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The effect of straw mulch and compost application on the soil losses in potatoes cultivation

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Abstract: The study aimed to evaluate the effect of the straw mulch and compost application on the soil losses in potatoes cultivation. The three-year (2016–2018) exact field plot trials with the potato cv. Dicolora was carried out at the experimental station in Prague-Uhříněves. Wheat straw mulch in two doses 2.5 t/ha (SM1) and 4.5 t/ha (SM2) was applied on the soil surface; the compost in a dose of 20 t/ha (CM) was shuffled to the surface soil layer. Both straw mulch and compost application contributed to the significant reduction of the soil losses compared to control untreated (C). In the average of 2016–2018, the lowest soil loss 17.54 g/m^2 (amount of the soil sediment caught) was found for the variant with the straw mulch treatment (SM2); it means the decrease of soil losses by 71.9% compared to C. Variant SM1 (lower rate of straw mulch in dose 2.5 t/ha) showed the soil loss 18.6 g/m^2 (the decrease by 70.2% compared to C). The similar results for both variants indicate that for effective soil protection, it is not necessary to use the high doses of the straw mulch. Regarding the distribution of precipitation during the vegetation season, intensive precipitation during the short time, especially when they came after the longer period of drought led to higher soil losses compared to the precipitation distributed regularly.

Keywords: erosion; sum of precipitation; rainfall; *Solanum tuberosum* L.; infiltration; organic matter

Soil erosion, as one of the forms of soil degradation, affects more than 1 billion hectares of soil around the world (Panagos et al. 2019). The erosion and decrease in organic matter are serious problems endangering sustainable potatoes cultivation in the Czech Republic (Vávra et al. 2019). The soil with low content of organic matter degrades faster and is more predisposed to water erosion (Gholami et al. 2013, Obalum et al. 2017). This soil is not able to keep more amount of water, and especially heavy clay soils have reduced infiltration in case of drought period (Soemitro and Asmaranto 2015, Eden et al. 2017). Due to the frequent occurrence of the years with extreme weather conditions, it is necessary to pay higher attention to the reduction of impacts of this situation (Intergovernmental Panel on Climate Change 2019). Changing of extreme precipitation with drought period can lead to the fluctuations of the hydrological cycle (Madsen et al. 2014, Orth et al. 2016). The frequent problem connected with these changes is the non-balanced distribution of precipitation during the vegetation season (Cornelis et al. 2019). Thus, the soil should face a short time a large amount of precipitation after a long period of drought (Soemitro and Asmaranto 2015). However, dried soil is usually not able to infiltrate such amount of water, and this leads to flow water away (Wang et al. 2015b). This problem is especially in wide-row crops like potatoes, particularly during the early stages of vegetation, when the canopy is not fully developed. The soil crust that occurs, especially in clay soil, is another problem for water infiltration (Hůla et al. 2010). Retention ability expressing time of possible intake of water by the roots of crops,

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especially during the later time of drought period, is another important soil characteristic (Hůla et al. 2010). Soil losses caused by surface runoff is another problem.

An increase in organic matter amount in soil using the straw mulch or compost can be the important measures of improvement of soil properties and reduction of mentioned problems because the content of organic matter in the soil is significant for a good level of infiltration and retention ability of soil. Several studies showed that surface mulching has many benefits for soil quality. One of the main benefits of surface mulching is soil conservation (Gholami et al. 2013, Rahma et al. 2017). Mulch primarily prevents excessive surface runoff and non-productive evaporation from the soil (Gholami et al. 2013, Prosdocimi et al. 2016). At the same time, surface mulching improves the water infiltration into the soil within the intensive rainfalls (Fehmi and Kong 2012, Alliaume et al. 2014, Rahma et al. 2019). The results published by Edwards (2009) showed the decrease of soil compaction by the surface mulching. The straw mulch is economic available organic material that improves the soil conditions in drought and decreases the soil loss (Bresson et al. 2001, Döring et al. 2005, Doan et al. 2015, Zhang et al. 2015, Wang et al. 2015a, Cerdà et al. 2017).

The objective was to evaluate the effect of the straw mulch and the compost application in potatoes cultivation on the soil losses during the vegetation period at the three-year exact field trials.

MATERIAL AND METHODS

Experimental site characteristics. The exact field experiment with the potato cv. Dicolora was performed on the experimental station of the Department of Agroecology and Crop Production, Czech University of Life Sciences in Prague-Uhříněves (50°2'0.4''N, 14°36'32''E, 298 m a.s.l., with the mean slope 3°). The average daily temperature during the growing season (from April to October) is 14.6 °C, the sum of precipitation 380 mm. The soil type is luvisol, and texture is loamy.

Experimental design and field management. The field experiment comprised two straw mulch variants, one compost variant, and untreated control; all variants in four replicates. A plot size of 9.6 m^2 (with the row spacing of 0.8 m × 0.30 m), resp. 40 plants in two rows were used. The straw and compost applications on experimental plots were made manually. Straw mulch (SM1, SM2) was applied in two doses (2.5 t/ha and 4.5 t/ha) after the planting. The compost (CM) in dose 20 t/ha was also applied after the planting and shallowly mixed into soil by the spring-tooth harrow in weed control. The control plots were without any modifications (none mulch or compost), only with mechanical weed management. The mulching material was wheat straw and commercial compost. The chemical and physical composition of commercial compost was: total nitrogen C:N rate to 30.

Evaluation of the soil losses. As an indirect indicator of infiltration ability was determined surface soil losses. The catching pot of 0.5 L was placed on the bottom between two ridges at the end of each experimental plot, so the catchment area was 4.05 m^2. Catching pots were installed three times per vegetation season, where the vegetation season was divided into three periods according to the DAP (days after planting). After each changing of catching pots, soil sediments were dried to the constant weight and weighed. The daily precipitation in evaluated periods at the experimental site was determined for defining the effect of precipitation on the soil losses.

Statistical analysis. The obtained data were statistically analysed by the ANOVA in the SAS program (SAS Institute, Carry, USA), version 9.4, at the level of significance P = 0.05. The differences between means were evaluated by the Tukey's *HSD* (honestly significant difference) test.

RESULTS AND DISCUSSION

The results showed decreasing in soil losses in all evaluated treatments – SM1, SM2, and CM compared to control variant (C); the statistically significant decrease of soil losses was found between all treatment variants and control for the 2016–2018 average (Table 1). Regarding the individual years, a significant decrease in soil losses compared to control was not found only for variant CM in the experimental year 2018 (Table 1).

On average of 2016–2018, the lowest soil loss 17.5 g/m^2 (amount of the soil sediment caught) was found for the variant with the straw mulch treatment (SM2); it means the decrease of soil losses by 71.9% compared to C (Table 1). This result was similar to findings reported by Tumsavas (2017) and Rahma et al. (2019). Edwards et al. (2000) stated that soil losses at the straw mulch in dose 4 t/ha were reduced by 50% compared to the control without any treatment. Niziolomski

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Table 1. The soil losses and sums of precipitation during the experimental years

Year	Variant	The average soil losses (g/m^2)	Percentage to control (%)	Sum of precipitation (mm)
2016	C	139.8^a	100.0	224.8
	CM	63.3^b	45.3	
	SM1	48.2^b	34.5	
	SM2	47.3^b	33.9	
	$HSD_{0.05}$	41.0		
	average	74.7		
2017	C	20.4^a	100.0	181.4
	CM	10.6^b	52.0	
	SM1	3.5^b	17.3	
	SM2	2.8^b	13.7	
	$HSD_{0.05}$	7.5		
	average	9.3		
2018	C	27.0^a	100.0	123.0
	CM	14.4^{ab}	53.2	
	SM1	4.0^b	15.0	
	SM2	2.5^b	9.2	
	$HSD_{0.05}$	15.2		
	average	11.1		
Average of 2016–2018	C	62.4^a	100.0	
	CM	29.4^b	47.1	
	SM1	18.6^b	29.8	
	SM2	17.5^b	28.1	
	$HSD_{0.05}$	19.8		

Tukey's *HSD* (honestly significant difference) test at the level of $P < 0.05$. C – untreated control; CM – compost in a dose of 20 t/ha; SM1 – straw mulch in dose 2.5 t/ha; SM2 – straw mulch in dose 4.5 t/ha

et al. (2020) observed a 72% reduction of total soil losses using the straw mulch at dose 5 t/ha. Bhatt and Khera (2006) found the highest decrease in soil losses in surface mulching at dose 6 t/ha compared to non-treatment control. Variant SM1 (lower rate of straw mulch in dose 2.5 t/ha) showed the soil loss 18.6 g/m^2 (the decrease by 70.2% compared to C) (Table 1). These results corresponded with the most effective straw mulch treatment used by Prosdocimi et al. (2016). Our results showed similar soil losses using different doses of the straw mulch (4.5 and 2.5 t/ha). Thus, the use of high doses of the straw mulch seems to be groundless. Variant with compost treatment showed the decrease of soil losses by 52.8% compared to C (Table 1); it was in line with the findings of Kovaříček et al. (2015).

The highest reduction of the soil losses in individual years was found for SM2 (2.5 g/m^2, i.e., the decrease by 90.7% compared to C) in 2018 (Table 1). A similar situation was recorded both in 2017 and 2016. However, while in 2017 the highest reduction of soil losses (2.8 g/m^2, i.e., the decrease by 86.3% compared to C) was similar to 2018, in 2016 the soil losses were higher (47.3 g/m^2, i.e., the decrease by 66.2% compared to C) (Table 1).

For a better understanding of the efficiency of different treatments, the relationship between the soil losses and sums of precipitation during the vegetation season divided into the three periods was investigated, too (Table 2, Figures 1–3). It is evident from the results that the occurrence of intense precipitation has a clear effect on the formation of the soil losses, and the use of mulching materials can reduce these losses significantly. It is interesting that in 2018 were the total soil losses higher compared to 2017 at a lesser sum of precipitation during the

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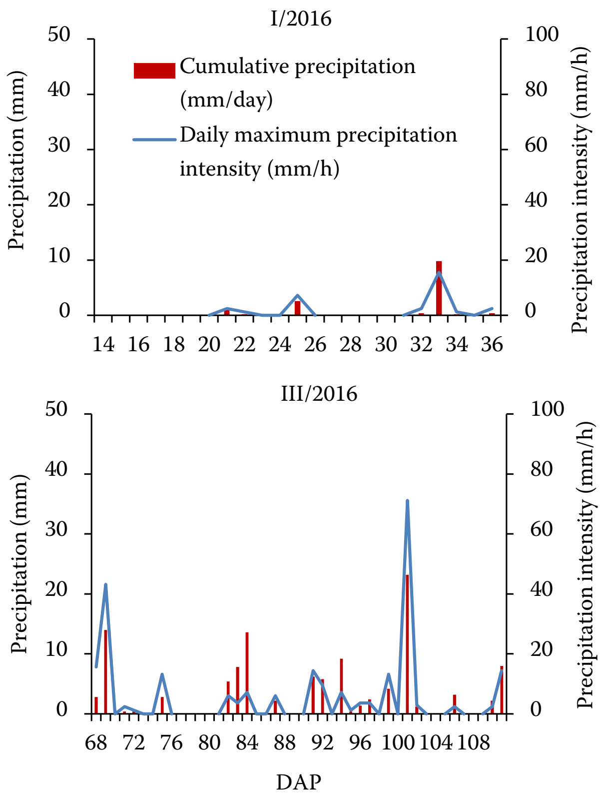
Table 2. The soil losses (g/m^2) and sums of precipitation (mm) during evaluated periods DAP (days after planting) in the experimental years

		Soil losses 14–36 DAP	Sum of precipitation	Soil losses 37–67 DAP	Sum of precipitation	Soil losses 68–110 DAP	Sum of precipitation
2016	C	4.8^a	14.6	51.8^a	93.4	83.2^a	116.8
	CM	6.8^a		46.2^{ab}		10.4^b	
	SM1	1.5^a		41.1^b		4.71^b	
	SM2	3.9^a		41.3^b		2.17^b	
	$HSD_{0.05}$	9.2		8.8		43.0	
		12–33 DAP		34–64 DAP		65–102 DAP	
2017	C	4.3^a	29.0	14.3^a	82.8	1.8^a	69.6
	CM	2.3^b		7.2^b		0.3^a	
	SM1	1.1^{bc}		2.1^b		1.1^a	
	SM2	0.5^c		2.0^b		0.3^a	
	$HSD_{0.05}$	1.6		7.0		2.0	
		27–47 DAP		48–76 DAP		77–100 DAP	
2018	C	18.1^a	48.6	2.1^a	33.0	6.9^a	41.4
	CM	10.6^{ab}		1.0^{ab}		2.9^b	
	SM1	1.6^b		0.7^b		1.1^b	
	SM2	1.1^b		0.3^b		1.8^b	
	$HSD_{0.05}$	11.3		1.3		3.2	

Tukey's *HSD* (honestly significant difference) test at the level of $P < 0.05$. C – untreated control; CM – compost in a dose of 20 t/ha; SM1 – straw mulch in dose 2.5 t/ha; SM2 – straw mulch in dose 4.5 t/ha



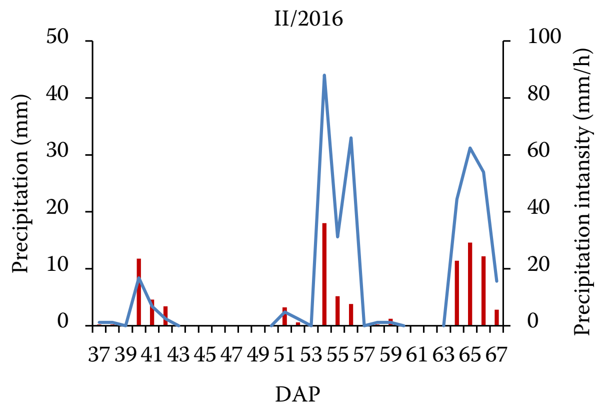


Figure 1. Cumulative daily precipitation and maximum daily precipitation intensity in three periods of soil losses evaluation in 2016. DAP – days after planting

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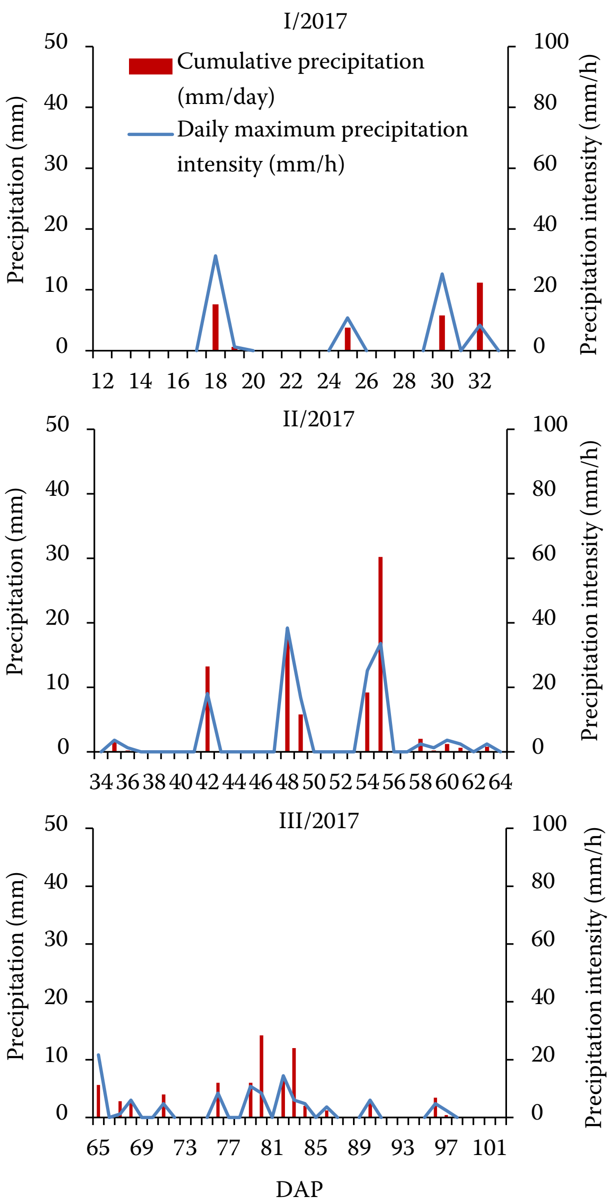

Figure 2. Cumulative daily precipitation and maximum daily precipitation intensity in three periods of soil losses evaluation in 2017. DAP – days after planting

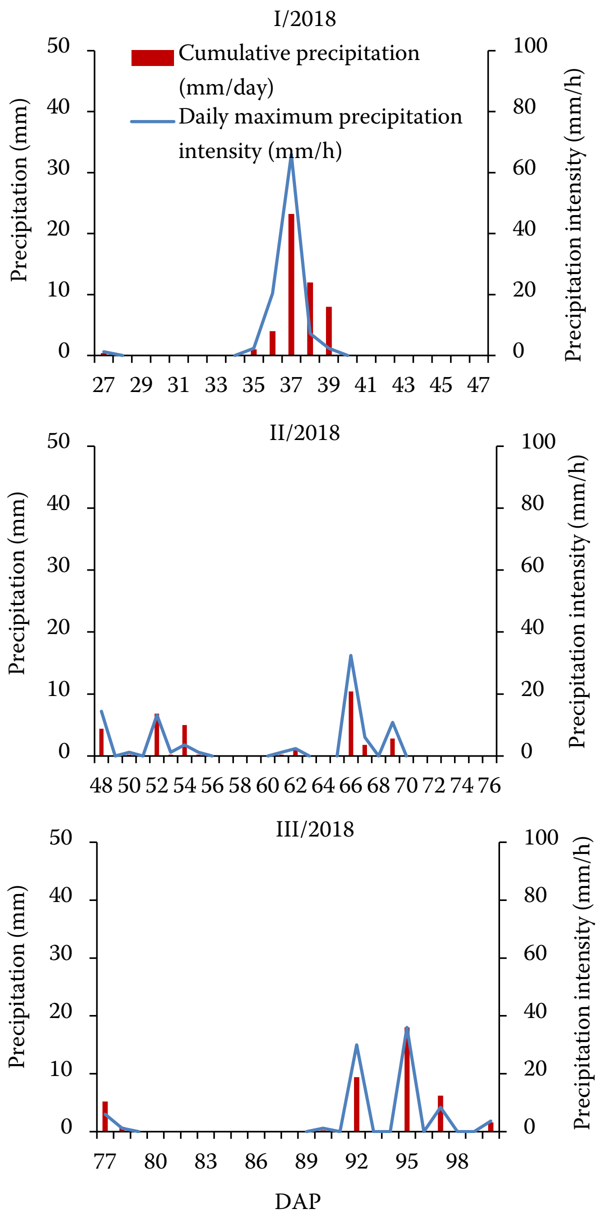

Figure 3. Cumulative daily precipitation and maximum daily precipitation intensity in three periods of soil losses evaluation in 2018. DAP – days after planting

vegetation season (Table 1). It was probably connected with the worse distribution of precipitation in 2018; there was high, intensive precipitation after the relative long period of drought. It is evident, especially from Figure 3/I and Table 2 (27–47 DAP); high soil losses were found, especially for C and CM variants. In 2017, the distribution of precipitation was more balanced, the intensity of precipitation was lower, and the soil losses were lesser despite the fact that the sum of precipitation was in total higher. It is obvious that soil surface, in case of heavy clay soil, which is typical for our experimental site in Prague-Uhříněves, had limited infiltration ability when intensive precipitation came after the long period of drought. Thus, non-balanced distribution of precipitation caused in higher soil losses. In principle, the more precipitation during the short time, the more soil losses. This finding is in accordance with the conclusion of Gholami et al. (2013) that intensive rainfalls falling on dried soil are not positive with regard to the protection against soil losses.

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The experimental year 2016 provided another interesting finding. There were high soil losses during the 37–67 DAP both in untreated control and all evaluated treatment variants. Nevertheless, in C and CM, the soil losses were highest. Moreover, this year was characteristic by a very high occurrence of potato late blight (*Phytophtora infestans* Mont de Bary). Very favourable conditions for its development caused the strong damage of potato leaf cover that can function concurrently as a protective factor for the soil, in our case, especially in the last evaluated period (68–110 DAP). Intensive precipitation during this period led to very high soil losses in the control variant (C). Despite the absence of the leaf cover, the soil losses were in the treatment variants lower, due to the protective effect of the mulch material (Table 2, Figure 1).

In conclusion, the results showed a positive effect of the straw mulch as same as compost application on the reduction of the soil losses during potatoes cultivation. The application of different doses of the straw mulch (2.5 and 4.5 t/ha) brought similar results. This indicates that for effective soil protection, it is not necessary to use the high doses of the straw mulch. Regarding the distribution of precipitation during the vegetation season, intensive precipitation during the short time, especially when they came after the longer period of drought led to higher soil losses compared to the precipitation distributed regularly.

Regarding the practical application of obtained findings, we would recommend to use the higher dose (4.5 t/ha) of straw mulch in the first year of its application on the farm and subsequently, in the following year (years), to use lower doses for verification of the effect of straw mulch application in concrete soil-climatic conditions. Then, it would be possible to optimise the dose of straw mulch for the conditions of the concrete farm. This method should contribute to the reduction of production costs. Cereal crops are frequent preceding crops for potatoes, and ploughing their straw is generally used. The cereal straw application in the form of mulch seems to be a better approach, especially in relation to soil protection.

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