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Ground Beetle Assemblages Affected by Oilseed Rape Management Practice

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Abstract: Ground beetle assemblages were compared in two oilseed rape fields with different management practices, in fallow and in succeeding winter wheat crop. A total of 11,615 specimens representing 52 species were collected over two years of sampling using epigeic pitfall and funnel traps. The ten most common species, represented 91% of the total number of specimens in oilseed rape, were *Amara aenea* (De Geer, 1774), *Amara similata* (Gyllenhal, 1810), *Harpalus distinguendus* (Duftschmid, 1812), *Brachinus explodens* Duftschmid, 1812, *Poecilus cupreus* (L., 1758), *Calathus fuscipes* (Goeze, 1777), *Calathus ambiguus* (Paykull, 1790), *Poecilus punctulatus* (Schaller, 1783), *Poecilus sericeus* Fischer von Waldheim, 1824 and *Anchomenus dorsalis* (Pontoppidan, 1763). Eight carabid species showed a clear preference for integrated oilseed rape management practice. Trapped beetles were three times more numerous in oilseed rape in integrated than in the field under organic management practice. Canonical Variate Analysis revealed that management practices applied on both fields in oilseed rape had a significant effect on carabid assemblages. Redundancy Analyses (RDA) showed that in the following year, in succeeding winter wheat crop, management practices applied in oilseed rape had a significant effect on carabid assemblages. Ground beetle activity on plants was registered in both oilseed rape management systems, but not on winter wheat plants. The most active carabids in crop canopy included *A. similata*, *C. fuscipes*, *Calathus erratus* (Sahlberg, 1827), *A. aenea*, *C. ambiguus*, *Calathus melanocephalus* (L., 1758) and *H. distinguendus*. In oilseed rape both management practices had a significant effect on carabid assemblages in crop canopy.

Key words: Ground beetles, oilseed rape, winter wheat, management practice, crop canopy, redundancy analysis.

Introduction

Ground beetles are one of the most common and species-rich families of ground-dwelling arthropods in agricultural ecosystems and are also important bioindicators for land-use and human impacts (Thiele 1977, Lövei & Sunderland 1996, Rainio & Niemelä 2003). They are reliable indicators for environmental factors or habitat conditions (Landers et al. 1988) as found in a number of studies (Jelaska et al. 2007, Pizzolotto et al. 2013, Sklodowski 2014, Eyre, Sanderson et al. 2016, Lami et al. 2016), likely owing to the fact that they are non-randomly distributed in the environment (Sklodowski 2005). Some species are critically endangered by human activities (Brandmayr et al. 2009). Also, they are the most important polyphagous predators within arable cropping systems in Europe (Kromp 1999) and are amongst the most abundant invertebrate predators in oilseed rape fields in Europe (Williams 2010). Community structure and especially the population density of carabids in agroecosystems are influenced by many synergistically acting factors, like pedological and hydrologi-

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cal conditions, microclimatic conditions specific for each crop stand, duration of crop presence in the field, agro-technical measures and chemical pest control (Booij & Noorlander 1992, Burgio et al. 2015, Eyre, McMillan et al. 2016). At the farm level, three main categories of factors, which affect predator occurrence, can be distinguished. The first category includes 'crop effects' which primarily indicates the kind of crops grown in a rotation with its own structure, prey availability and husbandry practices. The second category, 'system effects' concerns the general approach of farm management. This includes practices such as pesticide use, fertilisation, soil tillage, weed management, etc. Differences in the latter mainly characterise conventionally, integrated and organic farming systems (Vereijken 1989). The final category comprises the spatial pattern of fields, crops, field margins, hedges and the natural environment (Sotherton 1985). No case is known in which any carabid species are characteristically linked with particular crop plant in South-Eastern Europe, but Büchs et al. (2007) reported a very typical and even "standardised" set of ground beetle assemblages for oilseed rape fields in Middle and Northern Europe. A complete changeover of the carabid fauna from year to year with the changing crops is also most unlikely (Thiele 1977). On the other hand, Büchs et al. (2007) reported that *A. similata* is the only species extraordinarily abundant in oilseed rape fields. It also holds the top position as the most abundant species in European oilseed rape fields. High diversity and abundance of ground beetles are considered as a characteristic feature of an undisturbed ecosystem (Kromp 1999, Tuovinen et al. 2006). Oilseed rape grown in crop rotation with winter wheat has many advantages and thus it is very common in farmers practice. Most studies comparing carabid fauna in conventional and organic systems have found a greater abundance of ground beetles and species richness in organic management (Kromp 1999, Clark et al. 2006).

The objective of this study was to determine the within-field biodiversity of ground beetles in two differently managed winter oilseed rape fields. Another objective was to evaluate the short-term influence of these oilseed rape management systems on ground beetle assemblages in fallow and also their prolonged effect in the subsequent winter wheat crop.

Materials and Methods

Experimental site

The experiment was conducted in two fields during 2010–2012 in winter oilseed rape (OSR) and in winter wheat (WW) grown in crop rotation with oilseed rape. Fields were located in northern Serbia (N45 57.280 E19 37.554), 112 m a.s.l.. The soil belongs to the calcic chernozem, loamy type texture, with 50 – 70 cm organic rich topsoil, pH (H_2O) 8.1 and 3.3 % humus. The climate is mild continental with mean annual temperature of 11.2°C and annual precipitation of 530 L m^{-2}. The landscape of the studied area consists of farmland with winter wheat, corn, barley and winter oilseed rape as main crops.

The adjacent OSR fields (app. 1.5 ha each) were sown on 17 September 2010 with cultivar "Excalibur", while winter wheat was the crop for two preceding years. On OSR field 1, integrated management practice was applied (INT) and soil was prepared by disk harrowing, while on the OSR field 2, organic management practice (ORG) was applied and soil was prepared by ploughing. Row space in the INT was 12 cm, while in ORG it was 36 cm. In the INT, half a dose of mineral fertilisers were applied (N =80 kg ha^{-1}, P=39 kg ha^{-1}, K=39 kg ha^{-1}) from local practice and in the ORG there was no mineral fertilisation. On 25 March 2011 (BBCH 22-25), INT field was sprayed with Cypermethrin (40 g/ha a.i.) and on 6 April 2011, (BBCH 55-57) ORG field with Spinosad (96 g/ha a.i) against rape steam weevil, *Ceutorhynchus napi* (Gyllenhal, 1837). Standard tractor sprayer with 300 L water/ha was used. On both fields no herbicides, foliar fungicides, nor molluscides were applied. On the same date, 22 June 2011, both OSR fields were harvested. The fallow period started on 23 June 2011 and lasted until the sowing of WW (20 October 2011). Both WW fields were harvested on 19 June 2012.

The management of the WW was the same for INT and ORG field, with the application of manure (20 tons per field) before sowing; no mineral fertilisers nor pesticides were applied.

Ground beetle sampling

Carabid beetles were collected in OSR and WW fields from eight and in fallow from four epigeic pitfall traps, arranged in a line at the centre of each field. Epigeic pitfall traps consisted of a plastic cup, 11 cm in diameter and 10 cm in depth. The upper edge of a plastic cup was positioned in line with the ground surface. These traps were used to measure activity density of ground beetles on the soil surface. Active carabid beetles were collected from the OSR crop canopy using funnel traps. Originally, funnel traps were used to assess the area-related abundance of oilseed rape pests dropping from the crop plant canopy to the soil for pupation, but some ground beetles also dropped from plants. The funnel trap consisted of a funnel, 17 cm in diameter, which was connected

Table 1. Ground beetle species abundance, number of individuals per pitfall trap, percentage share and dominance class in OSR, fallow and WW fields, Stari Žednik, 2010–2012.

	Oilseed rape				Fallow				Winter wheat			
	no. ind.	ind/ trap	%	D	no. ind.	ind/ trap	%	D	no. ind.	ind/ trap	%	D
Acupalpus meridianus (Linnaeus, 1761)	2	0.13	0.02	S	0	0.00	0.00		0	0.00	0.00	
Agonum viridicupreum (Goeze, 1777)	1	0.06	0.01	S	0	0.00	0.00		0	0.00	0.00	
Amara aenea (De Geer, 1774)	1416	88.50	15.77	D	71	8.88	6.04	sD	130	8.13	20.93	D
Amara anthobia A. Villa & G. Villa, 1833	2	0.13	0.02	S	0	0.00	0.00		0	0.00	0.00	
Amara consularis (Duftschmid, 1812)	2	0.13	0.02	S	1	0.13	0.09	S	1	0.06	0.16	sR
Amara familiaris (Duftschmid, 1812)	40	2.50	0.45	sR	25	3.13	2.13	R	5	0.31	0.81	sR
Amara similata (Gyllenhal, 1810)	1349	84.31	15.02	D	32	4.00	2.72	R	5	0.31	0.81	sR
Anchomenus dorsalis (Pontoppidan, 1763)	212	13.25	2.36	R	0	0.00	0.00		5	0.31	0.81	sR
Asaphidion flavipes (Linnaeus, 1761)	1	0.06	0.01	S	0	0.00	0.00		0	0.00	0.00	
Brachinus elegans Chaudoir, 1842	159	9.94	1.77	R	2	0.25	0.17	S	0	0.00	0.00	
Brachinus explodens Duftschmid, 1812	1325	82.81	14.76	D	0	0.00	0.00		0	0.00	0.00	
Brachinus psophia Audinet-Serville, 1821	104	6.50	1.16	R	0	0.00	0.00		0	0.00	0.00	
Broscus cephalotes (Linnaeus, 1758)	2	0.13	0.02	S	71	8.88	6.04	sD	4	0.25	0.64	sR
Calathus ambiguus (Paykull, 1790)	387	24.19	4.31	sD	332	41.50	28.23	D	9	0.56	1.45	R
Calathus cinctus Motschulsky, 1850	26	1.63	0.29	S	3	0.38	0.26	S	1	0.06	0.16	sR
Calathus erratus (Sahlberg, 1827)	94	5.88	1.05	R	54	6.75	4.59	sD	4	0.25	0.64	sR
Calathus fuscipes (Goeze, 1777)	524	32.75	5.84	sD	156	19.50	13.27	D	14	0.88	2.25	R
Calathus melanocephalus (Linnaeus, 1758)	68	4.25	0.76	sR	16	2.00	1.36	R	1	0.06	0.16	sR
Calosoma auropunctatum (Herbst, 1784)	0	0.00	0.00		0	0.00	0.00		4	0.25	0.64	sR
Chlenius festivus (Panzer, 1796)	0	0.00	0.00		0	0.00	0.00		1	0.06	0.16	sR
Dolichus halensis (Schaller, 1783)	3	0.19	0.03	S	0	0.00	0.00		0	0.00	0.00	
Harpalus affinis (Schrank, 1781)	6	0.38	0.07	S	10	1.25	0.85	sR	4	0.25	0.64	sR
Harpalus albanicus Reitter, 1900	5	0.31	0.06	S	0	0.00	0.00		0	0.00	0.00	
Harpalus anxius (Duftschmid, 1812)	107	6.69	1.19	R	3	0.38	0.26	S	0	0.00	0.00	
Harpalus calceatus (Duftschmid, 1812)	0	0.00	0.00		5	0.63	0.43	sR	0	0.00	0.00	
Harpalus dimidiatus (Rossi, 1790)	1	0.06	0.01	S	0	0.00	0.00		0	0.00	0.00	
Harpalus distinguendus (Duftschmid, 1812)	1349	84.31	15.02	D	116	14.50	9.86	sD	198	12.38	31.88	D
Harpalus fuscicornis Ménétriés, 1832	2	0.13	0.02	S	0	0.00	0.00		0	0.00	0.00	
Harpalus hirtipes (Panzer, 1796)	6	0.38	0.07	S	1	0.13	0.09	S	0	0.00	0.00	
Harpalus pumilus Sturm, 1818	6	0.38	0.07	S	3	0.38	0.26	S	0	0.00	0.00	
Harpalus pygmaeus Dejean, 1829	15	0.94	0.17	S	0	0.00	0.00		0	0.00	0.00	
Harpalus rufipes (De Geer, 1774)	10	0.63	0.11	S	100	12.50	8.50	sD	28	1.75	4.51	sD
Harpalus serripes (Quensel in Schönherr,1806)	20	1.25	0.22	S	0	0.00	0.00		0	0.00	0.00	
Harpalus signaticornis (Duftschmid,1812)	19	1.19	0.21	S	21	2.63	1.79	R	0	0.00	0.00	
Harpalus taciturnus Dejean, 1829	4	0.25	0.04	S	0	0.00	0.00		0	0.00	0.00	
Harpalus zabroides Dejean, 1829	15	0.94	0.17	S	9	1.13	0.77	sR	1	0.06	0.16	sR
Laemostenus complanatus (Dejean, 1828)	2	0.13	0.02	S	2	0.25	0.17	S	10	0.63	1.61	R
Licinus depressus (Paykull, 1790)	0	0.00	0.00		1	0.13	0.09	S	0	0.00	0.00	
Metalina properans (Stephens, 1828)	2	0.13	0.02	S	0	0.00	0.00		0	0.00	0.00	
Ophonus azureus (Fabricius, 1775)	13	0.81	0.14	S	3	0.38	0.26	S	0	0.00	0.00	
Parophonus dejeani (Csiki, 1932)	0	0.00	0.00		2	0.25	0.17	S	0	0.00	0.00	
Parophonus maculicornis (Duftschmid, 1812)	7	0.44	0.08	S	1	0.13	0.09	S	0	0.00	0.00	
Poecilus cupreus (Linnaeus, 1758)	1003	62.69	11.17	D	8	1.00	0.68	sR	13	0.81	2.09	R
Poecilus punctulatus (Schaller, 1783)	328	20.50	3.65	sD	1	0.13	0.09	S	116	7.25	18.68	D
Poecilus sericeus Fischer von Waldheim, 1824)	277	17.31	3.08	R	75	9.38	6.38	sD	43	2.69	6.92	sD
Pterostichus melanarius (IIliger, 1798)	1	0.06	0.01	S	0	0.00	0.00		0	0.00	0.00	
Pterostichus melas (Creutzer, 1799)	0	0.00	0.00		1	0.13	0.09	S	0	0.00	0.00	
Stenolophus teutonus (Schrank, 1781)	1	0.06	0.01	S	0	0.00	0.00		0	0.00	0.00	
Trechus quadristriatus (Schrank, 1781)	1	0.06	0.01	S	1	0.13	0.09	S	18	1.13	2.90	R
Zabrus tenebrioides (Goeze, 1777)	62	3.88	0.69	sR	50	6.25	4.25	sD	6	0.38	0.97	sR
no. ind.	8979				1176				621			
no. species	44				31				23			

*Dominance class (Engelmann 1978)

Table 2. Mean ground beetle abundance and measured species richness per pitfall trap from two OSR fields, during fallow and in WW fields, Stari Žednik, 2010-2012.

	Means ± SD				
Ground beetles	INT	ORG	t	df	*P*
Abundance OSR	769.0±130.27	223.57±59.56	10.075	12	0.001
Species richness OSR	24.63±2.72	16.38±3.11	5.642	14	0.001
Abundance fallow	185.75±157.92	108.25±49.45	0.937	6	0.385
Species richness fallow	18.5±1.73	14.25±2.5	2.795	6	0.031
Abundance WW	42.63±26.37	35.0±14.51	0.534	14	0.601
Species richness WW	9.75±2.55	8.0±1.31	1.727	14	0.106

Table 3. Abundance of ground beetles with above-ground activity on oilseed rape plants, number of individuals per funnel trap, percentage share and dominance class, Stari Žednik, 2011.

	INT				**ORG**			
	no. ind.	ind/trap	%	D	no. ind.	ind/trap	%	D
Acupalpus meridianus (Linnaeus, 1761)	1	0.1	0.13	s	0	0.0		
Amara aenea (De Geer, 1774)	82	10.3	10.72	d	0	0.0		
Amara familiaris (Duftschmid, 1812)	3	0.4	0.39	sr	0	0.0		
Amara similata (Gyllenhal, 1810)	283	35.4	36.99	Eud	0	0.0		
Anchomenus dorsalis (Pontoppidan, 1763)	11	1.4	1.44	r	1	0.1	1.35	r
Metalina properans (Stephens, 1828)	1	0.1	0.13	s	0	0.0		
Brachinus elegans Chaudoir, 1842	3	0.4	0.39	sr	0	0.0		
Brachinus explodens Duftschmid, 1812	5	0.6	0.65	sr	0	0.0		
Calathus ambiguus (Paykull, 1790)	54	6.8	7.06	sd	15	1.9	20.27	d
Calathus erratus (Sahlberg, 1827)	87	10.9	11.37	d	18	2.3	24.32	d
Calathus fuscipes (Goeze, 1777)	127	15.9	16.60	d	16	2.0	21.62	d
Calathus melanocephalus (Linnaeus, 1758)	46	5.8	6.01	sd	14	1.8	18.92	d
Harpalus distinguendus (Duftschmid, 1812)	30	3.8	3.92	sd	0	0.0		
Harpalus fuscicornis Ménétriés, 1832	2	0.3	0.26	s	0	0.0		
Harpalus hirtipes (Panzer, 1796)	1	0.1	0.13	s	0	0.0		
Harpalus latus (Linnaeus, 1758)	1	0.1	0.13	s	0	0.0		
Harpalus rufipes (De Geer, 1774)	1	0.1	0.13	s	0	0.0		
Harpalus serripes (Quensel in Schönherr, 1806)	4	0.5	0.52	sr	0	0.0		
Harpalus signaticornis (Duftschmid, 1812)	1	0.1	0.13	s	1	0.1	1.35	r
Harpalus taciturnus Dejean, 1829	0	0.0			1	0.1	1.35	r
Harpalus zabroides Dejean, 1829	9	1.1	1.18	r	5	0.6	6.76	sd
Ophonus azureus (Fabricius, 1775)	0	0.0			1	0.1	1.35	r
Poecilus cupreus (Linnaeus, 1758)	1	0.1	0.13	s	0	0.0		
Poecilus punctulatus (Schaller, 1783)	1	0.1	0.13	s	0	0.0		
Poecilus sericeus Fischer von Waldheim, 1824	1	0.1	0.13	s	0	0.0		
Stenolophus teutonus (Schrank, 1781)	1	0.1	0.13	s	0	0.0		
Syntomus pallipes (Dejean, 1825)	1	0.1	0.13	s	0	0.0		
Trechus quadristriatus (Schrank, 1781)	8	1.0	1.05	sr	1	0.1	1.35	r
Zabrus tenebrioides (Goeze, 1777)	0	0.0			1	0.1	1.35	r
no. ind.	765				74			
no. species	26				11			

*Dominance class (Engelmann 1978)

to a plastic cup inserted into the soil. Eight funnel traps per OSR field were installed, arranged in a line at the centre of each field, approximately 3 m from the epigeic pitfall trap. A 5%-sodium benzoate solution was used as conservation fluid in both pitfall and funnel traps. Due to the high temperatures and fast evaporation during summer 2011 (fallow period), ethylene glycol was used in pitfall traps as a conservation fluid. The distance between neighbouring pitfall and between neighbouring funnel traps in OSR and between neighbouring pitfall traps in WW was 50 m, beginning at 50 m into the fields. In the fallow, distance between neighbouring pitfall traps was 70 m, beginning at 50 m into the fields.

Pitfall-trap sampling in OSR started on 1 October 2010 and continued in two-week intervals until 30 November 2010, when the temperature dropped below +5°C. In 2011 sampling continued from 12 February 2011, with monthly controls, and onward from 23 March 2011 traps were controlled in weekly intervals until OSR harvest. Funnel traps were installed on 14th April 2011 and were controlled in weekly intervals until OSR harvest. A sampling of epigeic pitfall traps during the fallow period started on 2 July 2011 and continued in four-week intervals until the sowing of WW (20 October 2011). Pitfall trap sampling in WW started on 25 October 2011 and continued in two weeks intervals until 28 November 2011. In 2012, sampling continued in two-week intervals from 10 January to 19 June. Ground beetle species were identified according to Trautner & Geigenmüller (1987), Hůrka (1996), Freude et al. (2004).

Weed and plant analysis

Weed and OSR plant densities were assessed by counting all weeds and OSR plants present in eight 1 m^2 quadrants randomly chosen at the centre of each field, in vicinity of each epigeic pitfall trap.

Data analysis

The dominance of the carabid species in OSR, fallow and WW is presented as percentage shares of specimens of a given species in a community. The following classification was applied: eudominant – EuD (>32.0 %), dominant – D (10.0 – 32.0 %), subdominant – sD (3.2 – 9.9 %), recedent – R (1.0 – 3.1 %), subrecedent – sR (0.32 – 0.99 %) and sporadic – S (<0.32 %) (Engelmann 1978).

Independent samples t-test was used to assess differences in species richness (±SD) and relative abundance (±SD) of carabid assemblages among OSR, fallow and WW fields. The differences in the mean number of trapped individuals and in species richness between INT OSR and INT WW and between ORG OSR and ORG WW fields were tested with paired t-test. The distribution of data used in the t-test and in the paired t-test was normal (tested by the Shapiro - Wilk test, (Sokal & Rohlf 1995)). When equality of variances was not assumed, data were SQRT- or log (x+1)-transformed (for data from epigeic pitfall traps and funnel traps, respectively). All statistical analyses were performed using SPSS version 21.0 (IBM Corp 2012).

In order to determine the preferences of the most common carabid species for management practices applied in OSR fields and their effect on species composition in the following crop (WW), data were analysed using a multivariate approach in CANOCO 5.0 for Windows (ter Braak & Šmilauer 2012). First, Detrended Canonical Analysis (DCA) was used to be test the character of the relationship between explanatory and dependent variables. Since the lengths of the first canonical axes were in all cases shorter than 3 (i.e. linear response), Redundancy Analysis (RDA) was used in the final analysis. It was followed by the Monte-Carlo permutation test to reveal the significance of individual environment variables (i.e. management practice applied in INT and ORG field) on the structure of the ground beetle community. The results were visualised using biplots, created in CANOCO 5.0.

Results

The ground beetle coenosis registered by pitfall traps in OSR, during fallow and in WW consisted of 10,776 individuals from 50 species. On 18 sampling dates in OSR, 6,877 individuals (43 species) in the INT field and 2,102 individuals (31 species) in the ORG field were registered. During fallow, on seven sampling dates 743 individuals (representing 29 species) were trapped in the INT field and 433 individuals (20 species) in the ORG field. On 12 sampling dates in WW, 341 individuals (19 species) were trapped in the INT field and 280 individuals (20 species) in the ORG field (Table 1).

The management practices applied in OSR had an impact on the number of ground beetle species caught in pitfall traps. Carabids were more abundant in the INT than in the ORG field. There was also a significant difference in measured species richness. A short-term effect of the OSR management practices on the ground beetle abundance during fallow showed no significant difference, but there was a significant difference in measured species richness. For a prolonged effect of OSR management practices on the number of carabid specimens and species caught in pitfall traps in the following WW crop, no significant differences were recorded (Table 2).

The total number of ground beetles collected in INT and ORG field were greater in the OSR as compared with the WW (t=15.531, df=6, p<0.001; t=8.438, df=6, p<0.001; respectively), and the measured species richness in INT and ORG field were greater in the OSR as compared with the WW (t=9.585, df=7, p<0.001; t=7.498, df=7, p<0.001; respectively). A paired t-test determined that carabids were more active in OSR in the INT field (769.00±130.27 ind./trap) than in the INT field with WW crop (45.71±26.87 ind./trap). In the ORG field carabids were more active in OSR (223.57±59.56 ind./trap) than in the WW crop (35.86±15.45 ind./trap). The same patterns were revealed in the mean number of carabid species caught in pitfall traps. Significant differences were recorded between OSR and WW crop in INT (24.63±2.72 and 9.75±2.55 species per trap, respectively) and ORG field (16.38±3.11 and 8.00±1.31 species per trap, respectively).

Besides the large number of ground beetles that were caught in the epigeic pitfall traps during their activity on the soil surface, also carabids with activity on the OSR plants were registered. Carabids which felt from plants were detected in the funnel traps from the end of flowering, during the dropping of pollen beetles, steam weevils and later brassica pod midge larvae, until harvest.

A total of 29 ground beetle species with 839 individuals were found in the funnel traps placed in the two differently managed OSR fields (Table 3). The most abundant ground beetle species were *A. similata* with 283 individuals, *C. fuscipes* (143 ind.), *C. erratus* (105 ind.), *A. aenea* (82 ind.), *C. ambiguus* (69 ind.) and *C. melanocephalus* (60 ind.). Two ground beetle species (*H. latus* and *S. pallipes*) were registered with only above-ground activity.

An independent sample t-test determined that the mean carabid abundance per funnel trap differed significantly between OSR fields (t=6.918, df=14, p<0.001). Ground beetles were more active on OSR plants in the INT field (95.63±50.51 ind./trap) than in the ORG field (9.25±6.89 ind. /trap). An independent t-test revealed the same pattern of significant differences between these two fields in the mean number of ground beetle species caught in funnel traps (t=5.864, df=14, p<0.001). The mean number of 10.88±2.8 species per trap in the INT field was significantly higher as compared with that in the ORG field (4.38±1.41 species per trap).

In INT the most active carabids on OSR plants were from the genera of *Amara* and *Calathus* (Table 3). In ORG, however, no *Amara* species were recorded and four *Calathus* species contributed more than 85% in total catch. The aboveground activity of the predatory species *T. quadristriatus* in both fields should also be noted.

In the INT OSR field the mean number of OSR plants per m^2 was 34.88±2.03, while the two-weed species chickweed (*Stellaria media*) and shepherd's purse (*Capsella bursa-pastoris*) were most abundant (31.25±1.83 and 35.25±1.91, respectively). In the

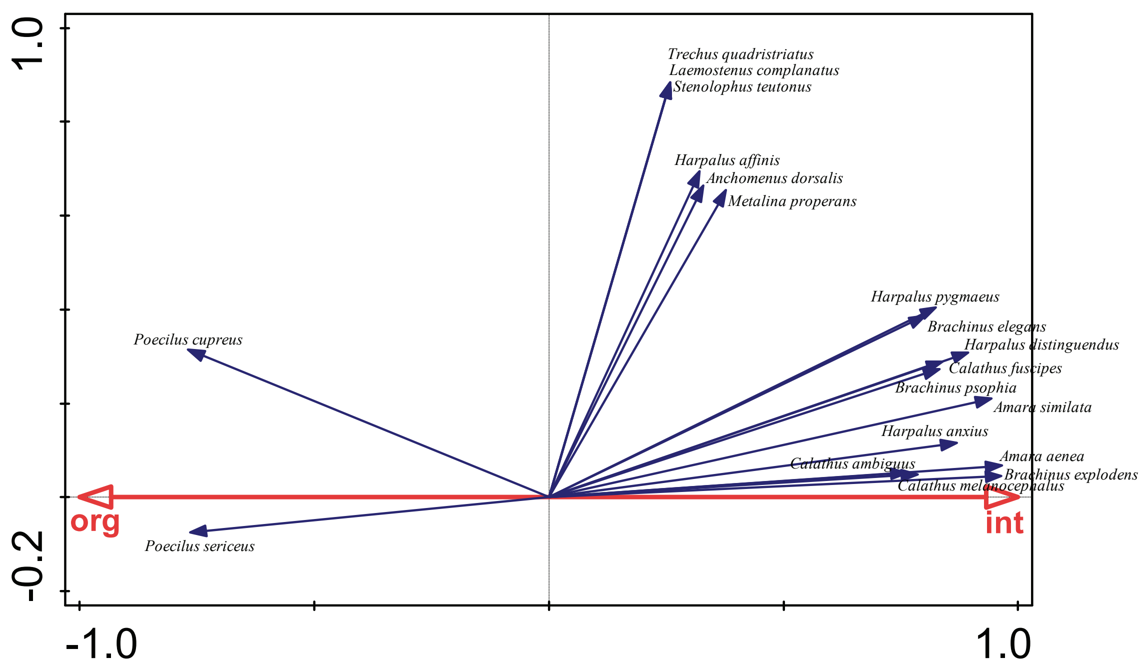

Fig. 1. Analysis of management practices effect on ground beetle abundance in OSR (RDA).

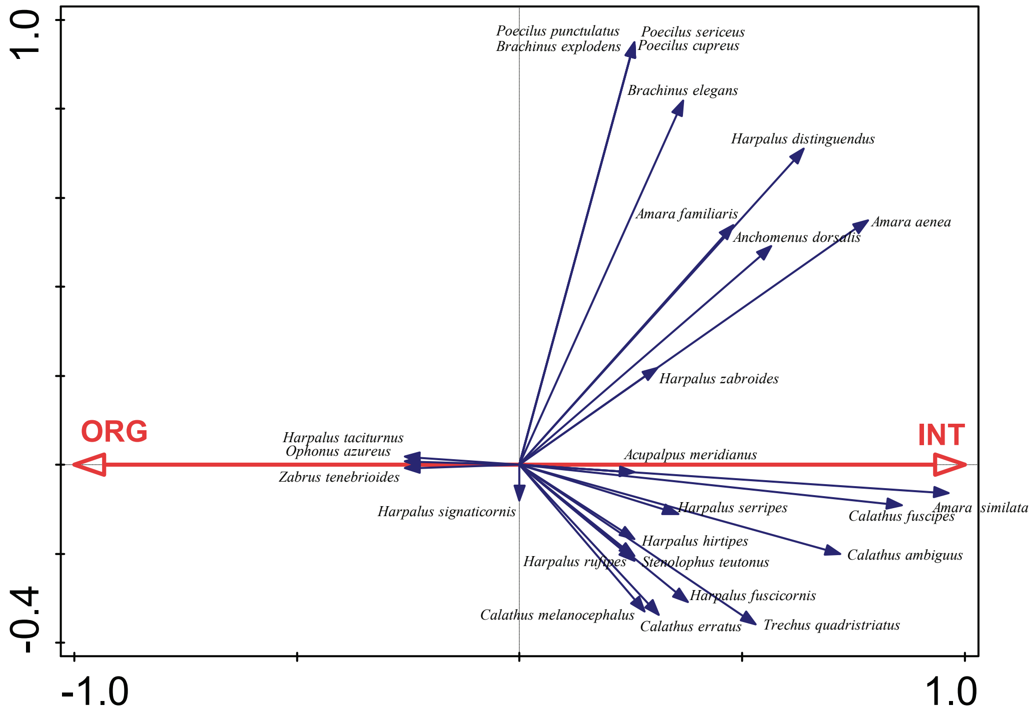

Fig. 2. Analysis of tillage and within-field plant and weed density on above-ground activity of carabid beetles on OSR plants (RDA).

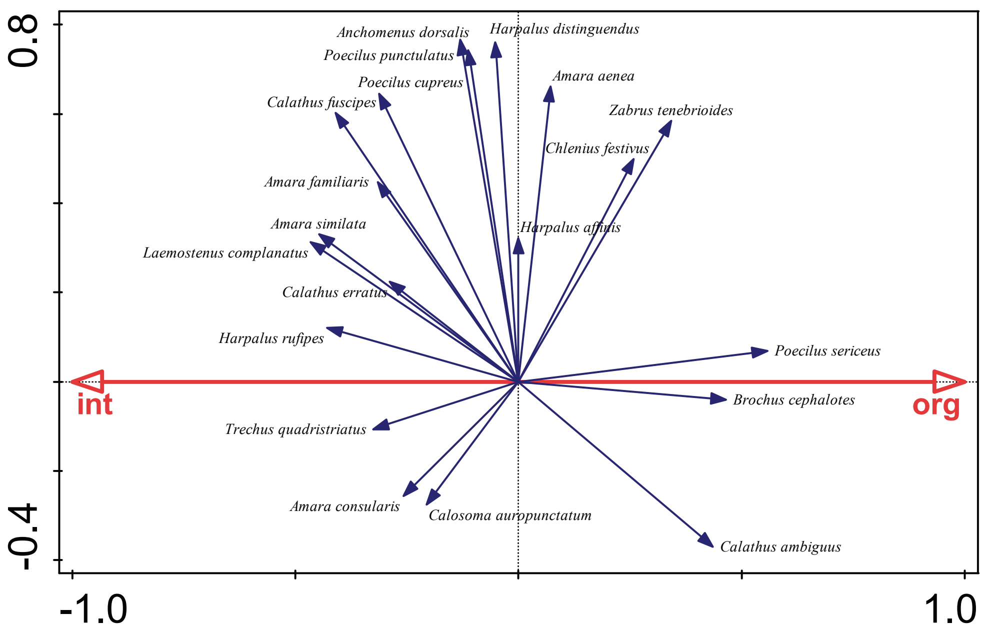

Fig. 3. Analysis of prolonged OSR management effect on the abundance of carabid beetles in WW (RDA).

ORG OSR field the mean number of OSR plants per m^2 was 22.25±1.49 and only the one-weed species field poppy (*Papaver rhoeas*) dominated the field (4.0±0.93).

The redundancy analyses (RDA) indicated an effect of the different management systems on the composition of ground beetle assemblages. The percentage of variance explained by the first canonical axes in OSR was 55.0%, while in WW it was 11.26%. In the OSR crop, the Monte-Carlo permutation tests showed that management practices significantly affected the structure of carabid species assemblages (INT: F= 17.1, p=0.002 and ORG: F= 17.1, p=0.004). In the WW crop, the Monte-Carlo permutation tests revealed that the management practices applied in OSR significantly affected the structure of carabid species assemblage in the INT (F= 1.8, p=0.03) and in the ORG (F=1.8, p=0.028) field. Biplots based on RDA indicated an affiliation of most common species to management practices in OSR and WW (Figs. 1 and 3).

The RDA analysis in OSR showed a clear preference of two ground beetle species (*P. cupreus* and *P. sericeus*) for ploughed ORG OSR field. A positive correlation with non-inversion tillage was found for 11 carabid species *(A. aenea, A. similata, B. elegans, B. explodens, B. psophia, C. ambiguus, C. fuscipes, C. melanocephalus, H. anxius, H. distinguendus and H. pygmaeus*). Six carabid species (*A. dorsalis, H. affinis, L. complanatus, M. properans, S. teutonus and T. quadristriatus*) showed no preference for non-inversion tillage, nor for ploughed field (Fig. 1).

The RDA indicated an effect of the different management systems on the above-ground composition of carabid beetle assemblages on OSR plants. The percentage of variance explained by the first canonical axes was 39.04%. Monte-Carlo permutation tests showed that tillage and within-field plant and weed density significantly affected the structure of ground beetle assemblages in the INT ($F=2.1$, $p=0.002$) and in the ORG OSR field ($F=2.1$, $p=0.002$). Biplots based on RDA indicated an affiliation of above-ground active carabid species to INT or ORG field with OSR crop (Fig. 2).

During the following year, in WW, which was in rotation with OSR, almost the same species were present (Fig. 3). *Poecilus sericeus* and *B. cephalotes* were highly correlated with the ORG field, while *H. rufipes*, *T. quadristriatus*, *C. erratus* and *A. similata* were highly correlated with the INT field. The majority of carabid species showed the same affiliation for the INT and ORG fields. The analysis showed that there is a repeated preference of the two common carabid species *A. similata* for the INT field and *P. sericeus* for the ORG field.

Discussion

Our objective was to examine how different OSR management practices influenced ground beetle assemblages and their effect on carabids in the succeeding WW crop. We found that there were major differences in the number of carabid individuals in OSR and WW. In OSR 8,979 individuals (561.19 ind. /trap), while in WW 621 individuals (38.81 ind. /trap) were trapped. Such large differences indicated that carabids preferred the OSR crop. On both experimental fields with the OSR crop we detected large abundance of brassica pod midge (*Dasineura brassicae* W.), steam weevils (*Ceutorhynchus napi* G. and *Ceutorhynchus. pallidactylus* M.) and cabbage steam flea beetle (*Psylliodes chrysocephala* L.) (Sivčev et al. 2012, Sivčev et al. 2015, Sivčev et al. 2016). Such large number of insect prey within the INT and ORG fields and seed prey within the INT field attract large number of carabids in both OSR fields. These four species are one of the six major insect pests in OSR crop in Europe (Williams 2010). The abundance of the pollen beetle (*Meligethes aeneus* F.) was below the economic threshold for both fields (Büchs et al. 2012). In WW crop on both fields, no insect pests were recorded. The absence of insect prey was reflected in more than ten times lower abundance of ground beetles in the WW crop. The crop type affected the carabid assemblage indirectly through cultivation practices and crop microclimate. Any soil cultivation affects the carabid species assemblage, but studies comparing ploughing with reduced tillage have shown varying results, according to local conditions (Holland & Luff 2000). Differences in the number of species and individuals were also recorded between the OSR management systems. In the INT field, there was no ploughing and, thus, the crop residues remained on the soil surface. The activity density of carabids was three times higher in the INT field in comparison to the ORG field. In contrast to the ORG experimental fields, our INT OSR field was very weedy which, according to the findings of Saska (2007), could encourage carabid abundance. Regarding the number of individuals there were notable differences between the OSR and WW fields. Ground beetle activity-density in the WW was 14 times lower than in the OSR. There were also large differences in the number of carabid species between the OSR and WW crops. In the OSR, we found 44 species, while in the WW - only 23 species, from which 21 species were common for both crops. In the WW were recorded two species, *Calosoma auropunctatum* and *Chlenius festivus*, which were not previously found in the OSR. Therefore, our results showed that there were significant changes in ground beetle abundance and species richness in the succeeding crop, while we also confirmed that there was no complete changeover of the carabid fauna with the changing crops (Thiele 1977). The differences observed between the management practices in this study probably reflect habitat preferences of individual carabid species and differences in food availability, with the INT field being the most favourable one.

Beside the applied management practices in the OSR, the within-field plant density, which consisted of oilseed rape and weed plants, had a major effect on carabid assemblages. In the INT OSR field dominated the chickweed (*Stellaria media*), which according to Saska (2007), positively affected carabid colonisation during spring. The chickweed was later replaced by the shepherd's purse (*Capsella bursa-pastoris*). The number of oilseed rape plants on the integrated field (35 per m^2) was equal to the number of shepherd's purse plants. Such high within-field plant density and a high number of oilseed rape pest larvae (Büchs et al. 2012) encouraged carabids to climb in search of prey. From the 26 ground beetle species with above-ground activity, three carabid species (*A. similata, C. ambiguus* and *C. fuscipes*) showed clear preference for the INT field with ground and above-ground (in the crop canopy) activity (Figs. 1. and 2). In the ORG field, only 22 OSR plants per m^2 and four field poppy (*Papaver rhoeas*) plants per m^2 were registered. The rarefied plant density and the absence of chickweed and shepherd's purse resulted in the absence of *Amara* species in the crop canopy and in their lowest epigeic activity. On the other hand, in the OSR crop canopy in the ORG field, four *Calathus* species were the most active (Table 2). In the WW, the absence of weeds and insect pests on both fields resulted in very low ground beetle activity on the soil surface and no activity on the WW plants.

The INT field with applied management practice was found to be very different from the ORG field with management practice. Other authors also showed that carabid species assemblages differ depending on management practices (Clark 1999, Kromp 1999). In the longer term, the type of cultivation influences the weed composition and the amount of soil organic matter. Non-inversion tillage encourages grass weeds and retains organic matter on the soil surface, thereby favouring spermophagous and saprophytic arthropods, which in turn may favour polyphagous and phytophagous carabids (Holland & Luff 2000). The regular use of reduced tillage in the integrated management system and its effect on the soil food web, as opposed to ploughing and its effect in the organic OSR management systems, may account for this difference.

Conclusions

The management practices applied on oilseed rape crops had a significant effect on the carabid assemblage. They also had a significant effect on carabid assemblage of the succeeding winter wheat crop. Ground beetle activity density in oilseed rape was 14 times higher than that in winter wheat. Beside the management practices applied in the oilseed rape, the within-field plant density which consisted of oilseed rape and weed plants, had also a major effect on the carabid assemblage. In addition, the abundant prey availability in the oilseed rape crop contributed to the large differences in ground beetle activity density between the oilseed rape and winter wheat crops. Differences between management practices in oilseed rape (integrated and organic) were recorded but less intensive than crop type differences. Three times higher carabid activity density was registered in the integrated than in the organic oilseed rape fields.

To the best of our knowledge, for the first time, ground beetle activity was registered in oilseed rape crop canopy. Management practices, prey availability and within-field plant density had a significant effect on the above-ground carabid assemblage.

For further studies, we intend to explore the effect of insecticides on carabid assemblages on two differently managed oilseed rape fields. Further, we plan to study which carabid species were the most active on the ground and in the crop canopy during the peak activity of the major insect pests in the oilseed rape crop.

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