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EFFECT OF MULCHING MATERIALS ON POTATO PRODUCTION IN DIFFERENT SOIL-CLIMATIC CONDITIONS

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ABSTRACT

This paper explores the effectiveness of organic and plastic mulching for potato production in two different regions (Highlands and Lowlands) of the Czech Republic. The mulching with chopped grass (GM) and black textile mulch (BTM) were compared to non-mulching control variant with mechanical cultivation (C). In plots with BTM, ridges were first formed and covered by the black polypropylene non-woven textile and then planting was done. During vegetation, the infestation of Colorado potato beetle (CPB), as well as weeds biomass, evolution of soil temperature and soil water potential, was assessed. The results showed that GM had a positive effect on increased the proportion of tuber size fraction above 56 mm. Use of GM and BTM in colder site (Highlands) in both treatments had a positive effect on increasing soil temperatures (by 1.3 and 1.6°C) and tuber yields (by 36.1% and 27.3%) compared with C. Also here, higher soil temperatures in both mulches correlated with a slightly higher occurrence of CPB. Same was observed in BTM in the Lowlands.

Use of GM and BTM in the Lowlands had different effects on soil temperatures (GM decreased soil temperatures and BTM increased soil temperatures compared to C).

GM reduced the soil temperatures, soil water potential (SWP) and significantly increased tuber yields in warmer site with limited rainfall (in Lowlands). The tuber yields were higher, even though weed biomass in GM increased as well. In warmer site (in the Lowlands) decreased yield in treatments with BTM (by 9.8% compared to C). This yield reduction was caused mainly by higher SWP and a higher incidence of CPB.

Key words: Colorado potato beetle, potatoes, quality of tubers, soil temperature, soil water potential.

INTRODUCTION

Mulching, which has become more popular lately, is an important way of soil protection in the plant production. Surface mulching is one of the most cost effective means (Shelton et al., 1995), because of a range of positive effects on the soil fertility and other factors important for plant production. Besides, mulching massively reduces soil erosion (Döring et al., 2005), virus vector in seed potatoes (Döring et al., 2006a) and it may also act as a tool for the control of nitrogen losses by immobilization of post-harvest nitrate (Döring et al., 2005).

Moreover mulch improves soil conditions, especially reduces water evaporation from soil and helps to maintain stable soil temperature (Ji and Unger, 2001; Kar and Kumar, 2007). Reduction of soil temperature has a great importance in countries with hot climate conditions, but now, as the climate is warming, temperature conditions for crops are becoming more unfavourable (Sinkevičiene et al., 2009). For that reason, mulching becomes more important also in moderate climate conditions.

The cover of mulch influences soil moisture as well (Ramakrishna et al., 2006). Mulch maintains stable soil moisture, especially in surface soil layer. The water content directly near the soil surface plays an essential role for degradation of natural organic material by soil microbes (Hood, 2001).

However, higher and stable soil moisture is favourable for weeds germination. According to Boyd and Acker (2003) the fluctuation of soil moisture, especially in upper soil layers, influences negatively seed germination and emergence.

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On the other hand, a sufficient layer of mulch can inhibit weeds emergence, as documented by results of some authors who showed a positive effect of mulching on weed density (Johnson et al., 2004; Sinkevičiene et al., 2009). For that reason mulching can be considered as an important weed control factor (Balalis et al., 2002; Radics and Bognar, 2004), especially in systems where using herbicides is not allowed (e.g. organic farming). Except weeds, insects and fungal diseases are the primary causes of yield loss in organic agriculture. In warmer areas of the Czech Republic the Colorado potato beetle (CPB) is considered as the most important pest species. The CPB is a great problem especially in organic growing potatoes, because the CPB has relatively few natural enemies (Rifai et al., 2004).

Uncontrolled CPB populations can completely defoliate the potato plants (Rifai et al., 2004) and can cause considerable yield damage (Döring et al., 2006b). Potatoes can usually tolerate substantial defoliation, up to 30% (when they are in vegetative stages), but they are more sensitive to the effects of defoliation when tuber are beginning to grow, when only about 10% defoliation can be tolerated (Hare, 1990).

Mulching can have an effect on the external quality of tubers (scab of tubers, mechanical damages, greening of potato-tubers) and inner quality (chemical composition) as well. From inner quality point of view, potatoes are valued mainly for the content of niacin, vitamin B6 and especially for the high content of vitamin C (Asghari-Zakaria et al., 2009). Vitamin C is the main vitamin in potatoes. Global dietary contribution of vitamin C from potatoes is important with an estimate of 40% of daily-recommended intake. Just the concentration of vitamin C is in most cases consequence of the reaction of potato varieties to climatic conditions and ways of agricultural crop management (Hamouz et al., 2009).

The aim of this paper was to evaluate the effect of different mulch materials (organic and plastic mulch) on the yield and quality of tubers and on some factors influencing potatoes production in two regions of the Czech Republic. The research was mainly focused on the effect of mulching on soil temperature, soil water potential, weed biomass and occurrence of the CPB.

MATERIAL AND METHODS

Field experiment design. Field experiments were conducted over two years on two sites: Leskovice (LE) in the Czech-Moravian Highlands (potato growing region) and Uhrineves (UH) (sugar beet region, Lowlands).

Leskovice is at 498 m a.s.l., the average of annual temperature is 6.9°C and annual rainfall is 630 mm. On the site the type of soil is pseudogleyic acid cambisol (brown gleysol); lighter loam-sandy soils mostly prevail.

Uhrineves is at 295 m a.s.l., the average of annual temperature is 8.4°C and annual rainfall is 575 mm. The type of soil is brown soil with high nutrient content; texture class of soil is clay loam. More details about sites, pre-crops, dates of planting, mulching and harvest are described in Table 1.

Table 1. Information about the agricultural treatments on both sites and in both experimental years

Event / site	LE		UH	
	2008	2009	2008	2009
Pre-crop	grass-clover	broad bean-pea	clover	winter wheat
Planting date	29.4.	14.4.	17.4.	16.4.
Mulching date (BTM / GM)	28.4. / 12.5.	14.4. / 27.4.	16.4. / 30.4.	16.4. / 29.4.
First incidence of CPB	13.6.	10.6.	27.5.	25.5.
Removing of the haulm and weeds	10.9.	19.8.	11.8.	9.8.
Date of harvest	12.9.	20.8.	12.8.	18.8.

Mulching. In the experimental sites LE and UH, mulching with chopped grass (GM) and black textile mulch (BTM) were compared to non-mulching control variant with mechanical cultivation (C). GM was spread manually in a 25 mm thick layer 14th day after planting (immediately after second hoeing). In plots with BTM ridges were formed firstly and then covered by the black polypropylene non-woven textile. Hand-planting of potato tubers was done in previously prepared holes in the textile at the planned spacing (450 mm x 800 mm). All treatments were divided into four blocks (plot size 7.2 m^2).

Harvest and measurement of the yield. Tubers were harvested by hand. Harvested tubers were sorted out with commercial potato sorters (tubers with potato blight, necrosis or grow green were previously removed) into four fractions (under 40 mm, 40-55 mm, 56-60 mm and over 60 mm).

Statistical analysis. Statistical calculations were done with SAS ver. 9.1.3. (SAS Institute Inc., 2003). To determinate the effect of the two mulching materials (BTM and GM) the GLM procedure was used. Next for the statistical analysis the Tukey test (P value 0.05) was used.

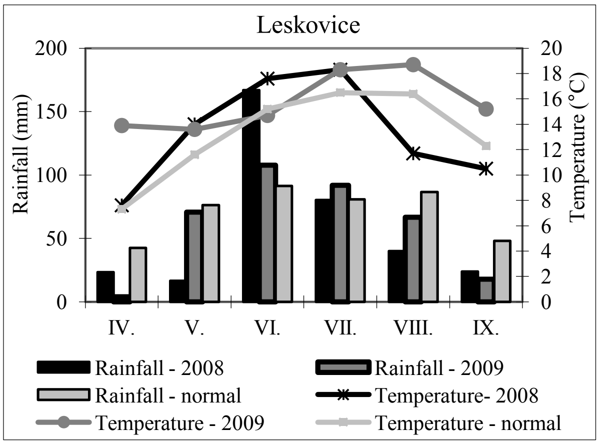
Colorado potato beetle, *Leptinotarsa decemlineata (Say), (CPB).* The date and the rate of infestation of potato plants with the CPB were assessed in all treatments (BTM, GM and C). For the evaluation of the rate of infestation three parameters were determined: the number of adult beetles per 10 plants; the number of egg clusters per 10 plants; the number of larvae on 10 plants.

The evaluation of these parameters was done at 7-10 days intervals since the first appearance of adult beetles to the removal of potato haulm (Table 1).

Weeds. The weight of weed biomass in all treatments (BTM, GM and C) was determined before harvest when the weeds were removed.

Soil temperature and soil water potential. Soil temperature was measured in all treatments (BTM, GM and C) at the depth of 100 mm in 15-min intervals during period from planting to harvest by MicroLog SP (EMS, Brno). Soil water potential (SWP) was measured in all treatments (BTM, GM and C) at the depth of 240 mm in 30-min intervals during period from planting to harvest with sensor Watermark 200SS-X cooperating with MicroLog SP (EMS, Brno).

Air temperature and rainfall. The average air temperature and total rainfall during the vegetation periods (April to September) were 13.3°C, 351 mm (2008), 15.7°C, 359 mm (2009) in Leskovice and 15.7°C, 358 mm (2008), 16.7°C, 357 mm (2009) in Uhrineves (Figure 1).



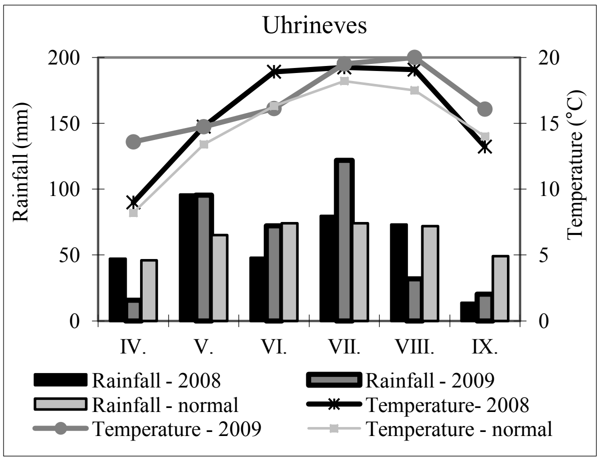


Figure 1. Air temperature and rainfall during the vegetation period at sites
(Leskovice and Uhrineves, in years 2008 and 2009)

Vitamin C. A sample of 25-30 g fresh potato was homogenized in 100 ml 3% metaphosphoric acid. The vitamin C content in this extract was determined by HPLC (HP 1200, Hewlett-Packard, equipped with DAD detector, USA) at UV 258 nm.

A reversed phase octadecylsilica column (Merck, Germany) LiChroCART (125-4 mm), LiChrospher 100 RP-18 (5 µm) with precolumn (Merck, Germany) LiChroCART (4-4 mm), LiChrospher 100 RP-18 (5 µm) was used for HPLC separation.

The mobile phase was 5% MeOH; pH=3 (H_3PO_4), the flow rate was 0.8 ml/min., the column temperature was 35ºC. Method performance characteristics: RSD of the method was 5%, recovery 95% and LOD 0.5 mg/kg.

Chlorogenic acid. 30 g of fresh potato sample were homogenized in 200 ml of methanol and after filtration of the crude extract, and dilution by water ten times, chlorogenic acid was determined by HPLC (HP 1200, Hewlett-Packard, equipped with DAD detector, USA) using UV detection at 324 nm. The reversed phase column (Merck, Germany) LiChroCART (125-4 mm), LiChrospher 100 RP-18 (5 µm) with precolumn (Merck, Germany) LiChroCART (4-4 mm), LiChrospher 100 RP-18 (5 µm) was used for HPLC separation.

The mobile phase was: A – methanol, B – 2% acetic acid (linear gradient A: 0%, 3 min.; 10-50%, 11 min.; 50-100%, 3 min., 4 min. post time), the flow rate was 0.6 ml/min., the column temperature was 40ºC. Method performance characteristics: RSD of method was 5%, recovery 95% and LOD 5 mg/kg.

Dry matter. 5 g of homogenized potatoes were dried at 105ºC 5 hours.

RESULTS AND DISCUSSION

Soil temperature (Table 2) was generally about 0.2-1.6°C higher in treatments with BTM (at both sites) than in control variant (without mulch). Higher soil temperatures were reported also with the plastic mulch by Ramakrishna et al. (2006) by 4°C at 100 mm depth and by Wang et al. (2009) by 2-9°C. In treatments with GM soil temperature was lower in comparison with the control variant in UH, but opposite effect was found out at site LE (higher by 1.7°C than in C). Comparing treatments with BTM at both sites in 2009, soil temperature was about 2.1°C higher in UH than in LE.

According to Brust (1994) potato is sensitive to higher soil temperature and low soil moisture and will not grow properly under these conditions.

Soil water potential (SWP). During vege-tation period, the evolution of SWP was more variable than the evolution of soil temperature, due to rainfall events (Figure 1) and soil conditions at experimental sites.

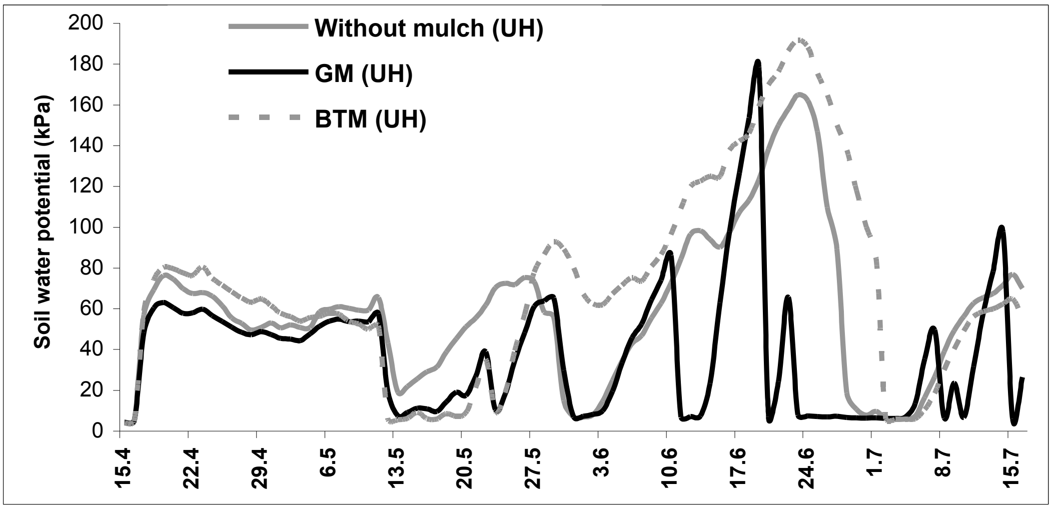
The evolution of soil moisture during the year is strongly influenced by annual rainfall and its distribution during the year. Nevertheless SWP was generally lower in the GM treatments than in the C variants in UH. Those trends were not measured in LE (Table 2). Rather higher differences were observed in BTM treatments (Figure 2). More significant differences of SWP in treatment of mulching were observed in LE, where SWP levels were lower than in UH overall (Table 2).

Weeds. The influence of different mulch treatment on weed biomass was not the same as the influence of these treatments on potato yield (Tables 1). The weight of weed biomass was extremely low on plots with BTM (Table 2), especially in UH. At both sites the weight of weed biomass was statistically significantly lower in BTM than in C variants. The effect of GM on weed biomass was equivocal. Whereas at site LE using GM significantly reduced the weight of weed biomass compared to C variant, at site UH the difference between GM and C variants was not statistically significant.

Table 2. Average of soil temperature (°C) at 100 mm depth below surface of ridge and soil water potential (kPa) at 240 mm depth below surface of ridge (in the period from April 15th to July 16th in 2009)

Mulching / Site	Soil temperature (°C)			Soil water potential (kPa)		
	LE	UH	Average of sites	LE	UH	Average of sites
C	13.2	16.7	15.0	33.8	59.1	46.5
BTM	14.8	16.9	15.9	21.3	70.7	45.7
GM	14.5	16.2	15.4	33.9	37.9	35.9

a. Uhrineves



b. Leskovice

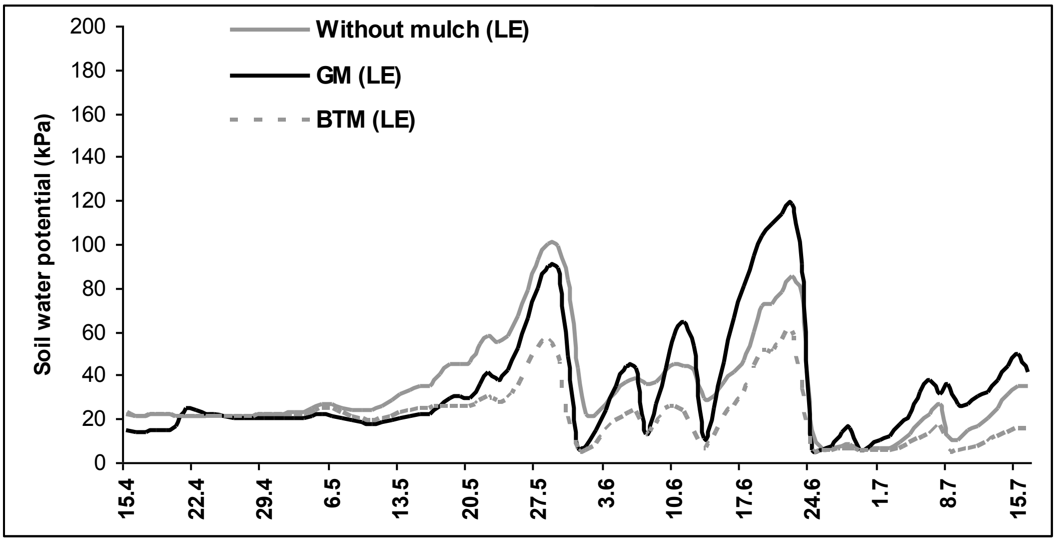


Figure 2. The evolution of soil water potential (kPa) on plots with BTM, GM and C variants without mulch at site Uhrineves (UH) and Leskovice (LE) in the period from April 15th to July 16th in 2009

Table 3. The weight of weed biomass (g per plot) in different variants of mulching before harvest (on average 2008-2009)

Mulching / Site	LE	UH	Average of sites
C	469.0 a	242.0 a	355.0 a
BTM	19.7 b	10.6 b	15.2 b
GM	86.1 b	297 a	191.7 a
$HSD_{0.05}$	*340.4*	*109.6*	*199.8*

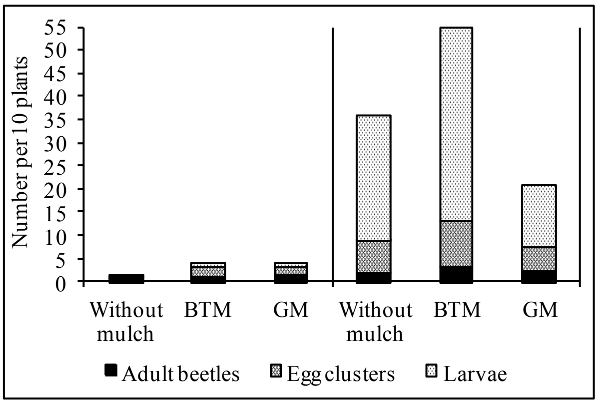
Plots that received GM had not significantly lower average weed biomass (on average years and sites) than C treatment without mulch. Other authors also found that organic mulch such as straw mulch has not consistent effect on biomass of weeds (Döring et al., 2005). Despite the fact that C treatment was mechanically cultivated, weed biomass overall was high on the organic farms (without herbicides).

This results correspond to Sinkevičiene et al. (2009) who mentioned that the effect of grass mulch on the weed emergence was not equal, when on average of 2005-2007 grass mulch significantly decreased the weed number (by 3.4-5.4 times in comparison with non-mulched plots), but, in 2008 weed density on plots with grass mulch was higher than in plots without mulch.

Colorado potato beetle. In 2009 significantly higher number of Colorado potato beetle (CPB) adults was found on plots with BTM in UH (compared to C treatment). At site LE the tendency to higher occurrence of CPB adults in variants with BTM than C treatment was also observed. Same trend was found out on plots with GM in comparison with C treatment at site LE (probably due to higher soil temperature in variant with GM). These results correspond to Johnson et al. (2004) who mentioned that potatoes with straw mulch at planting had more colonizing CPB adults than control variant without mulch. However, Brust (1994) claimed that mulching of straw placed after potato emergence had no significant effect on CPB adults.

On the other hand, Stoner (1993), Zehnder and Hough-Golstein (1990) found out significantly lower number of overwintered adult beetles and first generation larvae on plots with straw mulch compared to those without mulch. In our experiment significantly higher number of CPB egg clusters (Figure 3) was found at both sites only on plots with BTM compared to C treatments.

Comparing experimental sites, lower occurrence of CPB, especially larvae (Figure 3), was determined at colder locality LE (Highlands) than at warmer site UH (Lowlands). The differences of number of larvae among mulching variants were not statistically significant because of low incidence of CPB at site LE. In UH the number of larvae in BTM treatment was significantly higher than in C treatment, whereas significantly lower in GM treatment compared to C variant. In all experimental treatments the number of larvae increased with soil temperatures. At site LE this trend was also apparent (Table 2, Figure 3). Zehnder and Hough-Goldstein (1990) found that CPB populations in potato plots with mulch decreased, possibly due to physical obstruction and reduced soil temperature.



Note. Adult beetles $HSD_{0.05}$=1.58 (LE), 1.09 (UH); Egg clusters $HSD_{0.05}$=1.59 (LE), 2.56 (UH); Larvae $HSD_{0.05}$=1.45 (LE), 16.8 (UH).

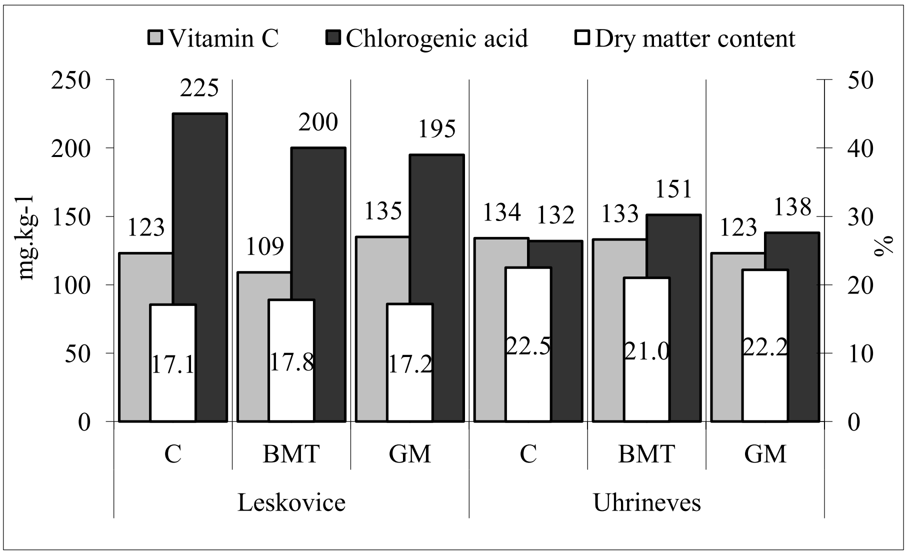
Figure 3. The effect of types of mulching on occurrence of Colorado potato beetle (CPB) as average infestation adults, egg clusters and larvae on plots during the vegetation in 2009

Dry matter. The results of the experiment did not prove any decreasing of dry matter of tubers in treatments with mulch (BTM or GM) in comparison with C variant without mulch (Figure 4). On average of years and sites the tendency of lower dry matter content of tubers in variant with GM and BTM in comparison with C variant (by 0.1, respectively 0.4 %) was found, whereas the difference between GM and BTM treatments was not significant. A probable reason of dry matter content reduction in variant with BTM in UH is the shorter period of existence of assimilation apparatus as a consequence of damaged leaves by beetles and larvae of CPB. It corresponds to Hamouz et al. (2005), who mentioned significant damaging of assimilation apparatus of organic growing potatoes by CPB and also by Late blight.

Comparing experimental sites, lower dry matter content (by 4.5 %) was determined in LE, which is locality with lower temperature and higher sum of rainfalls than UH. This result corresponds to experiments of Hamouz et al. (2007a); Zgórska and Frydecka-Mazurczyk (2000) where correlations between meteorological conditions and dry matter content had been found (higher sum rainfalls and lower air temperature determined lower dry matter content of tubers).

Vitamin C. In the experiment the differences of vitamin C content among variants with different types of mulching were not significant on average of both sites and years (Figure 4). Only a trend of lower content of Vitamin C in GM (by 0.08 %) and BTM (by 6.21 %) in comparison with C variant was recorded. Other authors (Hamouz et al., 2009; Hamouz et al., 2007b; Zgórska and Frydecka-Mazurczyk, 2000; Pawelzik et al., 1999) also found edifferences of vitamin C content among varieties and sites (in LE was found about 5.92 % lower content of vitamin C than in UH).

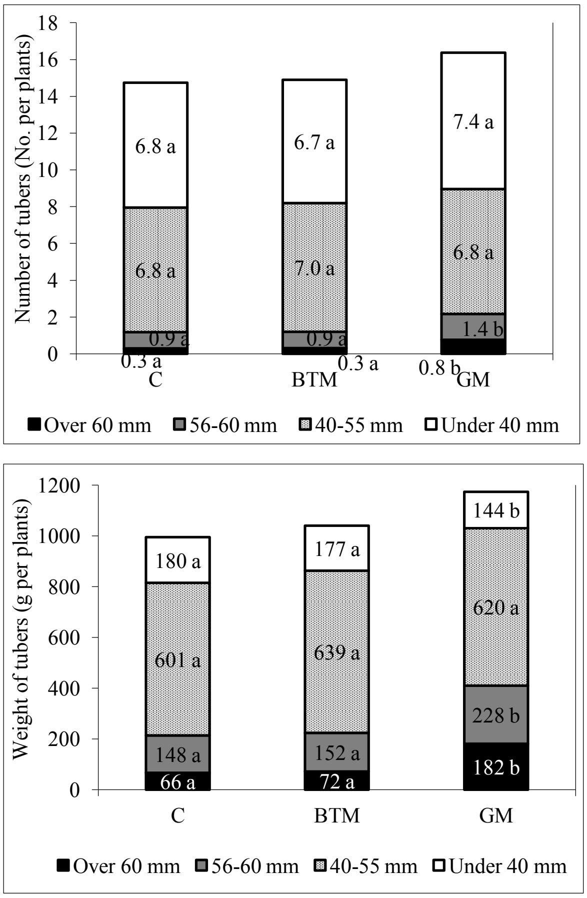
Chlorogenic acid. Also in case of chlorogenic acids we did not find a negative influence of mulch on chlorogenic acids content in potato tubers (Figure 4). A trend of lower content of chlorogenic acid in GM (by 6.61%) and BTM (by 1.67%) in comparison with C variant was recorded. The content of chlorogenic acid was significantly affected only by site conditions (chlorogenic acid content was higher by 32% in LE than in UH).



*Note. F*or dry matter content $HSD_{0.05}(LE) = 2.807$, $HSD_{0.05}(UH) = 5.689$; for vitamin C content $HSD_{0.05}(LE) = 97.00$, $HSD_{0.05}(UH) = 91.83$; for chlorogenic acid content $HSD_{0.05}(LE) = 122.4$, $HSD_{0.05}(UH) = 94.55$.

Figure 4. Effect of mulching on dry matter content (%), vitamin C ($mg.kg^{-1}$) and chlorogenic acid content ($mg.kg^{-1}$) of potatoes (var. Katka) on average 2008-2009

Tuber fractions and yields. The two-year experiment (2008-2009) confirmed the effect of GM on the structure of potato yield on average of sites (LE and UH). An application of GM (Figure 5) resulted in a significant increase of the number and weight of tubers (tuber fraction 56-60 mm and over 60 mm), on the other hand GM decreased weight of tubers under 40 mm (non ware potatoes). A positive effect of organic mulch (air-dry material from natural meadows *Festucetum falax rubrae*) on the structure of potato seed crop (*Solanum tuberosum L.*) cv. Desireé was mentioned also by Momirovic et al. (1997). For that reason very significant differences of yield of ware potatoes (Table 4) were found between GM (34.04 $t.ha^{-1}$) and C variant without mulch (26.23 $t.ha^{-1}$). No significant difference of yield of ware potatoes between BTM (28.33 $t.ha^{-1}$) and C was observed. Tuber yield also strongly differed between years, with generally lower yields in 2008 (by 5.5 $t.ha^{-1}$) than in 2009. Yield was not significantly influenced by site (although yields higher by 1.3 $t.ha^{-1}$ were recorded at LE than at UH).



Note. $HSD_{0.05}$(under 40 mm) = 26.74, $HSD_{0.05}$(40-55 mm) = 79.99, $HSD_{0.05}$(56-60 mm) = 51.65, $HSD_{0.05}$(over 60 mm) = 50.90.

Figure 5. The effect of different types of mulching on the number and weight of tubers (on average of the sites and years)

Table 4. The effect of different types of mulching on tuber yields ($t.ha^{-1}$) of ware potatoes (on average 2008-2009)

Mulching / Site	LE	UH	Average of sites
C	24.9 a	27.6 a	26.2 a
BTM	31.7 b	24.9 a	28.3 a
GM	33.9 b	34.2 b	34.0 b
$HSD_{0.05}$	*4.564*	*3.340*	*3.327*

The tendency of lower yield of tubers in treatment without mulch (on both sites) can be related to higher weed infestation on these plots (Table 3). This was also mentioned by Johnson et al. (2004). The lowest yield of tubers in treatment with BTM in UH (Table 4) were related to higher SWP, higher occurrence of larvae of CPB and therefore higher defoliation. At cooler site LE, with high rainfall, in the treatment with BTM soil temperatures were increased, and SWP decreased (Table 2) and thus crops got more suitable conditions for growth and development of tubers (Table 4).

At the warmer site UH, with limited rainfall, due to the use of GM, the soil temperatures and SWP were reduced (Table 2) and tuber yields were significantly higher (Table 4), even though GM increased weed biomass too (Table 3). In LE use of GM significantly increased tuber yields by 36.1% in comparison with C (Table 4), despite less favourable SWP (Table 2). Higher yields in straw mulch by 32-35% than in non-mulch plots were also reported by Brust (1994).

CONCLUSIONS

The mulching treatment systems affected the soil temperatures and water potentials of the soil on dependence of the physical and chemical properties of soil as well as organisms that live there. This study indicated a positive effect of GM on reducing larvae of CPB and showed higher incidence of larvae and higher defoliation in BTM than in non-mulched potato plots in Lowlands.

In the experiment the mulching of chopped grass significantly decreased the small size tuber fraction (under 40 mm), while the large size fractions (56-60 mm and over 60 mm) were significantly increased.

The mulching had a positive effect on tuber yield (on average of sites and years). Tuber yields were significantly higher by 22.9% on plots with GM and higher by 7.4% in BTM (in comparison with C treatment without mulch).

In the experiment the mulching of potatoes had not significantly negative effect on tubers quality (dry matter content, Vitamin C content, chlorogenic acid content).

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