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EVALUATION OF CHANGES IN SOIL COMPACTION DUE TO THE PASSAGE OF COMBINE HARVESTER

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Abstract

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This paper concerns the results of changes in soil compaction after the passages of combine harvester. The research was done on the maize-stubble; the soil was the mold formed in the sand. The measured parameter was a penetration of resistance in range of depth 0–60 cm. The measurements were done in the ruts after the passages the front and rear wheel of combine harvester. During the experiment two levels of vertical load of wheels were applied – these levels were dependent on filling of grain tank of harvester. Moreover, the influence of the lateral tilt of harvester on the soil compaction was analyzed (the harvester was equipped with the leveling system which allowed to obtain the tilt). The obtained results shows that the increase in vertical load caused greater compaction in ruts. Furthermore, it was found that the passage of tilted harvester caused lower compaction than the harvester without tilt.

Keywords: soil compaction, penetration resistance, wheel, combine harvester, vertical load

INTRODUCTION

One of main requirements of present agriculture is an achievement of maximum efficiency in the field operations. Modern agricultural machines have high external dimensions (first of all the operational widths) and high weights. The use of these heavy machines can cause negative changes in a soil structure.

For many years the research into the impact of agricultural machines exploitation on soil parameters were conducted. In the field operations the ruts are the result of passages of wheeled vehicles and machines. The soil in the ruts is compacted – the soil particles are tightly placed in the volume unit. This phenomenon may have negative consequences for the cultivated plants; by higher compaction, the resistance for the plant roots will be higher, the volume of soil pores will decrease and the retention properties will deteriorate (Nevens and Reheul, 2003; Horn *et al*., 2003; Lipiec *et al*., 2003; Chan *et al*., 2006). These negative changes may cause the decrease in the yield, therefore the ways to reduce the soil compaction should be considered. The knowledge of this subject must be based on field experiments.

Many scientific papers concerned the influence of vertical load of wheels on the soil compaction. Generally, it can observed that the increase in vertical load caused higher soil compaction in ruts (Raper *et al*., 1994; Botta *et al*., 2002; Arvidsson and Keller, 2007; Zink *et al*., 2011). Another factor, which can determinate the soil compaction is the tire size; many researchers showed that the wide tires have greater contact surface – the result of use these tires will be lower intensity of soil compaction (Arvidsson and Ristic, 1996; Sharma and Pandey, 1996; Antille *et al*., 2008).

The combine harvesters are the agricultural machines, which characterize by very high weights. These machines have high external dimensions and are equipped with grain tanks with large capacities. Such features can cause the high total weights of combine harvesters. The exploitation of heavy harvesters can have negative consequences:

high contact pressures between tires and soil and excessively soil compaction. To reduce the negative impact of harvesters exploitation, it is reasonable to analyze the changes in soil structure after the passages these machines.

The aim of research was the evaluation of changes in soil compaction due to the passages of combine harvesters.

METHODOLOGY

In general conception there was the assumption that, the research should be conducted in the field conditions. The analyzed parameter was the soil compaction, which was described by the changes in penetration resistance of soil. Main factor was the vertical load affected the soil. Furthermore, the influence of lateral tilt of harvester on the changes in the soil compaction was analyzed.

The research was carried out November 5, 2014 at the field in Brod nad Dyji, Pasohlavky municipality, district Breclav, Jihomoravsky country. The field belonging to the Vinofrukt a. s. enterprise.

The soil was classified as mold formed on loess. The soil particles size was described as light, the soil permeability was high. On the field, before the research, the maize was cultivated (research was conducted on the stubble, immediately after the harvest). A soil moisture before compaction was equal 29.7%, mean compaction in the range of depth 0–60 cm was 1.59 MPa. The changes in parameters of uncompacted soil were described in more detail in the section "Results" (as "control").

Measured parameter was the soil compaction after the passage of harvester John Deere 9880i STS Hillmaster, which was used for maize harvest. General view of this harvester was shown in Fig. 1.

2: *Electronic penetrometer PN-10*

Total weight of harvester (with the maize header) was 19 500 kg. By the completely filling of grain tank weight increased to 27 500 kg. The harvester was equipped with the tires, whose basic parameters were shown in the Tab. I.

Penetration resistance of the soil was measured using an electronic penetrometer PN-10, which was shown in Fig. 2.

Penetrometer had the cone with the apex angle 60° and base field 1 cm^2, the measurement range

1: *John Deere 9880i STS combine harvester*

I: *Parameters of harvester tires*

Axle	Tire designation	External diameter [mm]	Rim diameter [mm]	Tread width [mm]	Inflation pressure [MPa]
Front	800/65R32	1850	813	800	0.30
Rear	480/80R26	1430	660	480	0.25

was 0–10 MPa and the accuracy was equal 0.01 MPa. Penetration resistance was measured in the range of depth 0–60 cm. Each of measurement was done in three repetitions, and the arithmetic mean was calculated. Measurements were conducted in the rows after the passages of harvester, separately for front and rear wheels. When the harvester was laterally tilted, the measurements were done under the wheel on both side.

RESULTS

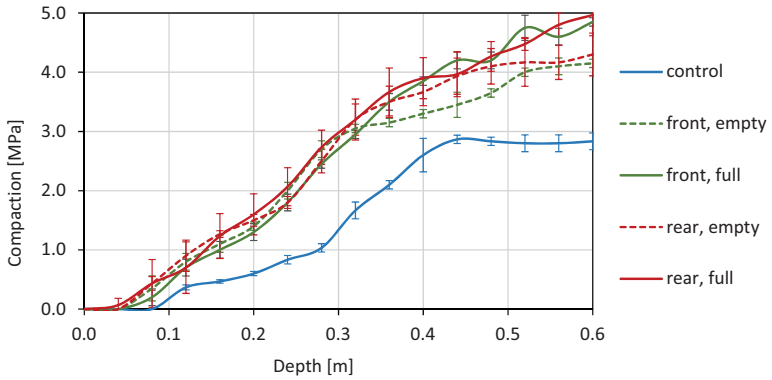
The results of the compaction measurements were shown as the function of depth. The courses of the compaction after the passages of non-tilted harvester were shown in Fig. 3.

Follow the Fig. 3, at low depth of measurement (0–30 cm) the level of vertical load has a negligible impact on the values of soil compaction. Moreover, there was small differences in values of compaction after the passage of rear and front wheel. Due to increase in measurement depth, it can observed increasing differences in values of compaction (compared to uncompacted soil – "control"). At the depth larger than 30 cm, the higher values of compaction concern the ruts after the passage of harvester with full grain tank – both for the front and rear wheels the values of compaction reach about 4.5 MPa (in the case of uncopacted soil the compaction does not exceed 3 MPa). Moreover, in the case of harvester with full grain tank higher values of compaction concerned the passage of rear wheel.

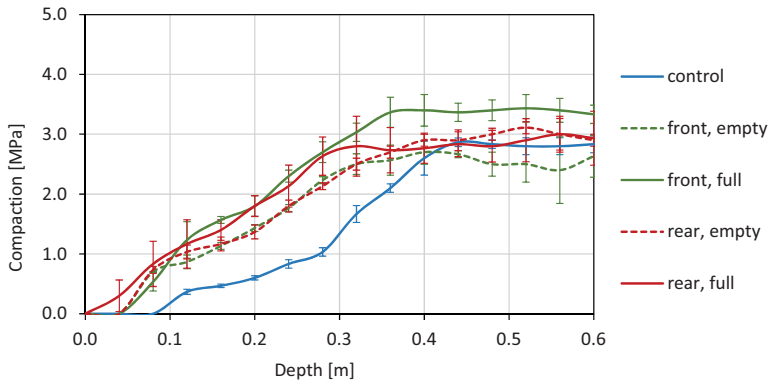
In Fig. 4 there are shown the courses of compaction after the passages of tilted harvester, on the side with higher vertical load.

Differences in compaction after the passage of tilted harvester were greater than in the previous described case. At low depth (from 0 to 30 cm) the continuous increase in compaction was observed. In this range of depth, the passages of harvester with full grain tank caused greater values of compaction (the compaction after the passage of harvester with empty tank was lower by 0.5 MPa). This trend was observed both after the passages of rear and front wheel. Moreover, at low depth of measurement, the highest differences in compaction between the ruts and uncompacted soil. At higher depth (more than 30 cm) the stabilization of courses was observed; the maximum values of compaction was observed for harvester with full grain tank. In other cases, values of compaction in ruts were similar like on the uncompacted soil (from 2.5 to 3.0 MPa).

The courses of compaction for the last variant of measurement (tilted harvester, ruts on the side with lower load) were showed in Fig. 5.



3: *Courses of compaction in the ruts after the passages of non-tilted harvester (vertical bars denote standard deviations)*



4: *Courses of compaction after the passages of tilted harvester, on the side with higher load (vertical bars denote standard deviations)*

Based on analysis the courses in Fig. 5, it can observed that the highest changes in compaction was at the depths below 40 cm. In the range of depth 0–20 cm, in ruts after the passages of harvester with full grain tank the values of compaction was lower than in the ruts after the passage of empty harvester – the difference was about 0.3 MPa. At lower depth of measurement (20–30 cm) this differences increase to 1 MPa. The differences between compacted and uncopacted soil were lower than in the two previous cases (average difference not exceeded 0.9 MPa). At the depth over 40 cm the courses were more stable – in this range higher values of compaction concerned the rut under front wheel. For the ruts after the passage of rear wheel the values of compaction was lower than on the uncompacted soil, but this situation could be due to local differences in soil compaction.

To compare the differences in values of compaction for all analyzed cases, the averages of compaction for the whole range of soil depth were calculated. These averages were shown in Fig. 6.

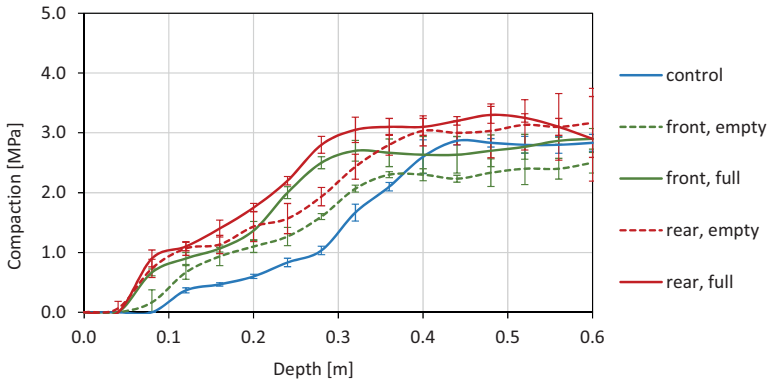
According to Fig. 6, the highest values of compaction were after the passage of non-tilted harvester. In these cases, the values of compaction were higher by 0.7–1 MPa (47–69%) compared to uncompacted soil. After the passages of tilted harvester (on more loaded side) the compaction was lower than after the passage of not-tilted harvester; for front wheel the differences were 30% and 9% each for empty and full tank (for rear wheels the differences were respectively 26 and 28%). Due to the fact that the tilt of harvester should cause an increase in vertical load on the size of tilt, it may be assumed that the deformation of tire will be greater (compared to non-tilted harvester). This phenomenon could be result in increase of contact area between the tire and soil – as a consequence the tires had less tendency to the sinkage into the soil, and the compaction was lower. This hypothesis is supported by the fact that the harvester was equipped with radial tires, which are more flexible than bias-ply tires.

Furthermore, in the ruts of rear wheels the compaction was higher than in the ruts of front wheels. A possible reason of this situation could be the fact that the rear wheels rolled in ruts, which was previously formed by the front wheel. Moreover, the rear tires were the narrower than the front tires and they could cause greater pressure on the soil.

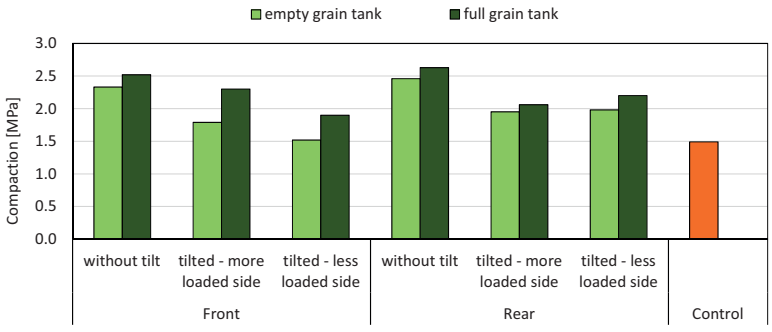
For averages of compaction the statistical analysis was conducted. The multifactor analysis of variance (with the probability level $\alpha = 0.05$) was done in

II: *Results of statistical analysis*

Factor	*p*-value
Filling of grain tank	0.00439
Tilt of harvester	0.00005
Wheel (front/rear)	< 0.00001



5: *Courses of compaction after the passages of tilted harvester, on the side with lower load (vertical bars denote standard deviations)*



6: *Averages of compaction values for whole range of soil depth*

Statistica 10.0; the results of this analysis were shown in Tab. II.

The p-values, which are shown in Tab. II describe the probability of influence of factors on analyzed parameter (soil compaction). When the *p*-value is greater than α-value, factor is not significant. Based on obtained results, it can concluded that all factors are significant for values of soil compaction.

DISCUSSION

The results are largely consistent with the results obtained by other researchers. It was found that the increase in vertical load of wheels (as a consequence of grain tank filling) resulted in a higher soil compaction in the ruts. This trend is in compliance with results in other papers whose authors founded that higher vertical forces may cause greater stress in the soil and increase in compaction (Raper *et al.*, 1994; Bailey *et al.*, 1996; Carman *et al.*, 2002; Knezevic *et al.*, 2007). Some authors stated that increase in vertical load of wheel may increase in contact area between tire and soil (due to deformation of the tire) – lower compaction will be consequence (Sharma and Pandey, 1996). This tendency is in accordance with results obtained in this paper; in the row after the passage of tilted harvester (on the side with higher load) the values of compaction were lower than after the passage of non-tilted harvester. Greatest changes in compaction were observed in depth range 0–30 cm – similar results were obtained by Arvidsson and Keller (2007) and Botta *et al.* (2002) – these authors shows that the highest intensity of compaction concerns the topsoil. Moreover, the values of compaction after the passages of rear wheels (with narrower tires) were lower than after the front wheel passage – similar results were showed in other papers (Sharma and Pandey, 1996; Antille *et al.*, 2008; Svoboda and Červinka, 2013) whose authors demonstrated that the wide tires may cause lower soil stresses and compaction compared to the narrow tires.

CONCLUSION

The paper presents the results of changes in soil properties after the passages of combine harvester. Research was conducted on the maize stubble. Analyzed parameter was the soil compaction, which were measured in the depth range 0–60 cm. The measurements were done in the ruts, after the passages of front and rear wheels of harvester. The passages of harvester were done by empty and full grain tank – thus the two levels of vertical load were obtained. Furthermore, the passages of harvester with lateral tilt were done – the measurements of compaction were conducted both on the more and less loaded side. Based on obtained results the following conclusion were formulated:

- The values of soil compaction were determined by the vertical load of wheel. At higher load (full grain tank of harvester) there were higher values of soil compaction – this trend was observed both for front and rear wheels.
- After the passage of lateral sloped harvester, in the ruts on more loaded size the values of compaction were lower than after the passage of harvester without slope. Probably, it can be result of greater tire deformation (of sloped harvester) and increase in contact area between tire and ground.
- After the passage of non-tilted harvester the changes in the compaction were observed for whole analyzed range of depth (above 30 cm the changes were smaller). For the sloped harvester, the changes in compaction at the highest depth were very small (there weren't the increases in values of compaction).

REFERENCES

ANTILLE, D. L., ANSORGE, D., DRESSER, M. L. and GODWIN, R. J. 2008. The effect of tire size on soil deformation and soil bulk density changes. *An ASABE Meeting Presentation*, Paper Number 083879: 1–11.

ARVIDSSON, J. and KELLER, T. 2007. Soil stress as affected by wheel load and tire inflation pressure. *Soil and Tillage Research*, 96: 284–291.

ARVIDSSON, J. and RISTIC, S. 1996. Soil stress and compaction effects for four tractor tires. *Journal of Terramechanics*, 33(5): 223–232.

BAILEY, A. C., RAPER, R. L., WAY, T. R., BURT, E. C. and JOHNSOHN, C. E. 1996. Soil stresses under tractor tire at various loads and inflation pressures. *Journal of Terramechanics,* 33(1): 1–11.

BASHFORD, L. L., AL-HAMED, S. and JENANE, C. 1993. Effects of tire size and inflation pressure on tractive performance. *ASAE Paper,* 92(1011): 343–348.

BOTTA, G. F., JORAJURIA, D. and DRAGHI, L. 2002. Influence of the axle load, tire size and configuration on the compaction of a freshly tilled clayey soils. *Journal of Terramechanics*, 39: 47–54.

CARMAN, K. 2002. Compaction characteristics of towed wheels on clay loam in a soil bin. *Soil and Tillage Research,* 65: 37–43.

CHAN, K. Y., OATES, A., SWAN, A. D., HAYES, R. C., DEAR, B. S. and PEOPLES, M. B. 2006. Agronomic consequences of a tractor wheel soil compaction on a clay soil. *Soil and Tillage Research*, 89: 13–21.

HORN, R., WAY, T. R. and ROSTEK, J. 2003. Effect of repeated tractor wheeling on stress/strain properties and consequences on physical properties in structured arable soils. *Soil and Tillage Research*, 73: 101–106.

KNEZEVIC, D., SUMANOVAC, L., JURIC, T., LUKAC, P. and ATANASOV, A. 2007. The effects of wheels or tracks on soil. In: *1st International Conference Research People and Actual Tasks on Multidisciplinary Sciences.* 6–8 June. Lozenec, Bulgaria: Bulgarian National Society of Agricultural Engineers, 128–132.

LIPIEC, J. and HATANO, R. 2003. Quantification of compaction effects on soil physical properties and crop growth. *Geoderma*, 116: 107–136.

NEVENS, F. and REHEUL, D. 2003. The consequences of wheel-induced soil compaction and subsoiling for sillage maize on a sandy loam soil in Belgium. *Soil and Tillage Research*, 70: 175–184.

RAPER, R. L., BAILEY, A. C., BURT, E. C. and JOHNSON, C. E. 1994. Prediction of soil stresses caused by tire inflation pressures and dynamic loads. *An ASAE Meeting Presentation,* No. 941547: 1–14.

SHARMA, A. K. and PANDEY, K. P. 1996. The deflection and contact characteristics of some agricultural tires with zero sinkage. *Journal of Terramechanics,* 33(6): 293–299.

SVOBODA, M. and ČERVINKA, J. 2013. Vliv různé pneumatiky u kloubového traktoru na utuženost půdy. *Komunální technika,* VII(5).

ZINK, A., HEIGE, H. and HORN, R. 2011. Verification of harmful subsoil compaction in loess soils. *Soil and Tillage Research,* 114: 127–134.

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