Agronomy Research **15**(4), 1629–1635, 2017
https://doi.org/10.15159/AR.17.015

Comparison of tillage systems in terms of water infiltration into the soil during the autumn season

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Abstract. The soil belongs to the most valuable parts of the planet Earth. It is, endangered by water erosion, which causes huge destruction every year, or damage to farmland. More than half of the agricultural land in the Czech Republic is threatened by water erosion. The measurement was performed in the location Nesperská Lhota. The trial has been established on loamy sand Cambisol. In the field experiment, there were created 6 different variants which wad differed by soil tillage and crop. In the individual variants maize and oats were located. The field trial has been existing for a long time, as it was founded in 2009. Two measuring methods of water infiltration were used for the measurements: a mini disk infiltrometer and a single ring. The measurement was performed in the period of September 2016 before the harvest of maize. The soil aggregates were already stabilized at that time after all tillage operations. The measurement result showed the difference between the methods of soil tillage. The greatest ability of infiltration had a variant of maize with inter-row oats. Surprisingly, it was followed by maize, which was processed by ploughing technology. The lowest infiltration capacity was showed by oats reduced by soil tillage. A variant without vegetation had the second lowest infiltration. Our results obtained at rate of water infiltration into the soil affirm the need to control measures in the late vegetative stages. It is important for most of the rainfall to be quickly infiltrated so that it prevents the formation of massive surface runoff.

Key words: mini disk infiltrometer; soil tillage; single Ring infiltrometer; water erosion.

INTRODUCTION

Soil tillage constitutes the mechanical interference into the soil, in which there is a difference in the intensity of processing of soil aggregates and a difference in the change of the soil structure and the distribution of organic material (Hanna et al., 1994; Titi, 2002). The given characteristics are reflected subsequently in water permeability. The type of tillage influences extend of water erosion, which is one of the global problems (Kovář et al., 2016). Water erosion causes each year the destroying or damaging of large areas of agricultural land. Apart from the kinds of sown crops, the type of tillage influence water erosion, too. Novák et al. 2012 reported that the loss of soil is significantly higher by water erosion in conventional tillage (during sowing of maize) than in conservation tillage.

The focus on cost reduction is the main feature of current trends in agriculture and the application of technologies that eliminate environmental risks in comparison with conventional technologies (Bocchi et al., 2000; Zhang et al., 2014). The technologies of differentiated tillage are introduced newly. It is possible to use a large number of methods to detect susceptibility to water erosion (Mloza-Banda et al., 2016). These methods include e.g. measurements by Mini Disk infiltrometer or using Single Ring infiltrometer. Both methods save both the time and as well as the complexity of the measurement. These characteristics cause that the two methods start being used as gradually spread measurement method. A single ring infiltrometer (SR) is widely used for field measurements of infiltration (Jačka et al., 2014).

The aim of the measurements was to compare differences in the rate of water infiltration into the soil and water conductivity according to the type of soil treatment and species sown crops.

MATERIALS AND METHODS

First the value of soil moisture through the moisture meter Theta probe (Delta devices) was determined before the measurement. Two methods were used for measurement of the rate of water infiltration into the soil. The measurement of both methods can be seen in Fig. 1.

The first method was the measurement through the Single Ring infiltrometer test. The method used was simplified falling-head (Bagarello et al., 2004). This device consists of a plate with a diameter of 15 cm and a wall thickness – 2 mm. Its height is 20 cm. 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 10 cm. 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 and it was entered into the table. It was performed in 10 repetitions.

Figure 1. Measurements by Mini Disk infiltrometer and by Single Ring.

The second method was the measurement through Mini Disk infiltrometer. The Mini Disk infiltrometer is very easy to be used, small, with low demands on the operator. Infiltrometer consists of polycarbonate tubes. The tube has a diameter of 31 mm, a height of 327 mm and it is divided into two parts. Both parts are filled with water. The upper part, which is called the bubble chamber, is used to set the air intake. The lower part of the tube has a stainless semipermeable membrane at the bottom, about the size 15.20 cm^2. through which the water is infiltrated into the soil. The scale is also marked in the lower part of the tube, from which the value of the water volume in milliliters is subtracted. It was performed in 10 repetitions. Each Mini Disc infiltrometer was filled with water and subsequently placed by percolation area in a given variation of the experiment. The readings from the scale of the circular infiltrometer were written into pretreated tables at 0 hours. Timer was set off on the prepared stopwatch and the values of the scale were subtracted and recorded every 2 minutes into the table. The measurements lasted for 30 minutes in each experimental area. Both methods of measurements were performed in parallel to the machinery passes and infiltration was measured in noncompacted area. The rate of water infiltration into the soil and complementary characteristics were measured in the experimental field experiment versions at locality Nesperská Lhota in Central Bohemia Region.

Measurements are carried out in the sandy loam Cambisol 30 September 2016. The experimental plot is on a slope with a uniform slope, average slope is 4.9°. The measurement was made in seven variants of the field trial, which had already been established in 2009. The options 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 mouldboard 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 0.08 m). 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 mouldboard 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 mouldboard 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).

RESULTS AND DISCUSSION

Table 1 lists the physical properties of soil. The table shows the average values of five samples. From the values it is evident that the variants with reduced technology have higher porosity and conversely lower bulk density. Data are affected by long-term nature of the experiment. Tillage is done the same way since 2009. The increase in porosity and bulk density decline has been gradual. Noticeable positive effect of reduced technology is evident in the physical properties of soil data.

Table 1. Physical properties of soil

Variation	Depth [m]	Porosity [%]	Bulk density [g cm^{-3}]
1	0.05–0.1	36.31	1.63
	0.1–0.15	38.76	1.57
	0.15–0.2	38.51	1.61
2	0.05–0.1	41.81	1.49
	0.1–0.15	41.2	1.48
	0.15–0.2	41.67	1.54
3	0.05–0.1	40.21	1.49
	0.1–0.15	40.62	1.53
	0.15–0.2	39.78	1.56
4	0.05–0.1	37.5	1.62
	0.1–0.15	39.48	1.57
	0.15–0.2	40.84	1.53
5	0.05–0.1	40.37	1.48
	0.1–0.15	44.32	1.47
	0.15–0.2	42.9	1.51
6	0.05–0.1	40.01	1.52
	0.1–0.15	41.59	1.5
	0.15–0.2	45.8	1.54
7	0.05–0.1	39.71	1.56
	0.1–0.15	34.92	1.7
	0.15–0.2	36.7	1.65

Water infiltration into the soil and other parameters are shown in the graphs in Figs 2 to 4. In Fig. 2 the results can be seen of measurements of hydraulic conductivity measured using a single ring. The maize with freezable catch crop had the largest hydraulic conductivity and it was 706 mm h^{-1} in this measurement method. The second highest hydraulic conductivity was oat, which was prepared by conventional tillage. Its value is almost one-third compared to maize with freezable catch crop. The soil without vegetation had the smallest hydraulic conductivity. Closely followed by oats processed by reduced tillage. Measured values are relatively high for all variants. This is probably due to broken soil crusts using this method. Water infiltration is greatly accelerated by this. Water is accepted by macropores below the soil surface. Infiltration is not slowed formed soil crust, which was surely created this term.

Fig. 3 is a graph of hydraulic conductivity measured using mini discs. The maize with interrow oats had the highest value during measuring of soil of hydraulic conductivity, during a mini disk infiltrometer and it was 17 mm h^{-1}. The smallest infiltration had variant oats with conventional tillage. Values differ substantially from the previous measurement. This is probably caused by the emergence soil crust on the soil surface. Crust caused slowdown water infiltration into the soil. Surface layer crust contains fine soil particles without the macropores. The highest value of the variant 3 is probably due to a partial disruption of surface residues mustard root system. Overall, the result obtained by this method differs from the previous ones and it is not possible unambiguous interpretation by the effects of soil crusting. The difference may be caused by application of mini discs on the treated soil surface using fine particles. Another option is a set of conditions of infiltration when using mini disks.

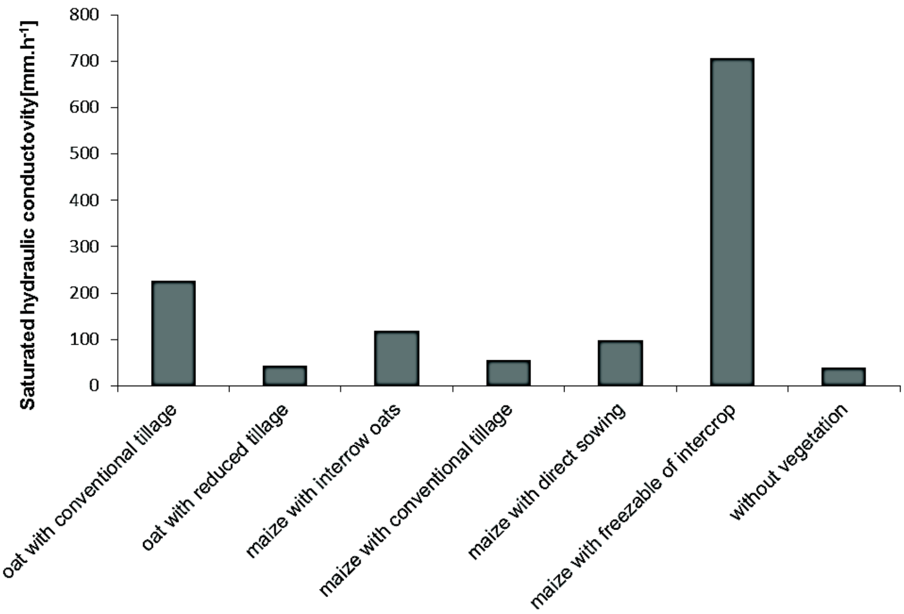

Figure 2. Hydraulic conductivity – measure with Single Ring infiltrometer.

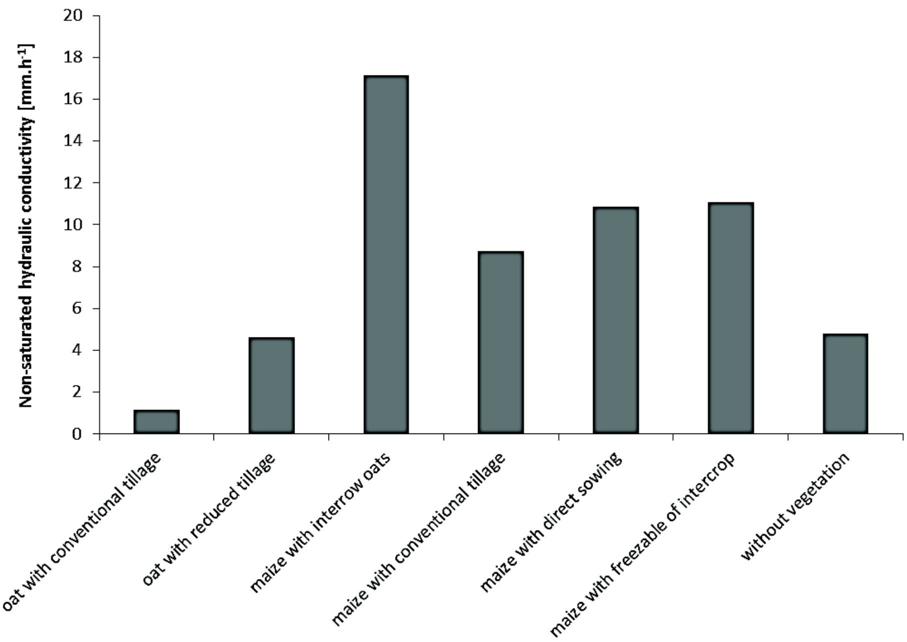

Figure 3. Hydraulic conductivity – measure with mini disk infiltrometer.

Fig. 4 shows the course of cumulative infiltration using mini discs. The measurement process can be successfully describing by quadratic interpolation. Very strong dependence was observed in all variants. From the values is evident gradual start of water infiltration into the soil. This is caused by the soil crust, as already indicated in the previous graph. Infiltration of water is very slow. The acceleration occurs after the saturation of topsoil.

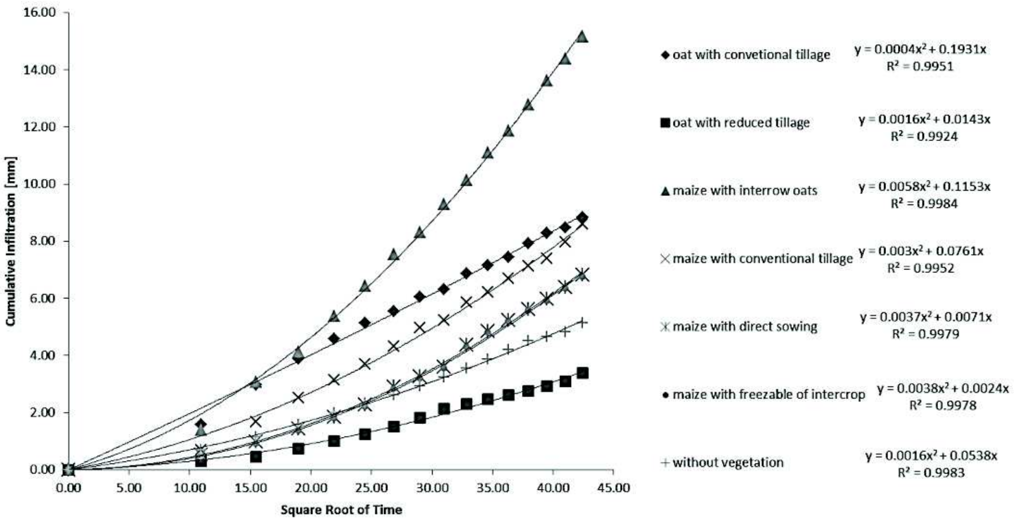

Figure 4. Cumulative infiltration of all variant.

Results of the evaluation of infiltration (hydraulic conductivity) are consistent with the results of other authors. Rasmussen (1999) and Truman et al. (2005) confirmed the benefits of technology without tillage in terms of a significant increase water infiltration into the soil. In terms of the field trial we confirmed a increase of hydraulic conductivity (especially non saturated) by use of technologies without ploughing only partially in comparison with alternatives, where ploughing was applied. During the growing season, maize and spring cereals, however, the discrepancies between variants decreased, indicating a higher adsorption capacity fading effect of soil water, which can be recorded after ploughing. For this issue, however, different behaviour of different soil types can´t be excluded.

On the other hand, Obi & Nnabude (1981) and also Heard (1988) didn´t find any differences on sandy soils with surface runoff and soil washes away with ploughing and conventionally processed soils or even the opposite effect better results with conventional surfaces.

CONCLUSIONS

Measurements show different values of surface runoff and water infiltration into the soil during the period of increased risk of torrential rainfall and possible subsequent erosion events. Variant 4 was most threatened by excessive run-off (conventional tillage with ploughing), which confirmed the risk of erosion on slope and light soil without the use of proper soil conservation technologies. Measurements show positive effect of soil cover with organic matter. The speed of water infiltration into soil also affects the water supply of plants. Soils with higher infiltration are able to maintain higher humidity during drought. Rapid infiltration also helps to retain water in landscape which is important during the risk of local flooding. It was also found different behavior of individual variants during measurement different methods. This behavior is likely to be affected by the formation of soil crusts.

ACKNOWLEDGEMENTS. The work was supported by the internal research project of the Faculty of Engineering IGA 2016:31160/1312/3112.

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