THE EFFECT OF SOME TILLAGE SYSTEMS ON THE DEGREE OF COMPACTION AND PRODUCTIVITY ON SOYBEAN CROP IN MOLDAVIAN PLAIN

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Abstract: *The purpose of this study consists in establish the optimal variant of soil conservation that ensure favorable conditions for plant growth and development, in pedoclimatic conditions of Moldavian plain. The experience was carried out in the eastern part of Romania in experimental field of Didactical Station of USAMV Iasi, Ezareni Farm and the main objective is to assess the degree of compaction and the productivity of soybean crop under the influence of conventional system: ploughed at 30 cm (V_1) and unconventional systems – paraplow (V_2) chisel (V_3) and disk harrow variant on a cambic chernozem with a clay loamy texture, 6.6 – 6.9 pH units, 33 – 34 % clay content middle provided in N and P_2O_5 and agreeably in K_2O. Studies of many researches has concluded that some areas such tillage systems are incomplete discussed and showed a new approach and a pronounced increase of research in the development of systems for their conservation. The results obtained from the research can be generalized in terms of production in Moldavian plain and in other areas with similar climatic conditions, farmers can apply these treatments to improve and maintain the physical condition of soil. Indicators of state of compaction increased from sowing to harvesting and with the depth in all experimental variants. The values of bulk density at the end of vegetation period change under the influence of tillage systems and soil depth. The values on 0 – 10 cm depth increased with 0.07 g/cm^3 compared with 10 – 20 and 20 – 30 cm, where the mean values of bulk density were 0.05 g/cm^{3}and respectively 0.03 g/cm^3. The degree of compaction at sowing showed reduced values, and then increased with depth, reaching to harvest at a slightly compacted soil. The values of penetration resistance showed a clear distinction through the soil profile, with maximum values at disk harrow (0.84 – 2.34 MPa), minimum values in ploughed at 30 cm variant (0.69 – 2.27 MPa) and intermediate values at chisel variant (0.65 – 2.29 MPa) and paraplow variant (0.67 to 2.30 MPa). The crop yield performed by unconventional tillage systems (2954 - 3134 kg/ha) have values of those obtained by plough variant (3339 kg/ha) except disk harrow variant (2656. 6 kg / ha).*

Key word: *physical properties, tillage systems, bulk density, resistance to penetration, soybean*

INTRODUCTION

An agricultural soil with poor quality may not possess all of the attributes required for good agricultural production, or it may be prone to environmental degradation [8]. Due to the extreme complexity of the soil environment, agricultural soil quality is often segmented into soil physical quality, soil chemical quality, soil biological quality [1], and these components interacting. Soil with good physical qualities has the ability to store and transmit water, air and nutrients in maximum productivity conditions and minimum environmental conditions [11]. The growth and development of pants, hydric regime and soil solution are related to its physical properties [7]. The unconventional tillage systems by the replacement of ploughed with paraplow, chisel and rotary harrow tillage systems; reduce the loosening intensity of arable layer of soil as well as amplitude loosening range during agrarian year [2.10]. The changes in physical properties reflect the evolution of its fertility and how these changes may influence the agricultural production. The influence of tillage system on soil properties has a special importance because according to it, we can appreciate the state of compaction and loosening that affects plant development and thus the production [4.5.6.9.12]. Soil physical

quality is important for the entire crop rooting zone which is approximately the top 1m of the soil profile. The top 10 cm of soil is particularly important because it controls many critical agronomic and environmental processes such as seed germination, aggregation tillage impacts, surface crusting, aeration, infiltration [3].

MATERIAL AND METHODS

The experimental field was located at Ezareni Experimental Station of USAMV "Ion Ionescu de la Brad" Iasi, between 2007 - 2008, on a cambic mezocalcaric chernozem (SRTS-2003 or haplic chernozem after WRB-SR, 1998) with a fine clay-loamy texture, containing 33 – 34 % loam, humus 3.4 % to 3.6 %, pH 6.6 to 6.9, medium supplied in N and P_2O_5 and well supplied in K_2O. The experimental design had three factors, (AxBxC type) and was a "divided plot design" with three replications and each experimental plot covering a surface of 54 m^2. Experimental treatments were as follows: the A factor: Tillage systems: a1 – ploughed at 30 cm depth + Lemkeen cultivator, a2 - paraplow + vertical rotary harrow, a3 - paraplow + horizontal rotary harrow, a4 - chisel + horizontal rotary harrow, a5 - disk harrow, B factor: fertilizer dose with two treatments (unfertilized and $N_{60}P_{60}$) and C factor represents the crop (soybean-winter wheat-corn rotation). The soil profile is Ap-Atp-Am-AB-Bv1-Bv2-Bvc-Cca1-Cca2-Ck. The experimental site has an annual average rainfall of 529 - 550 mm and the mean temperature ranging from 9.2 to 9.4 °C. The aim of this study is to analyze the effect of different tillage systems on soil compaction degree and soybean yield in the Moldavian Plain.

Soil measurements were carried out at crop sowing, growing and harvesting, and at three depths: 0 - 10 cm, 10 - 20 cm and 20 - 30 cm. In order to determine soil bulk density, undisturbed soil samples were collected with metal cylinder 5/5 cm and the penetration resistance was measured using a digital penetrologger (Eijkelkamp equipment, Netherlands). Tests performed are consistent with the methodology and STAS - existing papers (SRTS, 2003; MESP, vol. I - III, 1987, Soil Management and Experimental Design Advisor). Statistical data processing was done using the ANOVA test.

RESULTS AND DISCUSSIONS

Bulk density varied with depth during the growing season depending on the tillage system. At sowing, the bulk density values recorded after two years increased from 1.06 to 1.16 g/cm^3 in the 0 - 10 cm layer, from 1.21 to 1.40 g/cm^3 in 10 - 20 cm layer and 1.31 to 1.46 g/cm^3 on 20 - 30 cm depth. In both experimented years, in the 0 - 30 cm soil layer, a better soil loosening is observed for ploughed variant at 30 cm depth, with bulk density values ranging between 1.11 and 1.31 g/cm^3, and a high degree of compaction exists in disk harrow treatment, represented by 1.16 to 1.46 g/cm^3 bulk density values. The plots with minimum tillage system are showing intermediate values between plowing at 30 cm depth and disk harrow, with bulk density values of 1.06 and 1.43 g/cm^3 for paraplow and 1.09 to 1.41 g/cm^3 for chisel treatments. Comparing the bulk density values recorded after crop protection operations, an increase of the parameter is observed throughout the soil profile analysis, especially on the 10 - 20 cm horizon with values that reached a level of 1.33 g/cm^3 in chisel and plowed at 30 cm variants, from 1.38 to 1.39 g/cm^3 in paraplow and 1.44 g/cm^3 in harrow disk variants.

The increase of soil compaction degree was due to repeated mechanical operations for crop protection and maintenance this fact being obvious in 10 - 20 cm layer. Following the influence of tillage depth on bulk density in soybean, an increase of this parameter is observed on 20 to 30 cm layer, with rates between 11.6 % and 20.1 % compared with the surface layer and 3.6 % to 10.7 % facing the next 10 - 20 cm horizon. Value analysis from *table 1* shows that the disk harrow variant was less compacted compared to the sowing date of soybean crop, with 0.04 g/cm^3 on 10 - 20 cm depth and 0.05 g/cm^3 in 20 - 30 cm layer.

Table 1

The influence of tillage system on "*bulk density*" to soybean crop – mean values 2007 - 2008

Tillage system	Depth (cm)	Bulk density (g/cm^3)								
		2007			2008			Mean values 2006 - 2008		
		Sowing	Vegetation	Harvesting	Sowing	Vegetation	Harvesting	Sowing	Vegetation	Harvesting
Ploughed at 30	0-10	1,11	1,325	1,29	1,10	1,18	1,25	1,11	1,22	1,27
	10-20	1,25	1,36	1,42	1,16	1,30	1,36	1,21	1,33	1,39
	20-30	1,36	1,40	1,44	1,25	1,36	1,41	1,31	1,38	1,43
Average		1,24	1,34	1,38	1,17	1,28	1,34	1,34	1,31	1,36
Average			1,32			1,26			1,29	
Paraplow + Vertical rotarry harrow	0-10	1,10	1,22	1,26	1,09	1,16	1,26	1,10	1,19	1,27
	10-20	1,32	1,39	1,46	1,25	1,36	1,40	1,29	1,38	1,45
	20-30	1,46	1,53	1,53	1,37	1,45	1,46	1,42	1,49	1,50
Average		1,29	1,38	1,42	1,24	1,32	1,37	1,37	1,35	1,40
Average			1,36			1,31			1,33	
Paraplow + horizontal rotarry harrow	0-10	1,03	1,22	1,29	1,08	1,17	1,25	1,06	1,20	1,27
	10-20	1,34	1,42	1,46	1,24	1,36	1,43	1,29	1,39	1,45
	20-30	1,48	1,52	1,54	1,38	1,43	1,46	1,43	1,48	1,50
Average		1,28	1,39	1,43	1,23	1,32	1,38	1,38	1,35	1,41
Average			1,37			1,31			1,31	
Chisel + horizontal rotarry harrow	0-10	1,09	1,21	1,28	1,08	1,16	1,22	1,09	1,19	1,25
	10-20	1,26	1,34	1,45	1,22	1,31	1,33	1,24	1,33	1,39
	20-30	1,47	1,52	1,54	1,35	1,46	1,50	1,41	1,49	1,52
Average		1,27	1,36	1,42	1,22	1,31	1,35	1,35	1,33	1,39
Average			1,35			1,29			1,32	
Disk harrow	0-10	1,17	1,28	1,33	1,14	1,22	1,31	1,16	1,25	1,32
	10-20	1,41	1,48	1,51	1,38	1,40	1,45	1,40	1,44	1,48
	20-30	1,50	1,55	1,56	1,41	1,47	1,53	1,46	1,51	1,55
Average		1,36	1,44	1,47	1,31	1,36	1,43	1,43	1,40	1,45
Average			1,42			1,37			1,39	

The most compacted was the 30 cm plowed treatment, with mean differences ranging from 0.11 g/cm^3 in 0 - 10 cm depth, 0.12 g/cm^3 in 10 - 20 cm depth and 0.07 g/cm^3 in 20 to 30 cm. Bulk density values measured at the end of crop growth period are modifying under the influence of different tillage systems in relation to sampling depth. Values determined in 0-10 cm depth increased slightly, with 0.07 g/cm^3 on average, to a depth of 10 - 20 and 20 - 30 cm, where average value of BD mean differences is 0.05 g/cm^3 and 0.03 g/cm^3 respectively.

Table 2

"Bulk density" to soybean crop – average values on treatment depth and growing stages, 2007 - 2008

Tillage system	Bulk density (g/cm^3) - average (%)	Comparison with control variant (%)	Differences with control variant (%)	Statistical significations
Ploughed at 30	1,29	100,0	0,00	control variant
Chisel + horizontal rotarry harrow	1,33	102,6	0,03	x
Paraplow + Vertical rotarry harrow	1,34	103,6	0,05	xx
Paraplow + horizontal rotarry harrow	1,34	103,8	0,05	xx
Disk harrow	1,40	107,7	0,10	xxx

$LSD_{5\%}$ = 0,03 g/cm^3 $LSD_{1\%}$ = 0,04 g/cm^3 $LSD_{0,1\%}$ = 0,06 g/cm^3

Throughout the soil profile and in all phases of crop growth the lowest recorded values of BD (1.29 g/cm^3) were in plowed variant and highest in disk harrow variant (1.39 g/cm^3) and intermediate values in paraplow (1.34 g/cm^3) and chisel (1.32 g/cm^3).

Oscillated of mean values (*tab. 2*) throughout the soil profile shows that the indicator has depending on the soil tillage system, with statistically significant differences. Highest values were recorded in harrow disk variants (+ 7.7% vs. control) and lowest in chisel variants (+ 2.6%). Paraplow variants had similar evolution (1.34 g/cm^3), values that are intermediate between the chisel and disc harrow variants.

Mean penetration resistance values registered in 2007 - 2008 period, for soybean crop, are presented in *figure 1*. At sowing, in layers 0-5 and 5 to 10 cm the indicator has the lowest values in variants where seedbed preparation was performed by rotovator (0.33 to 0.34 MPa and from 0.42 to 0.44 MPa), intermediate values being found in conventional tilled soil (0.37 to 0.56 MPa) and maximum values (0.49 and 0.82 MPa respectively) recorded in disk harrow variants. Moldboard plowing conventional system determined lowest values of PR throughout the soil profile averaging 1.06 MPa but a maximum of 1.51 MPa was recorded in 35 - 40 cm layer. Soil compaction in the depth of 30 - 40 cm is given by the plowpan that is formed over a width of about 10 cm and not hinder the normal development of roots and plant growth in this stage. Experimental variants with minimum tillage are expressing a linear increase throughout the soil profile with a maximum of PR recorded in 35 - 40 cm soil layer of 1.40 MPa in chisel and 1.40 to 1.42 MPa in paraplow treatments. After the execution of crop protection operations, mean PR increased in all plots and at all depths, with a maximum recorded by disk harrow (2.54 MPa) in the soil layer between 25 and 30 cm, a value that is restrictive for root growth (ICPA, 1987, vol. III). The results obtained at harvest are indicating a higher soil compaction compared to the previously considered stage, with a maximum value in paraplow variants (2.49 and 2.50 MPa) and 2.47 MPa in chisel treatment, which are classified according to class limits proposed by ICPA (1987, vol. III) as low, while plowed at 30 cm plots (2.55 MPa) and disk harrow (2.64 MPa) are in the medium class with partial limitation of root growth.

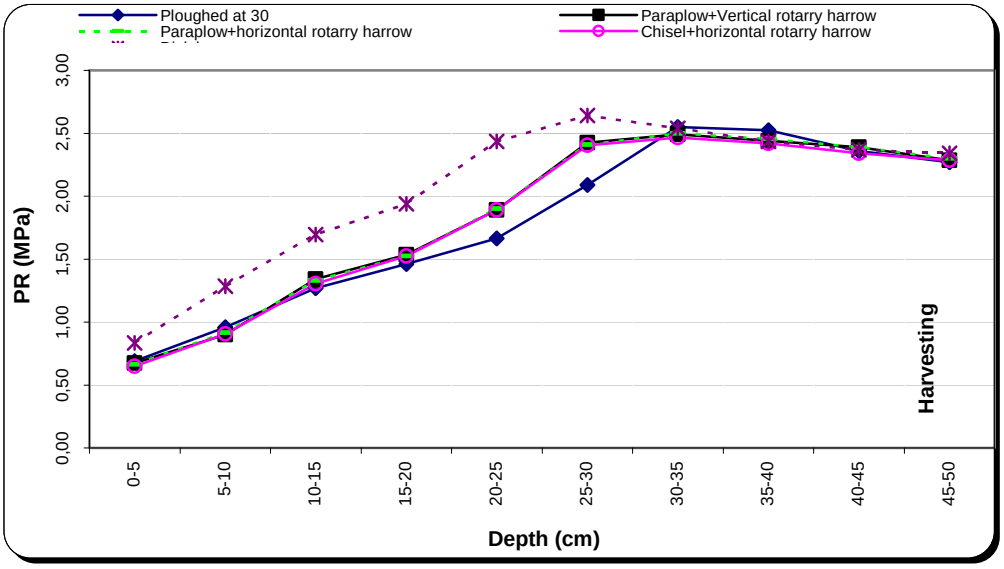

Figure 1. „Penetration resistance" at soybean crop – mean values 2007 - 2008

Values of the indicator for this growth phase recorded a lower increase in intensity compared to the phase between sowing and seedbed preparation and also the maintenance of increasing tendency of PR in soil profile, with minimum values (0.65 to 0.91 MPa) on depth 0 - 10 cm and higher in the lower horizons (25 - 35 cm).

The differentiation of treatments was clear throughout the soil profile, with peak values of disk harrow (0.84 to 2.34 MPa); minimum values encountered in conventional tillage plots - plowing at 30 cm depth (0.69 to 2.27 MPa) and intermediate values in chisel (from 0.65 to 2.29 MPa) and paraplow (from 0.67 to 2.30 MPa) variants.

Table 3

The influence of tillage systems on penetration resistance (averages at harvesting time), 2007 - 2008

Varianta de lucrare a solului	Penetration resistance (MPa)	Comparison with control variant (%)	Differences with control variant (MPa)	Statistical significations
Ploughed at 30	1,78	100,0	0,00	control variant
Paraplow + horizontal rotarry harrow	1,84	103.1	0,06	
Paraplow + Vertical rotarry harrow	1,84	103.0	0,05	
Chisel + horizontal rotarry harrow	1,82	102,1	0,04	
Disk harrow	2,07	116,9	0.29	xxx

$LSD_{5\%}$ = 0,10 MPa $LSD_{1\%}$ = 0,13 MPa $LSD_{0,1\%}$ = 0,18 MPa

Statistical analysis of mean values recorded at soybean harvest reveals a state of soil compaction in disc harrow treatment (2.05 MPa), evidenced by a very significant difference of 0.29 MPa. When compared to the control treatment, the minimum tilled plots with chisel and paraplow showed small differences, although not statistically assured (*tab. 3*).

Production data recorded in the soybean crop in the autumn of 2007 were influenced by climatic conditions of the agricultural year 2006-2007. Water deficit of 38.9 and 29.4 mm in June and July, coinciding with critical periods of reproductive organs forming, flowering and seed filling contributed to a yield decrease with values between 33.7% and 45. 7%. Average yields achieved in all tillage treatments varied from 894.3 kg/ha in disk harrow to 1320.5 kg/ha in chisel variants. Tillage with disc harrow gaved the lowest yields (894.3 kg/ha), chisel provides the most accessible yields (1320.5 kg/ha), while moldboard plowing at 30 cm depth and paraplow ensures yields close to those recorded in chisel variants, of 1320.5 kg/ha, and from 1234.6 to 1228.7 kg/ha respectively. Thus, for the soybean crop in 2007, the production differences obtained from some unconventional tillage treatments were lower, with values between 53.7 and 394.0 kg/ha in paraplow variants and disk harrow respectively and higher with 32.2 kg/ha in chisel, compared with the control treatment represented by the conventional tillage system, although with no statistical significance (except disk harrow treatment, where compared to control, the difference recorded is very significant negative). We can assume that in the climatic conditions of 2007, treatments without inverting the soil (paraplow and chisel) have yielded approximately the same as the control treatment (ploughed at 30 cm), with pluses or minuses statistically uninsured, the difference being made by the disk harrow which recorded a deficit of around 400 kg/ha in compared with the plowed variants.

In 2008 soybean crop has benefited from conditions conducive to plant growth with direct effects on mean yields. Under these conditions the yields were: 3339.0 kg/ha in plowed at 30 cm treatment, 3133.8 kg/ha in chisel, from 2954.9 to 2959.2 kg/ha in paraplow and 2656,6 kg/ha in disk harrow plots. Analyzing the data in *table 4* we see that in favorable weather conditions of this year, conventional tillage system registered higher yield values compared to unconventional treatments and the yields from paraplow and chisel variants are close, while disk harrow treatment emerges in this year also as the least productive. In soybean crop yields obtained by applying unconventional tillage systems were between 79.6 and 93.9% of the control treatment (plowed at 30 cm depth).

The statistical analysis of yield values recorded in 2008 leads to significant production deficiencies (205.2 kg/ha) in chisel variants, significant variations in paraplow (379.8 to 384.1 kg/ha) and very significant in disk harrow variants (682.4 kg/ha). The mean

production data obtained from soybean on both years shows that unconventional system treatments has lower mean yields over the conventional plots, with values ranging from 1775.5 kg/ha (76.7%) in disk harrow, from 2095.1 to 2096.9 kg/ha (90.6%) in paraplow and 2227.1 kg / ha (96.3%) in chisel variants. In terms of statistical variations paraplow and disc harrow has average yields below control with distinctive significant differences (-216.9 and -218.7 kg/ha) and very significant (-538.3 kg/ha).

Table 4

The influence of tillage systems on soybean yield (2007 – 2008)

Year	Treatment	Yield (kg/ha)	Comparison with control variant (%)	Differences with control variant (kg/ha)	Statistical significations
2007	**Ploughed at 30**	1288	100,0	0,0	Control variant
	Paraplow + Vertical rotarry harrow	1237	95,8	-54	
	Paraplow + horizontal rotarry harrow	1229	95,4	-60	
	Chisel + horizontal rotarry harrow	1321	102,5	32	
	Disk harrow	894	69,4	-394	ooo
LSD 5%=131,3kg/ha LSD 1%=191,0 kg/ha LSD 0,1%=286,5 kg/ha					
2008	**Ploughed at 30**	3339	100,0	0,0	Control variant
	Paraplow + Vertical rotarry harrow	3134	88,6	-380	oo
	Paraplow + horizontal rotarry harrow	2959	88,5	-384	oo
	Chisel + horizontal rotarry harrow	2955	93,9	-205	o
	Disk harrow	2657	79,6	-682	ooo
LSD 5%=180,6kg/ha LSD 1%= 262,7 kg/ha LSD 0,1%=394,1 kg/ha					
Average 2007 - 2008	**Ploughed at 30**	2314	100,0	0,0	Control variant
	Paraplow + Vertical rotarry harrow	2097	90,6	-217	oo
	Paraplow + horizontal rotarry harrow	2095	90,6	-219	oo
	Chisel + horizontal rotarry harrow	2227	90,3	-86	
	Disk harrow	1775	76,7	-538	ooo
LSD 5%=121,8kg/ha LSD 1%=177,1kg/ha LSD 0,1%=265,7 kg/ha					

CONCLUSIONS

1. In soybean, drought installed in 2006 - 2007 was manifested by increased soil compaction, aspect highlighted in 10 - 20 cm horizon after the maintenance and harvesting operations, where the bulk density values varied within 1.34 to 1.48 g/cm^3 and 1.42 to 1.51 g/cm^3. We can conclude that in these conditions, the minimum tillage system with the chisel was very close to 30 cm plowed treatment.

2. The absence of rainfall in spring and early summer led to the installation of a prolonged drought in the agricultural year 2006 - 2007, issue that has contributed to higher soil compaction in all experimental plots and throughout the soil profile. The phenomenon manifested itself more strongly from the second development stage to harvest of soybean.

3. Soil bulk density increased with depth from sowing to harvesting, in all tillage treatments for the three crops in rotation. The parameter variation amplitude is less during the growing season-harvest compared to sowing-growing season period. The superficial layer was compacted the most and phenomenon has decreased within soil profile.

4. Conventional seedbed preparation scheme resulted in a lower state of soil compaction from planting to harvest and throughout the soil profile compared to disc harrow witch recorded the highest penetration resistance values. Experimental plots tilled with chisel and paraplow are presenting intermediate values, close to control treatment, being even smaller in 30 - 40 cm soil layer.

5. After executing the crop maintenance operations, mean PR increased in all experimental plots and all depths, and compared with winter wheat, the penetration resistance in soybean has lower values in 0-5 cm and 5 - 10 cm layers, ranging from 0.51 to 0.64 MPa

and from 0.75 to 1.20 MPa respectively. Those limits are due to conditions resulting from operations executed during crop growth period and at the depth of 10 - 30 cm values are somewhat higher and reached approximately equal to the lower layers between 30 and 50 cm.

6. The analysis of average data from harvest, in both experimented years, shows a very significant change in PR by the degree of soil mobilization. Compared to the control (1.79 MPa), very significant differences can be observed indicating a gradual soil compaction in disk harrow (0.26 MPa) and lower values in chisel and paraplow variants but without statistical significance.

7. The general conclusion from soil penetration resistance determinations is that in all conventional or unconventional tillage system treatments roots penetration and normal growth are not limited.

8. In the climatic conditions of 2007, experimental treatments without inverting the topsoil (paraplow and chisel) have yielded approximately at the same level like moldboard plow treatment (control), with pluses or minuses statistically insignificant, the difference being made by the disc harrow witch recorded a minus of approximately 400 kg/ha in comparison to the control.

9. In 2008 soybean crop has benefited from favorable conditions for plant growth with positive effects on yield. Under these conditions we have obtained 3339.0 kg/ha in plowing at 30 cm, 3133.8 kg/ha in chisel, from 2954.9 to 2959.2 kg/ha in paraplow and 2656,6 kg/ha in disk harrow variants.

10. Mean soybean yields in both experimented years showed that the unconventional tillage system treatments has lower yields when compared to the conventional tillage system (2314 kg/ha), with limits ranging from 1,775.5 kg/ha (76.7%) in disk harrow, between 2095.1 and 2096.9 kg/ha (90.6%) in paraplow and 2227.1 kg/ha (96.3%) in chisel treatments.

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