THE EFFECT OF MULCHING ON THE ABUNDANCE AND DIVERSITY OF GROUND BEETLE ASSEMBLAGES IN TWO HUNGARIAN POTATO FIELDS

Péter DUDÁS[1] – Csongor GEDEON[2] – László MENYHÁRT[3] – Gergely AMBRUS[1] – Ferenc TÓTH[1]

[1]Institute of Plant Protection, Faculty of Agricultural and Environmental Sciences, Szent István University, Hungary, H-2100 Gödöllő, Páter Károly u. 1. E-mail: dudpet@gmail.com

[2] Department of Agrochemistry and Plant Nutrition, Institute for Soil Sciences and Agricultural Chemistry, Centre for Agricultural Research, Hungarian Academy of Sciences, Hungary, H-1022 Budapest, Herman Ottó út 15. E-mail: csongorg@gmail.com

[3] Department of Economic Methodology, University of Pannonia Georgikon Faculty, H-8360 Keszthely, Deák Ferenc u.16. E-mail: menyhart-l@georgikon.hu

Abstract: The benefits of mulching in potato (*Solanum tuberosum* L.) production are manifold, such as it provides shelters for natural enemies of pests. The aim of our study was to detect the effect of two organic mulch types on the abundance, diversity and species composition of carabid beetles. Our potato plots were located in two sites with similar habitats including similar soil characteristics. Each plot was treated with hay and leaf litter mulch (hay, leaf, control) with 4 replications at each site. It resulted in 24 samples in each study site annually. Carabid beetles were collected by using pitfall traps in between 2011-2013. We found that due to mulching a larger and more diverse carabid population occurred on potato plots. Both mulching types increased the total number of carabids captured having a 17% higher abundance on hay mulched plots and 14% higher abundance on leaf litter mulched plots. According to the results 28 % of the collected species was found only on mulched plots, whereas only 13 % of the captured species were found only on unmulched areas. For some of the species, especially for *Brachinus crepitans* (L.), the number of individuals was significantly higher on mulched plots. The two different mulching materials had very similar effects on assemblages of carabid species. The species composition of ground beetles was considerably affected by the two locations, and to a lesser extent by the different time periods. While the dominant species of Budaörs was *B. crepitans*, the most abbundant carabid beetle at Hidegkút belonged to genus *Harpalus*. Neither hay nor leaf litter were able to constantly increase the biodiversity of the carabid assemblages on potato plots, because the effect of the two years overwrote the between-treatment effects on carabid diversity. The positive effect of organic mulching on carabid diversity however, was found significant in both years of 2011 and 2012.

Keywords: potato, leaf litter mulch, hay mulch, pitfall trap, Carabidae

Introduction

Since the appearance of the potato beetle in most region of Hungary, potatoe can only be grown successfully if the defense against is regular (Sáringer, 1998). Several of the larger *Carabus* species are effective predators of the Colorado potato beetle (Scherney, 1959) and wireworms (Dunger, 1983). Sorokin (1976) described 14 carabid beetle species as natural enemies of the Colorado potato beetle in Eastern Europe (Heimpel and Hough-Goldstein, 1992). A survey of North American potato fields found that *Lebia grandis* (Hentz) and *Poecilus chalcites* (Say), both of the family Carabidae, were natural enemies of the Colorado beetle (*L. decemlineata*). An adult *L. grandis*, being one of the most important predators of the Colorado beetle (Hemenway and Whitcomb, 1967), can consume up to 47 eggs of the beetle a day (Groden, 1989). One of the most frequent carabid species in Hungary, *Poecilus cupreus* (*L.*) feeds on the egg and larvae of the Colorado beetle. The *Broscus cephalotes* (L.) is efficient predator of *L. decemlineata* too (Merkl and Vig, 2011). A North-American paper supported that the population size of the Colorado beetle (*L. decemlineata* Say) was lower on potato mulched with straw (Stoner et al., 1996; Brust, 1994) and claimed that the number of pest was lower because the straw applied on the soil surface provided the predators with

DOI: 10.18380/SZIE.COLUM.2016.3.1.45

hiding places, and the habitat suffered less disturbance. According to Dvořák et al. (2012) the number of Colorado beetle larvae was reduced in parcels covered by chopped grass and these parcels provided bigger potato tubers on average. The higher tuber yield in chopped grass mulch might have been due to the higher nitrogen availability in the soil (Dvořák et al. 2013). Straw mulch was found to be beneficial to the microflora of the soil (Flessa et al., 2002). The surplus of organic material distributed over the surface of the soil increases its organic matter content and has a beneficial effect on the macrofauna as well (Pauli et al., 2011). A study (Kromp, 1999) supported that the species composition and the number of individuals of carabid beetles were lower on conventional potato plots than on organic ones; it also suggested that geographical location may have a significant effect on the densities of carabid species. Another study on the carabid fauna in France found that the thickness of the leaf litter influences the density of *Abax ater*, Villers, as it may be harder for a carabid predator to catch the prey under a thick layer of leaf litter. This study indicated that the thicker the layer, the lower the number of carabid beetles was (Guillemain et al., 1997). That fenomenon may appear in mulched fields as well, since the width of leaf litter is increased. Tuovinen et al. (2006) tested whether covering of the soil surface itself has an effect on carabids and they found that organic mulch materials were more favourable for carabid beetles than the conventional plastic sheets on strawberry plots.

Our aim was to investigate the effect of two different organic mulching materials (leaf litter and hay) on the carabid assemblages. We conducted our experiments within similar conditions with two different mulch types at two locations. Then we investigated whether species composition would differ between sites and mulch types and studied the mulch preference of carabid species.

Materials and methods

For our research, we settled for a mountainous area with brown forest soil (Várallyay & Szűcs 1978). Quality of soils is shown in Table 1. 12 soil samples were collected from the upper 8 cm of the topsoil at each experimental plot. Our experimental plots were located in a suburban area with continuous mixed forests in the outskirts of Budaörs (47°47’25.6” N, 18°95’90.3” E) (Pest County, Central Hungary) and Hidegkút (47°00’20.6” N, 17°.83’05.9” E) (Veszprém County, West Hungary) with a total area of 168 m^2 per location, including tramlines. There were 12 plots, each were 3 × 4 m, with 4 repetitions and 3 treatments (hay mulch, leaf litter mulch and control).

There were 2 pitfall traps in each plot, a total of 24 traps per location. We grew the potato in organic farming system. We used Barber pitfall traps to sample the carabid beetles. All traps were emptied fortnightly between June and September of 2011-2013. On mulched plots we removed all mulch from the direct surroundings of the traps to level their rims with the soil surface. Animals were killed with acetic acid (5%). Carabids were identified to species level by using the guides “Carabidae of the Czech and Slovak Republics” (Hůrka, 1996) and “Die Käfer Mitteleuropas Band 2 Adelphaga 1 Carabidae (Laufkäfer)” (Müller-Motzfield, 2004). Effects of the mulching treatments and locations on the abundances of the captured Carabids were tested by using two-way ANOVA tests, the pairwise comparisons were performed with LSD test.

Table 1. Basic soil characteristics of potato plots at Hidegkút and Budaörs

Place	Soil sample depth (cm)	pH (H_2O)	$CaCO_3$%	Soil salinity (EC 2,5 mS/cm)	Saturation Percentage
Budaörs	0-8	7.63-7.68	24.41	0.303	58
Hidegkút	0-8	7.52-7.78	23.4	0.286	54

 DOI: 10.18380/SZIE.COLUM.2016.3.1.45

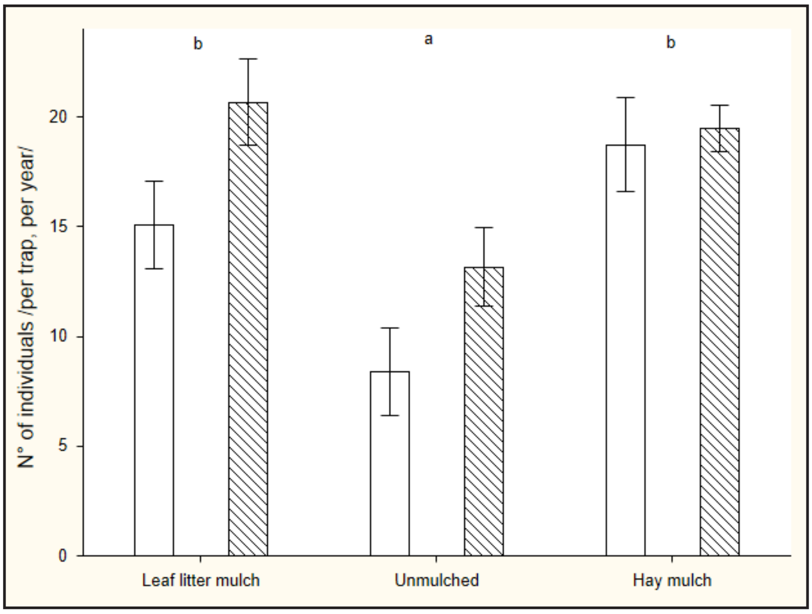

Figure 1. Average capture of carabid beetles of mulched and unmulched potato plots at Hidegkút and Budaörs from three years, 2011, 2012 and 2013 open bars: Budaörs, shaded bars: Hidegkút (bars denotes mean and whiskers standard error

Biodiversity was analyzed by using Shannon-index. Shannon index was calculated for each plot per site, per year and per treatment. Linear model was created to estimate Shannon index with three explanatory factor variables: site, year and treatment. Since the effect of the site was not significant, it was removed from the final model. The final model estimates the Shannon index as the function of the year and the treatment. Modell diagnostics justified the homogeneity of variance and the normality of the residuals.

Results and discussion

Application of organic mulches significantly increased the number of carabid individuals in potato plots (F(66,2)=11,72, p<0.001). During the whole sampling period the overall number of individuals collected on unmulched plots was 533, but the figure for leaf mulch was 439 higher, and for hay mulch, 641 higher. The averaged values of captured Carabids by treatment are shown in Figure 1. The results of the two-way ANOVA are presented in Table 2. Locations and mulching treatment affected the captured number of individuals significantly (p<0.001). We found a slightly but singnificantly higher abundance of carabid beetles at Hidegkút site (F(66,1)=5,94 (p=0,017). Mulching increased the number of individuals significantly (F(66,2)=11,72; p<0,001), with 66% at hay mulching and 77% at leaf litter mulching. According to LSD test there was no significant difference between the two types of mulching treatments, but number of individuals captured in either mulching was significantly higher compared to the captures of unmulched sites. Overall we found 46 species during the three years (Table 3). 13 species were solely captured on mulched plots, whereas 6 species occurred only on control (unmulched) plots. We found no difference in

Table 2. Results of the final 2-ways ANOVA model (dependent variable: number of individuals)

Effect	SS	Degr. of freedom	MS	F	p
Sites	245.7	1	245.7	5.94	0.018
Treatments	969.4	2	484.7	11.72	<0.001
Sites x treatments	80.1	2	40.1	0.97	0.385
Error	2729.4	66	41.4		

DOI: 10.18380/SZIE.COLUM.2016.3.1.45

Table 3. Carabid beetles of mulched and unmulched potato plots at Hidegkút and Budaörs in 2011-2013 (L: leaf litter mulch; U: unmulched; H: hay mulch)

Species	L	U	H	Grand total
Abax parallelepipedus (Piller et Mitterpacher 1783)	4	0	2	6
Amara similata (Gyllenhal 1810)	1	0	0	1
Calathus erratus (Sahlberg 1827)	1	0	1	2
Callistus lunatus (F. 1775)	18	0	27	45
Carabus scabriusculus Olivier 1795	0	0	1	1
Cicindela germanica L. 1758	0	0	1	1
Harpalus pumilus Sturm 1818	2	0	2	4
Ophonus laticollis Mannerheim 1825	0	0	1	1
Ophonus rupicola (Sturm 1818)	1	0	0	1
Poecilus cupreus (L. 1758)	2	0	6	8
Syntomus pallipes (Dejean 1825)	4	0	4	8
Trechus quadristriatus (Schrank 1781)	2	0	1	3
Zabrus tenebrioides (Goeze 1777)	1	0	3	4
Acupalpus meridianus (L. 1761)	1	1	3	5
Amara aenea (De Geer 1774)	6	6	8	20
Amara equestris (Duftschmid 1812)	4	3	3	10
Anchomenus dorsalis (Pontoppidan 1763)	6	8	80	94
Brachinus crepitans (L. 1758)	67	22	187	276
Brachinus explodens Duftschmid 1812	0	1	15	16
Calathus fuscipes (Goeze 1777)	22	14	35	71
Carabus coriaceus L. 1758	23	13	20	56
Harpalus affinis (Schrank 1781)	2	1	6	9
Harpalus albanicus Reitter 1900	2	3	1	6
Harpalus calceatus (Duftschmid 1812)	15	5	16	36
Harpalus caspius (Steven 1806)	59	41	51	151
Harpalus dimidiatus (Rossi 1790)	64	25	54	143
*Harpalus distinguend*us (Duftschmid 1812)	85	43	64	192
Harpalus griseus (Panzer 1797)	55	29	39	123
Harpalus rubripes (Duftschmid 1812)	3	6	0	9
Harpalus rufipes (De Geer 1774)	344	187	408	939
Harpalus serripes (Quensel 1806)	8	9	11	28
Harpalus smaragdinus (Duftschmid 1812)	3	1	1	5
Harpalus tardus (Panzer 1797)	76	49	61	186
Licinus cassideus (F. 1792)	1	2	5	8
Microlestes maurus (Sturm 1827)	30	15	9	54
Ophonus azureus (F. 1775)	28	19	25	72
Ophonus cribricollis (Dejean 1829)	11	10	16	37
Ophonus melletii (Heer 1837)	1	2	0	3
Ophonus signaticornis (Duftschmid 1812)	20	9	4	33
Pterostichus melas (Creutzer 1799)	0	1	3	4
Calathus ambiguus (Paykull 1790)	0	1	0	1
Cicindela campestris L. 1758	0	1	0	1
Harpalus atratus Latreille 1804	0	1	0	1
Ophonus diffinis (Dejean 1829)	0	1	0	1
Ophonus rufibarbis (F. 1792)	0	1	0	1
Parophonus dejeani Csiki 1932	0	3	0	3
Total number of individuals	972	533	1174	2679
Number of species	35	33	36	46

 DOI: 10.18380/SZIE.COLUM.2016.3.1.45

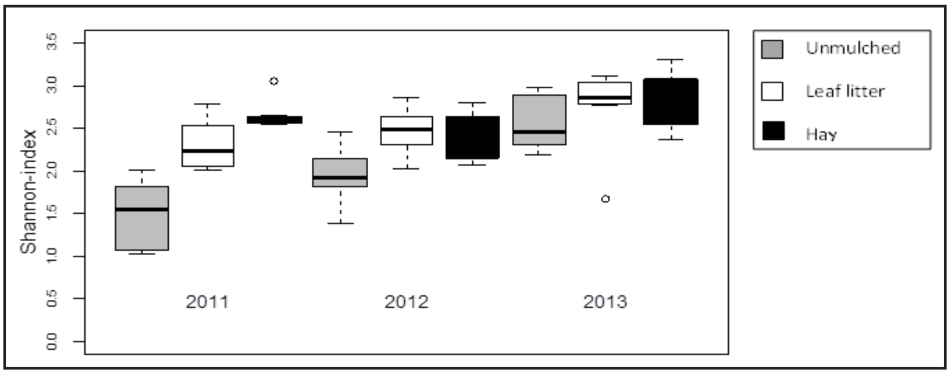

Figure 2. The biodiversity of captured carabid beetles of mulched and unmulched potato plots at Hidegkút and Budaörs from three years, 2011, 2012 and 2013

the number of species between the two types of mulching, however, the number of species on either mulching type was significantly higher than that on the unmulched, control area. The value of R^2 was 0.52. The results of the model are presented in Table 4. The biodiversity in 2012 did not differ significantly from 2011 but it was significantly higher in 2013. Both the leaf litter and the hay mulch significantly increased Shannon diversity (Figure 2). The most abundant carabid species of the study areas, in decreasing frequency, were *H. rufipes*, *Harpalus tardus* (Panzer), *Harpalus distinguendus* (Duftschmid), *Harpalus dimidiatus* (Rossi) at Hidegkút; and *Brachinus crepitans* (L.), *H. rufipes*, *H. distinguendus, Ophonus azureus* (F.) at Budaörs. The carabid fauna of the two locations overlapped considerably.The number of species was higher in Hidegkút, as there were only 37 species collected, while at Budaörs, the total number of species was 29. The combined number of individuals was 1636 for Hidegkút and 1043 for Budaörs. Carabid species that were captured in only one of the locations were found in small quantities, except for *Harpalus griseus* (Panzer), which was found in Hidegkút only, and was the fifth most frequent species of that location. Unmulched plots however, displayed lower diversity figures, and in every year, the mulched plots were the more diverse ones (Figure 2). There was no significant difference in species diversity between the two sites. Both locations (Hidegkút and Budaörs) had similar environmental conditions, which suggested similarity in species diversity.

For three consecutive years we studied the density of carabid assemblages of potato fields both without mulch and with organic mulch of two different structural types. The species composition of the two locations matches the typical carabid fauna of agroecosystems: the range is dominated by *Harpalus* species, while members of less frequent genera (*Ophonus, Brachinus*) prefer dry habitats (Saska and Honek, 2004; Kocourek, 2013).

Hidegkút and Budaörs are ruderal, agricultural open-habitats and as a result we found similar, mostly thermofilic species on both sites (Müller-Motzfield, 2004). The use of organic mulch, such as hay or leaf litter, had a positive effect on the carabid assemblages of potato, and this difference was significant. Mulching

Table 4. The averaged values of captured Carabids by treatment

	Estimate	**Standard error**	**t**	**p**
(Intercept)	1.77	0.09	18.83	<2×
year (2012)	0.14	0.10	1.34	0.186
year (2013)	0.56095	0.10	5.45	7.75×
treatment (leaf litter)	0.51	0.10	4.97	4.99×
treatment (hay)	0.62	0.10	6.04	7.52×

in general was found to increase the diversity of carabid species. We assume that organic mulch (hay and leaf litter, or similar materials) imitates natural habitat structures and has the potential to attract carabid species that do not occur on unmulched areas into arable plots. The species richness of mulched plots was significantly higher than that of unmulched ones. Carmona and Landis (1999) examined the influence of soil cover (mulching) and of the plot margin on the activity density of carabid beetles. They found a significant difference between the number of individuals of mulched and unmulched plots, although this finding was most prominent in the period between June and August. Shearin et al. (2008) marked and released *H. rufipes* individuals to compare the number of recaptured individuals on mulched and unmulched plots. They captured twice as many beetles on mulched plots than on unmulched ones. Enhancing the organic content of soil surface has an undoubtedly positive influence on the carabid assemblage of the habitat. Several studies of the movement patterns of carabid beetles have shown that carabids generally move randomly about in a favorable habitat but switch to a more straightforward course in an unfavorable habitat (Rijnsdorp, 1980; Wallin and Ekbom, 1988). The highest number of individuals captured belonged to species *H. rufipes*. This beetle is one of the most important carabids of agricultural areas and is found in great abundance from July to September on arable lands. *Poecilus cupreus* (L.) however, although described as a species of great abundance between May and June on arable lands (Juen et al., 2003), was scarcely captured in our experiment, with only 8 individuals caught on our plots. The activity peak of *H. rufipes* was observed between July and September. Similarly to our findings, the number of *Abax parallelepipedus* (Piller et Mitterpacher), *Amara aenea* (De Geer), *Calathus fuscipes* (Goeze), *Callistus lunatus* (F.), and *Carabus coriaceus* (L.) individuals captured by Traugott (1999) was also significantly lower than that of the most abundant species. This Austrian study found *H. rufipes* the most abundant species too, but *P. cupreus* was captured in notably larger abundance than in our experiment. Our study confirmed the presence of carabid species that are usually found along the edges of forests (Roume et al., 2011), namely *Anchomenus dorsalis* (Pontoppidan), *Trechus quadristriatus* (Schrank). The number of these species was relatively low, as they are not among the most important species of arable lands and are assumed to have been attracted into our experimental potato plots by of the presence of the organic mulching material. As a matter of fact, the appearance of both species was expected, because our experimental plots are surrounded by forested areas. The relatively high frequency capture of *B. crepitans* left us unsurprised, because this species is known for being frequent on disturbed areas such as mine tailings (Sár and Dudás, 2002), and on limestone terraces of abandoned quarries (Novotna and Šťastna, 2012). The occurrence of *B. crepitans* however, was especially high in one of the locations and we assume that the differences between the two habitats account for that. *H. distinguendus* (Tóthmérész et al., 2011), on the other hand, which prefers open habitats, was found in the largest number on plots covered with leaf litter mulch but was hardly found on unmulched plots. *H. tardus* (Small et al., 2006), which prefers open habitats and was also one of the most frequent species, was found in the largest number on mulched plots. There were other, frequent species such as *H. griseus* (Magura et al., 2008).

This species prefers open habitats generally. We found it in the largest number on plots covered with leaf litter mulch but it was hardly found on unmulched plots. One of the most frequent species of the Budaörs location, *B. crepitans* (Roume et al., 2011), which prefers open habitats, was found in large numbers on plots mulched with hay and was scarcely found on unmulched plots.

DOI: 10.18380/SZIE.COLUM.2016.3.1.45

Our results suggested that the two types of mulching materials did not cause a significant difference between the species diversity of carabid beetles (Figure 2). The reason of the similarity in diversity of carabids might be the small size of the plots or that the quality of cover is less important for ground beetles than the presence or absence of a shelter (and it seems that mulch as a soil cover that imitates the natural layer of decaying plant material is accepted as shelter). One must also note that the abundancy of potential prey also plays an important factor in the abundance and diversity of carabid beetles of an area (Guillemain et al., 1997). According to our study, year had no effect on the diversity of carabid beetles (Figure 2).

Conclusions

Our results suggested that our study should be extended to more locations and larger study plots and more types of mulch. In addition we should conduct further experiments to find out more about the micro-habitat preferences of the dominant species (*B. crepitans*, *Harpalus* spp.) of Carabid assemblages.

The impact of organic mulch types on the diversity of carabid beetles was significant in our plots. The number of individuals of species that were found only on mulched (covered) soil was low, leading us to the assumption that soil cover helps these somewhat rare species to spread and change their position between habitats.We found that the differences between the number of individuals of mulched and unmulched plots are explained by the presence or non-presence of the most frequent species of the area; whereas there are rare species behind the differences between the diversity figures. Mulching has a similar effect on both frequent and rare species, that is, to maximize their safety and survival on mulched areas both frequent and rare species prefer covered surfaces to open areas. The change that took place during the course of the study in land use (from grassland to potato production) increased the diversity of carabid beetles.

Acknowledgements

The authors would like to thank Győző Szél (Hungarian Natural History Museum, Budapest) for his help in the species identification of carabid beetles.

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