Ground beetles in Romanian oilseed rape fields and adjacent grasslands (Coleoptera: Carabidae)

Teodora Teofilova*

Institute of Biodiversity and Ecosystem Research, Bulgarian Academy of Sciences,
1 Tsar Osvoboditel Blvd., 1000 Sofia, Bulgaria

Abstract

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This study aimed at clarifying species composition and ecological structure of the ground beetles associated with oilseed rape fields during flowering, ripening and post-harvest, as well as pastures adjacent to them. Field work was carried out in 2017. Pitfall traps (5 in each site) were set in 20 sampling sites in the Transylvania region, Cluj County. A total of 8,151 individuals were collected (7,576 in rapeseed fields and 575 in pastures) belonging to 82 species from 29 genera. The richest tribes were Harpalini (25 species), Zabrini (12 species), Pterostichini (10 species), and Carabini (9 species). The most species-rich were the genera *Harpalus* (13 species), *Amara* (11 species), *Carabus* and *Ophonus* (8 species each). The most abundant species in the rape fields were *Poecilus cupreus* (1,760 ind.), *Brachinus explodens* (1,500 ind.), *Brachinus elegans* (1206 ind.), and *Anchomenus dorsalis* (875 ind.). The most abundant in the grasslands were *Pterostichus hungaricus* (101 ind.), *Calathus fuscipes* (74 ind.), *Harpalus caspius* (67 ind.), and *Cylindera germanica* (64 ind.). The species found only in rape fields were 36 while 13 species were exclusive to pastures; 34 species were discovered in both types of habitats. The investigation acquired some new data on carabid diversity in Romania, including two new country records.

Keywords

agrocoenoses, carabids, diversity, grasslands, Romania

Introduction

Ground beetles (Coleoptera: Carabidae) are considered an important group of beneficial insects known for its contribution to restricting pest activity (Symondson et al., 2002). They are among the most important elements of the natural environment's resistance in arable fields and natural habitats. The majority of carabid species found in oilseed rape fields are known to be polyphagous predators with significant impact within arable cropping systems (Kromp, 1999) and are amongst the most abundant invertebrate predators of economically important oilseed rape pests in Europe (Williams, 2010; Gotlin Čuljak et al., 2016).

A number of studies focusing on Carabidae in Romanian agrarian landscapes have been published with one earlier contribution by Voicu (1990) focusing on predators of agricultural pests. Several reviews of specific species presence in different parts of Romania have been added in more recent years, e.g. genus *Carabus* in the wheat fields of Moldavia during 1977–2002 (Varvara, 2009); *Calosoma auropunctatum* in seven types of crops during 1977–2010 (Varvara et al., 2012); *Poecilus cupreus* in wheat and potato crops during 1977–2002 (Varvara and Šustek, 2011). Prelipcean et al. (2014) conducted a study in rye crops in Suceava County. Biodiversity, species composition and natural pests' control were studied in comparative research performed in Transylvanian cereal agroecosystems, and the real environmental importance of anti-erosion agroforestry belts for sustainable agriculture development was proved (Malschi et al., 2010).

However, most of the research did not deal with oilseed rape predators in particular but rather with different crops such as for example vineyards and apple orchards (Tălmaciu and Tălmaciu, 2005, 2009), potatoes (Dănilă and Varvara, 1998/1999; Donescu and Varvara, 1999), sugar beet

*Corresponding author:
e-mail: oberon_zoo@abv.bg

(Varvara et al., 1981a), chicory (Varvara et al., 1992-1993), maize (Varvara et al., 1981b; Varvara et al., 1985), alfalfa (Lăcătuţu et al., 1981), clover (Varvara and Brudea, 1986), wheat (Varvara et al., 1992). Faunistic researches of ground beetles in Romanian oilseed rape (*Brassica napus* L.) agro-ecosystems are really scarce. Only 14 carabid species of 7 genera were collected during a 3-year study in rapeseed crop in Neamţ County (Buburuz and Trotuş, 2014). In a study in alfalfa and rapeseed fields in Giurgiu County in 2011, 18 carabid species were collected (Fiera et al., 2013).

The aim of this work is to broaden the knowledge on species composition of ground beetles associated with the oilseed rape during its flowering, ripening and after the harvest, and with the adjacent pastures in the Transylvania region of Romania, as well as to compare carabid coenoses of the two types of habitats.

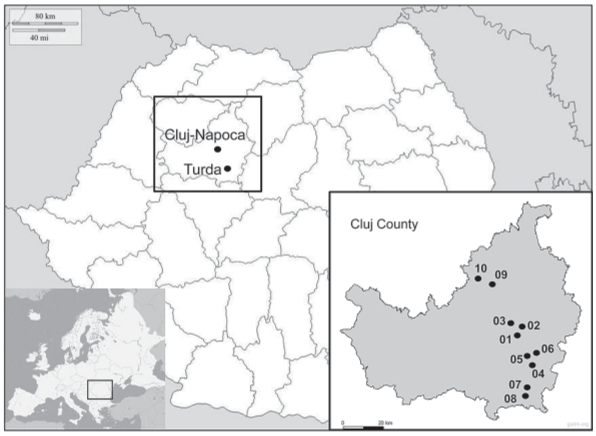

Fig. 1. Map of the STACCATO sampling sites in Romania.

Materials and methods

This study was based on material derived from fieldwork completed in 2017 in different localities in the Transylvania region, Cluj County, Romania. The material was collected in oilseed rape fields and adjacent pastures, in parallel with the implementation of the Project BiodivERsA-FACCE2014-47 "SusTaining AgriCultural ChAnge Through ecological engineering and Optimal use of natural resources (STACCATO)".

Pitfall traps (5 in each site) were set in 20 sampling sites (10 rapeseed fields and 10 grasslands). The traps were made of 500 ml plastic beakers, buried at the level of the substrate and filled with salt and 6% acetic acid saturated solution (with small amount of dishwashing detergent). Three sampling periods were chosen for both the rape fields and pastures corresponding to the following stages – oilseed rape's flowering [1], ripening [2] and after harvest [3]. The exact locations of the sampling sites and sampling periods are presented in Table 1 and on Figure 1.

Captured animals were identified according to several literary sources, e.g. Hůrka (1996), Arndt et al. (2011), Kryzhanovskij (Fauna Bulgarica – Carabidae, unpublished data), and are deposited in the author's collection in the Institute of Biodiversity and Ecosystem Research (Bulgarian Academy of Sciences, Sofia).

Species richness in both studied habitats was calculated using the Margalef's species richness index (Margalef, 1958) [$D_{Mg} = (S - 1) / \ln N$] and the Menhinick's species richness index (Menhinick, 1964) [$D_{Mn} = S / \sqrt{N}$], where S is the number of species, and N is the number of specimens. Dominance structure was estimated using the degree of dominance formula [$D = (n_i/N).100\%$], where n_i is the number of specimens collected for a given species, and N is the total number of specimens. For the mathematical processing of the data MS Excel and the software product PRIMER 6 (Clarke and Gorley, 2005) were used.

Table 1. List of the sampling sites and sampling periods. The letter in the sampling sites codes is, respectively, R – oilseed rape field, G – grassland (pasture). During the first and the third sampling, all traps in sites 09 and 10 were destroyed.

Site code	Locality	Coordinates	Altitude asl (m)	Sampling period 2017		
				[1]	[2]	[3]
R01	NE Crairât	N 46°39'29" E 23°49'14"	412	3.V–23.V	13.VI–5.VII	20.VIII–9.IX
G01	NE Crairât	N 46°39'33" E 23°49'35"	405	3.V–23.V	13.VI–5.VII	20.VIII–9.IX
R02	NE Crairât	N 46°40'35" E 23°49'42"	455	3.V–23.V	13.VI–5.VII	20.VIII–9.IX
G02	N Crairât	N 46°40'38" E 23°49'33"	467	3.V–23.V	13.VI–5.VII	20.VIII–9.IX
R03	NW Crairât	N 46°41'05" E 23°47'46"	513	3.V–23.V	13.VI–5.VII	20.VIII–9.IX
G03	NW Crairât	N 46°40'52" E 23°47'45"	461	3.V–23.V	13.VI–5.VII	20.VIII–9.IX
R04	NW Viişoara	N 46°34'55" E 23°53'29"	372	3.V–23.V	13.VI–5.VII	20.VIII–9.IX
G04	NW Viişoara	N 46°34'49" E 23°53'36"	366	3.V–23.V	13.VI–5.VII	20.VIII–9.IX
R05	NW Viişoara	N 46°36'08" E 23°53'15"	429	3.V–23.V	13.VI–5.VII	20.VIII–9.IX
G05	NW Viişoara	N 46°36'05" E 23°53'05"	425	3.V–23.V	13.VI–5.VII	20.VIII–9.IX
R06	N Viişoara	N 46°36'53" E 23°54'40"	328	3.V–23.V	13.VI–5.VII	20.VIII–9.IX
G06	N Viişoara	N 46°36'46" E 23°54'49"	358	3.V–23.V	13.VI–5.VII	20.VIII–9.IX
R07	N Călăraşi	N 46°29'43" E 23°51'14"	390	4.V–24.V	14.VI–6.VII	21.VIII–10.IX
G07	N Călăraşi	N 46°29'33" E 23°51'18"	383	4.V–24.V	14.VI–6.VII	21.VIII–10.IX
R08	SW Călăraşi	N 46°28'27" E 23°50'42"	429	4.V–24.V	14.VI–6.VII	21.VIII–10.IX
G08	SW Călăraşi	N 46°28'29" E 23°50'17"	426	4.V–24.V	14.VI–6.VII	21.VIII–10.IX
R09	NA	NA	NA	Destroyed	15.VI–7.VII	Destroyed
G09	W Borşa	N 46°55'58" E 23°38'39"	400	Destroyed	15.VI–7.VII	Destroyed
R10	NA	NA	NA	Destroyed	15.VI–7.VII	Destroyed
G10	N Vultureni	N 46°58'13" E 23°33'20"	460	Destroyed	15.VI–7.VII	Destroyed

Table 2. Number of taxa collected in both studied types of habitats during the three sampling periods: oilseed rape's flowering [1], ripening [2], and after the harvest [3]

Period/	Oilseed rape fields				Pastures			
Taxa	[1]	[2]	[3]	Total	[1]	[2]	[3]	Total
Genera	13	24	13	26	15	15	9	20
Species	34	60	31	71	32	33	16	47
Specimens	550	5,941	1,085	7,576	162	207	206	575

Results and discussion

A total of 8,151 carabid specimens were collected. They belonged to 82 species from 29 genera and 16 tribes. The complete list of the established species with their full name, author and year of description, and their abundance in the respective sampling sites, is presented in the Appendix. The current investigation resulted in new data acquisition on carabid diversity in Romania, including two new country records – *Brachinus bodemeyeri* and *Microlestes apterus*, and four additional species with no records for Romania in the last edition of the Catalogue of the Palaearctic Coleoptera: *Agonum viridicupreum, Notiophilus germinyi, Ophonus brevicollis* and *Pterostichus melas*. (For details see Teofilova, 2020b). Furthermore, the presence of a single male *Carabus hampei* in the rape field near Călărași represents a significant faunistic finding; the species being a vulnerable and rare regional "Carpathian" endemic species occurring in Hungary, Romania and Ukraine, and having protected status in all three countries (Szél et al., 2007; Rizun, 2011; Barloy and Prunar, 2012).

The taxonomic structure of the whole carabid complex demonstrated predominance of the open-habitat species from the tribes Harpalini (25 species, 30% of all species) and Zabrini (12 species, 15%), followed by the tribes Pterostichini (10 species, 12%) and Carabini (9 species, 11%) represented by primarily forest inhabitants. Such ratio seems unusual and differs from that established in corresponding pairs of habitats in Bulgaria, where the taxonomic structure demonstrated the prevalence of the openly living species from the tribes Harpalini, Zabrini, and Sphodrini (totally over 60% of all species) (Teofilova, 2021). However, in the course of the current work, we discovered a greater share of forest species compared to their openly living counterparts.

The most species-rich genera were *Harpalus* (13 species, 16%), *Amara* (11 species, 13%), and *Carabus* and *Ophonus* (8 species, 10% each). Such abundance of the genus *Carabus* is quite surprising and remarkable, given the initial mesophilic and forest nature of most representatives of the genus.

In the oilseed rape fields, we collected 7,576 carabid ind., 71 species and 26 genera, and in the grasslands – 575 ind., 47 species and 20 genera (Table 2). In the rape fields, 36 species were uniquely present, while 13 species were found exclusively in the pastures; 34 species were common for both types of habitats.

In the oilseed rape fields, the most species-rich genera were *Harpalus* and *Amara* (each with 11 species and 15.5% of the species in rape fields), *Carabus* (8 species, 11%), and *Ophonus* (6 species, 8%). Same genera were most highly represented in the pastures but in different ratios: *Harpalus* (11 species, 23% of the species in pastures), *Carabus* (5 species, 11%), and *Amara* and *Ophonus* (each with 4 species). Similar to our results, the genera *Harpalus* and *Amara* were shown to be the most species rich in rape and wheat fields in NW Croatia (Gotlin Čuljak et al., 2016), and in the STACCATO oilseed rape fields in Germany, Bulgaria and Switzerland (Teofilova, 2020a). *Ophonus* spp. are typical open habitat dwellers, which, however, is not the case with *Carabus* spp.

The most abundant genera in the oilseed rape fields were: *Brachinus* (3,105 ind., 41% of the individuals in rape fields), *Poecilus* (1,765 ind., 23%), *Anchomenus* (875 ind., 11%), *Harpalus* (779 ind., 10%), and *Amara* (493 ind., 6.5%). In the pastures, such genera were: *Harpalus* (148 ind., 26% of the individuals in pastures), *Pterostichus* (105 ind., 18%, mostly *Pt. hungaricus*), *Calathus* (74 ind., 13%, all of them *C. fuscipes*), *Cylindera* (64 ind., 11%, all of them *C. germanica*), *Amara* (44 ind., 8%), and *Carabus* (40 ind., 7%).

The most abundant species in the rape fields were: *Poecilus cupreus* (1,760 ind., 23% of all individuals in rape fields), *Brachinus explodens* (1,500 ind., 20%), *Brachinus elegans* (1,206 ind., 16%), and *Anchomenus dorsalis* (875 ind., 11%). The species with highest representation in the grasslands were *Pterostichus hungaricus* (101 ind., 18% of the individuals in pastures), *Calathus fuscipes* (74 ind., 13%), *Harpalus caspius* (67 ind., 12%), and *Cylindera germanica* (64 ind., 11%). All these species fall into the eudominant category of the dominance structure. Very impressive is the high abundance of *Brachinus elegans*, found in almost all rape fields, but not in the grasslands. Similarly, the total abundance of *Pterostichus hungaricus* seems unusual, as it was amongst the dominant species in the grasslands. Both species are not very common in agrocoenoses (e.g. Tălmaciu and Tălmaciu, 2005, 2009; Prelipcean et al., 2014; Sivčev et al., 2018). During the STACCATO research in Bulgaria, *Brachinus elegans* was also found only in rapeseed fields, but not in such numbers – it was in the subrecedent category (Teofilova, 2021). Relatively high was also the abundance of *C. coriaceus* and *C. violaceus* (both quite eurytopic and common in Romania) in some sites, but still, their numbers were not very high, similarly to the observations of Varvara (2009) in Moldavia.

The dominance structures of the rape field and pasture carabid complexes are presented at Table 3. The dominant component of the rapeseed fields' coenose consisted of 7 species, representing 88% of the total number of specimens in R-sites. The dominant component of the grasslands' coenose consisted of 8 species, representing 74% of the total number of specimens in G-sites. The four eudominants in rape fields had 70% of all specimens, and in the pastures eudominants had 54% of the specimens. The dominance structure of the ground beetles found in pastures was similar to that in the rapeseed fields, also consisting of 4 eudominants, although of different species. *Harpalus rufipes* was dominant both in pastures and fields.

Table 3. Dominance structure of the ground beetles found in Romanian rapeseed agrocoenoses and adjacent pastures

Category of dominance	Oilseed rape fields		Pastures	
	Species	No	Species	No
Eudominant > 10%	*Anchomenus dorsalis, Brachinus elegans, Br. explodens, Poecilus cupreus*	4	*Calathus fuscipes, Cylindera germanica, Harpalus caspius, Pterostichus hungaricu*	4
Dominant 5–10%	*Brachinus crepitans, Harpalus rufipes*	2	*Amara aenea, Harpalus rufipes*	2
Subdominant 3–5%	*Amara similata*	1	*Carabus coriaceus, Ophonus azureus*	2
Recedent 1–3%	*Amara ovata, Calathus fuscipes, Cylindera germanica*	3	*Anchomenus dorsalis, Brachinus crepitans, Carabus violaceus, Chlaenius decipiens, Harpalus griseus, H. hospes, H. rubripes, H. subcylindricus, Microlestes maurus, M. minutulus*	10
Subrecedent	All the rest	61	All the rest	29

Similar to our results, *Brachinus crepitans* was superdominant with more than 50% of all carabid specimens collected in oilseed rape fields in Giurgiu County (Fiera et al., 2013). *Brachinus crepitans* and *Poecilus cupreus* were dominant in rapeseed crops in Neamț County (Buburuz and Trotuș, 2014). *Amara similata, Brachinus explodens, Poecilus cupreus*, and *Anchomenus dorsalis* were among the ten most common species, representing 91% of the total number of individuals in oilseed rape in N Serbia (Sivčev et al., 2018). *Harpalus rufipes* and *P. cupreus* were eudominants in rye crop in Suceava County (Prelipcean et al., 2014), and dominants in agrocoenoses in steppe zone of Ukraine (Sumarokov, 2004). Research in wheat and potato crops in different parts of Romania showed that *P. cupreus* was eudominant in 72% of the studied wheat fields and in 42% of potato fields (Varvara and Šustek, 2011). Drmić et al. (2016) studied the endogaeic ground beetle fauna in oilseed rape field in Croatia and the most abundant species there were *Brachinus psophia* and *Anchomenus dorsalis*. These species were classified as eudominant, and had the highest frequency and only they were classified as constant species (species frequency 50–75%); *Brachinus explodens* was dominant; subdominant species were *Brachinus crepitans*, *Clivina fossor*, *Stenolophus teutonus*. Nine ground beetle species (including *Amara aenea*, *A. familiaris*, *Pterostichus melanarius, Agonum muelleri*) represented 80% of all carabids in heterogenous, but heavily grazed pastures; *Amara aenea* was eudominant with 43% of the total numbers (Byers et al., 2000). High values of the concentration of domination are characteristic to more disturbed ecosystems. In our case, these values are lower in grasslands, indicating more moderate environmental conditions there.

Eighteen species (25%) from the rapeseed fields and 16 species (34%) from the pastures were represented by a single specimen. This large percentage does not seem unusual, as it was also established in other studies (Coddington et al., 2009; Ferro et al., 2012; Teofilova, 2013). The results obtained during the STACCATO research in Bulgaria (Teofilova, 2021) showed that these rare species were 29% and 20% of all species, respectively, in rapeseed fields and pastures. Explanations of the presence of species represented by single specimen may be different – an insufficient number of samples or inappropriate collecting methods, as well as peculiarities in phenology or actual rarity of the species concerned (Novotný and Basset, 2000; Coddington et al., 2009). Many species were found rare (<0.1%) in agrocoenoses in Ukraine (Sumarokov, 2004), and some of them were rare in this study too: *Acupalpus interstitialis, A. meridianus, Amara chaudoiri, A. familiaris, Carabus convexus, Cicindela campestris, Poecilus versicolor, Pterostichus macer.*

In the rapeseed fields, *Calathus fuscipes* and *Harpalus rufipes* were constant species found in all sampling sites. In the grasslands, such euconstant species were missing. *Harpalus rufipes* was found euconstant (with 100% occurrence) in a rye crop, too (Prelipcean et al., 2014); in the same study, *Poecilus cupreus* had occurrence of 88%.

Brachinus crepitans, Br. elegans, Br. explodens, Amara aenea, A. similata, A. ovata, Anchomenus dorsalis, Carabus coriaceus, Harpalus calceatus, H. rufipes, and *Poecilus cupreu*s were collected in the rapeseed fields during all three sampling stages. In grasslands, *A. aenea, Calathus fuscipes, Carabus coriaceus, Harpalus caspius, H. rufipes,* and *Pterostichus hungaricus* appeared in all collecting periods.

Captured during the rapeseed flowering stage beetles belonged to 34 species (Table 2), representing 48% of all species found in the rape fields. The most diverse were genera *Amara* and *Harpalus* (with 8 species each). Genera *Carabus* and *Brachinus* had 3 species each. In this stage, there were no constant species occurring in all sampling sites. The share of the carabids from the flowering stage was 45% of all species found in the rape fields, during the STACCATO research in Bulgaria (Teofilova, 2021).

During the ripening stage of the rape, 60 species and 24 genera were found (Table 2), representing 84% of all species found in the rape fields. The most diverse were the genera *Harpalus* (10 species), *Amara* and *Carabus* (8 species each). *Harpalus rufipes* was the only constant species occurring in all sampling sites. *Poecilus cupreus* was not found only in sampling sites R08 and R09. Thirty-three species appeared during the ripening (they were absent during flowering), and 7 species disappeared (they were present during flowering).

Twenty-six species were present both during flowering and ripening. The share of the carabids from the ripening stage was 76% of all species found in the rape fields during the STACCATO research project in Bulgaria (Teofilova, 2021).

Captured in the harvested rapeseed fields beetles belonged to 31 species and 13 genera (Table 2), representing 44% of all species found in the rape fields. The most diverse was genus *Amara* (6 species), followed by the genera *Harpalus* and *Pterostichus* (4 species each). *Harpalus rufipes* again was the only constant species occurring in all sampling sites, except R09 and R10, where all traps were destroyed. Four species appeared after the harvest (they were absent during the flowering and ripening of the rape): *Amara saphyrea, Calathus ambiguus, Notiophilus germinyi, Ophonus rufibarbis*; 33 species disappeared (they were present during flowering or ripening). The share of the carabids from this stage was 60% of all species found in the rape fields, during the STACCATO research in Bulgaria (Teofilova, 2021).

Only 14 species (20%) were present in all stages: *Amara aenea, A. ovata, A. similata, Anchomenus dorsalis, Brachinus crepitans, Br. elegans, Br. explodens, Carabus coriaceus rugifer, Harpalus distinguendus, H. calceatus, H. rufipes, Poecilus cupreus, Pterostichus hungaricus,* and *Pt. melas*. During the STACCATO research project in Bulgaria, 29 species (27%) were present in all stages (Teofilova, 2021). Seven species were established only during the initial (flowering) stage: *Acupalpus meridianus, Amara familiaris, A. chaudoiri, Badister sodalis, Clivina fossor, Harpalus rubripes,* and *Microlestes apterus.*

The highest species richness and carabid abundance in rapeseed fields were found during the second sampling (Table 2), corresponding with the ripening of the rapeseed. For comparison, the results obtained during the STACCATO research initiative in Bulgaria followed the same pattern (Teofilova, 2021). Maximum activity of Carabidae has also been established in June and at the beginning of July in rye crop in Suceava County (Prelipcean et al., 2014).

From the pastures adjacent to the rape fields, in all three sampling periods we collected ground beetles belonging to 47 species and 20 genera (Table 2). The most diverse was genus *Harpalus* (11 species), followed by the genera *Carabus* and *Ophonus* (5 species each), and *Amara* (4 species). Only 8 species (17%) were present in all stages: *Amara aenea, Brachinus crepitans, Calathus fuscipes, Carabus coriaceus rugifer, C. violaceus, Harpalus caspius, H. rufipes,* and *Pterostichus hungaricus.*

According to the taxonomic structure and species abundance in the sampling sites, the similarity dendrogram showed that, although the studied grasslands were resembling each other in appearance, their similarity was not very high (under 50%) (Fig. 2), same as in Bulgarian STACCATO plots (Teofilova, 2021). However, quite different was the case with the rapeseed fields. Here we found a high similarity between sites R01 and R05, R04 and R06, and R07 and R08. Sampling site R02 significantly distinguished from the other R-sites and separated from them on a low level of similarity. This was the plot where both the greatest abundance and number of species were found (Table 4).

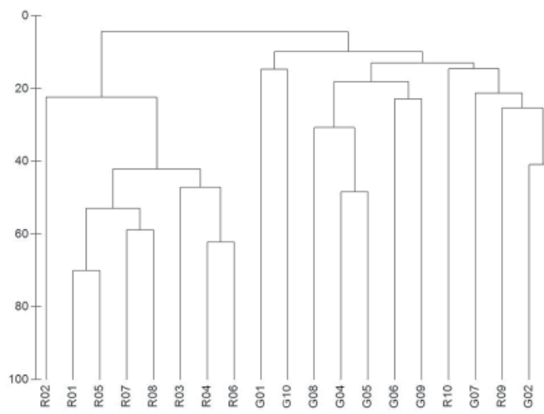

Fig. 2. Resemblance dendrogram, representing Bray Curtis similarity between the studied STACCATO sampling sites in Romania.

Table 4. Species richness in both studied habitat types during the three sampling periods. N – Number of specimens; S – Number of species; D_{Mn} – Menhinick's species richness index; D_{Mg} – Margalef's index

	Oilseed rape fields										
	R01	R02	R03	R04	R05	R06	R07	R08	R09	R10	*R-complex*
N	678	3,074	490	557	498	349	1,124	734	59	13	*7,576*
N (%)	8.9	40.6	6.5	7.3	6.6	4.6	14.8	9.7	0.8	0.2	*93% of all*
S	23	32	25	28	20	22	28	23	17	5	*71*
S (%)	32.4	45.1	35.2	39.4	28.2	31.0	39.4	32.4	23.9	7.0	*87% of all*
D_{Mn}	0.88	0.58	1.13	1.19	0.90	1.18	0.83	0.85	2.21	1.39	*0.82*
D_{Mg}	3.37	3.86	3.87	4.27	3.06	3.57	3.84	3.33	3.92	1.56	*7.95*
	Grasslands										
	G01	G02	G03	G04	G05	G06	G07	G08	G09	G10	*G-complex*
N	36	128	77	88	40	23	116	50	12	5	*575*
N (%)	6.3	22.3	13.4	15.3	6.9	4.0	20.2	8.7	2.1	0.9	*7% of all*
S	14	10	13	20	9	8	16	11	6	5	*47*
S (%)	29.8	21.3	27.7	42.5	19.1	17.0	34.0	23.4	12.8	10.6	*57% of all*
D_{Mn}	2.33	0.88	1.48	2.13	1.42	1.67	1.49	1.56	1.73	2.24	*1.96*
D_{Mg}	3.63	1.85	2.76	4.24	2.17	2.23	3.16	2.56	2.01	2.49	*7.24*

In contrast to the studied STACCATO plots in Bulgaria (Teofilova, 2021), Romanian sites definitely grouped according to their habitat type. The only exceptions were sites R09 and R10, which fell into the grasslands' cluster. This was probably due to the fact that all traps there were destroyed during the first and third period of collection, and thus the data obtained was scarcer in relation both to species composition and abundance, getting closer to those in pastures.

Species richness of the carabid communities calculated with Margalef's species richness index and Menhinick's index showed that, regardless of the lower number of species and lower abundance, the semi-natural grasslands were in fact quite ecologically diverse (Table 4, Fig. 3). This was probably resulting from the greater numbers of dominant species and the increased concentration of domination in agrocoenoses in general. Similar results were found during the STACCATO research in Bulgaria (Teofilova, 2021), where the soil pH and humus content were pointed as determining factors. In the current study, unfortunately, those parameters were not examined.

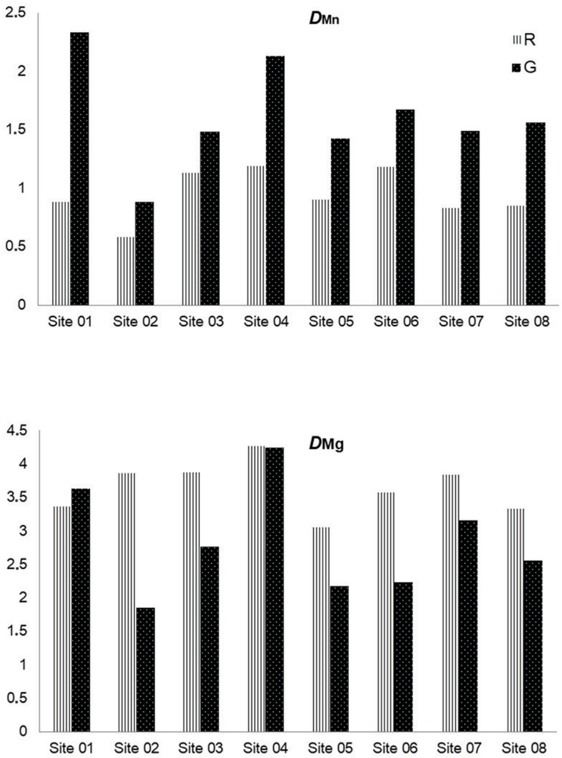

Fig. 3. Species richness in studied plots (R – rapeseed field, G – grassland); D_{Mn} – Menhinick's species richness index; D_{Mg} – Margalef's index.

It is known that cultivated land contains a typical ground beetle fauna, despite the regular implementation of cultivation measures (Kromp, 1999), but carabid community in arable land coenoses can be characterized as having low diversity and equitability, dominated by very ecologically plastic and eurytopic, nonspecific species of open habitats. We also found a lower species richness (D_{Mn}) in the oilseed rape fields than in the pastures. On the other hand, oilseed rape creates cooler and more shaded conditions and consequently attracts or deters some species (Holland and Oakley, 2007). Ground beetles prefer crop-shaded ground due to microclimatic differences caused by presence and density of crop cover (Honěk and Jarošík, 2000), which corresponds with the greater number of species and specimens found in rape fields. This probably explains the higher values of D_{Mg} in rapeseed plots, since this parameter is relating to more species-poor coenoses. Furthermore, the rape seeds attract the granivorous species and the presence of these seeds on the ground surface may influence the spreading of the beetles in the field (Honěk and Jarošík, 2000). This accounts for the greatest number of species and carabid abundance found during the second sampling (rapeseed ripening), which was also established during the STACCATO research in Bulgaria (Teofilova, 2021). It has also been found that large, medium-sized, herbivorous and Collembola feeding carabids all have considerable activity in oilseed rape, and among other crops, oilseed rape was proved to keep the greatest species richness of ground beetles (Eyre et al., 2013), and the presence of aphids was associated with the abundance of aphid predators, such as *Bembidion lampros* and *Trechus quadristriatus* (Honěk and Jarošík, 2000).

In natural ecosystems, the absolute numbers of ground beetles are usually lower than in anthropogenic, but their species diversity is significantly greater. Their distribution is uneven, with areas of high concentration and significant numbers of different species formed under favourable conditions (Kryzhanovskij, 1983). Poor species richness seems normal for actively grazed pastures, where soil structure might be deteriorated from the intense trampling and grazing by the animals (e.g. Aleksandrowicz and Bagińska, 2009; Teofilova and Kodzhabashev, 2020). Other important factors are the plant species diversity (Byers et al., 2000), and dry matter density (Toupet et al., 2020).

Conclusions

Due to various predetermined factors the oilseed rape seems to attract both grani- and herbivorous (*Amara* spp., *Dixus* spp., *Harpalus* spp.), and carnivorous species (*Anchomenus dorsalis, Calosoma auropunctatum, Carabus* spp., *Chlaenius* spp., *Poecilus* spp., *Pterostichus* spp.), in some cases with extremely high abundance. The pastures carabids on the other hand, are, by far, less numerous. At the same time, it seems that the catastrophic effect in agrolandscapes, according to their species richness, was more acute than initially evidenced by the greater number of species found in the rape fields.

The fact, that even mixophagous carabids are at least partly carnivores, together with the large number of ground beetle species recorded in the rape fields within this research, indicate carabids' great potential in reduction of pests. Their use in biological control could improve ecosystem conservation and sustainable development.

Further studies including analysis of different environmental factors as temperature and humidity of soil and air, precipitation, etc., or exploring the effect of insecticides and management practices on carabid assemblages, both in agroecosystems and grasslands, would provide valuable information about the connections and coexistence of ground beetles under different environmental conditions.

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Appendix
Species list, abundance and degree of dominance (D) of the ground beetles found in oilseed rape fields and grasslands

Species list	R (oilseed rape fields)												G (grasslands)											
	01	02	03	04	05	06	07	08	09	10	Total	*D%*	01	02	03	04	05	06	07	08	09	10	Total	*D%*
Abax (Abax) carinatus (Duftschmid, 1812)																1							1	*0.17*
Abax (Abax) parallelus (Duftschmid, 1812)													1										1	*0.17*
Acupalpus (s.str.) *meridianus* (Linnaeus, 1760)			1				1				2	*0.03*												
A. (Ancylostria) interstitialis Reitter, 1884		1	1	1		1	8				12	*0.16*												
Agonum (Olisares) viridicupreum (Goeze, 1777)		3									3	*0.04*												
Amara (s.str.) *aenea* (De Geer, 1774)		3	6	1			6	3			19	*0.25*	1	5		10	1	12		4	3	1	37	*6.43*
A. (s.str.) *communis* (Panzer, 1797)	1		14		1			3			19	*0.25*												
A. (s.str.) *eurynota* (Panzer, 1796)			3			1					4	*0.05*												
A. (s.str.) *familiaris* (Duftschmid, 1812)		4	1								5	*0.07*				1								
A. (s.str.) *lucida* (Duftschmid, 1812)		1	1								2	*0.03*			2			1					1	*0.17*
A. (s.str.) *ovata* (Fabricius, 1792)	13	8	69	1	1	2	24	8			126	*1.66*	2			2							4	*0.70*
A. (s.str.) *saphyrea* Dejean, 1828			1								1	*0.01*			1									
A. (s.str.) *similata* (Gyllenhal, 1810)	8	16	56	17	7	5	90	111			310	*4.09*	2										2	*0.35*
A. (Curtonotus) aulica (Panzer, 1796)									4		4	*0.05*												
A. (Percosia) equestris (Duftschmid, 1812)	1								1		2	*0.03*												
A. (Zezea) chaudoiri Schaum,1858	1										1	*0.01*												
Anchomenus (s.str.) *dorsalis* (Pontoppidan, 1763)	84	45	39	155	153	127	130	142			875	*11.5*	12									1	13	*2.26*
Anisodactylus (Pseudanisodactylus) signatus (Panzer, 1796)		17									17	*0.22*										3		
Badister (Badister) *bullatus* (Schrank, 1798)	1										1	*0.01*												
Badister (Trimorphus) sodalis (Duftschmid, 1812)							1				1	*0.01*												
Bembidion (Metallina) lampros (Herbst, 1784)			1							3	4	*0.05*												
B. (Metallina) properans (Stephens, 1828)														1									1	*0.17*
Brachinus (s.str.) *bodemeyeri* Apfelbeck, 1904					1						1	*0.01*												
Br. (s.str.) *crepitans* (Linnaeus, 1758)	26	251	1	61	21		9	29			398	*5.25*			6	1			3				10	*1.74*
Br. (s.str.) *elegans* Chaudoir, 1842	198	759	4	37	107		45	56			1,206	*15.9*												
Br. (Brachynidius) explodens Duftschmid, 1812	147	618	7	74	89	3	523	39			1,500	*19.8*			1								1	*0.17*
Calathus (s.str.) *fuscipes* Goeze, 1777	12	8	85	1	2	7	47	48	4	5	219	*2.89*	1	37	18	1			1	16			74	*12.9*
C. (Neocalathus) ambiguus (Paykull, 1790)							1				1	*0.01*												
C. (Neocalathus) melanocephalus (Linnaeus, 1758)						1			1		2	*0.03*												

Appendix. Continued.

Callistus lunatus (Fabricius, 1775)															1								1	*0.17*
Calosoma (Campatita) auropunctatum (Herbst, 1784)	1			9							10	*0.13*												
Carabus (Eucarabus) ulrichii Germar, 1824						1			1		2	*0.03*									2		2	*0.35*
C. (Megodontus) violaceus Linnaeus, 1758	4	3				2		4	23		36	*0.47*	1		6	2							9	*1.56*
C. (Morphocarabus) hampei Kuster, 1846								1			1	*0.01*												
C. (Pachystus) glabratus Paykull, 1790									1		1	*0.01*												
C. (Procrustes) coriaceus Linnaeus, 1758				1			14		4	1	20	*0.26*	2		10	1			10		1		24	*4.17*
C. (Tachypus) cancellatus Illiger, 1798	1	5	4			1					11	*0.14*			4								4	*0.70*
C. (Tomocarabus) convexus Fabricius, 1775	2	2									4	*0.05*												
C. (Trachycarabus) scabriusculus (G. Olivier, 1795)					1						1	*0.01*					1						1	*0.17*
Cicindela (s.str.) *campestris* Linnaeus, 1758								1			1	*0.01*					1						1	*0.17*
Chlaenius (Dinodes) decipiens (L. Dufour, 1820)				1	1	1	2		1		6	*0.08*				15				1			16	*2.78*
Clivina (Clivina) fossor (Linnaeus, 1758)		2	4								6	*0.08*												
Cylindera (Cylindera) germanica (Linnaeus, 1758)	4	3		9	4	2	4	60	1		87	*1.15*	6						57	1			64	*11.1*
Dolichus halensis (Schaller, 1783)	1	4		6	4						15	*0.20*		1		1							2	*0.35*
Dixus clypeatus (P. Rossi, 1790)																				2			2	*0.35*
Harpalus (s.str.) *affinis* (Schrank, 1781)	2	6	4		4	1		1			18	*0.24*										1	1	*0.17*
Harpalus (s.str.) *caspius* (Steven, 1806)	3			1	6	5		1	1		17	*0.22*	2		3	23	19	1	8	9	2		67	*11.6*
H. (s.str.) *distinguendus* (Duftschmid, 1812)	1	20	11	1	5		9	17			64	*0.84*	1										1	*0.17*
H. (s.str.) *flavicornis* Dejean, 1829				1							1	*0.01*				1	1	2					4	*0.70*
Harpalus (s.str.) *hospes* Sturm, 1818				2		1	3				6	*0.08*				4			2				6	*1.04*
Harpalus (s.str.) *politus* Dejean, 1829																1	1						2	*0.35*
Harpalus (s.str.) *rubripes* (Duftschmid, 1812)				1							1	*0.01*	1	1		6							8	*1.39*
H. (s.str.) *smaragdinus* (Duftschmid, 1812)																				3			3	*0.52*
Harpalus (s.str.) *subcylindricus* Dejean, 1829							3				3	*0.04*						2		7			9	*1.56*
H. (Pseudoophonus) calceatus (Duftschmid, 1812)				4							4	*0.05*												
H. (Pseudoophonus) griseus (Panzer, 1796)				16		1	4				21	*0.28*				1		1	7				9	*1.56*
H. (Pseudophonus) rufipes (De Geer, 1774)	99	59	41	39	75	25	139	160	1	2	640	*8.45*	1	16	3	9	5		3			1	38	*6.61*
H. (Semiophonus) signaticornis (Duftschmid, 1812)		1	1	1			1				4	*0.05*												
Laemostenus (Pristonychus) terricola (Herbst, 1784)			1								1	*0.01*												
Microlestes apterus Holdhaus, 1904							1				1	*0.01*							1				1	*0.17*
Microlestes maurus (Sturm, 1827)		2									2	*0.03*		1	2			3	7				13	*2.26*
Microlestes minutulus (Goeze, 1777)																			3		3		6	*1.04*

Appendix. Continued.

Nebria (s.str.) *brevicollis* (Fabricius, 1792)									4		4	*0.05*												
Notiophilus germinyi Fauvel, 1863							1				1	*0.01*							1				1	*0.17*
Ophonus (Hesperophonus) azureus (Fabricius, 1775)		2					1				3	*0.04*				3	10	1	1	3		1	19	*3.30*
O. (Hesperophonus) brevicollis (Serville, 1821)									1		1	*0.01*												
O. (Metophonus) laticollis Mannerheim, 1825																			1				1	*0.17*
O. (Metophonus) puncticeps Stephens, 1828														1									1	*0.17*
O. (Metophonus) puncticollis (Paykull, 1798)									2	2	4	*0.05*			1	1				2			4	*0.70*
O. (Metophonus) rufibarbis (Fabricius, 1792)		1									1	*0.01*												
Ophonus (s.str.) *ardosiacus* (Lutshnik, 1922)									1		1	*0.01*												
Ophonus (s.str.) *sabulicola* (Panzer, 1796)					1	2	2	3			8	*0.11*							1				1	*0.17*
Poecilus (s.str.) *cupreus* (Linnaeus, 1758)	64	1,213	131	111	14	158	48	21			1,760	*23.2*				1							1	*0.17*
Poecilus (s.str.) *koyi* Germar, 1823				2	1						3	*0.04*												
Poecilus (s.str.) *versicolor* (Sturm, 1824)				2							2	*0.03*												
Pterostichus (Adelosia) macer (Marsham, 1802)								3			3	*0.04*												
Pt. (Feronidius) hungaricus (Dejean, 1828)	3	1	3					18	8		33	*0.44*		64	19	4	1		10	2	1		101	*17.6*
Pt. (Feronidius) melas (Creutzer, 1799)	2	1					6				9	*0.12*												
Pt. (Petrophilus) melanarius (Illiger, 1798)		13									13	*0.17*												
Pt. (Phonias) ovoideus (Sturm, 1824)														1	3								4	*0.70*
Trechus (s.str.) *quadristriatus* (Schrank, 1781)		1		1		1	1	4			8	*0.11*												
Zabrus (s.str.) *tenebrioides* (Goeze, 1777)				1		1		1			3	*0.04*	3										3	*0.52*