SURFACE WATER RUNOFF AND SOIL LOSS IN MAIZE CULTIVATION

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Abstract
In a field trial with four variants of cultural practices in maize for silage cumulative surface runoff and soil loss were measured under artificial rainfall generated by a rainfall simulator. Measurements in June 2015 showed that water infiltration into the soil in a maize stand on ploughed land was markedly lower than in variants with soil tillage for maize without ploughing. The highest soil loss at surface water runoff in June was found out in variants of maize cultivation with ploughing. The results of measurement of water intake by the soil and soil loss due to the flow of water in the period of the events of intensive rainfall in storms indicated that maize cultivation with ploughing is a risky practice compared to soil tillage without ploughing.

Key words: rainfall simulation, soil tillage, soil moisture, water infiltration speed into soil.

INTRODUCTION
In the Czech Republic soil protection against water erosion is a particularly crucial issue – almost 50% of the arable land area is threatened by this type of erosion (JANEČEK ET AL., 2008). In farming practice permanent damage to the soil by excessive surface water runoff and soil washing away occurs also in those fields that meet the defined requirements for good farming practices with regard to the cultivation of maize and other broad-row crops. As the areas under maize have been increasing, especially because maize is used as an energy source and raw material for biogas plants, maize is planted on less sloping lands but in conditions with low soil resistance to water erosion where severe and irreversible deterioration of soil fertility by water erosion occurs. Many times, washing away of soil, mainly by torrential rains, may cause damage to the property of municipalities and inhabitants.

The commonly used maize planting on vast lands with long fall lines is risky when no crops with a higher protective effect against water erosion are included on these lands. The importance of soil conservation technologies for the planting of broad-row crops was accentuated by TRUMAN, SHAW AND REEVERS (2005).

To increase the efficiency of the soil erosion control it is necessary to decrease surface water runoff during intensive rains and to transfer the greatest possible amount of water from rainfall into the soil profile. An increase in the infiltration capacity of soil is assumed, as stated by SHIPITALO ET AL. (2000). If the surface water runoff cannot be prevented, it is necessary to decrease at least the velocity of flowing water so that the soil amount carried away by water would be reduced. BAUMHARD & JONES (2002) mentioned inappropriate soil tillage that can contribute to the creation of compacted layers in the soil profile. TITI ET AL. (2002) emphasized a decrease in soil permeability for water as a result of the creation of a homogeneous soil layer under the long-term use of conventional soil tillage. An increase in soil suction for water is another contribution to soil moisture management with respect to cultivated crops.

This paper presents the results of measuring the characteristics that indicate the risk of water erosion in the soil where maize (*Zea mays* L.) is planted and conventional tillage with ploughing and soil tillage practices without ploughing are used.

MATERIALS AND METHODS
Measurements of water intake by the soil were conducted in June 2015 after variants of soil tillage and planting for maize were used for several years. A field trial in the Nesperská Lhota locality has been conducted in this site since 2010. The locality is situated on the border of the Benešovská pahorkatina and Vlašimská pahorkatina hills. The trial was established on light loamy-sandy Cambisol at an altitude of 420 m a.s.l. and on a land of average slope of 5.4°. Surface water runoff and soil loss were measured in the variants of the field trial shown in Tab. 1.

To measure surface water runoff and soil loss a rainfall simulator was used (KOVAŘÍČEK ET AL., 2008). During artificially generated rainfall the soil was exposed to the effects of falling water drops at a rate of 87 mm/h. The flow of water washing away the soil was taken into a vessel located on an automated balance and the values of weight were continually recorded by a portable computer (Fig. 1). For determination of soil moisture and physical properties of soil standard methods of soil sampling and laboratory analyses were used (VALLA ET AL., 2008). The Vantage Vue meteorological station was used for rainfall registration during the field trial.

Tab. 1. – Variants of soil tillage practices and establishment of maize stand

Variants of maize cultivation		Description of maize cultivation
1	Conventional practice of maize cultivation with ploughing	Autumn ploughing, rough furrow left over winter, in spring seedbed preparation, maize sowing with Kinze 3600 planter.
2	Maize planted into cover undersown crop (with ploughing)	Autumn ploughing, rough furrow left overwinter, in spring seedbed preparation, sowing of spring cereal (common oat) with Flora 601 sowing machine with disk coulters (row spacing 0.125 m, 2 rows sown, 4 rows left out), maize planted into unsown strips of emerged spring cereal with Kinze 3 600 planter, visual navigation.
3	Minimization for maize with spring loosening	Skimming with disk harrow after forecrop harvest; in spring soil tillage with Kromexim 300 tine cultivator to a depth of 0.10 m, maize sowing with Kinze 3600 planter.
4	Maize sowing into winter killed catch crop	Skimming with disk harrow in autumn after forecrop harvest, sowing of winter kill catch crop, in spring maize sowing with Kinze 3600 planter (without seedbed preparation).

Fig. 1. – Rainfall simulator

RESULTS AND DISCUSSION

In the period from February to June 2015, when measurements were done with a rainfall simulator, precipitation was low – the precipitation amount from the beginning of February was only 48 mm on an experimental plot. It was reflected in low soil moisture at the time of measurements. In the surface layer of soil on 24th June 2015 there was a moderate increase in soil moisture as a result of rainfall events on 13th – 15th June with the precipitation amount of 17 mm (Figs. 2 and 3).

Figure 4 shows surface water runoff during artificial rainfall generated by a simulator. The graph illustrates that during artificial rainfall there was an increase in differences in cumulative surface runoff between the variants of maize cultivation with ploughing and without it. Differences between these variants further increased at subsequent measurements with a rainfall simulator after two weeks in the same space (Fig. 5). Figure 5 documents that lower values of cumulative surface runoff were recorded in the maize cultivation without ploughing (with spring seedbed preparation as well as without seedbed preparation) compared to maize cultivation by ploughing technology of soil tillage. High values of cumulative runoff were found out not only for the conventional practice of maize cultivation with ploughing but also for the cultivation technology using a cover crop (after ploughing).

Soil loss by the flow of water is an indicator with the still higher measure of relevance. Tab. 2 shows the values of soil loss at the second measurement (24th June 2015). Low values of soil loss were determined in variants of maize cultivation without ploughing (12.4 and/or 12.6 g per hour/square meter). The soil loss in the variant of conventional maize cultivation with ploughing was higher by an order – 142.2 g/(h.m^2), which is 1.42 tons per hectare per hour of artificial rainfall. In the variant of maize cultivation with ploughing and use of a cover crop (oat) the higher soil loss of 54.2 g/(h.m^2) was measured than in the variants of maize cultivation with minimization of soil tillage with spring seedbed preparation and without spring seedbed preparation (maize sowing into a winter killed catch crop). It does not confirm the expected effect of cover undersown crop in the maize cultivation that should contribute to soil conservation. Technologies of maize cultivation with ploughing appeared to be risky in conditions with lower natural resistance of soil to erosion. It is consistent with the results of the authors who reported a significant reduction in soil loss by erosion when soil tillage without ploughing is used – RASMUSSEN (1999) reported a reduction in soil loss by half or even by two thirds depending on the soil type. Truman, Shaw et Reeves (2005) found out twice lower surface runoff and five times lower soil loss for tillage without ploughing compared to the conventional soil tillage during rainfall simulation for 60 minutes.

Measurements of surface runoff and soil loss during artificial rainfall generated by a simulator confirmed previous findings: water infiltration into the soil after ploughing is usually high only for some time, and it markedly decreases with time. When the conventional practice of soil tillage with ploughing was used for maize cultivation, in the course of measurements in the maize stand in June water infiltration into the soil on ploughed land was markedly lower than in variants with soil tillage for maize without ploughing (HŮLA & KOVAŘÍČEK, 2010). An assumed reason is the creation of the surface layer of topsoil with a decreased proportion of macropores and hence reduced permeability for water on ploughed land. In variants with soil tillage for maize without ploughing no such a tendency of pronounced decrease in soil permeability for water in spring and summer was recorded. A relation between the creation of the surface non-structural layer of soil on conventionally tilled land with ploughing and the reduced permeability of soil for water was described by TEBRÜGGE & DÜRING (1999).

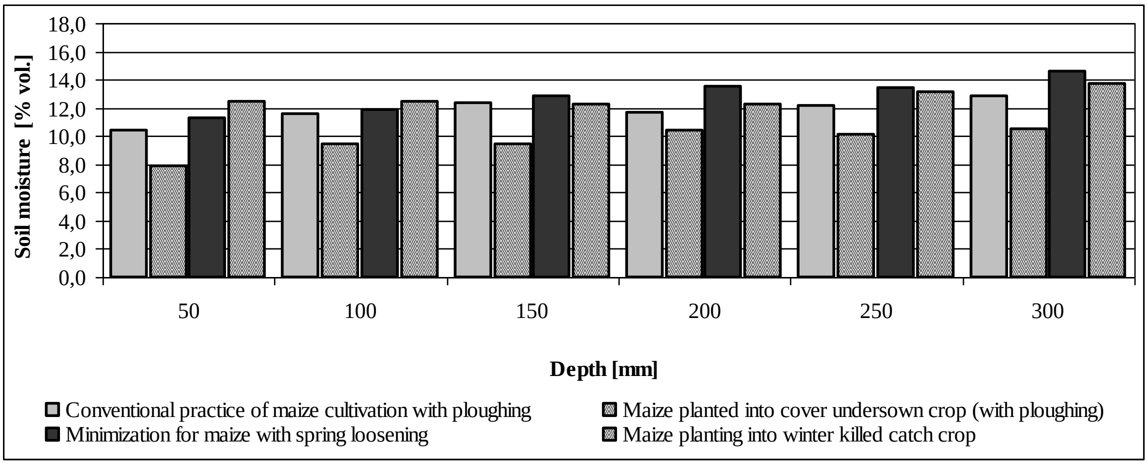

Fig. 2. – Soil moisture before measurement with rainfall simulator on 11th June 2015

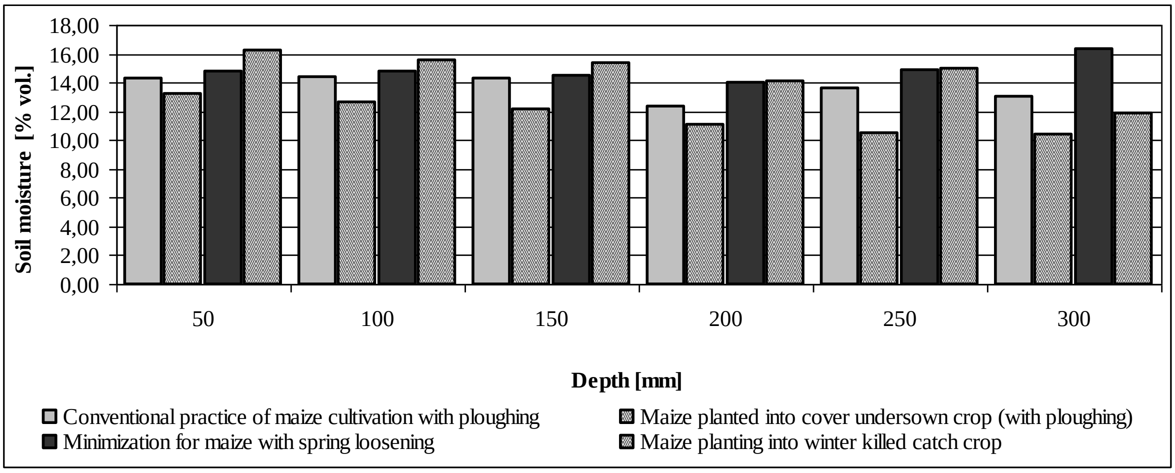

Fig. 3. – Soil moisture before measurement with rainfall simulator on 24th June 2015

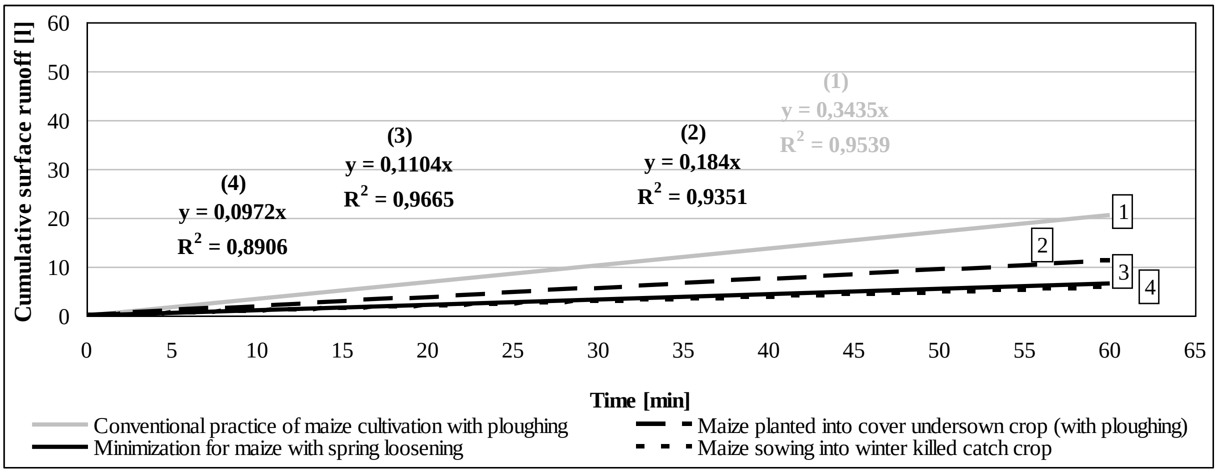

Fig. 4. – Surface water runoff during rainfall simulation on 11th June 2015

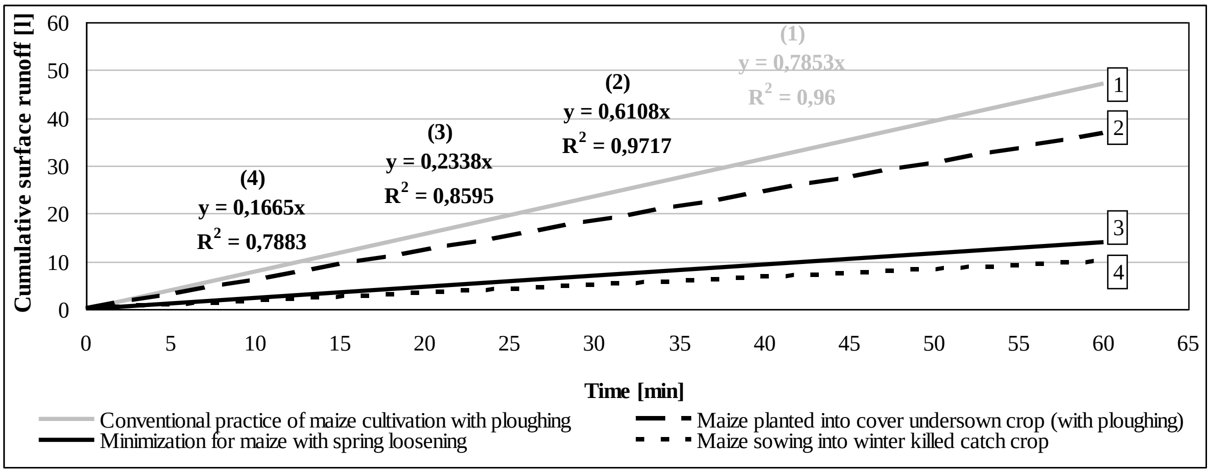

Fig. 5. – Surface water runoff during repeated rainfall simulation on 24th June 2015

Note: the order of variants from the lowest surface runoff – maize planting into a winter killed catch crop, minimization for maize with spring loosening, maize planted into a cover undersown crop (with ploughing), conventional practice of maize cultivation with ploughing.

Tab. 2. – Soil loss during a simulated rainfall event of 87 mm/h

Variant	Soil loss g/(h.m^2)
Conventional practice of maize cultivation with ploughing	142.2
Maize planted into cover undersown crop (with ploughing)	54.2
Minimization for maize with spring loosening	12.4
Maize planting into winter killed catch crop	12.6

CONCLUSIONS

The variant of maize cultivation by conventional soil tillage with ploughing was the most risky from the aspect of surface water runoff during rainfall and soil vulnerability to water erosion. Obviously, for maize cultivation it is necessary to use practices that will ensure sufficient permeability of soil for water in combination with the utilization of dead plant biomass on the soil surface. Promising from this aspect is the practice of strip tillage when deeper loosening of soil is used in a space under future maize rows, while in strips between maize rows there may remain untilled soil with crushed cereal straw on the soil surface.

ACKNOWLEDGEMENTS

Supported by the Ministry of Agriculture of the Czech Republic – Project No. QJ1210263 and RO0614.

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