ooo**
Plough 20 cm	**$N_{80}P_{80}$ (CV)**	6477	**100.00**	**0**	**control variant**
	N_0P_0	3545	54.73	-2932	**ooo**
Plough 30 cm	$N_{80}P_{80}$	6551	101.14	74	
	N_0P_0	3590	55.43	-2887	**ooo**

LSD 5% = 730.1 kg LSD 1% = 1001.3 kg LSD 0.1% = 1362.9 kg

Crops roots growth can be depressed when soil bulk density reaches 1.5 g/cm^3 (Hassan et al., 2007) and cone resistant overpasses a threshold of 2.5–3.0 MPa (Hakansson and Lipiec, 2000; Hamza and Anderson, 2005). These limits were generally not exceeded in.

The mean of grain yield was significantly lower on all five tillage systems under unfertilized variant compared with the control treatment, Plough at 20 cm $N_{80}P_{80}$ (table 3) Analyzing the fertilized variants ($N_{80}P_{80}$) the yield was significantly lower only in disk harrow (4830 kg ha^{-1}), probably as a result of a relative compaction degree on this unconventional variant. The highest yield was provided by the conservative variant paraplow 6847 kg ha^{-1}.

CONCLUSIONS

Generally, our results confirmed the hypothesis that reduced tillage would improve physical properties.

The changes produced by reduced tillage adoption on soil bulk density and cone index probably did not restrict severely roots growth, with a single exception – Disk harrow treatment where a subsoil compaction pan was detected at 30-35 cm. The potential effects of increased penetration resistance may have some influences on yield.

The results indicate that minimum tillage using chisel plow in fall can be considered as a substitute to conventional moldboard plowing without considerable reduction in terms of crop productivity. Also has been observed that paraplow had slightly higher yield compared with control treatment.

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