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The effect of soil tillage technologies on the surface of the infiltration speed of water into the soil

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Abstract. Water erosion is a problem of global significance. Water erosion causes destruction or damage to enormous areas of agricultural land every year (Morgan, 2005). Agricultural land in the Czech Republic is largely exposed to the risk of water erosion on grounds of habitat, but as well agro technology. More than half of agricultural land is endangered by water erosion in the Czech Republic (Janeček, 2005). Due to water erosion the soil is depleted of its most fertile part – topsoil. The physical and chemical properties of the Earth's surface are deteriorating, the content of nutrients and humus in the soil reduce, and the thickness of the soil profile decreases. However the grimness increases and prevents the growth of vegetation. The field trial was set up to evaluate the tillage technology. The measurements were carried out in Nesperská Lhota. The experiment was placed into a sandy loam Cambisol. The measurements took place in four variants of field trial which differed in soil tillage for maize. It was a different method combination of no-till and plough tillage. The simulation of intense rain was used to measure. A square area of the size 0.5 sq m was surrounded by sheet metal strips around the whole perimeter. The pantograph was placed on their underside and collected the runoff water. The soil washout was collected into the pipe and then into a graduated container. The surface runoff was collected in the container and weighed on automatic scales. Its values were recorded on a portable computer. The result of the measurement showed the difference between the various types of tillage. The beginning of the surface runoff at conventional tillage with ploughing was the shortest of all the variants. While the beginning of the surface runoff was reduced significantly longer by reduce tillage than by conventional tillage with ploughing. The results of the surface runoff speed and the speed of infiltration of water into the soil at the simulation of intense rains are in compliance with the results of those authors who report significant benefits of soil conservation tillage technology. This technology reduced the surface water runoff during the intense rainfall and increased water infiltration into the soil.

Key words: maize production; rainfall simulator; water erosion.

INTRODUCTION

The soil belongs to the most important and also the most valuable components on the planet Earth. The Earth is, however, compromised by various factors, among which water erosion belongs. During water erosion the uppermost – the most fertile part – is taken away. The way of tillage enormously influences the dimension of water erosion. Novak et al. (2012) report that conventional tillage (during sowing maize) significantly causes higher loss of soil by water erosion than processing soil conservation. An important factor for reducing water erosion is to leave crop residues on the soil surface. This is used in soil conservation tillage.

The increasing construction of biogas plants causes higher consumption of maize. This is related to increasing share of maize cultivation and also the danger of the increase of soil water erosion. The results confirm the importance of soil conservation technologies, tillage and seeding maize, in order to reduce the risk of soil degradation by water erosion. The positive impact on cover crop land was also confirmed in the space between the rows of maize (Novak et al., 2011).

The rate of water infiltration into the soil also affects the water supply of plants and water retention in the landscape during heavy rains, which is associated with the risk of flooding. Reduced technology has a significant influence on increasing the infiltration compared to the conventionally processed soil. It is all caused by the increased stability of the soil structure, more favourable distribution and pore size (Javůrek et al., 2010).

For the measurement of water erosion there is a possibility to use either natural rain or rain simulator. Although the studies are the best in natural conditions, the spatial and temporal layout of natural rain cannot be influenced and controlled. Therefore the collection of the data is slow, cumbersome and time consuming. In most cases the rainfall simulator is used. Its use diminishes the aforementioned time-consuming measurements in comparison to natural rainfall.

The aim of this measurement was to compare the dependence of the effect of tillage on the surface of water runoff during the simulated rainfall.

MATERIALS AND METHODS

Rainfall simulator was used for the measurement of the soil runoff, surface runoff and infiltration of water into the soil. Sprinkling equipment composes of sprinkling frame, on which a nozzle with a conical dispersion is placed. Water is pumped to the nozzle from the pump through a control valve and hose. With the control valve the spray pressure is controlled and regulates the intensity of watering as well as kinetic energy of drops (Kovaříček et al., 2008).

Measurements are performed on the experimental area of 0.5 sq m and a square shape. The measured area is bound by sheet metal strips. At the bottom part of the measured area the pantograph is placed. It concentrates drained soil and runoff water into the tube and subsequently into a volumetric container. The container is placed on automatic scale, which records the measured values every 5 s. The roughness of the soil surface in the direction of the fall line was evaluated by ‘chain method’ (Klick et al., 2002). Soil physical properties have been evaluated employing Kopecky’s cylinders with the volume of 100 cm^3 and subsequently analysed in the laboratories of the CULS Prague. Stand samples were taken in September 2015 for yield evaluation.

Water infiltration into the soil, surface water runoff and additional characteristics were investigated in the experimental field trial variants in Nesperská Lhota. The measurement was carried out on loamy Cambisol June 24, 2015. Each variation was measured 3 times in season 2015.The average content of Ct at the experimental plot: 2.15%. The experimental land is on a hillside with a uniform slope, average slope is 4.9°. The rainfall intensity was 90 mm h^{-1}.

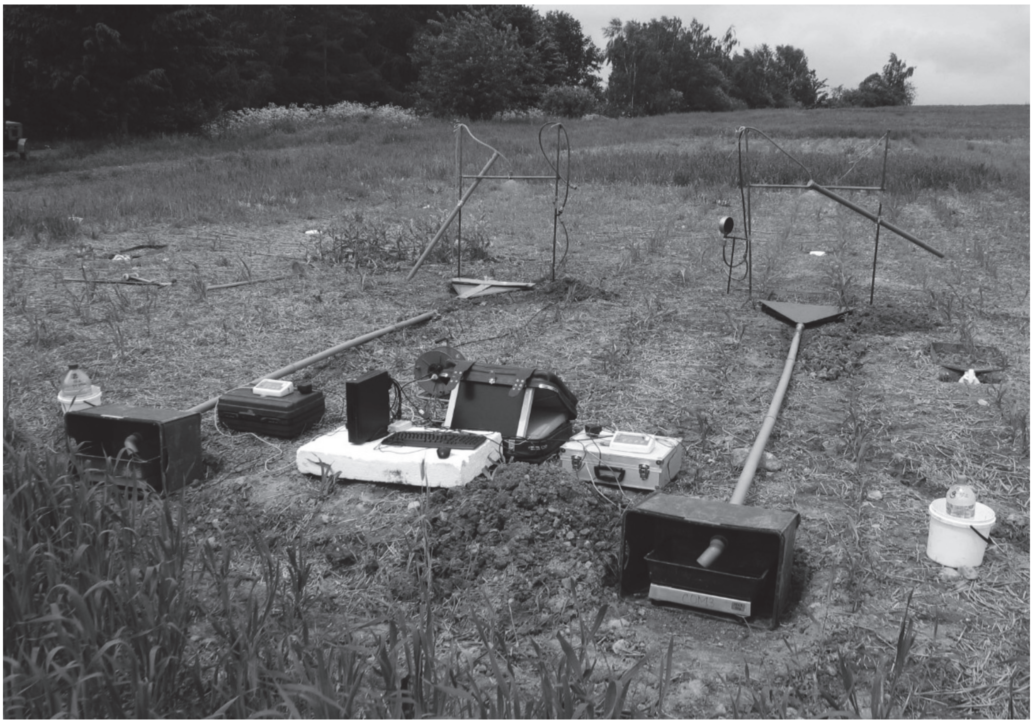

Figure 1. Measurements by rainfall simulator.

The measurement was made in four variants of the field trial, which was already established in 2009. The options differ in different tillage on maize.

Variants of trial:

Variation 1 – no till

After the harvest in the summer of 2014 the straw was crushed and left in the land, while the land was left without tillage. In the spring maize was directly sown into the land without tillage.

Variation 2 – reduced tillage with spring pre-sowing tillage

In the autumn of 2014 the crown stubble cultivator took place (depth 0.08 m). During the winter, the soil was left with a surface covered by plant residues. In the spring, before maize seeding, there was a loosening of the soil by tines cultivator to a depth of 0.08 meters.

Variation 3 – conventional tillage

In the autumn of 2014, part of the land was ploughed into the middle depth (0.20 to 0.22 meters), while tractor during ploughing rode down the contours. The soil was left over in the winter in a rough furrow. In the spring sowing soil preparation took place (skid and spike gate) and maize sowings. Coverage of the surface soil by organic material at planting time was almost zero.

Variation 4 – conventional tillage and inter-row crop

At the beginning of autumn stubble disc tiller was carried (0.08 m depth). After the germination of second growth ploughing perpendicular was done to the contours. During the winter, the soil was left in a rough furrow. In the spring sowing soil preparation was conducted by seedbed cultivator with two levelling bars and harrows followed by sowing oats. 14 days after sowing oats were sown maize.

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.

Table 1. Physical properties of soil

Variation	Depth [m]	Porosity [%]	Bulk density [g cm^{-3}]
1	0.05–0.1	40.37	1.48
	0.1–0.15	44.32	1.47
	0.15–0.2	42.90	1.51
2	0.05–0.1	40.01	1.52
	0.1–0.15	41.59	1.50
	0.15–0.2	45.80	1.54
3	0.05–0.1	37.50	1.62
	0.1–0.15	39.48	1.57
	0.15–0.2	40.84	1.53
4	0.05–0.1	40.21	1.49
	0.1–0.15	40.62	1.53
	0.15–0.2	39.78	1.56

Surface runoff, infiltration rate during rainfall simulator measurement and other parameters are shown in the graphs in Figs 2 to 5.

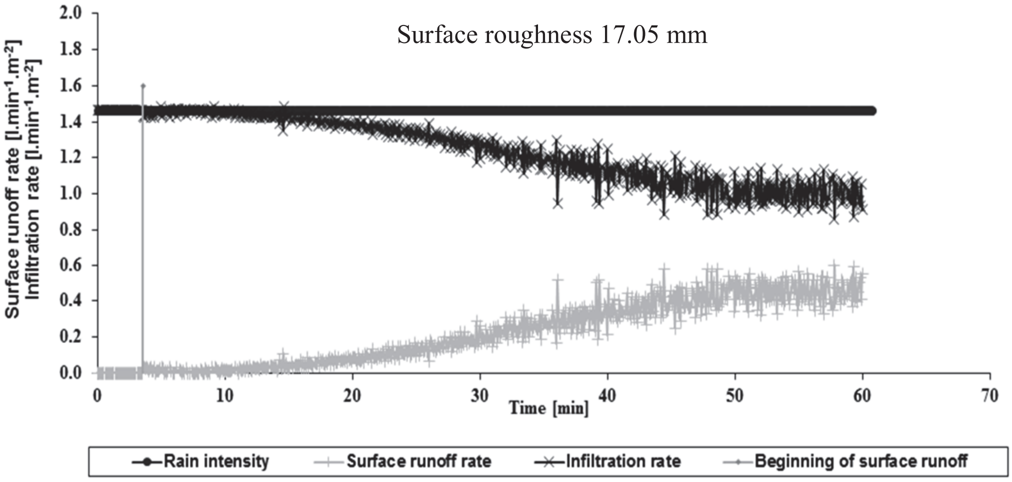

Figure 2. Process of observed values during rain simulation – Variation 1.

In the variant 1 (Fig. 2) at the onset the surface runoff was recorded 3.57 minutes after the beginning of intense rainfall simulation. Until the 15th minute the surface runoff was almost zero – the soil was able to infiltrate nearly all water. Subsequently infiltration gradually began to be reduced and at the end measurement stabilized.

Variation 2 was characterized by latest possible start of surface runoff from all four variants of the experiment. Then it was followed by a gradual increase of surface runoff, which was settled just before the end. This fact can be attributed to the spring loosening of soil to the depth of 0.08 meters. This variant showed excellent rate infiltration, but only until the loosening surface layer of soil was saturated with water.

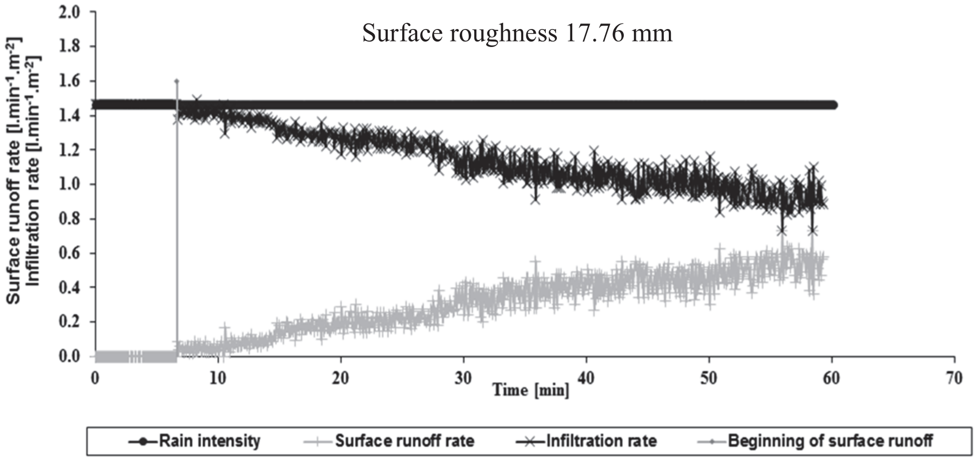

Figure 3. Process of observed values during rain simulation – Variation 2.

Variant 3 was characterized by the second earliest onset of surface runoff. This was followed by a sharp increase in short-term of surface runoff. The speed of surface runoff exceeded the values after 2 minutes of rain simulation. It conversely decreased rate of infiltration.

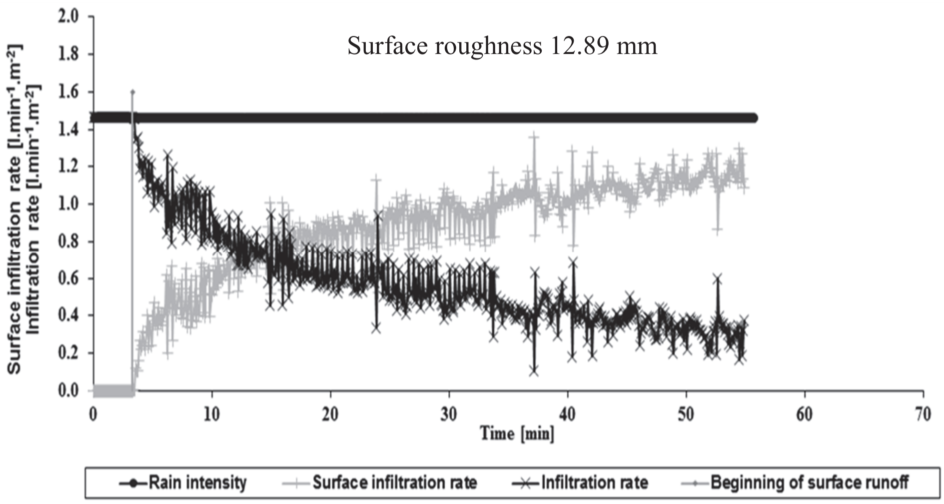

Figure 4. Process of observed values during rain simulation – Variation 3.

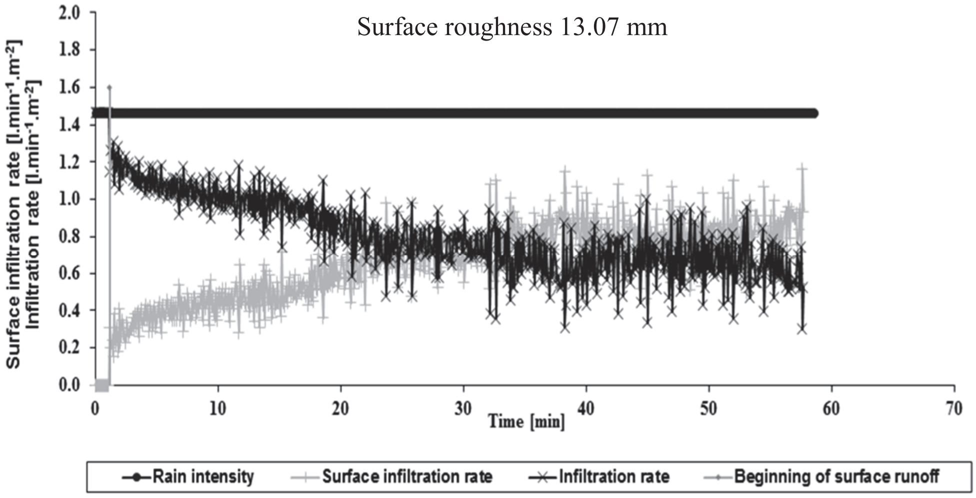

Figure 5. Process of observed values during rain simulation – Variation 4.

The time to onset of surface runoff was the shortest of all variants in the variant 4. This was caused by inter-row crops, which were filled by oats. Most area was covered by the crop. Though the time to onset of surface runoff was short, it did not manifest any significant way to the next rate of surface runoff.

The rain from the preceding measurements could also influence the conditions for the infiltration of water into the soil. The rain influenced the creation of soil crust at variant 3. The crust on the soil surface may significantly worsen the conditions for water infiltration into the soil.

The predicted reason for the low rate of infiltration is in this variant of the experiment the fact that there is a considerable deterioration of the conditions of water absorption during the following months, although just after ploughing, the soil contains macropores which facilitate infiltration of rainwater.

The measured results showed that there is a great influence of soil conservation technologies on cultivation of maize. The lowest cumulative runoff was in variant 1, which incorporated the amount of 13 kg. After that it was followed by variant 2 (autumn and spring plate preparation loosening) to 17.03 kg.

The classic tillage through plough had the largest cumulative runoff. It was 51, 35 kg. The variant 4 is to be seen as a demonstrable effect covered by organic matter. Nevertheless, given that the treated plot ploughing, it had a large influence on coverage of organic material.

Quick ability of water infiltration into the soil has a great influence on the supply of plants with water and runoff. During the intensive rainfall it leads to rapid saturation of the soil and the resulting susceptibility to flooding.

During maize cultivation on light soils land variant 3 (conventional tillage with ploughing) was most threatened by excessive surface runoff water.

Consequently in the cultivation of maize the soil should not be left without soil organic matter, thereby reducing the amount of outflowing precipitation.

The best emerged was variant 1 (no drill) for the reduced technologies which maintained the lowest value of surface runoff compared to variant 2 (disc loosening).

When comparing the measured values with the results of authors, who have dealt with the quantification of erosion processes in the application of different tillage practices in the production technology, positive protective effect of plant biomass in the soil surface and the surface layer of soil was confirmed (Truman et al., 2005; Terzoudi et al, 2007; Zhang et al., 2014; Mloza-Banda et al., 2016). Even under the conditions of the field the experiment showed that the cultivation of corn using conventional tillage technology with tillage is risky, alternative technology of maize cultivation without tillage significantly showed less erosion with the erosion events.

This experiment was designed as a multiannual. The maize yield has been also evaluated during the experiment. The five-year yield comparison reached the highest point in variation 3 (conventional technology). Variation 4 has reached only 62 percent of revenues compared to variation 3. Variation 1 has reached 81 percent of the yield, compared with variation 3. Variation 2 has reached 93 percent of the yield, compared to variaton 3

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 3 was most threatened by excessive run-off (conventional tillage with ploughing), which confirmed the risk of erosion on maize 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 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. Conditions in the Czech Republic are characterized by high average slope of the land. It is reported that approximately half of the land in the Czech Republic is threatened by water erosion.

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