INFLUENCE OF SOIL TILLAGE ON WATER INFILTRATION IN LIGHT SOIL CONDITIONS OF CENTRAL BOHEMIA

Adéla MELICHAROVÁ[1], Jiří MAŠEK[1], Stanislav KOVÁŘ[1]

[1]Department of Agricultural Machines, Faculty of Engineering, Czech University of Life Sciences Prague, Kamýcká 129, Praha 6, Prague, 16521, Czech Republic

Abstract
This paper focuses on the evaluation of infiltration abilities of light sandy loamy cambisoil. Measurements of water infiltration were performed on field experiment in Nesperská Lhota near Benešov (Central Bohemia Region) on sandy-loam soil at an altitude of 390 m. Seven variants of experimental plots with different tillage intensity and crops were evaluated. Simplified falling-head method was used. The measurements showed different infiltration abilities of individual variants. The measurement did not show a clear effect of depth of tillage on soil infiltration capabilities. Also, no clear effect of the crop on infiltration was demonstrated during the 2017 season.

Key words: *soil tillage; hydraulic conductivity; depth of loosening.*

INTRODUCTION

Soil is a non-renewable natural resource that is the main means of producing food in agriculture *(Morgan & Nearing, 2011).* Knowledge of the physical and hydraulics properties of soil is one of the basic cognition that should decide when and how the soil is to be treated *(Titi, 2002*). It is therefore a correct estimation of soil workability with regard to the specific conditions prevailing in the habitat, when the soil handling does not damage its quality, but on the contrary, the optimum condition of the soil environment suitable for plant cultivation is achieved *(Javůrek et al., 2008)*.

The beneficial effect of soil protection technologies is often associated with the reduction of soil water erosion. The basic pillar of these technologies is the use of organic matter on the soil surface (biomass of crops, post-harvest residues). This material partially covers the soil surface, thereby reducing surface runoff and soil wash. This is demonstrated by *Portela et al. (2010),* when the highest soil losses were on the surface with minimal plant residues. On this surface was also the highest measured surface runoff.

The reduced soil tillage significantly affects the hydraulic conductivity of the soil and thus the soil infiltration properties. *Kroulík et al. (2007)* found the highest average infiltration properties for ploughed land, while minimum values were recorded for shallow tillage. He also found that soil that is loosened has a higher water capacity than reduced soil tillage.

Reicosky et al. (2005) states that the course of infiltration depends on the amount of water and the way the water is transported to the soil surface (precipitation, irrigation, flooding). Equally important are the soil properties, of which the most important are the structure, granularity, porosity, soil profile construction and soil density.

Franzluebbers (2002) writes that infiltration of water into the intact sample for long-term no-till soil was higher than that of conventional cultivated land. Higher infiltration of untreated soil was measured only if the soil was so treated at the same site for an extended period of time. However, using these technologies for less than a few years, the infiltration of untreated soil may be the same or even lower than that of conventionally treated soil. This is due to the initial technogenic compaction and the lack of biological activity required to create a stable soil structure. This confirms the length of the transition period, which is necessary to create a certain soil structure, which is confirmed by previous authors. Soil-causing soil treatment has a direct effect on soil properties and environmental problems *(Paustian et al., 1997*).

The aim of this work was to assess and evaluate the individual technologies of soil cultivation in the cultivation of various crops in terms of water infiltration into the soil.

MATERIALS AND METHODS

Field trial with 7 variants was established at locality Nesperská Lhota in Central Bohemia Region. Measurements are carried out in the sandy loam Cambisoil during season 2017. The experimental plot is on a slope with a south-east slope, average slope is 4.9°. The variants vary in different tillage and different crops. Plot of land for each variant was 6 m x 50 m in length side is facing the fall line.

Variants of trial:

Variation 1 – oat with conventional tillage. Land was ploughed into the middle depth (0.2 m). It was used moldboard plough the soil was left in rough furrow through the winter. Seedbed preparation was performed using harrows and levelling bars. Last operation was sowing of oats.

Variation 2 – oat with reduced tillage. After the harvest the straw was crushed and left in the field. This was followed by reduced tillage with disc cultivator (into depth 0.08m). The oats were sowed in spring the following year.

Variation 3 – maize with conventional tillage and inter-row crop. Land was ploughed into the middle depth (0.2 m). It was used moldboard plough. The soil was left in rough furrow through the winter. Seedbed preparation was performed using harrows and levelling bars. Oats were seeded into inter-row space (2 rows- 0.125 m). After the germination of oats was sown maize.

Variation 4 – land was ploughed into the middle depth (0.2 m). It was used moldboard plough The soil was left in rough furrow through the winter. Seedbed preparation was performed using harrows and levelling bars. Last operation was sowing of maize. The soil surface was covered at the time of sowing almost by zero organic matter.

Variation 5 – maize with direct sowing. The straw was crushed and left on the land in the autumn of 2015. The soil remained without tillage over the winter. In spring maize was sown directly without any tillage.

Variation 6 – maize with freezable intercrop. After previously harvest tines cultivator was done into a depth of 0.18 meters followed by sowing intercrops (mustard). There was a freezing of intercrops during the winter. Maize was sown without tillage in the spring.

Variation 7 – without vegetation (black fallow). Land was maintained over time without vegetation through total herbicide Roundup (conventional tillage technology).

The method used was simplified falling-head (*Bagarello et al., 2004*). This device consists of a plate with a diameter of 0.15 m and a metal sheet wall thickness – 2 mm. Its height is 0.2 m. This single ring was thoroughly embedded in the soil, taking care to minimize the changes in the measured pore system. The ring was inserted into a depth of 0.1 m. Water volume of 0.5 $dm^3$was then poured into a single ring and the time was set off. When the water was soaked into the soil, the time was stopped and the value was subtracted. Consequently soil moisture was measured again using the moisture meter Theta probe (Delta Devices, UK). It was performed in 10 repetitions for each variant. Kopecky cylinders with the volume of 100 cm^3 were taken to determine the basic physical properties of soil (each variation: 12 pieces). Soil sampling was performed prior to measurement (15.6.2017).

The data obtained from the measurements was evaluated in the STATISTICA 12 program. Chart graphs were used to illustrate field trial data. Data were further evaluated by ANOVA analysis using the Tukey HSD test.

RESULTS AND DISCUSSION

Table 1 describes the basic physical properties of soil for each variant. The table shows a small difference between the variants. This is due to a long period between loosening and soil sampling. Meanwhile, the soil has declined and the differences are small. This is true for values of density and porosity. The values can be considered typical of the soil type. However, the whole 2017 season was marked by a significant drought, which was influenced mainly by the measurement of soil hydraulic properties.

Tab. 1 Selected properties of the soil

Variant	Depth [m]	Porosity [%]	Bulk density [g.cm^{-3}]
1	0,05-0,1	41,21	1,56
	0,1-0,15	38,96	1,62
	0,15-0,2	31,44	1,82
2	0,05-0,1	42,85	1,51
	0,1-0,15	42,68	1,52
	0,15-0,2	38,68	1,63
3	0,05-0,1	45,52	1,44
	0,1-0,15	46,06	1,43
	0,15-0,2	51,94	1,27
4	0,05-0,1	41,96	1,54
	0,1-0,15	42,62	1,52
	0,15-0,2	42,66	1,52
5	0,05-0,1	39,88	1,59
	0,1-0,15	41,43	1,55
	0,15-0,2	38,29	1,64
6	0,05-0,1	41,47	1,55
	0,1-0,15	44,92	1,46
	0,15-0,2	42,78	1,52
7	0,05-0,1	45,52	1,44
	0,1-0,15	42,73	1,52
	0,15-0,2	44,89	1,46

The first measurement took place on 15. 06. 2017. In this area since the beginning of May it was max. 15 mm. This long-term absence of precipitation has also been unfavourably reflected in the results of the field trial. The soil in this period was extremely dry and very difficult to absorb water.

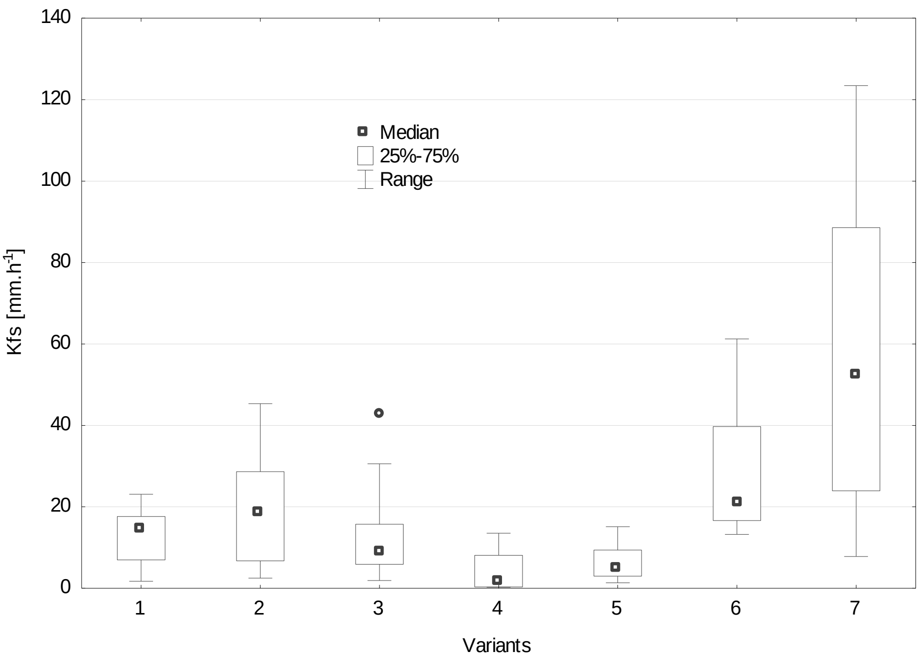

Fig. 1 Saturated hydraulic conductivity 15. 06. 2017

It can be seen from Figure 1 that the variant without vegetation had the highest hydraulic conductivity at the first measurement. By more than half, the maize variant with the freezing crop was second. It was followed by a variant of oats with direct sowing. A similar result was achieved with ploughing oats and maize prepared with ploughed crops. The lowest conductivity was measured in maize tilled by ploughing.

Another measurement took place in about three weeks on 07. 07. 2017. During this period more than 40 mm has already rained, which had a great influence on soil infiltration ability. In this measurement, Figure 44 showed the best cumulative infiltration for the ploughing variant of oats. With a large step, varieties of ploughed maize and intercrops and ploughed maize variants followed. The lowest result was achieved by the oat variant with direct sowing with an infiltration of 1.45 $mm.h^{-1}$. The second-smallest infiltration was shown by the vegetation-free variant of 3.5 $mm.h^{-1}$.

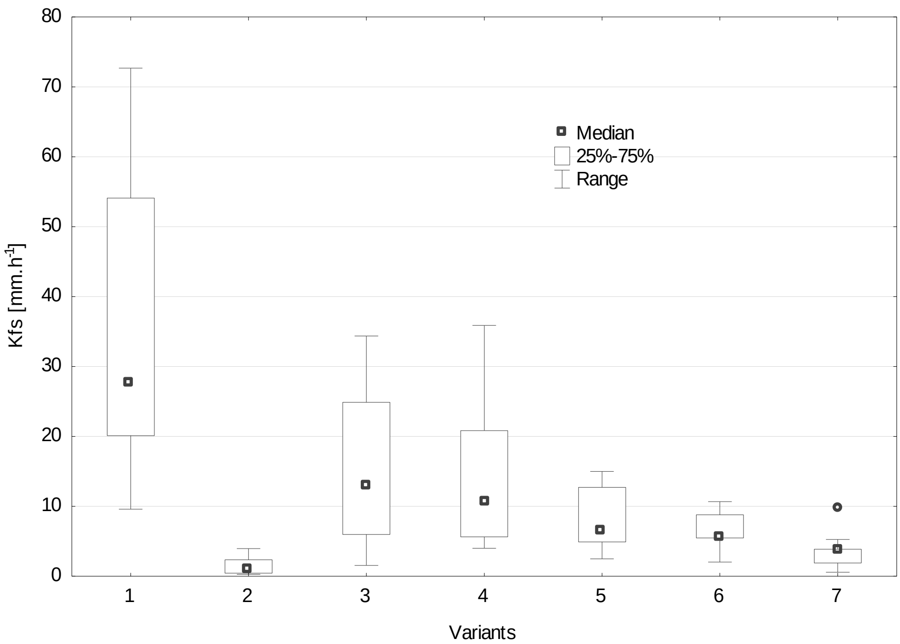

Fig. 2 Saturated hydraulic conductivity 07. 07. 2017

The last measurement in this year took place 08. 08. 2017. By this time the variants with oat were already harvested and there was only stubble.
The results of the last measurement are shown in Figure 36. Here, too, its value was twice as high as the second place. The smallest infiltration ability was shown by the variant of maize prepared by ploughing. Behind it was placed ploughing maize with sown crops.
Most studies confirm the beneficial effect of reduced or no-till technologies on soil hydraulic properties. However, the behavior of different soils cannot be excluded from this issue. In contrast to most studies, *Soracco et al. (2019*) concluded that no-till technology reduces the hydraulic conductivity of the soil, which affects the connectivity of pores, especially for finely structured soils. Conventional technology has shown higher overall pore connectivity in all monitored sites. The authors also used Mini Disks for this measurement. This is in line with our study.

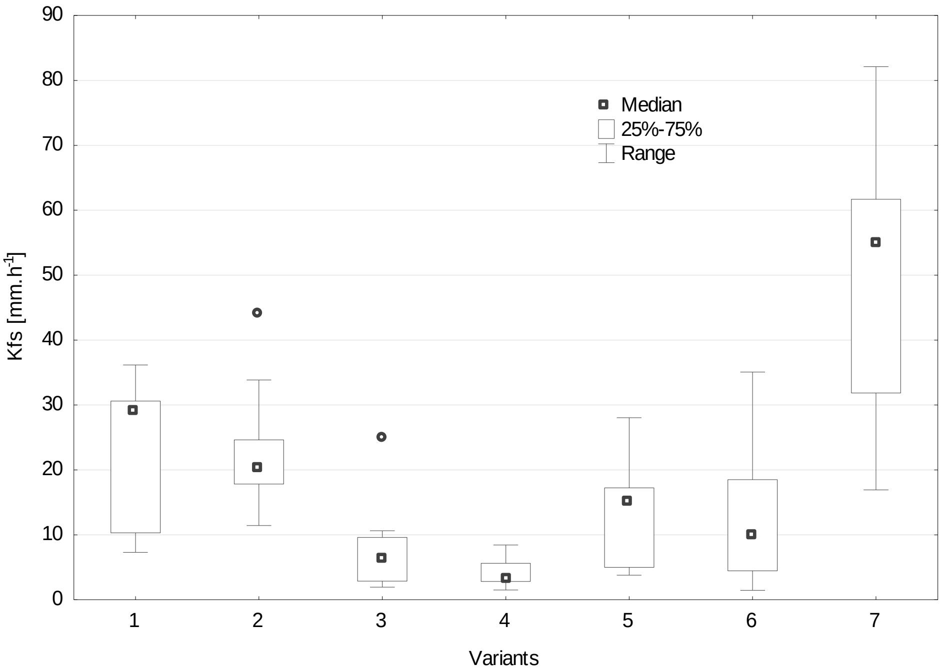

Fig. 3 Saturated hydraulic conductivity 08. 08. 2017

The Single ring method is rather less used. *Castellini et al. (2015*) emphasize the importance of organic matter for improving soil infiltration capabilities. *Alagna et al. (2016*) recommend the use just for the measurement of sandy-clay soils. The authors emphasize frequent fluctuations in values where the effect of soil and crop processing is not clear. The different behavior of the variants during a longer evaluation is confirmed by *Capello et al. (2017)*. This is also in line with the results of this work, when it is not possible to draw clear conclusions from the Single Ring measurement.

CONCLUSIONS

The input hypotheses of the thesis were only partially confirmed. The positive effect of non-tillage technologies on the increase of soil infiltration properties has not been clearly demonstrated. In the case of surface runoff, their meaning is not entirely clear. However, it should be noted that soil loss is far more severe than simple surface runoff. The measurement was certainly influenced by extreme drought during the 2017 season.
It was not possible to find optimal conditions during this season to measure the soil hydraulic properties.

ACKNOWLEDGEMENTS.
Supported by the Czech University of Life Sciences Prague, Project No. IGA 31160/ 1312/3115.

REFERENCES

1. Alagna, V., Bagarello, V., Di Prima, S., & Iovino, M. (2016). Determining hydraulic properties of a loam soil by alternative infiltrometer techniques. *Hydrological Processes*, *30*(2), 263-275.
2. Bagarello, V., Iovino, M., & Elrick, D. (2004). A simplified falling-head technique for rapid determination of field-saturated hydraulic conductivity. *Soil Science Society of America Journal*, *68*(1), 66-73
3. Capello, G., Biddoccu, M., Ferraris, S., Pitacco, A., & Cavallo, E. (2017). Year-round variability of field-saturated hydraulic conductivity and runoff in tilled and grassed vineyards. *Chemical Engineering Transactions*, *58*, 739-744.

4. Castellini, M., Giglio, L., Niedda, M., Palumbo, A. D., & Ventrella, D. (2015). Impact of biochar addition on the physical and hydraulic properties of a clay soil. *Soil and Tillage Research, 154,* 1-13.
5. Franzluebbers, A. J. (2002). Water infiltration and soil structure related to organic matter and its stratification with depth. *Soil and Tillage Research*, *66*(2), 197-205.
6. Javůrek, M., Hůla, J., Vach, M., & Kroulík, M. (2008). Impact of different soil tillage technologies on soil erosion effect mitigation. *Scientia Agriculturae Bohemica*, 39(2), 218-223.
7. Kroulik, M., Hůla, J., Šindelař, R. & Illek, F., (2007). Water Infiltration into Soil Related to the Soil, Tillage Intensity, *Soil Water Research*, 2(2), pp. 15-24.
8. Morgan, R. P. C., & Nearing, M. A. (Eds.). (2011). *Handbook of erosion modelling*. West Sussex: Wiley-Blackwell, 77 p.
9. Paustian, K., Collins, H. P. &Paul, E. A. (1997). *"Management controls on soil carbon." Soil Organic Matter in Temperate Agroecosystems*. Cole, eds. Boca Raton: CRC Press, pp. 5-49.
10. Portela, J. C., Cogo, N. P., Bagatini, T., Chagas, J. P. & Portz, G. (2010). Restauração da estrutura do solo por sequências culturais implantadas em semeadura direta, e sua relação com a erosão hídrica em distintas condições físicas de superfície. *Revista Brasileira de Ciência do Solo*, *34*, 1353-1364.
11. Reicosky, D. C., Lindstrom, M. J., Schumacher, T. E., Lobb, D. E., & Malo, D. D. (2005). Tillage-induced CO2 loss across an eroded landscape. *Soil and Tillage Research*, *81*(2), 183-194.
12. Soracco, C. G., Villarreal, R., Melani, E. M., Oderiz, J. A., Salazar, M. P., Otero, M. F. & Lozano, L. A. (2019). Hydraulic conductivity and pore connectivity. Effects of conventional and no-till systems determined using a simple laboratory device. *Geoderma*, *337*, 1236-1244.
13. Titi, A. (2002). *Soil tillage in agroecosystems*. USA: CRC press, 384 p.

Corresponding author:
Ing. Adéla Melicharová, Department of Agricultural Machines, Faculty of Engineering, Czech University of Life Sciences Prague, Kamýcká 129, Praha 6, Prague, 16521, Czech Republic, e-mail: melicharovaa@tf.czu.cz