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Impacts of technology and the width of rows on water infiltration and soil loss in the early development of maize on sloping lands

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ABSTRACT

Herout M., Koukolíček J., Kincl D., Pazderů K., Tomášek J., Urban J., Pulkrábek J. (2018): Impacts of technology and the width of rows on water infiltration and soil loss in the early development of maize on sloping lands. Plant Soil Environ., 64: 498–503.

Soil erosion by water has become an issue in the cultivation of maize (*Zea mays* L.) on sloping lands in recent years. The following three technologies of tillage have been assessed: disc cultivator, strip-till and no-till (raw land). Seeding machine Kinze 3500 was used for sowing maize cultivar Silvinio FAO 210. The experiments were conducted within the years 2013, 2014 and 2016. Erosion was evaluated under simulated rain in three stages of maize growth. The following parameters of each tested tillage treatment were measured: water infiltration (mm), soil loss (converted to t/ha), dry matter yield of the aboveground biomass and grain yield. The results confirmed that no-till technology reduced water erosion to the value of 0.40 t/ha. This technology along with the row spacing of 0.75 m tended to bring higher yields of aboveground biomass (13.40 t/ha). Tillage and phacelia as a catch crop increased water infiltration in the soil.

Keywords: *Zea mays* L.; precipitation; tillage technology; rain simulation; *Phacelia tanacetifolia*

Conventional tillage on sloping surfaces can lead to high losses of soil, especially if performed in the direction of the slope or slope line (de Alba 2003). New technologies and machinery are being tested with the aim to provide good conditions for the cultivation of maize on mild slopes and thus to exploit the potential of plants. Among them, it is the technique of deep loosening, which contributes not only to better water infiltration, but also to greater aeration of soil and more effective application of starter fertilizers. Plants are then able to better utilize the nutrients needed for their growth (Pulkrábek et al. 2016) and maize belongs among crops with high nutrients demands (Orosz et al. 2009, Maňásek et al. 2013).

The 'no-till' technology is suitable when soil is exposed to wind and water erosions, tillage is too difficult or the costs of soil cultivation are too high (Ghimire et al. 2017). There are several factors affecting the yield, all of which are essential for obtaining high-quality biomass and the maximum yield per surface unit. However, water erosion of soil appears a major problem in the cultivation of maize. Recently, soil protection practices such as zero and minimal tillage have been emphasized while maintaining soil moisture, saving fuel and eliminating erosion (Sharafi et al. 2013). Technologies of maize cultivation in erosion risk areas are not ready for application: measures to prevent or eliminate erosion sufficiently are missing. Maize as an erosive (wide-row) crop will disappear from our fields unless cultivated under soil conservation technology. Fehmi and Kong (2012) reported that covering the surface with mulch

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increased the speed of water infiltration into soil during stronger rains. This was also confirmed by Alliaume et al. (2014). Mulch as a surface cover plays an important role in the elimination of erosion and soil loss during water runoff.

The fertility of soil connected to the cycle of organic matter in the form of manure put back into soil is breached as well. Cultivated crops may affect the composition and microbial activity in soil by their root exudates and residues. One of the most significant plants is maize (*Zea mays* L.), which is widely used in agriculture and industry. In a number of countries, maize is grown as monoculture; the long-term impact of its inclusion in crop rotation has not been thoroughly explored yet (Galazka et al. 2017b).

Water erosion of soil is influenced by several factors: precipitations, sloping, tillage technology, soil structure and crop rotation. Long-term adverse effects of erosion often lead to irreversible changes in the physical, chemical and biological properties of soil (Bielek 1996). Soil erosion is a complex and multifaceted process arising from a variety of factors, a combination of conditions, variations and interactions which significantly affects the final soil loss (Wischmeier and Smith 1978).

The climate has been changing lately. The average annual precipitation has decreased in addition to changes in its intensity. Instead of regular lower precipitations, heavy rainfalls occur in short intervals. Water erosion is significantly affected by intense rainfalls of relatively short duration (Carvalho et al. 2016). In addition, rainfalls come in times when soil is the most vulnerable (without green cover). Carreker (1977) found that sloping and the direction of rows had a major influence on water runoff and soil loss. This was also confirmed by Dostál et al. (2002), who stated that half of the arable land is endangered by erosion only for its sloping nature. The cumulative average rate of soil erosion in the European agricultural holding is between 4.5 and 38.8 t/ha per year. There are 115 million hectares of land at high risk of water erosion and 42 million hectares at risk of wind erosion (European Environment Agency 1998). The potential average annual loss of soil from agricultural land on slopes in the Czech Republic is 13.7 t/ha, i.e. 0.9 mm of soil profile thickness or 25 million tons of soil per year (Dostál et al. 2002). The greatest danger comes in the early stage of maize cultivation. Soil is not protected and therefore, it is exposed to the highest risk of water erosion. Top-quality soil is then irreversibly washed down to the lower parts of plots.

There is the aim to grow maize using soil conservation technologies to prevent water erosion in susceptible areas. In the last thirty years, land management practices have been developed to minimise the need for tillage. Among such practices, there are zero tillage or leaving plant residues on the surface to control the erosion. Soil that is protected by green cover or roughly cultivated infiltrates precipitation faster and consequently prevents runoff (Boardman 1991). Malvar et al. (2013) reported 45% lower water runoff in the case of land with mulch on the surface compared to land with no mulch at all. This is confirmed by Mikanová et al. (2012) whose work reported better use of water and reduced non-productive evaporation depending on the use of mulch in soil conservation technologies.

Another option for soil conservation is sowing into raw land, which requires no soil treatment in order to preserve protective vegetation and maintain certain level of organic matter in soil (Baker et al. 1996). Inclusion of fodder plants, on arable land of the Fabaceae family, or legumes in crop rotation also produces a positive effect on land. If fodder plants or legumes are used in crop rotation, soil erosion is reduced and the plot is protected in those years (Evans 1996).

The main objective of this work was to evaluate the effect of monitored cultivation technologies and different soil tillage on soil erosion and infiltration of water. At the same time impact on the dry matter yield of aboveground biomass and the grain yield was evaluated.

MATERIAL AND METHODS

Three technologies of tillage were assessed at the maize cultivation. Two of them are designed for soil conservation while the third is a conventional technology using a disc cultivator. Treatment I – sowing into a freezing-out catch crop of *Phacelia tanacetifolia* Bentham with no tillage in spring. Treatment II – strip-tillage with treatment only in spring. Treatment III – conventional technology using disc cultivator in spring.

In terms of yields, the aboveground biomass was evaluated at 110 thousand individuals and the

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grain at 90 thousand individuals per hectare. In all treatments, maize was sown in two widths of rows: 0.75 m and 0.375 m. After sowing, a non-selective herbicide (glyphosate – IPA 588 g/L) along with pre-emergence protection (Gardoprim Plus Gold 500 SC) for maize were used. The experiments were conducted within the years 2013, 2014 and 2016 on a farm in Petrovice near Sedlčany (GPS 49.560795, 14.320530) – potato-oat production area. The sloping of the experimental area ranged between 5.04–8.03° (slight danger of soil erosion).

Each treatment was evaluated for its dry matter yield of aboveground biomass and grain yield. The yield was calculated from green to dry mass using the formula [(weight of biomass/100) × dry matter yield]. Seeds of cultivar Silvinio FAO 210 from the KWS Seeds Inc. company was used for the experiment.

The impacts of soil conservation technologies were assessed with the help of a field rainfall simulator, developed and after long-term experiments they were gradually improved by the Research Institute for Soil and Water Conservation. In addition to the staff of Research Institute for Soil and Water Conservation, the experts of Czech Technical University and Czech University of Life Sciences also participated on the 'Verification of efficiency of erosion control technologies with the use of a field rainfall simulator' and on the verification of measurement accuracy. The verification of erosion control efficiency with a field rainfall simulator is run in the raining mode of 30 + 15 min, i.e. 30 min of raining on naturally dry soil (first phase), then technical break of 15 min and afterwards additional 15 min of raining on saturated soil (second phase). The intensity of raining corresponds to the rainfall of 1.22 mm, i.e. the experimental area receives in total a rainfall of 54.86 mm. The pressure in the nozzles of the simulator is set to 0.5 bar. The size of area for simulated water erosion is 25 m^2 (2.5 × 10 m). The erosion control technology was tested during the germination of maize seeds, i.e. after the crop has emerged and covered at most 10% of land. For control, the values measured in each treatment are compared to bare fallow. In the first phase (30 min), the rainfall simulation is performed on dry soil. The second phase (15 min) of the simulation is performed after a 15-minute break on soil wet from previous raining.

During the rainfall simulation, surface water runoff in seconds and its intensity in millimetres were assessed. Among other data processed were: water infiltration into soil in millimetres of rainfall and soil loss converted to t/ha. The main monitored parameters were infiltration of water into soil and loss of soil per a surface unit. Both values are very important as they determine the size and intensity of water erosion.

RESULTS AND DISCUSSION:

Table 1 give the values for water infiltration and soil loss. Table 1 shows the values of first phase raining (30 min). The best values of the monitored technologies were achieved in treatment I (no-till), which showed the lowest loss of soil (0.50 t soil/ha)

Table 1. The first and second phase of rainfall simulation in the first testing (average for the years 2013, 2014 and 2016)

Technology	First phase				Second phase			
	infiltration (mm)	soil loss (t/ha)	biomass yield (t/ha)	grain yield (t/ha)	infiltration (mm)	soil loss (t/ha)	biomass yield (t/ha)	grain yield (t/ha)
Ploughed bare fallow	20.05^{ab}	5.33^{a}	0	0	11.3^{a}	6.17^{a}	0	0
Disc (treatment III)	18.54^{b}	3.58^{a}	12.56^{a}	5.71^{a}	8.84^{b}	2.58^{b}	12.56^{a}	5.71^{a}
No-till (treatment I)	25.72^{a}	0.50^{b}	12.15^{a}	5.44^{a}	8.07^{b}	0.40^{b}	12.15^{a}	5.44^{a}
Strip-till (treatment II)	20.47^{ab}	2.83^{ab}	13.00^{a}	5.61^{a}	8.36^{b}	1.87^{b}	13.00^{a}	5.61^{a}
$HSD_{0.05}$	6.00	2.88	1.72	1.26	1.77	3.27	1.72	1.26
Rows 0.75 m	21.26^{a}	3.00^{a}	13.08^{a}	6.21^{a}	2.83^{a}	8.75^{a}	13.08^{a}	6.21^{a}
Rows 0.375 m	21.13^{a}	3.24^{a}	12.14^{a}	4.97^{b}	2.68^{a}	9.53^{a}	12.14^{a}	4.97^{b}
$HSD_{0.05}$	3.15	1.51	1.15	0.84	0.92	1.74	1.15	0.84

HSD – honestly significant difference

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in the first phase of raining. As for infiltration, the technology of no-till (treatment I) ranked also the best (25.72 mm). Overall, the technology of no-till met the requirements for soil conservation in terms of water erosion.

The results of different technologies showed the progress of infiltration and soil loss. The lowest statistically significant infiltration value and thus the lowest water absorption into soil, was achieved in treatment III, DISC technology (18.54 mm). In terms of infiltration, ploughed bare fallow (20.05 mm) was statistically similar to strip-till technology in treatment II (20.47 mm). The highest statistically significant value of water infiltration into soil was proved by no-till technology, treatment I (25.75 mm). In this technology, soil surface contained approximately 80% of post-harvest residues of *Phacelia tanacetifolia* Bentham pre-crop. Moreover, the roots of phacelia catch crop left a well rooted profile, so water could be absorbed better. This is confirmed by Wischmeier et al. (1971), who found sufficient cover and the involvement of mulch crop playing an important part in water runoff and erosion control protection. The statistical assessment of soil loss (Table 1) showed the highest value for ploughed bare fallow (5.33 t of soil/ha) and, on the contrary, the statistically smallest loss for no-till technology of treatment I (0.50 t of soil/ha). The values of treatment II, strip-till technology, reached 2.83 t of soil/ha and was therefore closer to the value of no-till, treatment I. Infiltration and soil loss seemed to work alike. Catch crop can enhance infiltration but at once eliminates the loss of soil by water erosion. Gyssels et al. (2005) stated that the elimination of erosion and the reduction of water runoff are in correlation with growing green cover, which corresponds to our results. Maňásek et al. (2016) found out that phacelia catch crop brings high amounts of primary soil organic matter that is object of humification and mineralization.

Results of the second phase of rainfall simulation (15 min) in the early stage of vegetation are also shown (Table 1). The values of monitored technologies in water infiltration into soil were very similar to the results of the first phase. They ranged from 8.84 mm (treatment DISC) to 8.07 mm (treatment I, no-till). The highest value (11.3 mm) was achieved at ploughed bare fallow. In terms of soil loss, the results were similar to those of infiltration. The highest, most erosive values were reached by fallow (6.17 t/ha). Overall, the impact of a technology was apparent compared to the bare fallow option in both water infiltration and soil loss. Using soil conservation technologies enhanced infiltration of water in soil, which is favourable. Truman et al. (2005) confirmed that if appropriate agrotechnical measures are adopted, in particular the application of soil conservation technology, water runoff should be reduced and infiltration into soil enhanced. The same results were declared by Morgan (1991).

The data of soil loss in both phases of the experiment significantly differ. Expectedly, the highest losses of soil were observed at the control treatment of bare fallow (5.75 t/ha). Treatment DISC with the value of 3.21 t/ha proved that this technology had a significant effect on the reduction of soil loss. The technology of strip-till (treatment II) with the statistical value of 2.35 t/ha showed even lower soil loss than the previous technology. The best results in the soil loss monitoring were achieved in treatment I (no-till technology); the value of infiltration was 18.51 mm, whereas the value of soil loss in the same treatment was 0.45 t/ha. These statistically significant results confirm that both technologies, strip-till (treatment II) and no-till (treatment I), met the cultivation requirements in terms of erosion control. The soil contained enough organic residues on and beneath the surface. De Baets and Poesen (2010) saw the roots as one of the key factors affecting the stability of soil aggregates, which corresponds to our results. Technologies protect soil from water erosion. This problem can be significantly reduced with the use of appropriate agricultural techniques – particularly soil conservation technologies, which should reduce runoff and increase water infiltration into soil (Truman et al. 2005).

The graphs assess the influence of row spacing on the infiltration of water into soil and the loss of soil caused by water erosion. Figure 1a shows that the treatment I (no-till technology) held the most water in the monitored area. Furthermore, there was a visible difference in the water infiltration in the first and second phase of raining.

Data in Figure 1a describe water infiltration. The largest amount of water was absorbed in the first phase of raining (from 20 to 25 mm). The highest values of infiltration were achieved by no-till technology in the first phase of raining, followed by strip-till technology (20 mm). The second parameter assessed was soil loss. High losses of soil

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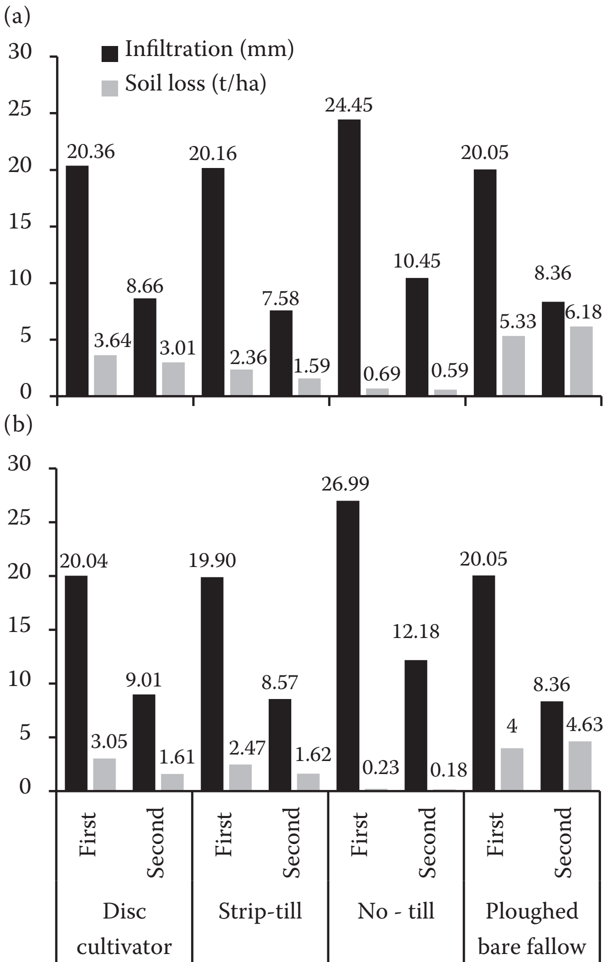

Figure 1. Infiltration and soil loss in the first raining simulation of maize with row spacing of (a) 0.75 m and (b) 0.375 m (average for the years 2013, 2014 and 2016)

occurred in the case of fallow. Fallow in the first raining gave the values of 5.33 t of soil/ha and 6.18 t of soil/ha. The lowest losses of soil were achieved by no-till technology (0.59 t of soil/ha).

Figure 1b presents the results for row spacing of 0.375 m. The highest infiltration was in treatment I, no-till (26.99 mm) as well as the lowest soil loss (0.18 t of soil/ha). Among the benefits of reduced processing may be an increase in crop production, an improvement of infiltration and a reduction of runoff. Different techniques of tillage are also supplemented by porosity and diversity of surface, which are processed with the aim to improve water infiltration (Cogle et al. 1997).

The above-stated values reveal that the monitored soil cultivation technologies did not statistically differ with the row spacing (Figure 2). However, there was a tendency of higher yields at the row spacing of 0.75 m and the no-till soil cultivation. Among other parameters observed, there were the dry matter yield of aboveground biomass and the grain yield of each technology. As obvious in Figure 2a, the values for all technologies ranged from 13.40 t/ha in treatment I to 12.88 t/ha in treatment II. Statistically, technology did not seem to affect the yield of biomass dry matter. The Figure 2b shows similar statistical values of grain yield for no-till (6.54 t/ha), strip-till (5.88 t/ha) and disc (6.17 t/ha). Here again, the use of different technologies did not seem to affect the grain yield. The experiment did not prove that the technologies used would have statistically different values for biomass and grain yields. The monitored soil cultivation technologies do not statistically differ, because the range of values was too high in statistical repeats (years 2013, 2014, 2016). Galazka et al. (2017a) stated that the yields of maize achieved by conventional system, reduced tillage and no tillage were similar.

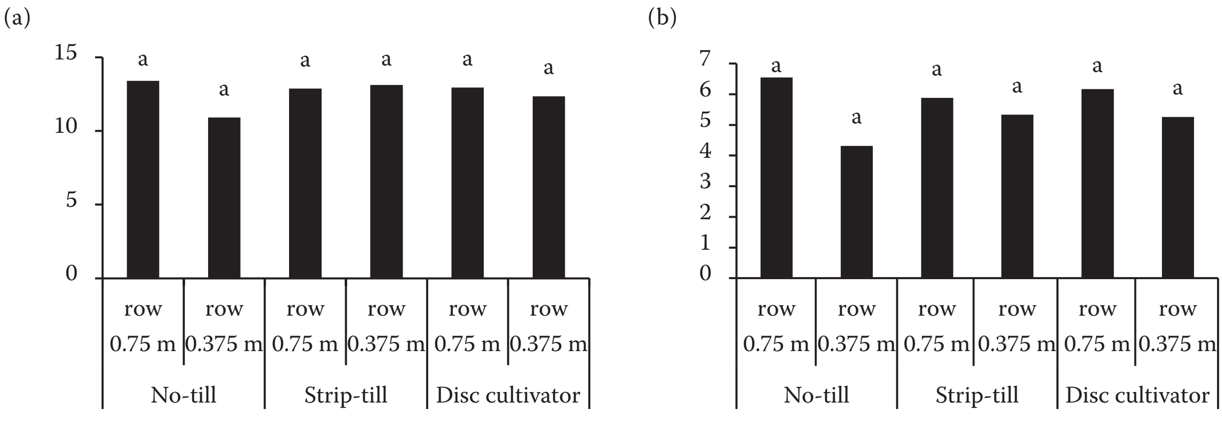

Figure 3. (a) Dry matter yield of aboveground biomass (t/ha) and (b) grain yield (t/ha) for different technologies and row spacing (average for the years 2013, 2014 and 2016)

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