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RESEARCH ON THE IMPACT OF TILLAGE OPERATIONS FOR AUTUMN WHEAT CROP SET UP OVER SOME SOIL PROPERTIES

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Abstract. Soil has an important role in sustaining life on earth and represents the support for the practice of agriculture, which provides the population's food security and safety. Preserving the land production potential and ensuring a durable development is a key factor in the present times. In this context the researches presented in the paper analyze the effects of soil compaction and of the type of tillage machinery over some soil properties for autumn wheat crop set up. Twelve experimental variants were considered, based on two influencing factors: factor A = soil compaction, with 3 variants; factor B = tillage machinery system, with 4 variants. The following indices were taken into account for each experimental variant: apparent volumetric mass, penetration resistance and stability of the soil structural elements, expressed by the means of two indices: weighted average diameter and water stability of the aggregates. The results of the experiments regarding the effect of soil compaction and tillage machinery system led to the conclusion that the technological variants that create favorable conservation conditions were the ones leading to minimum soil compaction, obtained through direct seeding into the stubble and no plowing.

Key words: Soil compaction; Tillage machinery; Autumn wheat crop; Soil physical properties.

INTRODUCTION

At a macro-economic level soil has a foremost role in maintaining life on earth. Its main function consists in being the support for the practice of agriculture, which plays an important part for the population's food security and safety; soil provides nutritive elements and water to the crops, in a simultaneous and continuous process, during the entire vegetation phase.

Under these circumstances we may consider soil as one of the most complex natural systems of our planet, a structured system of substances in permanent transformation, a biological system where life pulsates continuously, a catalyst for the wealth of the environment, a system indispensable to life; soil contributes to the maintenance of genetic biodiversity, of the rich spectrum of living beings, each species being the keeper of valuable genes that contributes to the improvement of life quality and wealth.

Under the present day conditions, characterized by the intensive development of agriculture, a new concept is imposed to humanity in order to preserve the functions of soil; the new concept of „durable agriculture" involves not only the agricultural sector, but also the other domains of social life (Guş, P. et al. 2003).

Within the systems based on durable agriculture the new concept of „conservative agriculture" is based on the use of renewable natural resources; soil is one of the main renewable natural resources and its use and regeneration in real time are a key component of conservative agriculture (Bailey, C.C. et al. 1984; Bailey, C.C. et al. 1986; Butnaru, L. 2011; Guş, P. et al. 2003; Hera, C. 2001).

Under these circumstances, no matter whether the genetic potential of crops increases or not, all the farmers need technologies leading to cost reductions and ensuring the long term sustainability of production, based on three main principles: minimum soil disturbance, crop rotation and keeping the vegetal waste on soil (30% minimum). Therefore conservative agriculture is a complex technology that implies changes in the entire production system, starting with the seeding and planting equipments, seeding method, management of the vegetable waste, fertilizer distribution, pest and disease control, crop rotation etc. (Hera, C. 2001; Horn, R. et al. 2001; Kasper, M. et al. 2009; Kroulik, M. et al. 2009).

Conservative agriculture considers soil into a new paradigm, more as an integrated system and less as a collection of components and processes. The success of conservative agriculture proves that this technology may be developed in different climate conditions. A complete package of practices, based on intensive research performed in each agricultural region, should be identified in order in order to adopt the conservative agriculture.

All these facts clearly show that durable and especially conservative agriculture represents a system of technologies and practices aimed not only to obtain satisfactory productions, but also to preserve the biodiversity (Chung, S.O. et al. 2006; Guş, P. et al. 2003; Hera, C. 2001).

Within the above-mentioned framework the studies presented in this paper are aimed to study the effect of different soil tillage operations over the main soil properties when setting up the autumn wheat crop. We consider the researches as very important and convenient and having the potential to increase the production level and productivity, while preserving soil condition.

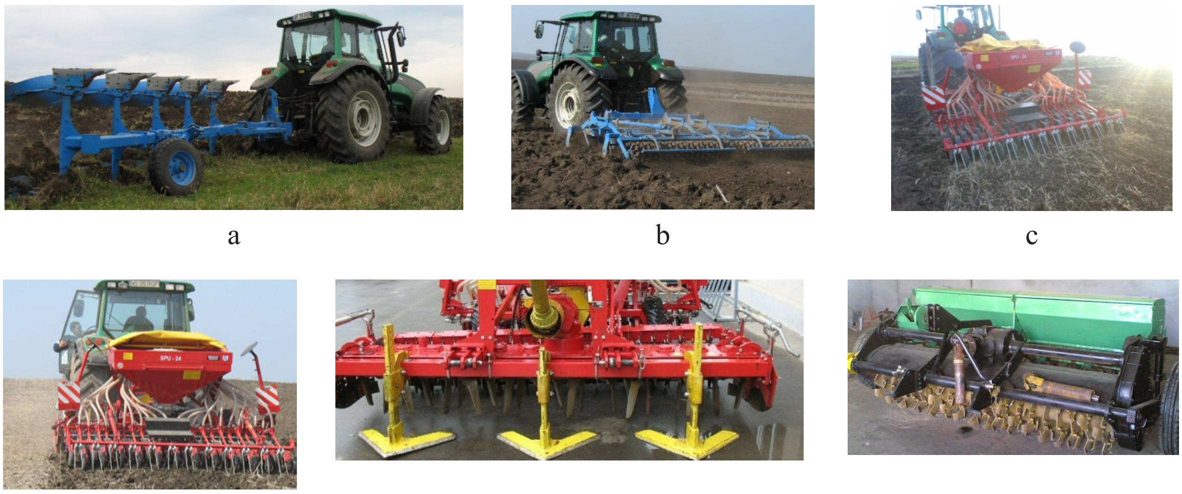
MATERIAL AND METHODS

The researches were performed over a period of three years at the Ezăreni farm of the University's research station placed in the south-western part of the Moldavian Plain; the morphological characterization of soil is cambic chernozem, mezocalcaric, poorly degraded, clay loam texture. The experiments were aimed to evaluate the effect of different tillage machinery used in order to set up the autumn wheat crop and the effect of soil compaction over the indices referring to soil compaction and its structure.

The following tillage units were used during the research:

- Valtra T-190 tractor + PRP 5x35 reversible plow unit (fig. 1.a);
- Valtra T-190 + BS 400 A Combinator unit (fig. 1.b);
- Valtra T-190 + AGPS-24DR complex unit for seedbed preparation and seeding (fig. 1.c);
- Valtra T-190 + chisel tools OA+ AGPS-24DR complex unit for plowing, seedbed preparation and seeding (fig. 1.e);
- Valtra T-190 + MCR-2,5 combined unit for strip tillage and seeding (no-tillage seeding, fig. 1.f.).

In order to evaluate the physical properties of soil adequate equipments and installations were used: the Eijelkamp apparatus with eight sieves for dry sieving of soil sample, in order to evaluate the weighted average diameter of the soil's structural elements; wet sieving apparatus for evaluating the water stability of the aggregates using the Tiulin-Erikson method; Eijelkamp Penetrologger static penetrometer for evaluating the penetration resistance (Țenu, I. et al. 2011; Țenu, I. et al. 2015).



a b c

d e f

Figure 1. *Tillage units for the set up of autumn wheat crop:* ***a*** *- Valtra tractor T-190 + PRP 5x35 reversible plough;* ***b*** *- Valtra tractor T-190 + BS 400 Combinator;* ***c*** *- Valtra tractor T190 + AGPS-24DR complex unit,* ***d*** *and* ***e*** *- Valtra tractor T 190 + OA chisels + AGPS-24DR complex unit;* ***f*** *- Valtra tractor T 190+ MCR-2,5 combined unit.*

The tested variants were based on experiments with two influencing factors: factor A = soil compaction, with 3 graduations; factor B = the tillage machinery system, with 4 graduations; this arrangement led to a total of 4 x 3 = 12 experimental variants (*Table 1*).

The experimental variants (*Table 2*) were based on the above-mentioned facts; for each variant the following soil properties were evaluated, over a period of three consecutive years: apparent density, penetration resistance and stability of structural elements, expressed by the means of the weighted average diameter and water stability. These parameters were used in order to express the negative effects consisting in the degradation of soil structure.

Table 1. *Two factor experiment for autumn wheat crop set-up*

Factor A: soil compaction	**Factor B**: Tillage machinery system
graduation 1 – non-compacted	graduation 1 – plowing, seedbed preparation, seeding: T190 tractor + PRP 5x35 plow; T190 + BS 400 Combinator; T-190 + SUP-24DR seeding machine
graduation 2 – compacted, one time pass	graduation 2 – plowing and seedbed preparation in the same time with seeding: T190 + PRP 5x35; T190 + AGPS-24DR complex unit;
graduation 3 – compacted, two times pass	graduation 3 – seedbed preparation in the same time with seeding: T 190 + OA chisels + AGPS-24DR
	graduation 4 – no tillage seeding: T 190+ MCR-2,5 combined unit

Table 2. *Summary of the experimental variants*

Experimental variant	**Soil compaction**	**Tillage machinery system**
V_1 (control sample)	non-compacted	plowing with the Valtra T-190 tractor + PRP 5x35 reversible plough; seedbed preparation with Valtra T-190 + Combinator BS 400 A; seeding with Valtra T-110 + SUP-24DR.
V_2		plowing with the Valtra T-190 tractor + PRP 5x35 reversible plough; seedbed preparation and seeding with Valtra T-190 + AGPS-24DR complex aggregate;
V_3		plowing, seedbed preparation and seeding with Valtra T-190 + chisel tools OA+ AGPS-24DR complex aggregate
V_4		no-tillage seeding with Valtra T-190 + MCR-2,5 combined strip tillage and seeding machine.
V_5	compacted, one pass *	plowing with the Valtra T-190 tractor + PRP 5x35 reversible plough; seedbed preparation with Valtra T-190 + Combinator BS 400 A; seeding with Valtra T-110 + SUP-24DR.
V_6		plowing with the Valtra T-190 tractor + PRP 5x35 reversible plough; seedbed preparation and seeding with Valtra T-190 + AGPS-24DR complex aggregate;
V_7		plowing, seedbed preparation and seeding with Valtra T-190 + chisel tools OA+ AGPS-24DR complex aggregate
V_8		no-tillage seeding with Valtra T-190 + MCR-2,5 combined strip tillage and seeding machine.
V_9	compacted, two passes**	plowing with the Valtra T-190 tractor + PRP 5x35 reversible plough; seedbed preparation with Valtra T-190 + Combinator BS 400 A; seeding with Valtra T-110 + SUP-24DR.
V_{10}		plowing with the Valtra T-190 tractor + PRP 5x35 reversible plough; seedbed preparation and seeding with Valtra T-190 + AGPS-24DR complex aggregate;
V_{11}		plowing, seedbed preparation and seeding with Valtra T-190 + chisel tools OA+ AGPS-24DR complex aggregate
V_{12}		no-tillage seeding with Valtra T-190 + MCR-2,5 combined strip tillage and seeding machine.

* compacted with the Valtra T-190 tractor (rear wheels), one pass „rut near rut”, before plowing.
** compacted with the Valtra T-190 tractor (rear wheels), two perpendicular passes „rut near rut”, before plowing

The apparent soil density represents the ratio between soil mass and its total volume; it is an aggregate property of soil, which is composed of a solid part and gaps (pores) between the solid particles (Canarache, A. 1990; Chung, S.O. *et al*. 2006):

$$DA = \frac{M}{V_t} = \frac{M}{V_s + V_p} \quad (1)$$

where DA – apparent soil density (g/cm^3); M – soil mass (g); $Vt = Vs + Vp$ = total volume of soil (cm^3);

Vs – volume of the solid part (cm^3); Vp – volume of pores (cm^3).

The apparent density was calculated according to the following procedure: the soil samples for each variant were drawn ten days after seeding, from the depths of 0-10 cm, 10-20 cm, 20-30 cm and 30-40 cm, using 100 cm^3 metal cylinders. The net mass and humidity were measured in laboratory; the apparent density resulted from the mass and volume of the samples.

The specific penetration resistance was measured ten days after seeding with the Eijkelkamp penetrologger. The measurements were performed to the depth of 0.4 m, using a 30° penetration cone with the base area of 1 cm^2.

The average weighted diameter of the structural elements represents the average diameter of the different classes of structural macro-elements, obtained when sieving of the soil samples with the sieving apparatus, equipped with eight sieves having orifices with a diameter of 10, 5, 3, 2, 1, 0.5 and 0.25 mm; the average weighted diameter was calculated using the following relationship (Canarache, 1990, Chung *et al*., 2006):

$$DMP = \frac{\sum (p_i . d_i)}{100} \quad (2)$$

where: *DMP* – average weighted diameter (mm); p_i – percentage of each class of structural elements (%);

d_i - average diameter for each class of structural elements (mm).

Water stability is the property of the structural elements to withstand the dispersive action of water. The evaluation of this property was performed in two stages: first a 20 g average soil sample was prepared, through dry and wet sieving of the sample on a sieve with orifices having different diameters, according to the Tiulin-Ericson method. The sieves were positioned from bottom to top in the increasing order of the orifice diameters: 0.25, 0.5, 1.0, 2.0 and 3.5 mm.

The soil sample was positioned on the upper sieve, was flooded with water in order for the capillaries to get saturated, and then 30 sieving operations were performed, during 15 minutes. During these operations the unstable aggregates broke apart and the smaller aggregates passed through the orifices of the sieves, being retained on the surface of the sieve having orifices smaller than the aggregate diameter. The particles with dimensions smaller that 0.24 mm passed through all the sieves, being evacuated by the current of water. The soil particles collected on each sieve were then dried and weighted.

The quality indices of the structure were calculated as ratios between the different classes of soil aggregates (Chiriţă, 1955):

$$I_1 = \frac{I + I \ + III}{V \ + V}, \quad (3)$$

$$I_2 = \frac{V}{V + V}, \quad (4)$$

where: I = percentage of aggregates bigger than 5 mm; II = percentage of aggregates with the diameter between 3 and 5 mm; III = percentage of aggregates with the diameter between 2 and 3 mm; IV = percentage of aggregates with the diameter between 0.5 and 1 mm: V = percentage of aggregates with the diameter between 0.25 and 0.5 mm.

In the present study only the results for the index I_1 were analyzed.

The statistical processing of the results was based on the analysis of variance and comprised the following steps: establishing the degrees of freedom (df), calculation of the squared deviations, preparation of the table of variances, calculation of the limit differences (DL) for the 5%, 1% and 0.1% transgression probabilities, calculation of the differences and establishment of the significance level.

In order to establish the significance the differences between the experimental variants and the control sample were compared with the limit differences or the minimum significant differences; the scale presented in *Table 3* was used in this process (Ţenu, I. et al. 2011**)**. The limit difference (DL) was calculated with the formula:

$$DL = t * s_d \quad (5)$$

where: **t** is the normal error, corresponding to the given degree of freedom (df) and $\mathbf{s_d}$ is the standard error of the differences.

Table 3. *Significance scale*

Specification	Differences		Significance
	positive	negative	
d ≥ DL 5%	-	-	not significant
DL 5% < d < DL 1%	X	O	significant
DL 1% < d < DL 0,1%	XX	OO	distinct significant
DL 0,1% ≤ d	XXX	OOO	very significant

where: **d** – differences between variants and control sample.

RESULTS AND DISCUSSIONS

The results of the experimental research, performed during three consecutive production years, together with statistical analysis, are presented in *Table 4*.

The results concerning the penetration resistance show that the maximum values were recorded for the variants „compacted, one pass” and „compacted, two passes” and for the control sample, but the upper limit of 1.08 MPa, imposed by the agro-technical requirements (Blaszkiewicz, Z. 1998; Braunack, M.V. 1989), was not exceeded.

The results concerning soil apparent density prove that this index was affected mainly by the compaction degree, but also by the tillage machinery system. For the „non-compacted” variants the values of the apparent density were lower than the ones imposed by the agro-technical requirements, but compaction led to a significant increase of this index, especially for depths under the tilled layer.

The experimental results concerning the weighted average diameter of the structural elements showed that all the variants fulfilled the agro-technical requirements, with values of this index comprised between 2 and 5 mm. The weighted average diameter for variant V_4 (non-compacted soil, no-tillage seeding with Valtra T-190 + MCR-2,5 combined strip tillage and seeding machine) was the closest to 3.5 mm, value which is considered to correspond to the best soil structure.

The analysis of soil water stability, as the property of the structural elements to withstand the dispersing action of water, evaluated by the means of the Tiulin-Erikson method through the I_1 index (the structure is considered to be very good for values comprised between 3.00 and 5.00) was performed with respect to the control sample, taking into account soil compaction and tillage machinery system. The best results were recorded for variant V_4 (non-compacted soil, no-tillage seeding with Valtra T-190 + MCR-2,5 combined strip tillage and seeding machine).

Table 4. *Results concerning the effect of compaction and tillage machinery system for autumn wheat crop*

Variant	Soil density (g/cm^3)		Penetration resistance (MPa)		Weighted average diameter of the structural elements (mm)		Water stability (I_1)		Variants order according to performance
	Avg. 0-40 cm	Statistical signifi-cance	Average 0-40 cm	Statistical signifi-cance	Average 0-40 cm	Statistical signifi-cance	Average 0-40 cm	Statistical significance	
V1	1.286	Control sample	0.247	Control sample	3.684	Control sample	3.619	Control sample	XII
V2	1.265	OO	0.215	OOO	3.357	OOO	3.686	-	XI
V3	1.326	XXX	0.260	XXX	3.407	OOO	3.702	-	II
V4	1.338	XXX	0.286	XXX	3.568	O	3.431	-	I
V5	1.403	XXX	0.315	XXX	3.094	OOO	2.967	OOO	IX
V6	1.395	XXX	0.306	XXX	3.189	OOO	3.024	OOO	VIII
V7	1.435	XXX	0.347	XXX	3.203	OOO	3.180	OO	IV
V8	1.450	XXX	0.356	XXX	3.347	OOO	3.431	-	III
V9	1.496	XXX	0.390	XXX	2.882	OOO	2.686	OOO	VII
V10	1.265	OO	0.387	XXX	2.904	OOO	2.778	OOO	XI
V11	1.540	XXX	0.410	XXX	2.968	OOO	2.777	OOO	V
V12	1.583	XXX	0.438	XXX	3.297	OOO	2.930	OOO	VI

CONCLUSIONS

The experimental results regarding the effect of soil compaction and tillage machinery system over some physical properties of soil when setting-up the autumn wheat crop prove that the technological variants leading to conservation conditions are the ones leading to minimum soil compaction and seeding is performed directly into the stubble, in a single pass, without plowing.

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