RESEARCH REGARDING THE IMPACT OF AGRICULTURAL MACHINES TRAFFIC ON SOME PHYSICAL PROPERTIES OF THE SOIL AT WINTER WHEAT CROP

CERCETĂRI PRIVIND IMPACTUL TRAFICULUI UTILAJELOR AGRICOLE ASUPRA UNOR PROPRIETĂȚI FIZICE ALE SOLULUI LA CULTURA GRÂU DE TOAMNĂ

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Abstract*. The agricultural machines traffic, involved in carrying out mechanized agriculture, has a great impact on physical and mechanical properties of the soil and, consequently, on agricultural production. In this paper experimental investigations were performed to quantify the effect of soil compaction induced by the running systems of the agricultural tractors and agricultural machines on winter wheat crop. To this end there has been carried out several experimental variants, with different degrees of compaction, and the evolution of the following parameters: resistance to penetration, bulk density, the mean weight diameter of the structure elements and the water stable aggregates of these elements.*
Key words: winter wheat, compaction, soil properties.

Rezumat. *Traficul utilajelor, implicate în realizarea mecanizată a lucrărilor agricole, are un impact deosebit asupra proprietăților fizico-mecanice ale solului şi, implicit, asupra producțiilor agricole. În cadrul acestei lucrări s-au efectuat cercetări experimentale pentru cuantificarea efectului de tasare asupra solului realizat de sistemele de rulare ale tractoarelor şi maşinilor agricole la cultura grâu de toamnă. În acest scop s-au efectuat mai multe variante experimentale, cu grade diferite de tasare şi s-a determinat evoluția următorilor parametri: rezistența la penetrare, densitatea aparentă, diametrul mediu ponderat al elementelor de structură şi hidrostabilitatea acestor elemente.*
Cuvinte cheie: grâu, tasare, proprietățile solului.

INTRODUCTION

The problem of soil compaction is usually associated with tillage practices or with naturally formed restrictive layers found in many soils. Conventional tillage system usually involves mouldboard ploughing and additional secondary tillage to prepare the seedbed. Soil compaction can result particularly when weather conditions force tillage operations to be completed under unfavourable soil moisture and by unnecessary secondary tillage. During conventional soil tillage cycle may appear two different problems of soil compaction. First is

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compaction of the cultivated horizon, which can be solved by annual tillage. Second is compaction of layer below the annual tillage horizon or subsoil compaction, where the problem worsens because compaction has cumulative effect which is more complex and expensive to solve than compaction within the tilled layer. Conservation tillage systems are usually a result of reduced tillage practices. Those systems try to disturb the soil as little as possible to conserve its natural structure and should lead to less soil compaction (Varsa E.C. et. al., 1997)

Soil tillage allows a rapid and uniform seed emergence, deep penetration of the roots, good soil drainage, weed control and seedbed preparation. Cultivation can alter the physical and mechanical properties of the soil, whereby plant growth, development, and yield are influenced. The physico-mechanical properties of the soil are extremely vital for plant growth. Tillage systems have significant effect on the physical properties of soil (Grant C.A., Lafond G.P., 1993).

The degree of compaction created by tillage and heavy machinery traffic is often also a function of soil texture (Ellies S.A. et al., 2000), soil bulk density (Hakansson I., Lipiec J., 2000), soil structure (Mosaddeghi M.R. et. al., 2000) and soil resistance to penetration (Hamza M.A., Anderson W.K., 2003).

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 Iasi, Ezareni Farm, during farming years 2009-2010. The experimental site is located in the North-East part of Romania (47°07` N latitude, 27°30` E longitude) on a chambic 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 12%. The experimental site has an annual average temperature of 9.6°C and precipitation of 517.8 mm. The experimental design was with a single factor of influence, in three replications, having as influence factor the degree of soil compaction. There were established three experimental plots, with the same system of agricultural machines, but with different degrees of soil compaction (table 1). The soil compaction was realized by many "wheel by wheel" passages, using the tractor with 190 horse power, before plowing, by one or two passages in order to achieve different degrees of compaction. Experimental plots covered surface of 150 m^2 each, being cultivated with wintewr wheat, Glosa variety (approved in 2005, Hungary), drilled on October 21 2010 using the Valtra T190 tractor with the complex aggregate AGPS-24-DR (vertical harrow + universal pneumatic drill). The distance betwen rows was of 0.125 m and the and the depth at which the wheat was drilled was about 5 cm.

Table 1

Experimental plots layout at wheat crop in agricultural year 2009-2010

Experimental plots	Soil compaction degree	Agricultural machines system used
$V_{1\text{-control}}$	Uncompacted	Valtra T190 tractor + AGPS-24-DR
V_2	Compacted once	
V_3	Compacted twice	

In this experimental research the influence of soil compaction degree on some soil physical and mechanical properties was studied. In order to determine soil bulk density, mean weight diameter of soil structural elements and the hydro stability of these elements, soil samples were taken from each plot in ten days after the wheat seeding.

Soil penetration resistance was measured in ten days after sowing, by using a digital penetrologger (Eijkelkamp equipment, The Nederlands). The measurements were realised at a soil depth of 40 cm by using the Eijkelkamp penetrologger which had a 30° cone angle and a 1 cm^2 base area and by making ten repetitions for each experimental plot.

After seeding, in order to determine the soil bulk density soil samples were taken from each experimental plot using a steel cylinder of 100 cm^3 volume (5 cm in diameter, and 5.1 cm in height) (Blake G.R. et. all, 1986), which were carried out at four depths (0-10 cm, 10-20cm, 20-30 cm and 30-40 cm).

The analysis of hydro aggregate stability of soil structural elements and the analysis of soil structural elements distribution was measured by using the dried and wet sieving, after Tiulin-Erikson procedure. The soil samples were taken on three depths: 0-10 cm, 10-20 cm and 20-30 cm and each sample was air-dried. The soil samples were sieved by using a sieve shaker machine named „Granular composition test set" (Eijkelkamp, Nederlands), provided with a set of overlapping sites (sites with holes: 10, 5, 3, 2, 1, 0.5 and 0.25 mm), in order to achieve the dry seiving. The eighth sieve, mounted below the sieve with 0.25 mm holes, is blind (without holes). After finishing the dry sieving, the soil fractions for each sieve were weighed and the percentage of soil structural elements for each fraction was calculated: soil structural elements larger then 10 , between 10 to 5, 5 to 3, 3 to 2, 2 to 1, 1 to 0.5, 0.5 to 0.25 mm and smaller than 0.25 mm. According to Tiulin-Erikson procedure, in order to determine the hydro stability of soil structural elements, twenty grams of average soil sample of dry soil structural elements were placed on a set of six overlapping sieves, having holes of 0.25, 0.5, 1, 2, 3, 5 mm diameter. The fractions of soil structural elements retained by each sieve were gently back-washed off the sieve. The soil samples were rinsed, the water was removed, and then, the soil structural elements were put in numbered aluminum vials and they were weighed. Forwards, the vials were placed in a forced-air oven at ~105°C and then, after 8 hours, they were weighed. Certain indicators, as mean weigh diameter of soil structural elements, were determined by calculation (Canarache A., 1990).

The wheat seed yield was determined from 5 m^2 of each experimental plot by taking ten repetitions for each experimental plot.

Statistical processing of data was done by means of the analysis of variance.

RESULTS AND DISCUSSIONS

The influence of soil compaction degree on some soil physical and mechanical properties and wheat seed yields are presented herein.

The soil penetration resistance values are presented in table 2. It is noted that, once with the increasing of the soil compaction degree, the values of soil penetration resistance increase. Regarding the variation in depth of the soil resistance to penetration, we find that in the upper soil layers of 0-10 cm, the soil penetration resistance has lower values due to the action of active working bodies of vertical harrow whithin the complex aggregate AGPS-24-DR. In the soil layers, in the range of 10-40 cm, due to compaction produced by the agricultural machinery wheals, we can observe a systematic increase of the amount of soil resistance to penetration, as the depth increases. The experimental plot with the highest value of soil resistance to penetration is V_3, respectively 0.526 MPa, a very significant positive difference towards the experimental plot $V_{1\text{-control}}$.

Table 2

Soil resistance to penetration at wheat crop in agricultural year 2009-2010

Experimental plots	**Depth (cm)**										Statistical significations
	0-5	5-10	10-15	15-20	20-25	25-30	30-35*	35-40*	Average 0-30	Average 0-40	
	Soil resistance to penetration (MPa)										
$V_{1\text{-control}}$	0.2	0.31	0.32	0.336	0.352	0.416	0.426	0.466	0.322	0.353	-
V_2	0.24	0.386	0.4	0.426	0.454	0.481	0.528	0.572	0.397	0.436	xxx
V_3	0.285	0.419	0.494	0.501	0.536	0.594	0.658	0.724	0.471	0.526	xxx

*the subsoil layers was not tilled with the plow

LDS 5%=5%=0.032 MPa   LDS 1%=0.047 MPa   LSD 0.1%=0.062 MPa

The soil bulk density, as well as the soil resistance to penetration, is having the same variation, depending on the degree of the soil compaction. As seen in table 3, the experimental plot which has the highest value of the soil bulk density is V_3. This value is of 1.49 g/cm^3, having a very significant positive difference towards the experimental plot $V_{1\text{-control}}$. It is also found that the soil bulk density increases continuously with the depth's increase.

Table 3

Soil bulk density at wheat crop in agricultural year 2009-2010

Experimental plots	**Depth (cm)**						Statistical significations
	0-10	10-20	20-30	30-40*	Average 0-30	Average 0-40	
	Soil bulk density (g/cm^3)						
$V_{1\text{-control}}$	1.08	1.31	1.35	1.43	1.25	1.29	-
V_2	1.21	1.39	1.44	1.55	1.35	1.4	xxx
V_3	1.31	1.47	1.57	1.61	1.45	1.49	xxx

*the subsoils layer was not tilled with the plow

LSD 5%=0.038 g/cm^3 LSD 1%=0.057 g/cm^3 LSD 0.1%=0.092 g/cm^3

Table 4

Mean weight diameter at wheat crop in agricultural year 2009-2010

Experimental plots	**Depth (cm)**				Statistical significations
	0-10	10-20	20-30	Average 0-30	
	Mean weight diameter (mm)				
$V_{1\text{-control}}$	3.159	4.132	4.413	3.901	-
V_2	2.641	3.067	3.705	3.138	0
V_3	2.528	2.762	3.246	2.845	00

LSD 5%=0.466 mm   LSD 1%=0.772 mm   LSD 0.1%=1.443 mm

In table 4 we can observe that the mean weight diameter of the structural elements of the soil decreases once the degree of soil compaction increases. The lowest value of the mean weight diameter of the soil structural elements is recorded at V_3, the experimental plot with a distictly significant negative difference towards the experimental plot $V_{1\text{-control}}$.

Regarding the hydro stability of the soil structural elements we can conclude that, from the values of the I_1 quality parameter of soil structure presented in table 5, the hydro stability of the structural elements of the soil are decreasing once the degree of the soil compaction is increasing.

As it resulted from the data presented in table 5, by making an extrapolation to the value classes of the hydro stability of the soil structural elements (I_1=3 to 5, the soil structure is very good; I_1=0.61 to 3, the soil structure is good; I_1=0.3 to 0.61, the soil structure is medium; I_1=0.18 to 0.3, the soil structure is weak), we can conclude that the experemintal plot V_1 is having the best soil structure from the soil hydro stability's point of view by belonging to the value class „soil with a very good structure", respectively 3.67, while the experemintal plot V_3 belongs to the value class „soil with a good structure", respectively 1.76. The experimental plot V_2 is having a distictly significant negative difference towards the experimental plot $V_{1\text{-control}}$ meanwhile the experimental plot V_3 is having a very significant negative difference towards the experimental plot $V_{1\text{-control}}$.

Table 5

Values of the I_1 quality parameter of soil structure at wheat crop in agricultural year 2009-2010

Experimental plots	Depth (cm)				Statistical significations
	0-10	10-20	20-30	Average 0-30	
	The values of I_1 quality parameter of soil structure				
$V_{1\text{-control}}$	2.584	3.115	3.355	3.018	-
V_2	1.911	2.221	2.814	2.315	00
V_3	1.055	1.584	2.167	1.602	000

LSD 5%=0.271 LSD 1%=0.450 LSD 0.1%=0.842

The wheat seed yields obtained in the three experimental plots are presented in table 6. It can be noted that the increase of the soil compaction degree leads to drastic yield decrease. The experimental plots V_2 and V_3 have a very significant negative difference towards the experimental plot $V_{1\text{-control}}$.

Table 6

The yields obtained at wheat crop in agricultural year 2009-2010

Experimental plots	Wheat seed yield (kg/ha)	Statistical significations
$V_{1\text{-control}}$	4539	-
V_2	3583	000
V_3	3196	000

LSD 5%=248.7 kg/ha LSD 1%=412.4 kg/ha LSD 0.1%=770.2 kg/ha

CONCLUSIONS

1. The increase of the soil compaction degree, induced by the traffic of the agricultural machines, has a negative impact on the soil physical and mechanical properties.

2. The soil resistance to penetration increasis once with the increase of the soil compaction degree, having lower values in the upper soil layers of 0-20 cm.

3. The soil bulk density is having the same variation as the soil resistance to penetration, this two parameters being the most used indicators of the soil state of compactness. As the soil bulk density increases, it's of soil compaction degree increases too.

4. The mean weight diameter of the soil structural elements presents major modifications, it's values decreasing once with the increase of soil compaction degree.

5. The hydro stability of the soil structural elements is also decreasing once with the increase of soil compaction degree.

6. All these negative modifications of the physical and mechanical properties have lead to drastic yield decrease.

REFERENCES

1. **Blake G.R., Hartge K.H., 1986 -** *Bulk density, In: Klute, A. (Ed.), Methods of soil analysis. Part 1, physical and mineralogical methods, 2nd Edition*.: Agronomy Monograph No. 9. Soil Science Society of America, Madison, WI, pp. 363–375.
2. **Canarache A., 1990** – *Fizica solurilor agricole*. Ed. Ceres, Bucharest.
3. **Ellies Sch. A., Smith R.R., Jose Dorner F.J., Proschle T.A., 2000 -** *Effect of moisture and transit frequency on stress distribution on different soils*. Agro Sur. 28, 60–68.
4. **Grant C.A., Lafond G.P., 1993 -** *The effects of tillage and crop sequences on bulk density and penetration resistance on a clay soil in southern Saskachewan.* Can. J. Soil Sci. 73, 223–232.
5. **Hakansson I., Lipiec J., 2000** - *A review of the usefulness of relative bulk density values in studies of soil structure and compaction*. Soil Tillage Res. 53, 71–85.
6. **Hamza M.A., Anderson W.K., 2003** - *Responses of soil properties and grain yields to deep ripping and gypsum application in a compacted loamy sand soil contrasted with a sandy clay loam soil inWestern Australia*. Aust. J. Agric. Res. 54, 273– 282.
7. **Mosaddeghi M.R., Hajabbasi M.A., Hemmat A., Afyuni M., 2000** - *Soil compactibility as affected by soil moisture content and farmyard manure in central Iran.* Soil Tillage Res. 55, 87–97.
8. **Varsa E.C., Chong S.K., Abolaji J.O., Farquhar D.A., Olsen F.J., 1997 -** *Effect of deep tillage on soil physical characteristic and wheat (Zea mays L.) root growth and production*. Soil Tillage Res, 43:219–28.
9. **Weise G., Bourarach E.H, 1999 -** *Tillage machinery. In: CIGR handbook of agricultural engineering.* Plant production engineering, vol. 3. St. Joseph: ASAE.