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# Reply of mulch systems on weeds and yield components in potatoes

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**ABSTRACT**

Surface mulch is an important factor of soil protection technology in the cultivation of potatoes. Presented herein are the results of three years (2009–2011) of field trials at two sites (Leškovice and Uhříněves), where two cultivars (Finka and Katka) were grown. Three mulching treatments (grass mulch after planting, grass mulch before germination and black polypropylene mulch textile) were used in the study. The weight of marketable tubers (tuber over 40 mm) and tuber size distribution were influenced significantly by mulching. The application of grass mulch on surface of the row ensured a 20.5–24.8% increase of weight of marketable tubers and higher occurrence of tubers over 56 mm (resp. tubers 56–60 mm and over 60 mm). There was no consistent effect of grass mulch on the aboveground biomass of weeds. Higher occurrences of larvae of Colorado potato beetle was found on the plots with black polypropylene textile in warmer site Uhříněves.

**Keywords**: water erosion; weed control; crop production; soil moisture; *Solanum tuberosum*

Potatoes as well as other wide-crops are in many places in the Czech Republic associated with water erosion. This risk can be significantly reduced by the use of appropriate farming techniques – mainly by the application of soil protection technologies which should reduce runoff and increase infiltration of water into the soil (Truman et al. 2005).

The principle solution is in the targeted use of biomass to protect the soil surface. During the vegetation period when the main grown crop does not protect the soil surface from the effects of intense rainfall, we can use protective functions of intercrops and crop residues left on the soil surface (Novák et al. 2011) or mulch applied to the soil surface. Mulching in this manner can influence the physical and chemical properties of the soil (Govaerts et al. 2007) and improve soil nitrogen availability, which supports plant growth (Fang et al. 2011).

A sufficient layer of mulch can also inhibit the emergence of weeds, as documented by the results of some authors who showed a positive effect of mulching on weed density (Johnson et al. 2004, Sinkevičiene et al. 2009). The organic mulching promotes microbial activity in the soil (Debosz et al. 1999), provides shelter for natural enemies (Brust 1994) and even reduces the incidence of certain diseases, such as virus Y (Saucke and Döring 2004).

Plastic mulch, such as polypropylene textile that has features similar to the polyethylene film, is popular for commercial vegetable production. However, polypropylene textile durability permits multi-year use, thus reducing excessive waste produced from the typical single-season use of polyethylene film. On the other hand, plastic mulch providing excellent weed suppression, water retention (Feldman et al. 2000) and increase of tuber yield (Chang et al. 2011).

Surface mulching of potatoes is a major component of soil protection, where other benefits are not fully identified. The aim of this study evaluated the effect of various mulches (organic and plastic mulch) on the weed biomass, tuber yields and the yield components of potatoes in conditions of the Czech Republic.

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## MATERIAL AND METHODS

**Field experiments**. Field experiments were carried out at the Experimental Station of the Czech University of Life Sciences Prague in Uhříněves (50°2'0.4''N, 14°36'32''E, 298 m a.s.l.) and Leškovice (49°45'46''N, 15°32'16''E, 498 m a.s.l.) in 2009–2011. Leškovice is a region with long-term average (1971–2010) annual temperature of 6.9°C and annual precipitation of 630 mm. On the site the type of soil is pseudogleyic acid Cambisol, and lighter, loam-sandy soils, mostly prevail. Uhříněves is a region with long-term average annual temperature of 8.4°C and annual precipitation of 575 mm. The soil used in the experiment was Luvisol.

The field experiment comprised three mulch treatments with four replicates and a plot size of 7.2 $m^2$ (with the spacing of 0.8 m × 0.33 m). The potatoes were grown by means of ploughing (in depth of 0.35 m in November) and organic fertilization (20 t/ha green manure pea and mustard 1:1, no other nutrients were applied). Mechanical cultivation was used for weed control in C variant without mulch (3 times up to closed crops and one before emergence) and for GM2 (once into application of mulch). The control of diseases and pests in line with organic agriculture practices was the same for all treatments (2 times copper fungicide Flowbrix in rate 2.4 L/ha and without insecticides).

**Mulching**. Mulching with chopped grass (GM) and black textile mulch (BTM) were compared to non-mulching control variant (C) with mechanical cultivation. GM is a material from natural meadows. GM1 was spread manually in a 25-mm thick layer after planting and GM2 was spread on the $14^{th}$ day after planting (immediately after the second hoeing). In plots with BTM, first ridges were formed which were then covered by the black polypropylene textile and subsequently hand planted.

The weight of weed biomass in all treatments (BTM, GM1, GM2 and C) was determined before harvest when the weeds were removed.

**Colorado potato beetle (CPB)**. The evaluation of the rate of larvae was done at 7–10 day intervals since the first appearance until the removal of potato haulm in accordance with the procedure described by Dvořák et al. (2013).

**Harvest and measurement of the yield**. 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, 40–55, 56–60 and over 60 mm). Number and weight of marketable tubers (consists tubers > 40 mm) were determined for each plot.

**Statistical analysis**. Collected data were subsequently analyzed using ANOVA with SAS ver. 9.1.3. (SAS Institute Inc., 2003). Means were separated using the Tukey's protected honestly significant difference (*HSD*) test at 95% level of probability only when the ANOVA *F*-test showed significant at 0.05 probability levels.

## RESULTS AND DISCUSSION

**Weed biomass**. The type and term of application of mulch affected the presence of weeds (Tables 1, 2 and 3). The lowest weeds biomass was found in BTM (weed biomass 53.8% lower than C). A positive effect on weed control was also found at polyethylene mulch (Ramakrishna et al. 2006). Polyethylene foils are used for mulching in crop production, even though they have many disadvan-

Table 1. Response of different types of mulching materials to yield components and weeds (on average sites and years 2009–2011)

| Treatment | Weed biomass (g FW/plot) | Total no. of tubers (per plant) | Total weight of tubers (g/plant) | No. of marketable tubers (per plant) | Weight of marketable tubers (g/plant) |
|---|---|---|---|---|---|
| C | $934^{a}$ | $10.8^{a}$ | $1045^{a}$ | $7.7^{a}$ | $973^{a}$ |
| GM1 | $1171^{b}$ | $11.6^{ab}$ | $1246^{b}$ | $8.6^{b}$ | $1172^{b}$ |
| GM2 | $862^{a}$ | $12.0^{b}$ | $1295^{b}$ | $8.7^{b}$ | $1214^{b}$ |
| BTM | $431^{c}$ | $10.9^{a}$ | $1043^{a}$ | $7.2^{a}$ | $958^{a}$ |
| $HSD_{0.05}$ | 217.3 | 1.060 | 136.8 | 0.847 | 145.5 |

Values with the same letter are not significantly different at $P \leq 0.05$. C – non-mulching control with mechanical cultivation; GM1 – grass mulch in a 25-mm thick layer after planting; GM2 – grass mulch on the $14^{th}$ day after planting; BTM – black textile mulch; *HSD* – honestly significant difference of Tukey's test; FW – fresh weight

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Table 2. Weed biomass, number of Colorado potato beetle (CPB) larvae, number and weight of tubers were affected by different types of mulching materials (Leškovice in 2009–2011)

| Treatment | Weed biomass (g FW/plot) | No. of CPB larvae (per plant) | Total No. of tubers (per plant) | Total weight of tubers (g/plant) | No. of marketable tubers (/plant) | Weight of marketable tubers (g/plant) |
|---|---|---|---|---|---|---|
| **2009** | | | | | | |
| C | 932[a] | 0.13[a] | 12.3[a] | 1175[a] | 9.0[ab] | 1081[a] |
| GM1 | 140[b] | 0.00[a] | 14.9[a] | 1654[b] | 10.5[a] | 1533[b] |
| GM2 | 168[b] | 1.34[a] | 12.6[a] | 1290[a] | 8.6[b] | 1177[a] |
| BTM | 39[b] | 1.34[a] | 13.9[a] | 1311[a] | 9.0[ab] | 1166[a] |
| $HSD_{0.05}$ | 452.4 | 3.249 | 2.928 | 226.1 | 1.608 | 224.1 |
| **2010** | | | | | | |
| C | 1214[ab] | 0.02[a] | 14.2[a] | 1284[ab] | 9.1[a] | 1161[ab] |
| GM1 | 1918[a] | 0.60[a] | 12.9[a] | 1390[a] | 9.0[a] | 1289[a] |
| GM2 | 1336[ab] | 0.30[a] | 14.9[a] | 1509[a] | 10.0[a] | 1386[a] |
| BTM | 310[b] | 0.72[a] | 14.4[a] | 1060[b] | 8.2[a] | 912[b] |
| $HSD_{0.05}$ | 1544 | 1.468 | 3.038 | 355.2 | 2.416 | 355.2 |
| **2011** | | | | | | |
| C | 2683[ab] | 0.00 | 7.3[a] | 815[a] | 5.9[a] | 774[a] |
| GM1 | 3093[a] | 0.00 | 8.7[ab] | 1015[a] | 7.0[a] | 969[ab] |
| GM2 | 2154[ab] | 0.00 | 10.3[b] | 1257[b] | 8.1[a] | 1190[bc] |
| BTM | 1811[b] | 0.00 | 9.3[ab] | 1339[b] | 7.8[a] | 1301[c] |
| $HSD_{0.05}$ | 1094 | – | 2.073 | 207.1 | 2.240 | 222.0 |
| **2009–2011** | | | | | | |
| C | 1610[a] | 0.10[a] | 11.3[a] | 1091[a] | 8.0[a] | 1005[a] |
| GM1 | 1717[a] | 2.00[a] | 12.2[a] | 1353[b] | 8.8[a] | 1264[b] |
| GM2 | 1219[ab] | 1.43[a] | 12.6[a] | 1352[b] | 8.9[a] | 1251[b] |
| BTM | 720[b] | 2.85[a] | 12.5[a] | 1237[ab] | 8.3[a] | 1126[ab] |
| $HSD_{0.05}$ | 362.9 | 4.424 | 1.614 | 216.3 | 1.271 | 221.6 |

Values with the same letter are not significantly different at $P \leq 0.05$. C – non-mulching control with mechanical cultivation; GM1 – grass mulch in a 25-mm thick layer after planting; GM2 – grass mulch on the $14^{th}$ day after planting; BTM – black textile mulch; *HSD* – honestly significant difference of Tukey's test; FW – fresh weight

tages (Warnick et al. 2006). Polypropylene textiles are (in contrast to polyethylene foils) permeable to precipitations (in dry areas so there is no need to lay a drip irrigation, thus increasing costs) and have higher strength.

We found the trend of lower weed biomass (Table 2) at GM2 (by 24.3%) and trend higher weed biomass at GM1 (by 6.7%) comparison with C in Leškovice (on average of 2009–2011). The highest weed biomass was found in variants with GM1 in Uhříněves (Table 3), where weed biomass was about 101% higher than in C. Mulch was probably washed away due to heavy and pelting rain in 2009 and 2010 in the time when rows were not still closed off with haulm. Decomposition of grass mulch and growth of weeds were faster. Probably also due to higher soil moisture on plots with organic mulching (Sinkevičiene et al. 2009). The critical period was (in both years) the month of May which recorded higher rainfall (by 30 mm more than in the long-term average) in Uhříněves. It is evident from Table 4, when the month of May 2011 was poor in rainfall and weed biomass was reduced by 30% for GM1 (compared to preceding rich years 2009 and 2010). Flushing or rapid decomposition of grass mulch creates conditions for secondary weed infestation (in the period between the end of vegetation and harvest). Weeds during this period have not a significant effect on the reduction of the yield, but complicate harvesting.

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Table 3. Weed biomass, number of Colorado potato beetle (CPB) larvae, number and weight of tubers were affected by different types of mulching materials (Uhříněves in 2009–2011)

| Treatment | Weed biomass (g FW/plot) | No. of CPB larvae (per plant) | Total No. of tubers (per plant) | Total weight of tubers (g/plant) | No. of marketable tubers (per plant) | Weight of marketable tubers (g/plant) |
|---|---|---|---|---|---|---|
| **2009** | | | | | | |
| C | 248$^{ab}$ | 4.48$^{a}$ | 11.5$^{a}$ | 1171$^{a}$ | 8.4$^{ab}$ | 1092$^{a}$ |
| GM1 | 1194$^{c}$ | 2.26$^{b}$ | 11.9$^{a}$ | 1328$^{a}$ | 8.6$^{ab}$ | 1243$^{a}$ |
| GM2 | 490$^{b}$ | 2.21$^{b}$ | 11.7$^{a}$ | 1351$^{a}$ | 8.9$^{a}$ | 1278$^{a}$ |
| BTM | 24$^{a}$ | 7.01$^{c}$ | 11.3$^{a}$ | 956$^{b}$ | 6.9$^{b}$ | 852$^{b}$ |
| $HSD_{0.05}$ | 366.4 | 1.697 | 2.219 | 184.9 | 1.754 | 189.2 |
| **2010** | | | | | | |
| C | 533$^{a}$ | 2.3$^{ab}$ | 15.4$^{ab}$ | 827$^{ab}$ | 7.7$^{ab}$ | 637$^{ab}$ |
| GM1 | 1412$^{b}$ | 1.0$^{a}$ | 15.9$^{a}$ | 956$^{a}$ | 9.1$^{a}$ | 776$^{b}$ |
| GM2 | 409$^{a}$ | 2.2$^{ab}$ | 17.5$^{a}$ | 990$^{a}$ | 9.4$^{a}$ | 782$^{b}$ |
| BTM | 103$^{a}$ | 3.2$^{b}$ | 12.9$^{b}$ | 696$^{b}$ | 5.8$^{b}$ | 527$^{a}$ |
| $HSD_{0.05}$ | 552.6 | 1.602 | 2.592 | 198.3 | 1.994 | 217.8 |
| **2011** | | | | | | |
| C | 721$^{a}$ | 3.3$^{a}$ | 7.8$^{a}$ | 949$^{a}$ | 6.4$^{a}$ | 916$^{a}$ |
| GM1 | 1183$^{b}$ | 2.5$^{a}$ | 9.2$^{a}$ | 1145$^{ab}$ | 7.7$^{a}$ | 1105$^{ab}$ |
| GM2 | 830$^{ab}$ | 2.2$^{a}$ | 8.8$^{a}$ | 1332$^{b}$ | 7.6$^{a}$ | 1299$^{b}$ |
| BTM | 45$^{c}$ | 2.4$^{a}$ | 8.1$^{a}$ | 992$^{a}$ | 6.6$^{a}$ | 950$^{a}$ |
| $HSD_{0.05}$ | 403.8 | 2.125 | 1.782 | 226.8 | 1.579 | 221.8 |
| **2009–2011** | | | | | | |
| C | 480$^{a}$ | 3.1$^{ab}$ | 10.9$^{ab}$ | 892$^{a}$ | 6.8$^{a}$ | 882$^{a}$ |
| GM1 | 965$^{b}$ | 2.1$^{c}$ | 11.9$^{b}$ | 1061$^{b}$ | 7.9$^{b}$ | 1041$^{b}$ |
| GM2 | 506$^{a}$ | 2.2$^{bc}$ | 11.9$^{b}$ | 1102$^{b}$ | 8.0$^{b}$ | 1120$^{b}$ |
| BTM | 42$^{c}$ | 3.9$^{b}$ | 10.1$^{a}$ | 832$^{a}$ | 6.1$^{a}$ | 776$^{a}$ |
| $HSD_{0.05}$ | 238.2 | 0.907 | 1.203 | 127.4 | 0.954 | 151.7 |

Values with the same letter are not significantly different at $P \leq 0.05$. C – non-mulching control with mechanical cultivation; GM1 – grass mulch in a 25-mm thick layer after planting; GM2 – grass mulch on the 14$^{th}$ day after planting; BTM – black textile mulch; *HSD* – honestly significant difference of Tukey's test; FW – fresh weight

**Yield components**. The incidence of weeds reduces tuber yield the most from the 40–60$^{th}$ day after the planting. Tuber yield is reduced at moderate weed infestation by 20–30%, but high weed infestation reduces tuber yield by up to 85% (depending on the species spectrum and the intensity of incidence).

The type of mulch materials and term of its application affected the weight of marketable tubers (Table 1). The highest weight of marketable tubers was found when using grass mulch (GM1 and GM2). The weight of marketable tubers after application of grass mulch was higher by 199 g (20.5%) at GM1 and by 241 g (24.8%) at GM2 compared to C (973 g per plant). The increase of weight of tubers by 24.9% was mentioned by Momirovic et al. (1997) in connection with the application of organic mulch (air-dry material from natural meadows).

Unlike grass BMT mulch has no positive effect on weight of tubers on average years 2009–2011 (Table 1). With BTM we experienced seasonal fluctuations of tuber yields in Uhříněves. Therefore a trend of lower weight of marketable tubers by 1.5% at BTM (compared with C) was found on average of both sites for 2009–2011. The lower marketable yield at BTM (in 2009 and 2010) was supported by higher incidence of CPB larvae (Table 3) and further, the less favourable conditions for growth of tubers due to a significant decrease of leaf area. On the plots with

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Table 4. The average monthly air temperatures and precipitations during the vegetation period compared with the long-term average (LTA) at station Uhříněves

| | Month | 2009 | 2010 | 2011 | LTA (1981–2010) | 2009–LTA | 2010–LTA | 2011–LTA |
|---|---|---|---|---|---|---|---|---|
| Air temperature (°C) | IV. | 13.59 | 10.05 | 11.91 | 8.2 | 5.39 | 1.85 | 3.71 |
| | V. | 14.74 | 12.64 | 15.21 | 13.4 | 1.34 | –0.76 | 1.81 |
| | VI. | 16.12 | 17.92 | 18.67 | 16.3 | –0.18 | 1.62 | 2.37 |
| | VII. | 19.50 | 21.58 | 17.59 | 18.2 | 1.30 | 3.38 | –0.61 |
| | VIII. | 20.00 | 18.35 | 19.02 | 17.5 | 2.50 | 0.85 | 1.52 |
| | IX. | 16.07 | 12.38 | 15.47 | 14.0 | 2.07 | –1.62 | 1.47 |
| Precipitation (mm) | IV. | 15.6 | 32.0 | 20.3 | 46 | –30.40 | –14.00 | –25.70 |
| | V. | 95.3 | 93.1 | 46.5 | 65 | 30.30 | 28.10 | –18.50 |
| | VI. | 72.2 | 62.2 | 94.8 | 74 | –1.80 | –11.80 | 20.80 |
| | VII. | 121.9 | 118.0 | 166.2 | 74 | 47.90 | 44.00 | 92.20 |
| | VIII. | 31.80 | 139.6 | 85.30 | 72 | –40.20 | 67.60 | 13.30 |
| | IX. | 20.20 | 106.4 | 33.60 | 49 | –28.80 | 57.40 | –15.40 |

BTM, incidence of 7.0 (2009) and 3.2 (2010) CPB larvae per plant was found (resp. higher by 56.5% and 39.1% in comparison with C) in Uhříněves. A correlation was found ($r^2 = -0.399$; $P \leq 0.01$) of yield of ware potatoes and CPB larvae for mulching with BTM (Dvořák et al. 2013). Therefore it was weight of marketable tubers lower by 22% (2009) and 17% (2010) comparison with C. In this case, the created tubers did not have suitable conditions for their growth and the number of marketable tubers (Table 3) was lower by 17.9% (2009) and 24.7% (2010) on the plots with BTM. Also the experiments of Wang et al. (2009) suggest that plastic mulch reduced marketable tuber numbers per plant.

GM1 and GM2 increased the marketable tubers on average by 1 tuber per plant (Table 1). Momirovic et al. (1997) reported an increase in the number and weight of tubers in connection with mulching. Also, the numerical representation of other size fractions of tubers shows that marketable yield at GM was mainly formed by tubers of the size 40–55 mm and tubers over 60 mm (Figures 1 and 2). Because the conditions for the growth of tubers were favourable at GM1 and GM2, the number of tubers

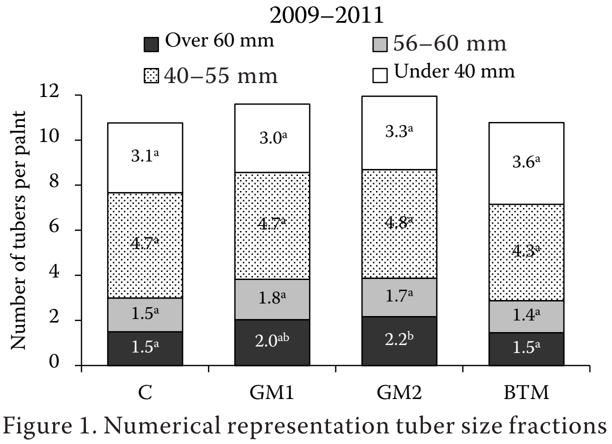


Figure 1. Numerical representation tuber size fractions for each type of mulching. The same letters indicate statistically not significant averages; $HSD_{0.05}$(over 60 mm) = 0.594; $HSD_{0.05}$ (56–60 mm) = 0.395, $HSD_{0.05}$(40–55 mm) = 0.907, $HSD_{0.05}$(under 40 mm) = 0.782; C – non-mulching control with mechanical cultivation; GM1 – grass mulch in a 25-mm thick layer after planting; GM2 – grass mulch on the 14th day after planting; BTM – black textile mulch

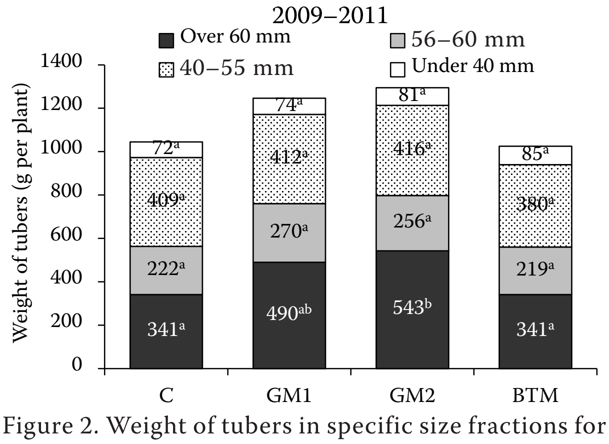


Figure 2. Weight of tubers in specific size fractions for each type of mulching. The same letters indicate statistically not significant differences; $HSD_{0.05}$(over 60 mm) = 149.8, $HSD_{0.05}$(56–60 mm) = 62.42, $HSD_{0.05}$(40–55 mm) = 79.98, $HSD_{0.05}$(under 40 mm) = 22.35; C – non-mulching control with mechanical cultivation; GM1 – grass mulch in a 25-mm thick layer after planting; GM2 – grass mulch on the 14th day after planting; BTM – black textile mulch

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of the 56–60 mm size increased on average by 16.6% compared to C (Figure 1). Also, the tuber size fraction above 60 mm was higher by 59.2% at GM2 (compared to C). This confirms initial results from 2008 and 2009, mentioned by Dvořák et al. (2009, 2012). Altogether grass mulch (on average GM1 and GM2) increased total weight of tubers per plant by 21.2%, compared to C (Table 1).

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