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The straw as mulch and compost as a tool for mitigation of drought impacts in the potatoes cultivation

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Abstract: The frequent occurrence of years with extreme drought leads to the investigation of measures for mitigation of their impacts. The efficiency of organic mulch materials – straw and compost application as the preservation of potato production in drought conditions were verified in this study. Three mulching treatments were verified during the three experimental years (2016–2018) in an exact field trial with potatoes cv. Dicolora. Wheat straw mulch in the rate of 2.5 t/ha (SM1) and 4.5 t/ha (SM2), compost in the rate of 20 t/ha (CM), and control block without any treatments (C) were used. The yield of marketable tubers (tuber over 40 mm) showed a significant increase by 21.2% at the straw mulch treatment (SM2) in comparison with control. As for the straw mulch (SM1) and compost mulch (CM), tubers yields increased by 12.8% and 10.1%, respectively, compared to control.

Keywords: drought stress; soil moisture; potato tubers; mulching material; *Solanum tuberosum* L.

In central Europe, the impact of changing weather conditions on potato production is evident during the last years (Orth et al. 2016, Grzebisz et al. 2017). The climatic predictions suggest a long-term increase in temperature, irregular precipitation and more frequent occurrence of the heat waves (Pražan et al. 2007, Lhotka et al. 2018). Increased values of evapotranspiration and less water content in the soil during the growing period are possible to appear as a result of this actual trend (Vlček et al. 2010, Kohut et al. 2012). Weather extremes during cultivation have a negative impact on drought and heat-sensitive potato plants (Sofyan et al. 2014, Minhas 2016). Therefore, potato yields will be probably lower (Raymundo et al. 2018). Hlavinka et al. (2009) found a statistically significant correlation (89%) between drought and potato yield. If a drought period is connected with high day temperature, the soil cannot provide good conditions for potato tubers development. The sufficient and available soil water is a key factor for the successful growth of stems and development tubers for all the time of vegetation. Developing potato tubers need regular water supply and optimal soil temperature between 16–20°C (Welbaum 2015, Adamchuk et al. 2016). The soil drought and temperature higher than optimum have a negative effect on tuber formation. The malformation of tubers and chain-like growth of new small tubers can be results of these unfavorable vegetation conditions (Minhas 2016). The next negative effect of high temperature is a change of tuber quality, especially changes in the content of storage matters as starch (Geigenberger et al. 1997, Minhas 2016). One of the measures to solve these problems is mulching. Mulching by organic materials like straw, compost and other agricultural remains is used around the world. Cereal straw is available and effective mulch material. The main benefits of straw mulch treatment are an easy application, decrease of soil temperature, mitigation of day temperature fluctuation, and increase of soil moisture (Elbl et al. 2014, Adamchuk et al. 2016, Dudás et al. 2016). However, the straw mulch application could cause

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some partial problems, too. For example, it could be lower soil temperature at the beginning of vegetation, slower air convection in potatoes rows and subsequently increased the occurrence of the Late Blight (*Phytophthora infestans* (Mont.) de Bary), voles and slugs (Ilyas and Ayub 2017, Akhtar et al. 2018). Compost is another perspective mulching material. A big amount of organic matter in different forms, fertilizing effect, accumulation of heat from sunshine at the beginning of growth, and contribution to the development of organic-mineral complex are the main benefits of this mulching material (Elbl et al. 2014). The disadvantage could be a high price, lesser availability, and impurities. Concerning climate development, it is necessary to optimize the use of mulch in soil-climatic conditions of the Czech Republic. Mulch will probably become an important measure mitigating the negative impact of drought on potato stands and tubers production.

MATERIAL AND METHODS

Characterization of the growing locality. The exact field trials with potatoes cv. Dicolora were conducted at 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 mean slope 3°). The average day temperature and the sum of precipitation are 14.6°C and 380 mm during the growing season (from April to October). The soil type is brown ground Luvisol, and texture is loamy. The sum of precipitation during the vegetation season in experimental years is given in Figure 1a; average temperatures are given in Figure 1b.

Experimental design and field management. The field trials included three mulch treatments in four replicates. A plot size of 9.6 m^2 (with the row spacing of 0.80 m × 0.30 m), resp. 40 plants in two rows were used. Straw mulch was applied in two doses – 2.5 t/ha (SM1) and 4.5 t/ha (SM2) after mechanical cultivation and left on the surface of the hill. Compost (as a mulch) (CM) in the ratio of 20 t/ha was applied after planting and then was partly incorporated into the soil (to the depth of 25 mm) during mechanical cultivation. The control plots (C) were without mulching treatments. Wheat straw used as a mulching material was obtained from the field experiments with wheat conducted at the

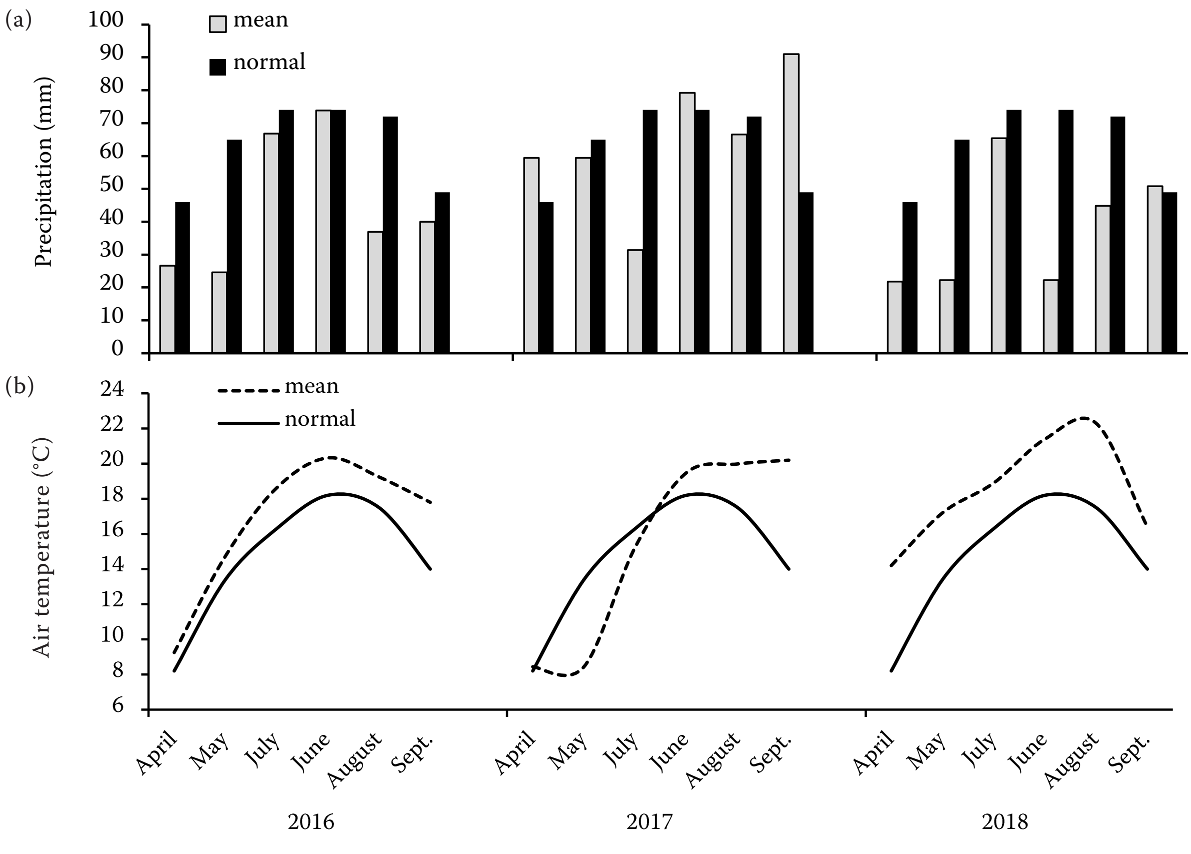

Figure 1. (a) Sum of precipitation and (b) average temperatures in vegetation season of the experimental years in comparison with the long-term average (1980–2010)

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Experimental Station Prague-Uhříněves. A commercial compost was used. The straw and compost were applied manually. Chemical composition of compost was: moisture content 40–65%, combustible substances min. 25%, total nitrogen min. 0.6%, pH value 7–9, C:N rate max. 30. All of the plots were fertilized using mineral NPK fertilizer at the dose of 80 kg N/ha, 28 kg P/ha and 48 kg K/ha.

Selected soil characteristics were measured during the growing seasons and were evaluated for soil of the root zone: relative soil moisture in the depth of 40 mm (Theta Probe Soil Moisture Sensor ML2x + Moisture Meter HH2, Cambridge, UK), soil water potential (SWP) in the depth of 200 mm (Watermark 200SS-X with data logger MicroLog SP, EMS, Brno, Czech Republic); soil temperature was recorded continually with soil water potential in the depth of 100 mm (data logger MicroLog SP, EMS Brno, Czech Republic).

Plant production characteristics. In the frame of the post-harvest classification on the screen (with the holes of 40 mm), the number and weight of tubers in these fractions were determined, and the weight of tubers was recalculated to tons per hectare.

Statistical analysis. The obtained data were analyzed by the ANOVA method using the SAS ver. 9.1.3. (SAS Institute Inc., 2003) programme. Significance between means was verified using Tukey's test with an expression of honestly significant difference (*HSD*) at a 95% probability level.

RESULTS AND DISCUSSION

A significant increase of marketable tubers (over 40 mm) yield by 21.2% compared to control was observed in variant with straw mulch treatment (SM2) for the 2016–2018 average. The variant with straw

Table 1. The number of tubers per plant and yields of potato tubers

Year	Treatment	Average number of tubers per plant		Average yield of tubers (t/ha)	
		total	over 40 mm	total	over 40 mm
2016	C	12.20^{a}	8.97^{a}	48.59^{b}	45.07^{a}
	CM	12.02^{a}	9.16^{a}	53.77^{ab}	50.52^{a}
	SM1	12.66^{a}	9.98^{a}	51.63^{ab}	48.46^{a}
	SM2	13.19^{a}	10.36^{a}	58.80^{a}	55.61^{a}
	$HSD_{0.05}$	2.10	1.86	8.61	10.30
2017	C	6.05^{b}	5.48^{b}	35.51^{a}	34.70^{b}
	CM	7.00^{ab}	6.27^{ab}	39.91^{a}	38.88^{ab}
	SM1	8.64^{a}	7.49^{a}	42.81^{a}	41.37^{a}
	SM2	8.93^{a}	7.83^{a}	45.48^{a}	44.06^{a}
	$HSD_{0.05}$	2.31	1.95	10.44	10.77
2018	C	8.80^{a}	6.03^{a}	26.98^{a}	24.08^{a}
	CM	8.69^{a}	6.14^{a}	27.73^{a}	24.94^{a}
	SM1	8.75^{a}	6.35^{a}	29.94^{a}	27.31^{a}
	SM2	8.20^{a}	6.04^{a}	28.44^{a}	26.18^{a}
	$HSD_{0.05}$	1.86	1.67	7.56	8.75
2016–2018	C	9.02^{a}	6.83^{c}	37.08^{b}	34.62^{c}
	CM	9.24^{a}	7.19^{abc}	40.54^{ab}	38.11^{abc}
	SM1	10.02^{a}	7.94^{ab}	41.52^{ab}	39.05^{ab}
	SM2	10.11^{a}	8.08^{a}	44.30^{a}	41.95^{a}
	$HSD_{0.05}$	1.26	1.01	5.26	3.56
2016		12.52^{a}	9.62^{a}	53.19^{a}	49.84^{a}
2017		7.66^{c}	6.77^{b}	40.93^{b}	39.69^{b}
2018		8.61^{b}	6.14^{b}	28.27^{c}	25.59^{c}
$HSD_{0.05}$		0.91	0.76	3.73	3.83

C – control; CM – compost; SM1 – wheat straw mulch in the rate of 2.5 t/ha; SM2 - wheat straw mulch in the rate of 4.5 t/ha; *HSD* – honestly significant difference

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mulch treatment (SM1) showed marketable tubers yield increase by 12.8% and compost mulch treatment by 10.1% in comparison with control. The highest total yield of tubers was found in variant SM2; this total yield was by 19.5% higher in comparison with control. The total yield of tubers of variant SM1 was by 12.0% higher in comparison with control. These results are in accordance with the findings of Oljača et al. (2018). Also, compost mulch treatment had a positive effect on the total yield of tubers – this was by 9.3% higher in comparison with control. Douglas (2004) published an increased yield by 7% using compost before planting in comparison with no treatment control. Similar results regarding the increasing tubers yield in variant with compost were published by Halloran et al. (2013). An increase of marketable tubers yield (over 40 mm) found at straw mulch treatment (SM2 by 21.2% and SM1 by 12.8%) in comparison with control is consistent with the results of Adamchuk et al. (2016) and Ilyas and Ayub (2017). As for the compost treatment, statistically non-significantly increased the number of marketable tubers yield by 5.3% in comparison with control was observed. Also, Taheri et al. (2012) mentioned an increased number of large tubers using compost treatment at potatoes; it was connected with better soil structure and soil aeration.

Tubers formation at all treatments was strongly affected by the experimental year. A significant difference in the total yield of tubers and yield of tubers over 40 mm (Table 1) was recorded between straw mulch and control in year 2016 with subnormal precipitation at the end of vegetation period (Figure 1a), when the growth of tubers in the control treatment was affected by the lack of water in the soil (Figure 2).

This difference was not confirmed in the following years 2017 and 2018. Another aspect that could be very important was a strong occurrence of late blight (*Phytophtora infestans*) in the second part of the 2017 vegetation period. Higher precipitation in September 2017 (Figure 1) and favorable temperature conditions this year led to the development of late blight in all variants, where higher soil moisture in SM1 and SM2 caused even better oospores mobility and thus higher mold infestation of tubers and reduced marketable tuber yields. Ilyas and Ayub (2017) reported a higher level of *Phytophthora infestans* at the straw mulch treatment during the years with high air moisture (slower air convection in the potatoes rows).

The better productivity of potato plants in both years (2016 and 2017) can be the result of a higher level of relative water content for the straw mulch (Figure 2). No significant differences in the yield of tubers were found between individual treatments in 2018, either. In all the treatments, the growth of tubers was strongly limited by drought (from June to July) and heat during the entire vegetation (July) 2018 (Figure 1b), even though treatments SM1, SM2, and CM had a higher level of relative content water (Figure 2). However, improvement of soil water conditions in the mulch treatments in 2018 was also confirmed by observing soil water potential (SWP) (Figure 3). A significant correlation $r^2 = -0.47530$; $P < 0.0004$ between SWP and the yield of tubers (large over 40 mm) was found. The results given in Figure 4

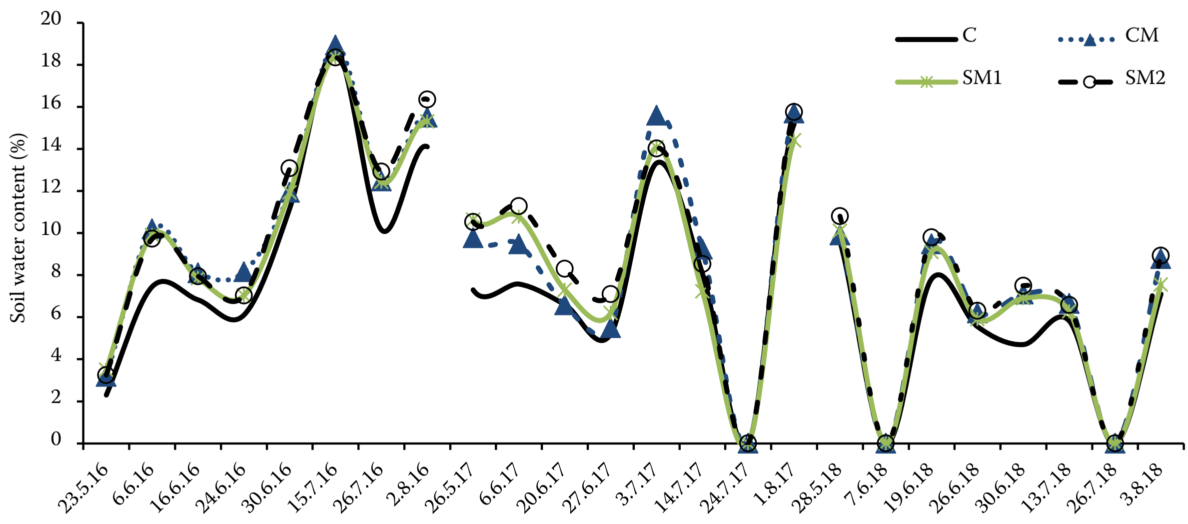

Figure 2. Mean values of the soil water content in 2016–2018. C – control; CM – compost; SM1 – wheat straw mulch in the rate of 2.5 t/ha; SM2 - wheat straw mulch in the rate of 4.5 t/ha

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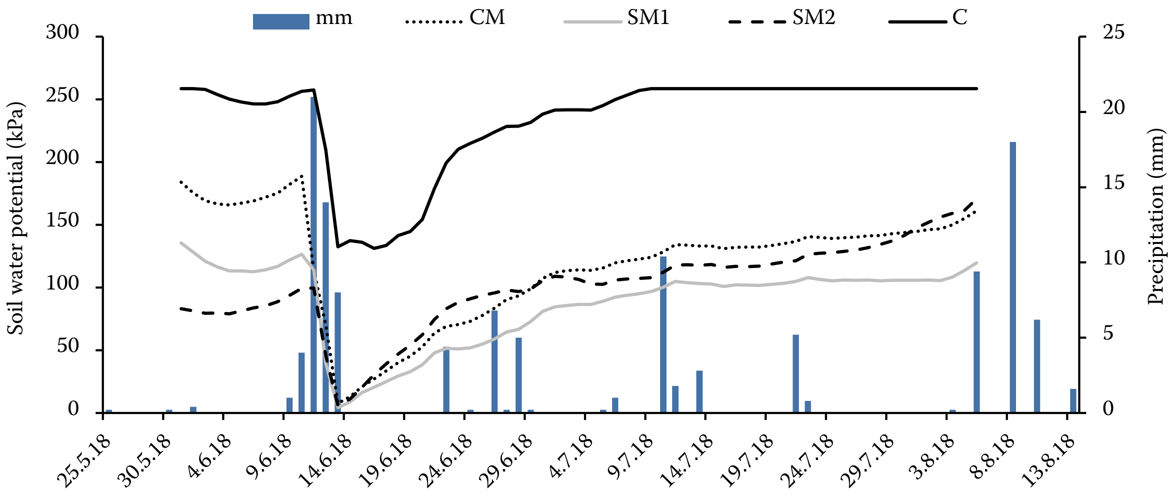

Figure 3. Course of mean daily values of the soil water potential and sum of precipitation in 2018. C – control; CM – compost; SM1 – wheat straw mulch in the rate of 2.5 t/ha; SM2 - wheat straw mulch in the rate of 4.5 t/ha

confirm that treatments with straw mulch helped the desired reduction of soil temperature in the hot 2018 vegetation period. A decrease of soil temperature by 1–2°C is in accordance with results of Dudás et al. (2016) and Dvořák et al. (2017). Increased yield at the use of organic materials is usually associated with stabilized soil moisture in drought conditions (Dvořák et al. 2015). Ranjan et al. (2017) ascribed this finding to a decrease of non-productive evaporation at plots treated by organic materials. This finding was confirmed even in similar studies (Adamchuk et al. 2016, Ilyas and Ayub 2017, Sreyashi et al. 2017, Oljača et al. 2018). The level of soil water was higher in all of the variants (SM1, SM2, CM) compared to the no treatment control, especially in 2018 (Figure 2).

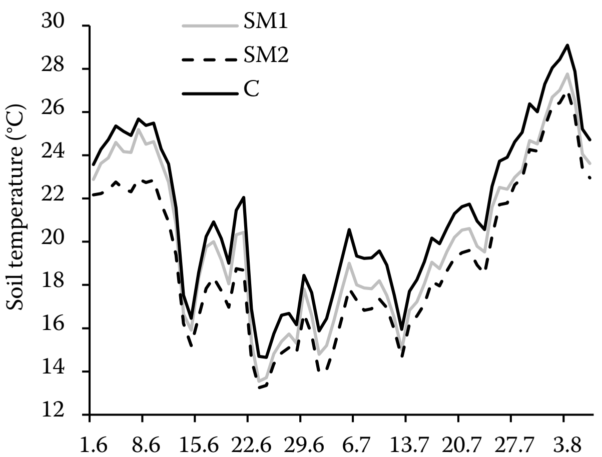

Figure 4. Course of mean daily values of the soil temperature in 2018. C – control; SM1 – wheat straw mulch in the rate of 2.5 t/ha; SM2 - wheat straw mulch in the rate of 4.5 t/ha

Straw mulch (SM1, SM2), in comparison with control, also resulted in a higher number of marketable tubers on average for 2016–2018 (Table 1). This would indicate the possibility of higher tuber formation during tuberization even in low rainfall conditions (Figure 1a), but with mulch (SM2 and SM1) support, soil moisture conditions improved significantly compared to control, as shown by the progress of SWP, for example in the experimental year 2018 (Figure 3). The soil temperature during the tuber formation can be another significant effect. In mulch straw treatment, a positive decrease in soil temperature was found during the stages of tuberization for hot vegetation conditions (Figure 4) in comparison with no treatment control. Sofyan et al. (2014) also pointed out this effect.

The obtained results are consistent with the results of other studies and brought the following conclusions. Mulching with straw and compost had a positive effect on the formation of marketable tubers. Drought affects the formation of tubers significantly but the impact of drought depends on the phase of potatoes growth when drought hits and its duration.

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