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Impacts of some cultivated crops on water erosion in the Central Bohemia Region

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Abstract. This paper aims at assessing the impact of crops on water erosion parameters. Water erosion is the most common cause of damaging agricultural land in the Czech Republic. This is due to the large average slope of land and the prevailing soil types. The field trial was based on a site with an average slope of 5.4°. The primary objective was to assess the effect of the crop on the surface runoff and soil loss. The crops cultivated in the experiment were winter wheat, rape, potatoes, corn and oats (conventional tillage for all variants). Black fallow was used as the comparative variant (without vegetation). There is a light cambisol on the experimental field. To assess erosion, the method of microplots was used. The physical properties of the soil were also evaluated. The results show the risk of growing wide-rows crops (potatoes, corn). The soil loss in these crops was similar to the variant without vegetation.

Key words: water erosion, wide rows crops, surface runoff, erosion wash-out.

INTRODUCTION

One of the most important input parameters with a great influence on erosion processes is organic matter (Franzluebbers, 2002). This effect can take many forms, but the two basic ones are the soil vegetation cover formed by plants and also the soil cover formed by organic plant residues (Kovář et al., 2016).

A sufficient vegetation cover affects the course and intensity of erosion processes (Hangen et al., 2002). Its aim is to protect the soil against the impact of rain drops, to improve soil consolidation through the root system of plants especially in subsurface layers, to increase the infiltration capacity of the soil due to the growth of the root system and to improve the physical, chemical and biological properties of the soil (Šařec & Novák, 2017). The roots of some plants can destroy the compacted layer of soil created especially by the technogenic compaction (Kroulík et al., 2011). The choice of the appropriate crop is the most important issue for each plot. The study by Morgan et al. (2005) is based on data collected from the authors around the world. Morgan also states that soil losses caused by water erosion can be reduced up to 4.7 times by soil fertilization, by adjusting the microrelief up to 30 times and choosing a suitable crop to 37 times.

The greatest danger for the soil consists in the inappropriately created stands of broad-leaved crops, especially in the early stage of development, as well as in newly established vineyards. The above mentioned problem under the conditions in the Czech Republic will mainly touch the corn crops sown on sloping land. The crops that are mainly threatened are grains and temporary grasslands, while permanent grasslands are less threatened (Zhang et al., 2014).

The initial hypothesis based on the assumed reduction of surface runoff and subsequent soil erosion wash-out in crops that have a higher cover of soil by plant cover at the time of intense rainfall. Furthermore, what is anticipated is higher surface runoff and soil erosion washout in wide-row crops.

MATERIALS AND METHODS

A field trial was established for the needs of measurements in the village Nesperská Lhota (see Fig. 1). The plot is situated on the border of the Vlašimská pahorkatina Hills (typical annual rainfall 700 mm). The experiment was based on light, sandy loam soil at an altitude of 450 m a.s.l. The average slope of the land is 5.4°. The soil contains particles smaller than 0.01 mm – 32.3& and organic C of 3.8&.

Figure 1. Experimental location (a), field photo (b),

The field experiment consists of five basic variants and one comparative variant. Each variant has an area of 300 m^2 with dimensions of 6 x 50 m. The long side of each variant is oriented to the slope. Each version represents a different crop growing typical for local conditions.

Variants of the experiment:

1. Winter rape (slope 5.6°): Conventional soil tillage cultivation technology. Primary and secondary tillage (a plough and seedbed cultivator) was done before sowing; sowing was carried out on August 17^{th}, 2017.

2. Winter wheat (slope 5.4°): Conventional soil tillage cultivation technology. Primary and secondary tillage during autumn; sowing was carried out on October 2^{nd}, 2017.

3. Oats (slope 5.2°): Conventional soil tillage cultivation technology. In autumn – plowing was carried out and a rough furrow was left during winter; in spring - secondary tillage (using a combinator) was effected, after which sowing took place on April 6th, 2018.

4. Corn (slope 5.3°): Conventional soil tillage. In autumn - plowing was carried out and a rough furrow was left during winter; in spring - secondary tillage and sowing corn took place on April 28th, 2018).

5. Potatoes (slope 5.5°): Conventional soil tillage technology. In autumn - ploughing was carried out and a rough furrow was left during winter; in spring - pre-seed preparation using a tine tiller was followed by potato planting on 29th April 2018.

6. The last variant is black fallow and it is comparative variant for whole exporiment (slope 5.4°): the soil was treated by implementing conventional technology (the same as in the case of the previous variants), a non-systemic herbicide (glyphosate) was used to destruct plants; this eradication with the above mentioned herbicide was repeated several times during the 2018 season.

For each of the described variants, four outflow microplots were installed after sowing. The microplots were surrounded by 1.5 mm thick steel sheet. The walls of the microplots were pushed into the soil to the depth of 0.08 m (see Fig. 2). The collector is located at the bottom of each micro plot. It transports water into a plastic container buried below the catching microplots. The area of each microplots is 0.4 m x 0.4 m.

Figure 2. Microplot with a plastic container for measurement.

For the purpose of measuring the volume and intensity of precipitation weather station Vantage Vue was placed near the experiment.The surface runoff was measured after every heavy rainfall. The surface runoff was detected by measuring the volume, the amount of soil washed by filtering runoff (erosion wash-out values) and subsequent soil drying at 105°C and weighing the soil on a laboratory scale. The measurement and evaluation method used in the study was published by Bagarello & Ferro (2007).

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

RESULTS AND DISCUSSION

Table 1 shows the results of the measurements of physical properties of soil. In general, the values are very similar. At the time of measurement, the effect of spring secondary tillage in the spring variants could be observed. The data reveal similar physical soil conditions. Thus, a similar effect on water infiltration into the soil can be assumed. There is no significant compacted layer in the measurement range.

The first soil erosion event occurred as a result of two storms from May 10th and 13th. Total precipitation in this period was 33 mm. The precipitation intensity ranged from 80–100 mm h^{-1}. The results in Figs 3 and 4 show that the lowest surface runoff and erosion wash-out were recorded in the first three variants. The lowest surface runoff and erosion wash-out is in winter rape, which is already involved in this period and begins to bloom. On the contrary, the largest surface runoff and wash-out was expected in the case of the conventional soil cultivation for corn and potatoes (variants 4 and 5). In these variants, the soil is still insufficiently protected by the growth of plants. Variant No. 6 also showed a high surface runoff and erosion wash-out. The highest surface runoff was reached by variant No. 5 (potatoes), but the soil was a bit lower than the comparative variant (black fallow).

Table 1. Soil bulk density and total porosity

Variant	Depth [m]	Porosity [%]	Bulk density [g cm^{-3}]
1	0.05–0.1	37.50	1.62
	0.1–0.15	39.48	1.57
	0.15–0.2	40.84	1.53
2	0.05–0.1	36.31	1.63
	0.1–0.15	38.76	1.57
	0.15–0.2	38.51	1.61
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	37.04	1.57
	0.1–0.15	38.51	1.47
	0.15–0.2	42.41	1.61
5	0.05–0.1	40.99	1.59
	0.1–0.15	37.90	1.58
	0.15–0.2	40.86	1.51
6	0.05–0.1	38.63	1.54
	0.1–0.15	41.23	1.48
	0.15–0.2	40.97	1.52

The difference in soil loss weight between rape, wheat and oat variants is below statistical significance. On the contrary, the soil erosion wash-out in the corn, potatoes and control variants, is statistically significantly higher than in the first three variants (Fig. 3 and Fig. 4).

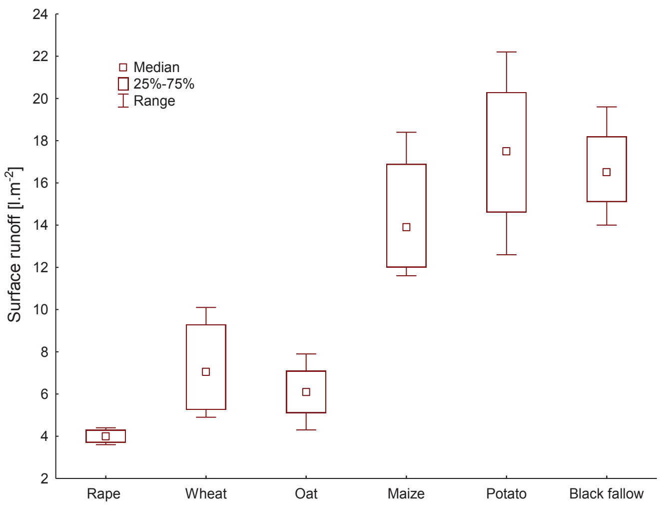

Figure 3. Surface runoff after two storms in May 2018.

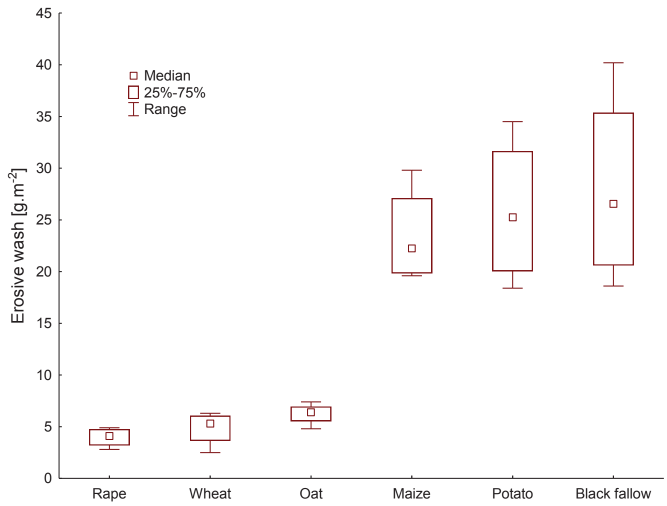

Figure 4. Erosion wash-out after two storms in May 2018.

Two more significant erosion events occurred during June. The first event occurred between June 10th and 14th, when the rain and two storms with a rainfall of 34 mm were recorded. The precipitation intensity ranged from 80–100 mm h^{-1}. The graphs in Figures 5 and 6 show that again the lowest surface runoff and erosion wash-out were recorded in the first three variants. Conversely, the highest surface runoff and erosion wash-out was measured for variant 5. High values were observed in the corn variant whose surface runoff was higher than in the comparative variant, but the soil wash-out was smaller than in the case of the potato variant and comparative one. The surface runoff of the comparative variant was lower than that of the corn variant and the potato, but the erosion wash-out reached similar values here (Fig. 5).

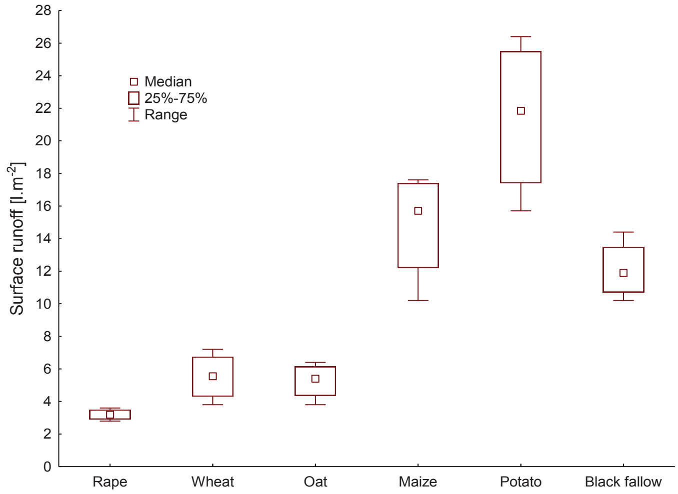

Figure 5. Surface runoff after two storms in the period 10th to 14th June 2018.

The difference in erosion wash-out between rape, wheat and oat variants is below statistical significance. On the contrary, the soil loss in the corn, potato and control variants is statistically significantly higher than in the first three variants (Fig. 6).

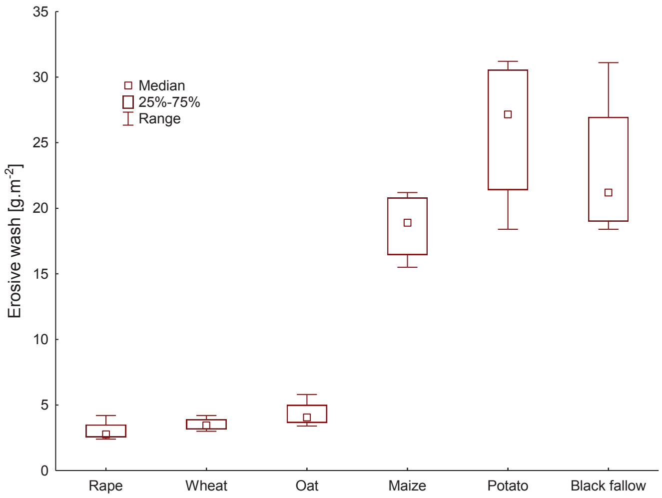

Figure 6. Erosion wash-out after two storms in the period 10th to 14th June 2018.

The second significant event was occurred between June 26th and 28th. There were two storms with a total precipitation of 44 mm. The intensity of these precipitation reaches up to 200 mm h^{-1} for a short time. The graphs of Figs 7 and 8 show that the lowest surface runoff and erosion wash-out were recorded in the first three variants. In these variants the plants are already involved and the soil is well protected against erosion hazardous rainfalls. The lowest surface runoff and erosion wash-out were observed in winter rape. On the other hand, the highest surface runoff and wash-out were achieved by variant 5. Similarly, high values were achieved with the corn and comparative variants, but erosion wash-out was slightly lower than in the potato variant.

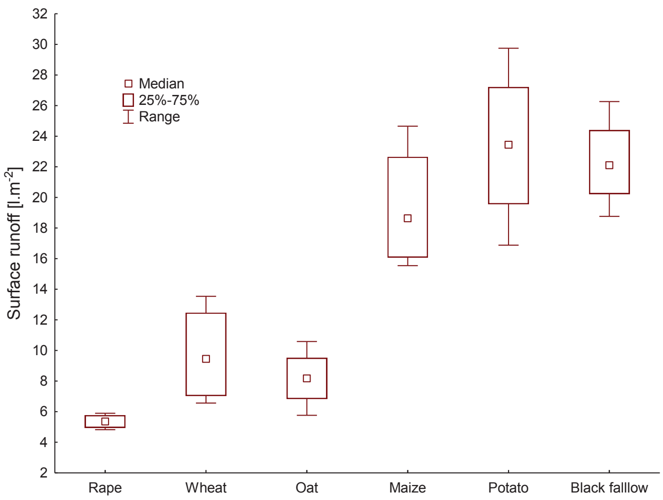

Figure 7. Surface runoff after two storms in the period 26th - 28th June 2018.

Again, there is a problem of poorly protected soil by plant residues. Another problem can be seen in wide rows crops production. This measurement reveals the most extreme values of erosion wash-out measured during the season 2018. The difference in erosion wash-out weight between rape, wheat and oat variants is below statistical significance. On the contrary, the soil runoff in the corn, potato and comparative variants is statistically significantly higher than in the first three variants (Fig. 7 and Fig. 8).

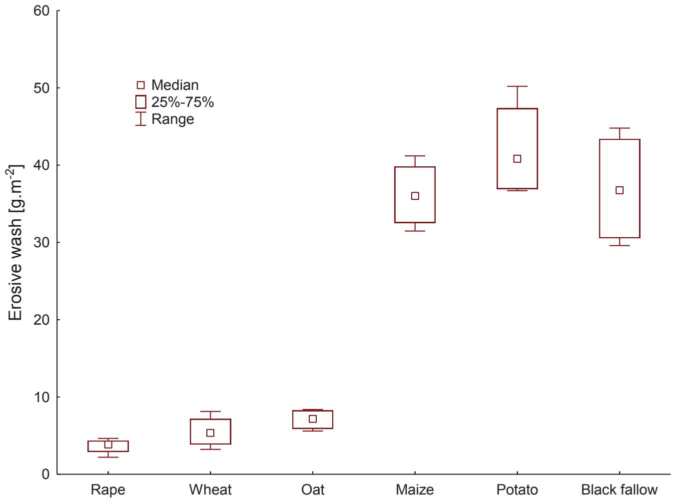

Figure 8. Erosion wash-out after two storms in the period 26th – 28th June 2018.

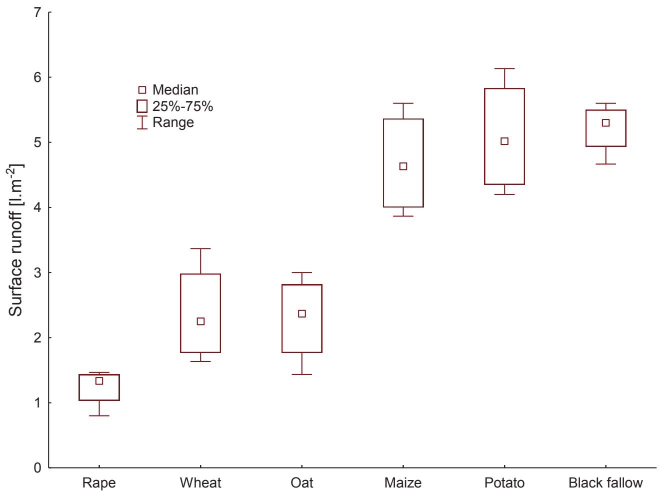

Figure 9. Surface runoff after a storm on July 6th, 2018.

Last erosion event occurred on July 6th during a short storm, when the rainfall was 9 mm and the intensity of the rain reached up to 80 mm h^{-1}. The graphs in Fig. 9 and Fig. 10 show that the lowest surface runoff and erosion wash-out were recorded in variant No. 1. In the case of wheat and oats, a slightly higher surface runoff was recorded than in the case of the rape variant. Higher values of surface runoff were captured in the potato and comparative variants, where the highest value was reached by the black fallow variant compared with the corn and potatoes variants. The highest values of surface contours were achieved by variant 4 compared with the comparative and potatoes variants.

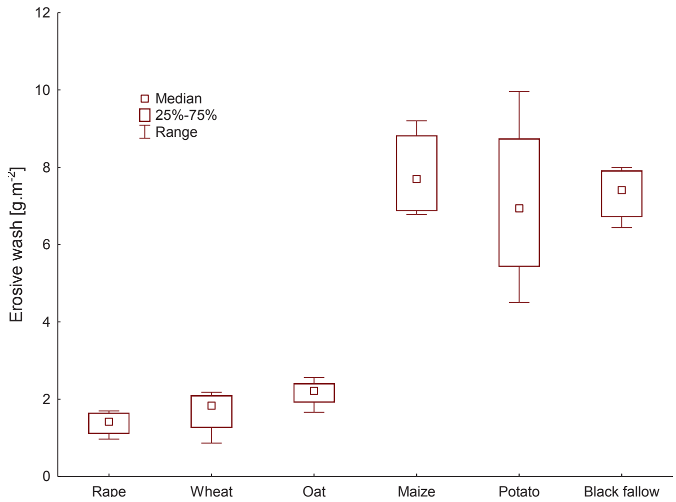

Figure 10. Erosion wash-out after a storm on July 6th, 2018.

The difference in the erosion wash-out weight between rape, wheat and oat variants is below statistical significance. On the contrary, the soil loss in the corn, potato and comparative variants is statistically significantly higher than in the first three variants.

The highest surface runoff and erosion wash-out were in variants with broad-leaved crops, in this case corn and potatoes. This has also been confirmed by Karlen et al. (1994). The soil is not well protected by the associated crop and the large kinetic energy of the falling droplets results in increased surface drainage and consequently an undesirable loss of the soil. The negative aspect for comparative variant (No. 6) was leaving the soil without any surface coverage by plant residues. In this case as well as in the other cases, there was also an increased surface drainage and consequent soil loss down the slope.

Brown et al. (1989) measured that for all monitored soil conditions (soil with plants or fallow) the amount of erosion of discrete particles decreased with increasing time since the beginning of the experiments. Generally, freshly treated soil is more inclined to soil erosion than the soil that has undergone several cycles of drying and rewetting. This phenomenon may be due to differences in cohesive forces between soil particles. This assertion has also been confirmed in the case of the above mentioned assessment, in which the differences between experimental variants of surface water drainage values during intensive rains events in the case of soil erosion have diminished. This is confirmed by Bradford et al. (1994).

Microplots were used to evaluate erosion parameters by Bagarello & Ferro (2007). This study confirmed the different behavior of the soil surface at a different cover. Most similar studies have focused on the impact of soil tillage. Novák et al. (2012) found a significant reduction in surface runoff by implementing reduced tillage technologies. The crop effect both on surface runoff and soil loss is evident and approved by many authors.

CONCLUSIONS

The hypothesis stated in the introduction has been confirmed by the field experiment. Clearly, a beneficial effect of vegetation soil cover during erosion hazardous precipitation has been demonstrated as a protection of the soil against the large kinetic energy of the falling droplets. It has also been proved that the infiltration of water into the soil has increased, which has led to minimum surface runoff and soil loss. On the contrary, it has been confirmed that broad-line or wide-rows crops considerably suffer from surface runoff and soil loss, which are much higher than in narrow rows sown crops. These crops are under risk of creating soil crust, which has a negative effect on the infiltration of water into the soil and the consequent increased surface drainage and soil loss.

The results of this study cover only for one year, one site and one soil type. The results obtained for different soil types might differ from these results.

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