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SOIL CHARACTERISTICS IN THE SYSTEM WITH PERMANENT TRAFFIC LANES AFTER TWO YEARS OF ITS BEGINNING

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In a field experiment on a plot of 10 ha in sugar beet production area physical soil properties and the soil's ability to absorb water from rainfall were evaluated thereafter two years since the system of controlled crossings had been applied. Soil conditions: calcaric Leptosols soil type, loamy soil, slope of 2.0 to 4.2 degrees. Therefore the benefits of controlled crossings system to protect the soil from excessive compaction have been confirmed. Concentration of wheel tracks into permanent lines improved conditions for the movement of machinery on the field. Bearing capacity of soil increased in the areas of wheel tracks – penetration resistance of the surface soil layer in summer was 2.7 to 4.4 times higher in the parts of wheel tracks than in areas outside of tracks. In the parts of the area with random traffic penetration resistance was measured 1.9 times higher than in the parts without wheel tracks. Concentration of wheel tracks also contributed to improve the quality of soil tillage – the area without wheel tracks accounted for 68% of the land area when the working width of 6 m module was used. When measuring surface water runoff by rain simulator the water runoff occurred at 10.0 minutes, respectively at 11.6 minutes in the parts with wheel tracks, while in areas without wheel tracks the surface water runoff occurred after 29.6 minutes and the rate of water runoff was significantly lower in the parts without traffic than in the wheel tracks. Concentration of wheel tracks into permanent traffic lines may be one of the ways to increase the soil ability to absorb water during intense rainfall.

Keywords: controlled traffic farming, soil physical properties, surface water runoff.

INTRODUCTION

Current technologies of field crop cultivation are connected with intensive wheel traffic in fields that causes undesirable soil compaction. Soil can have different resistance to compression by heavy machines. The crucial factors are soil moisture, soil texture and content of organic matter in the soil. Soil compaction can lead to a decrease in the yield of crops, moreover the consequences for the environment are particularly alarming. Reduction of rainfall infiltration in compacted soil increases surface water runoff during intense rainfall, which means a high risk of soil water erosion. At the same time the necessary ability of soil for accumulation of water in the soil is reduced. Increase in energy requirements for tillage, tillage quality deterioration associated with worsening of conditions for sowing are the other undesirable consequences of soil compaction.

Soil compaction cannot be eliminated in technological systems but it is possible to contribute to a reduction in the intensity of soil compaction. One of the possibilities is to concentrate the wheel traffic in fields to permanent traffic lanes in order to ensure that a major part of the production area of fields will be without the negative influence of wheel traffic (Chamen et al., 2003; Tullberg, 2010). This is the basis of the system CTF (Controlled Traffic Farming). CTF system can be used in farming conditions due to the existence of precise navigation systems in combination with the automated steering of tractors and other machines passing in fields. A contribution of the CTF system is a reduction in the rolling resistance of wheels, and also lower energy requirement for soil tillage if the major part of the field area is without soil compression by wheels (Kroulík et al., 2011; Tullberg et al., 2007).

The aim of the field trial was to specify the differences in topsoil after two years of use in the system with permanent traffic lanes and compare selected soil properties with parts of field with random traffic.

MATERIALS AND METHODS

Field trial was established in conditions of the farm in sugar beet production area in spring 2010 – Krinec locality, Central Bohemia (50°13'50.82" N, 15°06'9.65" E), agricultural company ZAS Podchotuci, joint-stock company, altitude of 190 to 198 meters. Climate region is slightly warm, mildly arid. Soil conditions in the experimental plot: calcaric

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Leptosols, loamy soil (content of particles smaller than 0.01 mm in the topsoil layer: 38.3% by weight). Carbon content in topsoil: 3.8%. The slope of 2,0 to 4,2 degrees.

Medium deep loosening took place in October 15, 2009 (Horsch Tiger 4MT, tillage depth: 0.25 m). The field remained without wheel traffic until spring 2010, when traffic on the field was organised in the CTF system with utilizing OutTrac (Chamen, 2006) – Fig. 1. On this experimental plot the soil properties were evaluated in four variants (treatments) of wheel impact on soil:

Treatment 1 – Traffic lanes including application of pesticides and mineral fertilizers (working width 18 m);
Treatment 2 – Traffic lanes without application of pesticides and mineral fertilizers;
Treatment 3 – Outside the traffic lanes;
Treatment 4 – Random traffic - part of the field with uncontrolled wheel traffic (area of 3 ha).

On the experimental plot were used these machine sets: CASE 335 + FARMET Hurikan 600 (shallow loosening), CASE 335 + Simba SLD 600 (medium deep loosening), NEW HOLLAND + VÄDERSTAD Rapid 600P (SOWING), CASE JX 1100U + AGRIO NAPA 18 (pesticides application), ZETOR 10145 + AMAZONE 1000 (mineral fertilizers application), CLAAS Lexion 460 (harvest).

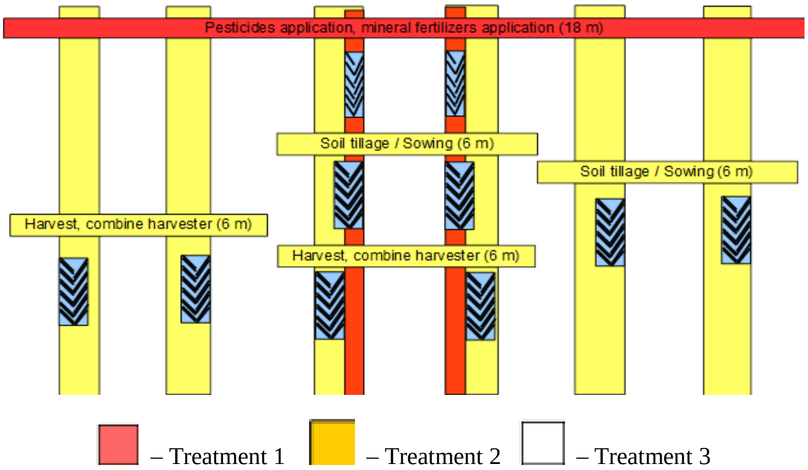

Figure 1. Permanent traffic lanes of tractors and combine harvester – machines working width of 6 m and 18 m

Basic soil physical properties were evaluated in the particular variants of the field experiment by means of undisturbed soil samples taken into Kopecky´s rings (100 cm^3). Sample analysis was done by the standard way (Valla et al. 2008). The results show the total porosity of the soil. This characteristic is related to soil ability to absorb water from intense rainfall. Undisturbed soil samples were taken from a depth of 0.05 to 0.10 m, 0.15 to 0.20 m, 0.25 to 0.30 m and 0.35 to 0.40 m (in five replications).

PN 100 self-recording soil cone penetrometer was used for measurements of penetration resistance (the apex angle of 30° – ASAE S313.2). Pocked penetrometer Eijkelkamp with cylindrical body (foot diameter 6.35 mm, depth of pushing the cylinder: 6.35 mm) was used to measure the penetration resistance of surface soil layer.

Rain simulator was used to measure the surface water runoff in April 2012. The measurement area was 0.5 m^2 in size and at rainfall intensity of 87.8 mm h^{-1} using three replications for each treatment. Infiltration rate is determined by the defined rainfall intensity that is constant for the time of measurement and from surface water runoff from the measurement area (Kovaříček et al., 2008). Measurements by the rain simulator were held in April 2012.

Software MS Excel 2010 and STATISTICA CZ software version 12 (StatSoft) and the statistical analysis ANOVA with Tukey HSD test –homogeneous groups test ($\alpha = 0.05$) were used for data processing.

For navigation of machine sets during soil tillage, sowing, pesticides application, application of mineral fertilizers and during harvest a GPS satellite system with the correction signal of RTK VRS was used. Machines were steered by assisted steering system AgGPS EZ-STEER (Trimble). Table 1 shows field operations and machine sets used for work operations on the experimental field.

Table 1. Field operations and machines sets

Field operation	**Machines**	**Working width [m]**	**Distance of tracks [mm]**	**Tyre width [mm]**
Shallow loosening	CASE 335 + FARMET Hurikan 600	6	2220	720x2
Medium deep loosening	CASE 335 + Simba SLD 600	6	2220	720x2
Sowing	NEW HOLLAND 7060 + VÄDERSTAD Rapid 600P	6	2150	500x2
Mineral fertilizers application	ZETOR 10145 + AMAZONE 1000	18	1800	300x2
Pesticide application	CASE JX 1100U + AGRIO NAPA 18	18	1800	320x2
Harvest	CLAAS Lexion 460	6	2750	650x2

The paper gives the results of evaluation of wheel traffic influence on the soil in a field trial in 2012 (the third year of the consistent application of controlled traffic system on the experimental field). On the experimental field was winter wheat in 2012.

RESULTS AND DISCUSSION

Soil physical properties were determined at sites with different intensity of the wheel traffic effect on soil in the third year of the field experiment in spring 2012. Graph in Fig. 2 shows total porosity of soil in the topsoil layer.

In April 2012, as expected the highest soil porosity was at sites without wheel tracks (variant 3), the values of soil porosity were lowest in treatment 1 where was the highest intensity of wheel traffic. At a depth of 0.25–0.30 m and 0.35 –0.40 m there were small differences in the values of soil porosity between the variants. Porosity was in the range of 36.2 % to 37.7 % (depth 0.25–0.30 m) and 38.3 % to 39.5 % (depth 0.35–0.40 m respectively).

It was confirmed that the CTF system was favourable for indicators of soil physical properties in the most area of the field. This corresponds to the results of McHugh et al. (2009): controlled traffic system can improve the physically degraded soil after random field wheeling. Reduction even elimination of soil compaction can be achieved by applying of CTF system (Controlled Traffic Farming) in combination with suitable mechanical loosening, addition of organic matter and a suitable crop rotation (Hamza and Anderson, 2005).

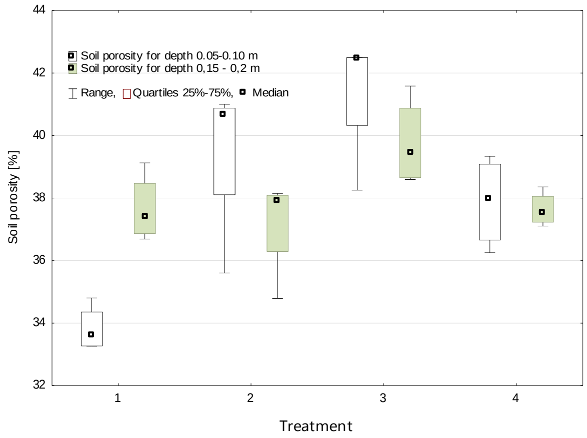

Figure 2. Total soil porosity at a depth of 0.05-0.10 m and 0.15-0.20 m (26th April 2012)

Treatment 1 – Traffic lanes including application of chemicals for plant protection and mineral fertilizers; Treatment 2 – Traffic lanes without application of chemicals for plant protection and mineral fertilizers; Treatment 3 – Outside the traffic lanes; Treatment 4 – Random traffic.

The graph in Fig. 3 shows the soil penetration resistance values in spring. In this term penetration resistance in treatment 1 was significantly higher than in the other variants at depths of 0.04 m and 0.08 m when the average soil moisture in these depths was 25.6 % vol. These differences can be attributed mainly to effects the tractor wheels on the soil in operation of the regeneration fertilizing of winter wheat. Significant differences of penetration resistance were not found in other measured depths. The average soil moisture (weight %) in the topsoil: 28.3 % (Treatment 1), 27.5 % (Treatment 1, 2), 26.9 % (Treatment 3), 28.2 % (Treatment 4).

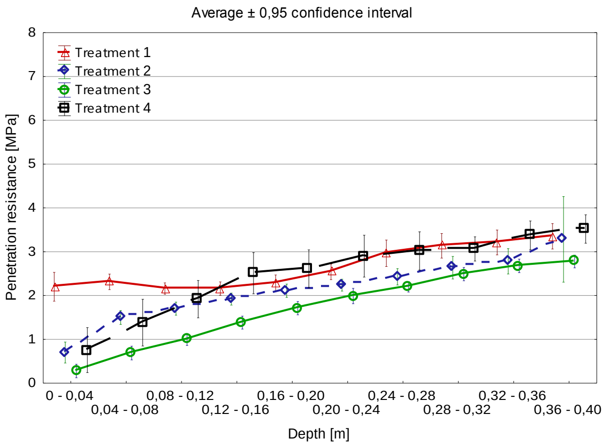

Figure 3. Penetration resistance in spring (26th April 2012)

Treatment 1 – Traffic lanes including application of chemicals for plant protection and mineral fertilizers; Treatment 2 – Traffic lanes without application of chemicals for plant protection and mineral fertilizers; Treatment 3 – Outside the traffic lanes; Treatment 4 – Random traffic.

On the Fig. 4 there are the values of the surface soil layer resistance to the penetration of the cylindrical body of a pocket penetrometer (in summer). At the beginning of July there were statistically significant differences in the measured values between treatments 1, 2, 3 and 4 (Tukey HSD test). Fig. 5 illustrates the values of the penetration resistance measured during the crumbling of clods by autumn soil tillage. At this time the penetration resistance of clods was significantly lower in variant 3 than in the other variants (treatments 1, 2 and 4). These results show better conditions for soil tillage in the areas without wheel tracks than in the areas with tracks and in the areas with random traffic. Penetration resistance of topsoil was greatest in areas where there were most concentrated crossings (Treatment 1 – spraying rows). On the other hand these results showed a greater bearing capacity in the areas of traffic rows due to crossings and improving "riding" these tracks and create conditions for reducing rolling resistance, which is not contrary with the results of other authors (Keller and Arvidsson, 2004; Defossez and Richard, 2002).

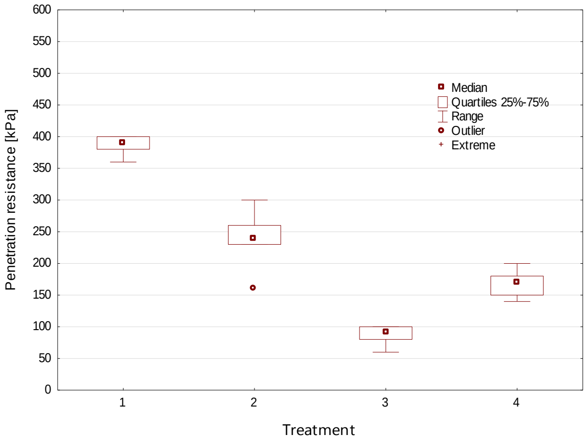

Figure 4. Penetration resistance at a depth of 0.05 m (2nd July 2012) – soil moisture content (weight, %): 9.8 % (Treatment 1), 15.7 % (Treatment 2), 18.0 % (Treatment 3), 17.3 % (Treatment 4)

Treatment 1 – Traffic lanes including application of chemicals for plant protection and mineral fertilizers; Treatment 2 – Traffic lanes without application of chemicals for plant protection and mineral fertilizers; Treatment 3 – Outside the traffic lanes; Treatment 4 – Random traffic.

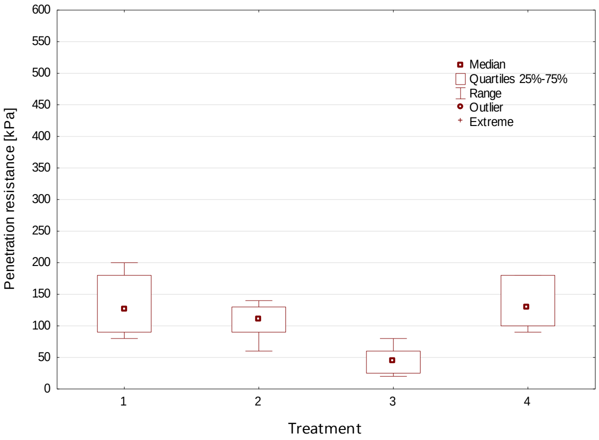

Figure 5. Penetration resistance measured during the crumbling of clods by autumn – depth of 0.05 m (11th November. 2012) – soil moisture content (weight, %): 20.1 % (Treatment 1), 19.8 % (Treatment 2), 19.6 (Treatment 3), 20.1 (Treatment 4)

Treatment 1 – Traffic lanes including application of chemicals for plant protection and mineral fertilizers; Treatment 2 – Traffic lanes without application of chemicals for plant protection and mineral fertilizers; Treatment 3 – Outside the traffic lanes; Treatment 4 – Random traffic.

The graphs in Fig. 6, 7, 8 and 9 show the results of surface water runoff values measured by rain simulator. These results confirmed the research hypothesis: part of the area without tracks has a high soil ability to absorb water from intense rainfall, but with increasing compaction of soil in wheel tracks the soil ability for water infiltration is reduced and surface water runoff increases. An important indicator is the beginning of flooding (tp).

During simulated rainfall process the soil absorbed all the water for less than ten minutes in the parts of the area with the highest intensity of wheel tracks (treatment 1, Fig. 6). After this measured time there was a surface water runoff which increases progressively. After approximately thirty minutes the surface water runoff was stabilized at approximately consistent value. Higher ability of soil to absorb water from rainfall was measured in treatment 2 (Fig. 7). High degree of water infiltration into the soil, late beginning of surface water runoff and generally low values of surface water runoff were found in treatment 3 (area without wheel tracks, Fig. 8). Rate of surface runoff on treatment 4 (Random traffic) is in Fig. 9. These results confirm the data published by Raper and Kirby (2006) and Hamza and Anderson (2005). Favourable effect of CTF on water infiltration into the soil is also confirmed by Yuxia et al. (2001).

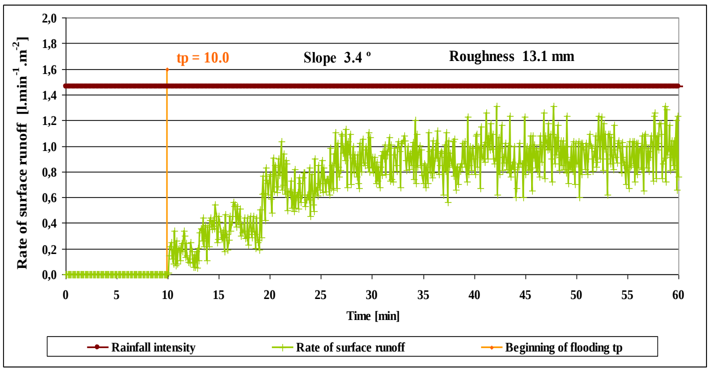

Figure 6. Rate of surface runoff (26th April 2012) tp – beginning of surface water runoff (beginning of flooding) Treatment 1 – Traffic lanes including pesticides application and mineral fertilizers application.

During intense rainfall even excessive water infiltration into the soil may occur in the parts of the area without wheel tracks. Therefore it would be appropriate to apply differentiated soil tillage in the CTF system – to reduce the depth and intensity of tillage in the parts of the area without wheel tracks.

It is possible to confirm that a major barrier to adoption of CTF system in practice is the deficiency of compatibility in equipment as reported Tullberg (2010).

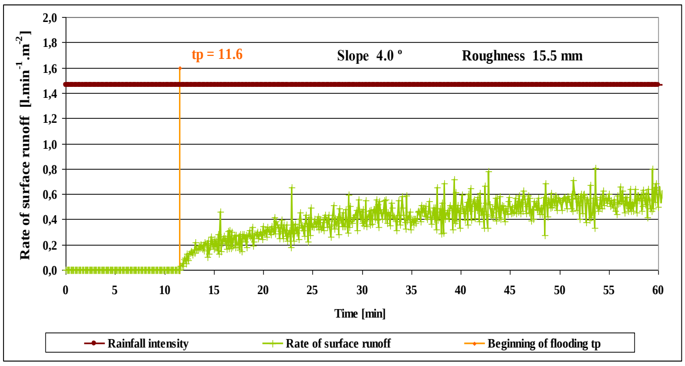

Figure 7. Rate of surface runoff (26th April 2012)
Treatment 2 – Traffic lanes without pesticides application and mineral fertilizers application.

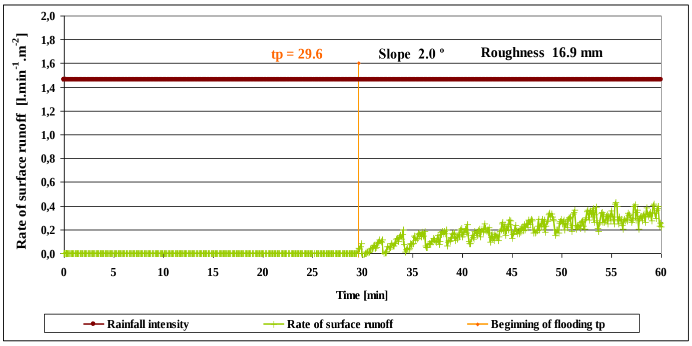

Figure 8. Rate of surface runoff (26th April 2012)
Treatment 3 – Outside the traffic lanes.

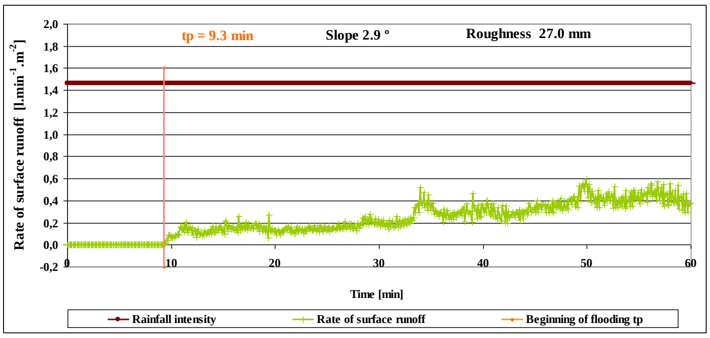

Figure 9. Rate of surface runoff (26th April 2012)
Treatment 4 – Random traffic.

CONCLUSION

The evaluation of soil physical properties two years after the start of a field experiment showed favourable soil physical properties on a part of the field without wheel tracks (68 % of the field area when the working width module of 6 m was used). The technological characteristics of soil were also better on a part of the field without wheel tracks. It was found considerably different soil's ability to infiltrate water in places with different intensity of wheels effect on the soil. In areas without wheel tracks the surface water runoff occurred after 29.6 minutes. That is almost three times longer period than in the traffic lanes and 3.2 times longer time than in the treatment with random traffic. The results indicate that the Controlled Traffic Farming (CTF) technology can improve the soil water absorption during rainfalls. Concentration of wheel tracks into permanent traffic lanes improves the bearing capacity of soil for tractors – penetration resistance of the soil surface layer in summer was 2.7 to 4.4 times higher in the wheel tracks than outside the tracks.

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REFERENCES

1. Chamen, W.C.T. 2006. Controlled traffic farming on a field scale in the UK. In: Horn, R., Fleige, H., Peth, S., Peng, X.H., (Eds.): Soil Management for Sustainability. *Advances in geoecology*, Vol. 38, pp. 251–260.
2. Chamen, W.C.T., Alakukku, L., Pires, S., Sommer, C., Spoor, G., Tijink, F., Weisskopf, P. 2003. Prevention strategies for field traffic - induced subsoil compaction: a review, Part 2. Equipment and field practices. *Soil & Tillage Research*, Vol. 73, pp. 161–174. http://dx.doi.org/10.1016/S0167-1987(03)00108-9
3. Defossez, P., Richard G. 2002. Models of soil compaction due to traffic and their evaluation. *Soil and Tillage Research*, Vol. 67, pp. 41–64. http://dx.doi.org/10.1016/S0167-1987(02)00030-2
4. Hamza, M.A., Anderson, W.K. 2005. Soil compaction in cropping systems. A review of the nature, causes and possible solutions. *Soil & Tillage Research*, Vol. 82, Iss. 2, pp.121–145. http://dx.doi.org/10.1016/j.still.2004.08.009
5. Keller, T., Arvidsson, J. 2004. Technical solutions to reduce the risk of subsoil compaction: effects of dual wheels, tandem wheels and tyre inflation pressure on stress propagation in soil. *Soil and Tillage Research*, Vol. 79, pp. 191–205. http://dx.doi.org/10.1016/j.still.2004.07.008
6. Kovaříček, P., Šindelář, R., Hůla, J., Honzík, I. 2008. Measurement of water infiltration in soil using the rain simulation method. *Research in Agricultural Engineering* Vol. 54, pp. 123–129.
7. Kroulík, M., Kvíz, Z., Kumhála, F., Hůla, J., Loch, T. 2011. Procedures of soil farming allowing reduction of compaction. *Precision Agriculture*, Vol. 12, Iss. 3, pp. 317–333. http://dx.doi.org/10.1007/s11119-010-9206-1
8. McHugh, A. D., Tullberg, J. N., Freebairn, D. M. 2009. Controlled traffic farming restores soil structure. *Soil & Tillage Research*, Vol. 104, pp. 164–172. http://dx.doi.org/10.1016/j.still.2008.10.010
9. Raper, R., Kirby, J., 2006. Soil compaction: How to do it, undo it, or avoid it. In.: Agricultural Equipment Techonology Conference. Louisville, Kentucky, USA, 2006. 14 pp.
10. Tullberg, J. 2010. Tillage, traffic and sustainability – A challenge for ISTRO. *Soil & Tillage Research*, Vol. 111, pp. 26–32. http://dx.doi.org/10.1016/j.still.2010.08.008
11. Tullberg, J. N., Yule, D. F., McGarry, D. 2007. Controlled traffic farming - From research to adoption in Australia. *Soil & Tillage Research*, Vol. 97, pp. 272–281. http://dx.doi.org/10.1016/j.still.2007.09.007
12. Valla, M., Kozák, J., Němeček, J., Matula, S., Borůvka, L., Drábek, O. 2008. Pedological practicum. ČZU v Praze, Praha, (in Czech).
13. Yuxia, L., Tullberg, J. N., Freibairn, D. M. 2001. Traffic and residue cover effects on infiltration. *Australian Journal of Soil Research*, Vol. 39, pp. 239–247. http://dx.doi.org/10.1071/SR00017
14. ASAE S313.2. Soil cone penetrometer. ASAE Standards 1997, pp. 821–822.