THE INFLUENCE OF TRAFFIC IN PERMANENT TRAFFIC LANES ON SOIL COMPACTION PARAMETERS

Dumitru Gutu[1], Josef Hula[2*], Frantisek Kumhala[2], Pavel Kovaricek[3]

[1]ZAS Podchotuci a.s., Krinec, Czech Republic,
[2]Czech University of Life Sciences Prague, 165 21 Prague 6 – Suchdol, Czech Republic,
Phone: +420-224383123, E-mail: hula@tf.czu.cz
[3]Research Institute of Agricultural Engineering, Prague, Czech Republic

Abstract

In a field trial in a field of 10 hectares all field operations were carried out by machine sets in the system of permanent traffic lanes at the module of 6-metre working width. The total area of machine tracks in the field accounted for 32 % of the field area, which represents a significant reduction in comparison with a conventional method of driving in fields, when the proportion of the track area is 75 up to 100 % of the total field area. The present paper contains results of measurement of soil physical properties in variants with traffic lanes and outside the traffic lanes. The results confirm a benefit from confining the wheel traffic to permanent traffic lanes aimed at protection of the most part of the field from soil compaction. Another advantage of the above-mentioned permanent traffic lanes is an improvement of soil tillage quality in the most part of the field.

Keywords: permanent traffic lanes, soil compaction, soil physical properties

Introduction

Modern technologies of field crop cultivation are connected with wheel traffic in fields that causes undesirable soil compaction. Soil compaction can result in a crop yield decrease, however, environmental consequences are particularly alarming. In the course of intensive rainfalls, decreased infiltration of precipitation water on compacted soils increases surface water runoff, implying a high risk of soil water erosion. Necessary water accumulation in the soil is diminished at the same time. Another consequence of soil compaction is an increase in energy requirements for soil tillage, impairment of soil tillage quality associated with the worsening of conditions for sowing.

In recent years intensive researches on problems of undesirable soil compaction have been conducted (Håkansson, 1995; Unger, 1996). The load of wheel traffic may cause different reactions in the soil profile during the year, first of all in relation with instantaneous soil moisture and degree of preceding soil loosening or compaction.

Proposals to confine the necessary wheel traffic of farm machines in fields to permanent tracks already appeared in the eighties of the last century. At that time no technical equipment was available that would allow using the system of permanent traffic lanes – reliable and precise navigation of machinery during its movement in fields was missing. Currently, there are great efforts to restrict the wheel traffic of farm machines in fields to defined tracks in order to maintain a major part of the area under crops without negative influence of wheel traffic (Chamen et al., 2003; Tullberg, 2007). The system of controlled traffic farming (CTF) is currently considered as promising also because satellite navigation systems are available that make it possible to ensure the required accuracy of passes during field operations including sowing.

In an agricultural enterprise possessing high-performance farm machinery a field trial was established in which besides the influence of wheel traffic restriction to permanent lanes on soil properties and on the quality of soil tillage a possibility of CTF technology realization in farming conditions was tested.

Material and method

A field trial on a land of 10 ha in size was established in the spring 2010. Soil conditions in the field: loamy soil (content of particles smaller than 0.01 mm in the topsoil layer: 38.3 % by weight). Content of combustible carbon in topsoil: 3.8 %.

In 2009 after winter wheat harvest the field was worked by a sweep cultivator to a depth of 80 mm, in autumn the soil tillage by a combined cultivator to a depth of 200 mm followed. After this medium-deep cultivation of soil the field remained without wheel traffic until spring 2010, when wheel traffic was organised within the CTF system using OutTrac (Chamen, 2006) – Fig. 1. It is typical of this wheel traffic system that the wheel tracks of a harvester-thresher that has a wider wheel gauge than tractors are on the outer side of common permanent traffic lanes.

Tab. 1 gives an overview of farm machines used for field operations in the field. Those machines were chosen whose working width corresponded to the basic module of 6 m. The field operations of soil tillage and sowing were performed at the working width of 6 m. The wheel rows established during sowing were used for the application of chemicals for plant protection while the working width of a sprinkler was 18 m. The same wheel rows were also used for the application of mineral fertilisers.

To evaluate the influence of wheel traffic of farm machines on the soil in a system of restricted wheel traffic four variants of traffic lanes were defined:

1. Traffic lanes of tractors during sowing, application of chemicals for plant protection, application of mineral fertilisers and during stubble breaking and other soil tillage.
2. Traffic lanes of dual wheels of a tractor during sowing, lanes of a combine harvester and lanes of a tractor during stubble breaking and other soil tillage.
3. Outside the traffic lanes.
4. Part of the field with uncontrolled wheel traffic (area of 3 ha).

In the particular variants of the field trial measurements were done with a PN 100 self-recording penetrometer and basic physical properties of soil were evaluated in the spring and autumn season. After soil tillage was carried out, the indicators of soil tillage quality were assessed. To measure the shearing strength of soil a CL-100 vane probe (Terratest) was used.

A GPS satellite system with the correction signal of RTK VRS was used for the navigation of farm machines during sowing, soil tillage, application of chemicals for plant protection and during harvest. An assisted steering system AgGPS EZ-STEER (Trimble) was used. The vehicles for grain transport during the operation of a harvester-thresher did not pass across the field, the grain tank of a harvester-thresher was emptied to a tractor semi-trailer on the edge of the field near the road.

The present paper contains the results of evaluation of wheel traffic impacts on the soil in a field trial in 2011 (the second year of the consistent application of controlled traffic farming in a field). In that year winter wheat was grown in the field concerned, after its harvest soil tillage for winter wheat sowing followed.

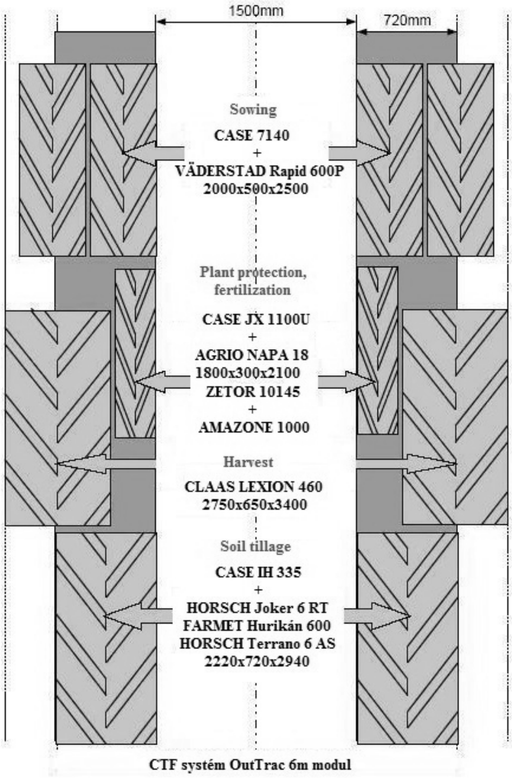

Fig. 1 Wheel ruts of tractors and combine harvester after their restriction to permanent traffic lanes – the area of lanes is enlarged by the wheel track of combine harvester that is larger than that of tractors and by dual wheels of tractor during sowing

Tab. 1 Field operations in 2011 and data of farm machines

Field operation	Time	Machines	Working width [m]	Distance of tracks [mm]	Tyre width [mm]
Sowing of winter wheat	12.10. 2010	CASE 7140 + VÄDERSTAD Rapid 600P	6	2000	500x2
Fertilization with mineral fertilizers	11.3. 2011	ZETOR 10145 + AMAZONE 1000	18	1800	300x2
Pesticide application	6.5. 2011.	CASE JX 1100U + AGRIO NAPA 18	18	1800	320x2
Fertilization with mineral fertilizers	9.5. 2011	ZETOR 10145 + AMAZONE 1000	18	1800	300x2
Fertilization with mineral fertilizers	30.5. 2011	ZETOR 10145 + AMAZONE 1000	18	1800	300x2
Pesticide application	13.6. 2011.	CASE JX 1100U + AGRIO NAPA 18	18	1800	320x2
Winter wheat harvest	18.8. 2011	CLAAS Lexion 460	6	2750	650x2
Shallow loosening (depth 80-100 mm)	3.9. 2011	CASE IH 335 + FARMET Hurikan 600	6	2220	720x2

Results and discussion

Fig. 2 shows the average values of some physical properties of soil after undisturbed soil samples were taken on 14th April 2011. At a depth of 50-100 mm the highest bulk density of soil was recorded in variant 1 – in this variant only one pass of machines across the field was done from wheat sowing in October 2010 (application of mineral fertilizer on 11th March 2011). The lowest values of bulk density of soil were found out on the land outside the wheel tracks. The values of minimum air capacity expressing the volume of pores that remain filled with air after capillary pores have been filled with water are a significant indicator of the degree of soil compaction (Fig. 3). The values of minimum air capacity lower than 10 % of the volume document undesirable soil compaction; the graph illustrates that these low values were measured at a depth of 50-100 mm in variant 4 (uncontrolled wheel traffic). A similar trend of differences in physical properties of soil was observed at a depth of 150-200 mm while at other evaluated depths (250-300 mm and 350-400 mm) there were no differences that would indicate a different degree of soil compaction in the particular variants.

Fig. 3 illustrates the values of soil penetration resistance measured on 12th April 2011. On that date statistically significantly higher penetration resistance was recorded in variant 1 compared to variants 2, 3 and 4 at measurement depths of 40, 80 and 120 mm, with the average soil moisture of 15.8 % of the weight at these depths. This difference can be ascribed mainly to soil compression by the tractor wheels during regeneration fertilization of winter wheat with mineral fertilizer (11th March 2011). These distinct differences were not recorded at other measured depths any more – penetrometer measurements were done to a depth of 500 mm.

Tab. 1 shows that in 2011, besides regeneration fertilization on 11th March, one field operation of chemical plant protection and two operations of production fertilization were performed in the course of May; these field operations necessitated tractor passes in wheel rows – variant 1. Measurements with vane probe on 29th June showed increasing differences between variant 1 (wheel rows) and the other variants. From these measurements values of the shearing strength of soil at a depth of 50 mm (in kPa) are presented (Fig. 4). Values of the shearing strength of soil in variant 1 were more than four times higher than in the other evaluated variants while the differences were statistically significant. Average soil moisture at the measurement depth was 11.3 % of the weight in variant 1 and 14.1 % of the weight in variants 2, 3 and 4. These results document the increasing soil bearing capacity within wheel rows as a consequence of wheel traffic in the spring 2011 and increasing differences in the degree of soil compression between variant 1 and the other variants. From the aspect of machine movement on the land repeated passes in the same tracks improve the “passability” of these tracks and conditions for a reduction of rolling resistance are created.

Using machinery of the ZAS Podchotuci, a.s. agricultural enterprise in Krinec, a system of controlled traffic farming with consistent separation of wheel tracks of machines from the production area of the field without traffic was realized on the land of 10 ha in area this agricultural enterprise is farming on. Although the wheels of tractors and harvester-threshers are not designed for their use in the CTF system (wider wheel gauge of harvester-threshers than the wheel gauge of tractors), a relatively good situation was reached when the total area of wheel tracks in the field (with the exception of headland) accounted for 32 % of the land area if the module of the 6-metre working width of machines was used. If the module of the 8-metre working width of machines were used, it would be realistic to decrease the area of wheel tracks to 20 – 25 % of the field area. It is a significant reduction of the wheel-tracked field area – according to Chamen (2006) the wheel-tracked area amounts to 75 – 100 % of the field area in a conventional system of machine passes. In conditions of the CR the monitoring of wheel traffic in fields showed that the proportion of wheel tracks accounted for 86 % of the field area in the production system of winter wheat with conventional soil tillage (Kroulik et al., 2011).

A decrease in the proportion of wheel tracks in the total area of fields could be reached by unification of the wheel gauge of tractors and harvesting machines. It is a costly approach, but these adaptations of machines for the CTF system are already implemented in other countries (Tullberg, 2010).

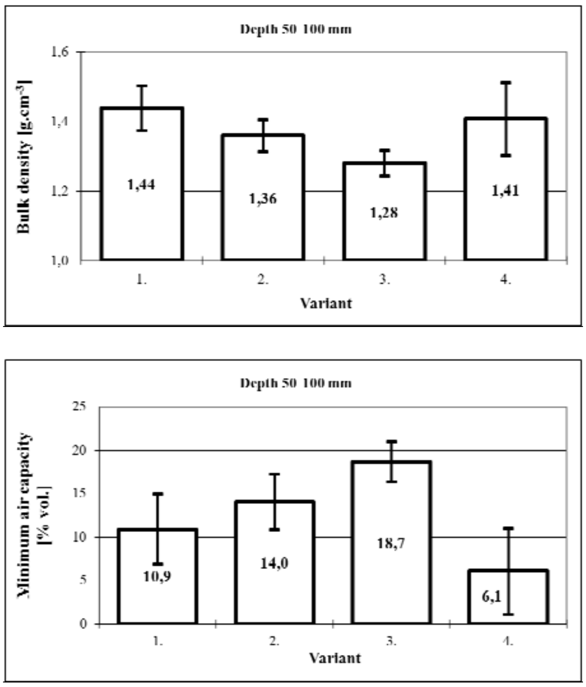

Fig. 2 Bulk density and minimum air capacity at a depth of 50-100 mm (14th April 2011)

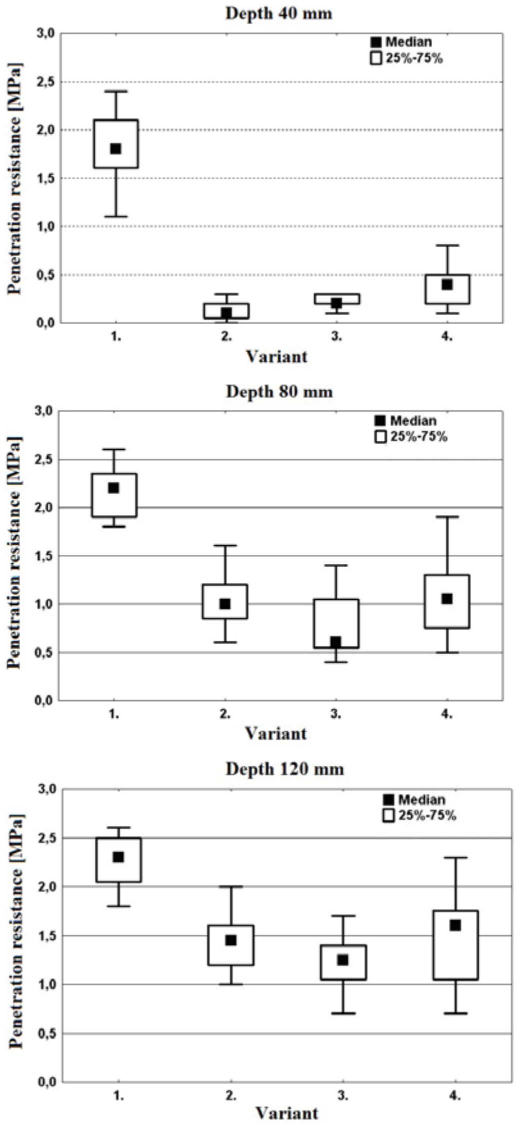

Fig. 3 Soil penetration resistance at a depth of 40, 80 a 120 mm (12th April 2011)

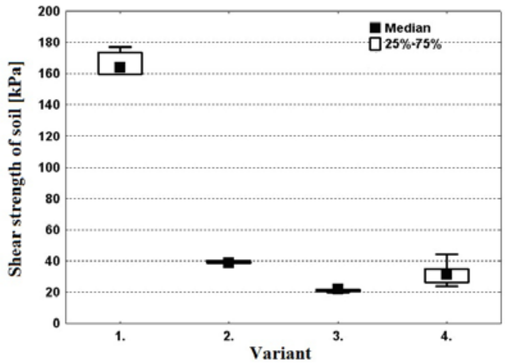

Fig. 4 Shear strength of soil at a depth of 50 mm (29th June)

Conclusion

The results of a pilot field trial obtained in 2011 demonstrate that the controlled traffic farming system can be realized in conditions of an agricultural enterprise. It should be based on the use of a precise navigation satellite system with the correction signal in connection with the assisted or automated steering of tractors and combine harvesters, and of course on the willingness to apply this non-traditional technology.

The findings from the assessment of machine work quality during soil tillage in 2011 did not confirm the impairment of the quality of soil preparation for sowing in a situation when the passes of machine sets were not diagonal to the direction of crop rows. Naturally, the controlled traffic farming system is not suitable for soil tillage with ploughing but it can be used in minimum tillage and soil conservation technologies for the production of crops harvested by combine harvesters.

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