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AN EFFECT OF STRIP-MANAGEMENT ON CARABID BEETLES (*COL., CARABIDAE*) IN SUGAR BEET CROP

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Abstracts: The attractiveness of uncultivated (weedy) and cultivated strips (planted with a mixture of flowering plants) and the adjacent sugar beet crop to *Carabidae* was studied in 1999–2000 at the Experimental Research Station near Wrocław, Poland. Obtained results showed that greater plant abundance and their diversity on weedy strips had a positive effect on the number of carabid beetles. Also more carabid species were identified in uncultivated strips than in strips of mixture of *Phacelia tanacetifolia*, *Coriandrum sativum* and *Sinapis alba*. The lowest number of species was trapped in sugar-beet crop and bare soil. The most numerous species in all treatments were *Pseudoophonus rufipes*, *Anchomenus dorsalis* (Pont.), *Poecilus cupres* and the species of the *Bembidion* genera.

Key words: carabid beetles, strip-management, sugar-beet crop, species diversity

INTRODUCTION

Carabids occur in a wide range of habitats and are important elements of agroecosystems. Most species are polyphagous and some economically important species prey on aphids (Thiele 1977; Edwards et al. 1979; Sunderland et al. 1980; Jaworska 1996). The structure of the agricultural landscape and with special regards to potential refuge areas such as forest margins, shrubs, field boundaries or roadsides have a very positive influence on the number of carabid beetles (Gravesen and Toft 1987; Desender and Alderweireldt 1988; Andersen 1997). These undisturbed places are important mainly as overwintering sites and/or sources of food (Sotherton 1985; Varchola and Dunn 2001). Vegetationally diverse agricultural areas show also higher diversity of carabid beetles than those without them (Hance et al. 1990; Lys and Nentwig 1994; Twardowski 2002). To enhance within-field predator density researchers divided large fields into 1.5–3 m wide strips of weeds and different herbaceous plants (Lys and Nentwig 1992; Thomas et al. 1992). Significantly higher carabid beetles activity was found in the strip-managed area than in the control one.

In Poland, in many regions the fields are small (0.1–1.0 ha). Field margins are very narrow and uncultivated, covered by grass species and broad leaf weeds. Hurej et al. (1998) suggested the extension of field margins to a width of at least 1 m and the growing of certain flowering plants as food plants for entomophagous species in low-input production systems. The same authors suggested the creation of strips of flowering plants within larger fields. Such strips attracted higher numbers of beneficial insects, like syrphids, bumblebees and bees than uncultivated weedy strips (Hurej et al. 1998; Hurej and Twardowski 1999; Twardowski and Hurej 1999).

The main object of our study was to compare the attractiveness of uncultivated (weedy) strips with cultivated strips (planted with a mixture of flowering plants), strips of the bare soil and the adjacent sugar beet crop to carabid beetles.

MATERIALS AND METHODS

The study was carried out in the Agricultural Experimental Station at Pawłowice near Wrocław, Poland in 1999–2000. The field was located in an intensively used agricultural landscape. The type of soil is luvisol developed from light loam on medium loam with good-formed A_1 horizon. A sugar beet field of 1 ha was divided by four 1 m wide strips each consisting of three parts. The first part was planted with a mixture of *Sinapis alba* L. (25%), *Phacelia tanacetifolia* Benth. (25%) and *Coriandrum sativum* L. (50%) (cultivated). The second one was herbicide treated (bare soil), and the third one was uncultivated and weedy (Fig. 1). The size of each plot was 432 m^2 and the distance between the strips was 12 m. Every year the new sugar-beet field was chosen and the new strips were set up.

Vegetation assessment

The number of plants and their species composition were calculated within 1 m^2 sample areas taken randomly on each strip of flowering plants as well as on weedy strips.

Assessment of carabid beetles number

Adult carabid beetles were sampled by using pitfall traps. Each trap consisted of a glass jar (90 mm diameter x 110 mm high). Traps were filled up to one third with 100% ethylene glycol as a preservative. Traps were protected from rainfall by plastic covers located 10 cm above the ground. There were four traps placed in each variant of the experiment, i.e. on cultivated strips (mixture of flowering plants), bare soil strips (in 2000 only), uncultivated strips (weedy) and sugar-beet plots (one trap in the middle of each part). They were emptied once a week, starting when plants emerged on cultivated strips until the end of flowering. In the laboratory, insects were kept without any preservation agents till identification. In 1999, independently from the authors, not all carabid beetles were identified.

Statistical analysis

The comparison of the numbers of carabid beetles caught in semi-natural strips and arable field was carried out using the analysis of variance (ANOVA) followed by Tukey's post-hoc RIR (HSD). The species richness of each habitat

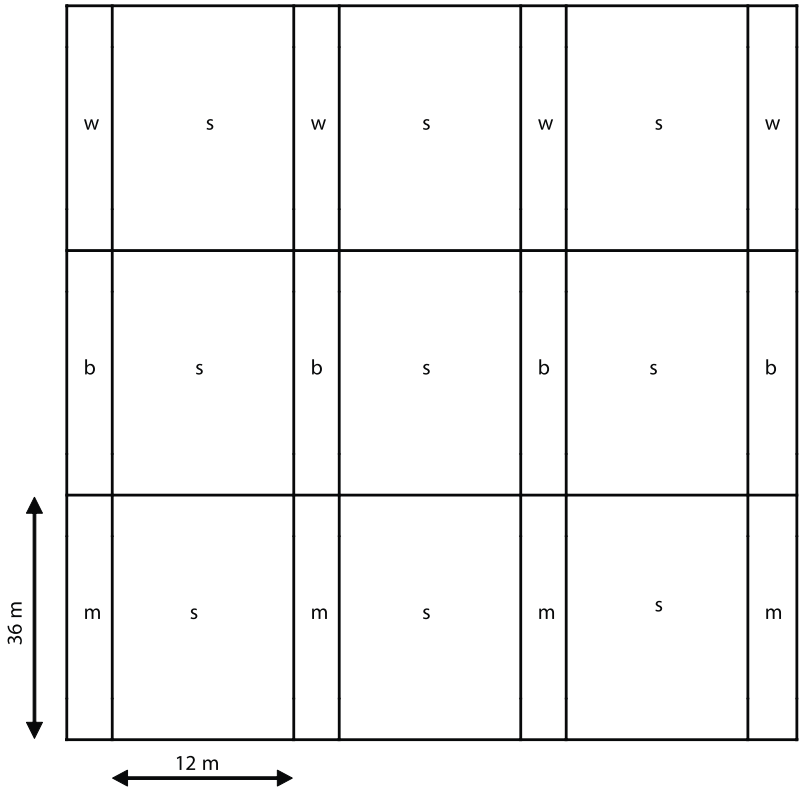

Fig. 1. Experimental design, Pawłowice 1999–2000

w – weedy strips
b – bare soil strips
m – mixture of flowering plants strips
s – sugar-beet crop (plots)

was estimated using a Shannon-Weaver index (H′) and its evenness (E′). H′ is an estimate of the diversity of the total population of individuals in the species pool, whereas E′ refers to the distribution of individuals among species in the pool (Magurran 1988). To confirm Shannon-Weaver values, the dominance index (D′) was also used. For statistical analysis MS Excel (2002) and Statistica 6.1 were chosen.

RESULTS

Vegetation structure on semi-natural strips

In 1999, 17 species of weeds were identified in uncultivated strips. The most numerous was *Thlaspi arvense* (Table 1). *Matricaria chamomilla* and *Chenopodium album* also showed higher numbers. The greatest number of weeds was recorded on July 10 (294.0 plants per m^2). In cultivated strips *Phacelia tanacetifolia* was the dominant species followed by *Coriandrum sativum* and *Sinapis alba.* A peak number of 192.2 plants per m^2 was observed on May 26 in these strips. In 2000, 27 species

of weeds in uncultivated strips were identified. The most numerous were *Thlaspi arvense*, *Chenopodium album* and *Amaranthus retroflexus*. *Matricaria chamomilla*, *Polygonum persicaria* and *Euphorbia helioscopia* also occurred in higher numbers. Weeds occurred in the greatest number at the end of May (395.0 plants per m^2). In cultivated strips, *Phacelia tanacetifolia* was again the dominant species. At the beginning of the growing season (May 12) a maximum of 150.3 plants per m^2 was found.

Table 1. Mean number of the most abundant plant species on each treatment per $1m^2$ throughout the season

Species	1999	2000
Mixture of flowering plants		
Sinapis alba L.	31.5	6.4
Phacelia tanacetifolia Benth	72.3	94.1
Coriandrum sativum L	40.8	7.0
Weeds		
Thlaspi arvense L.	29.4	15.2
Chenopodium album L.	9.7	11.8
Matricaria chamomilla L.	5.9	5.1
Veronica arvensis L.	2.4	–
Lamium amplexicaule L.	1.5	0.7
Viola arvensis Murr.	1.2	0.7
Amaranthus retroflexus L.	0.4	13.8
Polygonum persicaria L.	–	4.9
Euphorbia helioscopia L.	0.1	4.5
Total number of weedy species	17	27

Abundance of carabid beetles

In 1999, in uncultivated weedy strips, cultivated strips (mixture of flowering plants) and the sugar-beet crop a total number of 1351 carabid beetles were captured by pitfall traps from the beginning of June to mid July. The greatest numbers were noticed in weedy strips (Table 3). Carabids were less numerous in samples collected in cultivated strips and in sugar-beet crop. Traps were emptied seven times that year and in one case significantly more carabids were caught in weedy strips than in two other treatments (July 12) (Table 2). Once during the observation period more beetles were caught in weedy strips than in the cultivated one (June 2), and twice more in weedy strips than in sugar beet crop (June 28 and July 5). Nevertheless, through whole season carabids were more abundant on weedy strips, thus obvious tendency could be observed as to which treatment was preferred by this insects.

Table 2. Seasonal distribution of carabid beetles captured in pitfall traps in 1999–2000 (mean number ± SE)

Year 1999	2-June	7-June	14-June	21-June	28-June	5-July	12-July
Mixture	10.3±3.3 b	12.0±2.9 a	15.3±2.4 a	9.3±2.2 a	11.0±1.8 ab	16.0±2.4 ab	16.5±2.2 b
Weeds	30.5±5.2 a	28.8±3.4 a	21.3±5.7 a	12.3±0.5 a	12.3±1.3 a	27.3±3.8 a	27.8±4.4 a
Sugar beet	18.3±4.8 ab	27.0±5.8 a	18.5±4.4 a	8.0±1.4 a	4.3±0.3 b	10.8±3.7 b	10.8±2.1 b

Year 2000	12-May	18-May	25-May	1-June	8-June	15-June	21-June	29-June	6-July	13-July	20-July
Mixture	13.5±2.0 b	7.0±2.8 ab	7.5±1.8 b	10.8±1.1 ab	8.5±1.0 ab	9.0±4.3 b	4.3±1.1 b	10.3±1.5 ab	6.0±1.9 b	10.8±1.4 b	23.3±5.5 a
Weeds	34.3±6.8 a	15.8±4.2 a	22.5±3.6 a	15.8±6.4 ab	19.8±2.9 ab	25.0±5.7 a	19.3±2.8 a	14.3±2.8 ab	19.0±4.8 a	30.5±5.9 a	19.0±0.7 ab
Sugar beet	23.0±4.8 ab	4.5±1.0 b	7.5±2.5 b	17.5±4.4 ab	17.0±3.5 ab	8.5±1.9 b	5.8±2.6 ab	6.3±0.6 ab	3.0±0.7 b	8.0±1.2 b	6.8±1.5 b
Bare soil	9.0±0.8 b	11.0±2.2 ab	6.3±1.4 b	14.0±3.9 ab	12.8±1.9 ab	10.5±2.5 ab	7.0±1.4 ab	5.5±1.0 ab	7.5±1.5 b	6.0±0.8 b	6.5±1.3 b

Means within columns followed by different small letters differ significantly (Tukey HSD test, $p \leq 0.05$)

In the first catches at the beginning of June 1999, almost three times as many carabid beetles were recorded in weedy strips (30.5 per trap) than in cultivated ones (10.3) (Table 2). The highest number of beetles was recorded in the weedy strips at this time. Also in cultivated strips and sugar-beet crop, the greatest number of beetles was caught in the first half of June i.e. 15.3 and 27.0 insects per trap, respectively (Table 2). In the second half of June the number of caught beetles decreased in all studied combinations. In turn, in samples collected in the first half of July an increase in abundance was recorded.

In 2000, a total number of 2199 carabids were trapped. The greatest number was found, as in the previous year, in the weedy strips (938) followed by cultivated strips (453), sugar-beet crop (417) and bare soil (391) (Table 4). Traps were emptied 11 times that year. Significantly more beetles were trapped in the weedy strips in comparison to all other treatments on three occasions: May 25, July 6 and 13 (Table 2). In five other cases, there were significantly more beetles on weedy strips than at least on one other site. Almost through whole catching season *Carabidae* were significantly more abundant in weedy strips. Therefore, we assume that more diverse habitat has a strong pressure on density of analysed group of epigeal insects.

In 2000, in mid-May, beetles were numerous in all treatments (Table 2). In the second half of May and in June a decrease in catches was noted in uncultivated and cultivated strips. In these strips carabids occurred in greater number again in July. In the bare soil and sugar-beet treatments, after a small decrease in number of trapped beetles in the second half of May, an increasing numbers were observed in the first half of June. Later in the season a slow decrease in carabids catches was found in these treatments. The largest number of beetles was trapped in the uncultivated, cultivated and sugar-beet crop in the first catches 34.3, 13.5 and 23.0 insects per trap, respectively. Only in bare soil strips the peak of the catches was noted later i.e. at the beginning of June (14.0 beetles per trap, Table 2). The lowest number of *Carabidae* on bare soil as compared to all other treatments indicates that there is a link between its presence and vegetation cover.

Species richness

In 1999, altogether 34 carabid beetle species were identified, in weedy strips – 26 species, in strips of mixture of cultivated plants – 22 and in sugar-beet crop – 16 (Table 3). In the weedy strips six species (*Pseudoophonus rufipes, Bembidion quadrimaculatum, Anchomenus dorsalis, B. properans, B. femoratum*) were the most numerous, making-up from 10.0 to 19.2% of all identified carabids. In the cultivated strips *B. properans* was trapped in the greatest numbers, (31.1% of all catches) while in the sugar-beet crop *B. femoratum* was the dominant species (30.3%) followed by *B. quadrimaculatum* (20.8%) and *B. properans* (16.4%).

In 2000, 37 *Carabidae* species were identified (Table 4). In weedy strips 32 species were found, whereas in planted strips 22 and in strips of bare soil 19. The lowest number of species (16) was found in the sugar-beet crop. *Pseudoophonus rufipes* was the most numerous in weedy strips. This species made up 30.2% of all trapped carabids. *Poecilus cupreus* and *Bembidion lampros* were also numerous and represented 19.0 and 16.8% of all catches, respectively. In the planted strips *P. rufipes* was again the most numerous making up 31.9% of catches followed by

B. lampros (18.5%) and *Harpalus affinis* (12.2%). *B. lampros* was the most numerous in bare soil strips (30.7%) and in the sugar-beet crop (35.6%). *B. properans* was also trapped in great numbers in latter treatments. In bare soil strips it made up 17.9% and in sugar beet crop 18.6% of all carabids.

According to the Shannon-Weaver index, the highest carabid diversity in 1999 was found in the weedy strips (Table 3). The index value (H'= 2.36) on these strips was significantly higher in comparison to the other treatments (both, on cultivated strips and on sugar-beet plots H'=2.12). In the weedy strips only few species were abundant and many were trapped in a very small numbers. The dominance index also confirms this phenomenon.

In 2000, the same as in the past year, the highest carabid biodiversity was calculated in the weedy strips (H'=2.19) (Table 4). Extremely low diversity was found in the sugar-beet crop (H'=1.90).

Table 3. Carabid species collected in pitfall traps in 1999 in different sites within sugar beet field

Species	Weeds		Mixture		Sugar-beet	
	No.	% total capture	No.	% total capture	No.	% total capture
1	2	3	4	5	6	7
Bembidion properans (Steph.)	86	13.9	93	31.1	71	16.4
Bembidion quadrimaculatum (L.)	105	17.0	30	10.0	90	20.8
Bembidion femoratum (Sturm)	62	10.0	14	4.7	131	30.3
Pseudoophonus rufipes (De Geer)	119	19.2	44	14.8	39	9.0
Anchomenus dorsalis (Pont.)	97	15.7	33	11.0	21	4.9
Bembidion lampros (Herbst)	68	11.0	21	7.0	37	8.6
Harpalus affinis (Schrank)	10	1.6	15	5.0	9	2.1
Poecillus cupreus (L.)	8	1.3	12	4.0	6	1.4
Pterostichus melanarius (Ill.)	15	2.4	6	2.0	5	1.2
Trechus quadristriatus (Schrank)	10	1.6	6	2.0	10	2.3
Microlestes minutulus (Goeze)	8	1.3	4	1.3		
Amara similata (Gyll.)	2	0.3	8	2.7		
Anisodactylus binotatus (Fabr.)	5	0.8	1	0.3	2	0.5
Clivina fossor (L.)	3	0.5	1	0.3	4	0.9
Amara aenea (De Geer)	4	0.6	2	0.7	1	0.2
Badister sodalis (Duft.)	3	0.5			3	0.7
Harpalus cupreus (Fald.)			4	1.3	2	0.5
Amara aulica (Panz.)	3	0.5				
Demetrias atricapillus (L.)	2	0.3				
Pterostichus niger (Schaller)	2	0.3				
Amara fulva (O. F. Müll.)	1	0.2				
Asaphidion flavipes (L.)			1	0.3		
Broscus cephalotes (L.)	1	0.2				
Calathus erratus (Sahl.)	1	0.2				

1	2	3	4	5	6	7
Calathus fuscipes (Goeze)					1	0.2
Dolichus halensis (Schaller)			1	0.3		
Ophonus melleti (Heer)			1	0.3		
Harpalus latus (L.)	1	0.2				
Harpalus tardus (Panz.)	1	0.2				
Harpalus flavescens (Pill. Et Mitt.)	1	0.2				
Harpalus attenuatus Steph.			1	0.3		
Loricera pilicornis (Fabr.)			1	0.3		
Notiophilus aquaticus (L.)			1	0.3		
Stomis pumicatus (Panz.)	1	0.2				
Total number of carabid beetles	619	100.0	300	100.0	432	100.0
Total number of species	26		22		16	
Dominance Index (D)	0.682		0.590		0.632	
Shannon-Weaver Index H′	2.36		2.12		2.12	
E′	0.72		0.67		0.75	
Var H′	±0.001		±0.003		±0.002	
Total number of samples	28					

Table 4. Carabid species collected in pitfall traps in 2000 in different sites within sugar beet field

Species	Weeds		Mixture		Bare soil		Sugar-beet	
	No.	% total capture	No.	% total capture	No.	% total capture	No.	% total capture
1	2	3	4	5	6	7	8	9
Pseudoophonus rufipes (De Geer)	282	30.2	144	31.9	38	9.7	69	16.5
Poecilus cupreus (L.)	177	19.0	44	9.7	45	11.5	42	10
Bembidion lampros (Herbst)	157	16.8	84	18.5	120	30.7	149	35.6
Amara aenea (De Geer)	76	8.1	21	4.6	8	2		
Bembidion properans (Steph.)	76	8.1	45	9.9	70	17.9	77	18.6
Bembidion quadrimaculatum (L.)	23	2.5	5	1.1	27	6.9	24	5.7
Harpalus affinis (Schrank)	21	2.2	55	12.2	26	6.6	8	1.9
Anchomenus dorsalis (Pont.)	19	2.0	15	3.3	3	0.8		
Bembidion femoratum (Sturm)	18	1.9	3	0.6	23	5.9	18	4.5
Pterostichus melanarius (Ill.)	17	1.8	5	1.1	8	2	11	2.9
Clivina fossor (L.)	13	1.4			6	1.5	6	1.4
Calathus fuscipes (Goeze)	12	1.3	10	2.2	4	1	5	1.2
Pterostichus niger (Schaller)	7	0.7						
Calathus erratus (Sahl.)	6	0.6	3	0.6	2	0.5		
Notiophilus aquaticus (L.)	5	0.5			2	0.5		
Anisodactylus binotatus (Fabr.)	5	0.5	2	0.5	3	0.8	3	0.7

1	2	3	4	5	6	7	8	9
Harpalus cupreus (Fald.)	4	0.4	2	0.5	1	0.3	1	0.2
Calathus melanocephalus (L.)	3	0.3	1	0.2				
Amara similata (Gyll.)	2	0.2						
Carabus hortensis L.	2	0.2					1	0.2
Amara plebeja (Gyll.)	2	0.2						
Amara ovata (Fabr.)	1	0.1						
Broscus cephalotes (L.)	1	0.1	1	0.2				
Badister bullatus (Schrank).	1	0.1	1	0.2				
Badister sodalis (Duft.)	1	0.1	1	0.2	1	0.3	1	0.2
Trechus quadristriatus (Schrank)	1	0.1	2	0.5	1	0.3		
Amara aulica (Panz.)	1	0.1						
Carabus violaceus L.	1	0.1						
Carabus coriaceus L.	1	0.1						
Harpalus latus (L.)	1	0.1						
Pterostichus strenuus (Panz.)	1	0.1						
Loricera pilicornis (Fabr.)	1	0.1						
Amara fulva (O. F. Müll.)			6	1.3				
Harpalus distinguendus (Duft.)							1	0.2
Microlestes minutulus (Goeze)					3	0.8		
Pterostichus oblongopunctatus (Fabr.)			2	0.5				
Stomis pumicatus (Panz.)			1	0.2			1	0.2
Total number of carabid beetles	938	100.0	453	100.0	391	100.0	417	100.0
Total number of species	32		22		19		16	
Dominance Index (D)	0.608		0.612		0.628		0.574	
Shannon-Weaver Index H′	2.19		2.11		2.16		1.90	
E′	0.63		0.68		0.73		0.69	
Var H′	±0.002		±0.003		±0.003		±0.002	
Total number of samples	64							

DISCUSSION

One approach to enhance populations of endemic natural enemies, such as carabid beetles, is to modify the habitat to favour their immigration, tenure time and recruitment (Gross 1987). We propose to enhance the population of these insects within the sugar-beet crop by the leaving natural weedy strips at least 1 m wide. In our trials significantly more carabid beetles were trapped on these strips. Also the number of *Carabidae* species in weedy habitat was richer than in the remaining treatments. Probably, the greater number of plants and the higher diversity of vegetation in the weedy strips had a positive effect on carabid community. Similar results were obtained by Lys and Nentwig (1992; 1994) and Zangger et al. (1994). They found that strips of wild flowering herbs in a winter cereal

fields had a positive effect on species diversity and activity of carabid beetles. Therefore, this ecological structure may be considered as a hunting ground for most of the carabid species that utilized the sugar-beet field.

A mixture of flowering plants such as *Phacelia tanacetifolia*, *Sinapis alba* and *Coriandrum sativum* grown in strips in sugar-beet crop attracted more syrphids, bees and bumblebees than the weedy strips (Hurej et al. 1998). In the case of carabid beetles, more insects and their higher diversity was observed in weedy strips than in the cultivated ones. As it was explained earlier, probably the higher biodiversity in uncultivated strips caused an increasing of insect density. The lowest number of species in our study was trapped in sugar-beet crop and in bare soil. The most numerous species in all treatments were *Pseudoophonus rufipes*, *Anchomenus dorsalis*, *Poecilus cupres* and the species of the genus *Bembidion*.

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POLISH SUMMARY

WPŁYW PASÓW ROŚLIN NA BIEGACZOWATE (*COL., CARABIDAE*) NA PLANTACJI BURAKÓW CUKROWYCH

Badania przeprowadzono w Rolniczej Stacji Doświadczalnej w Pawłowicach koło Wrocławia w latach 1999–2000. Celem było porównanie atrakcyjności pasów naturalnie zachwaszczonych, pasów mieszanki kwitnących roślin, pasów ugoru oraz plantacji buraków cukrowych dla chrząszczy z rodziny biegaczowatych.

Uzyskane wyniki wskazują, że większa liczebność oraz różnorodność gatunkowa roślin porastających pasy naturalnie zachwaszczone istotnie zwiększała liczebność biegaczy oraz liczbę oznaczonych gatunków. Najniższą liczebność *Carabidae* notowano na pasach ugoru oraz na plantacji buraków. Najliczniejsze gatunki stwierdzone we wszystkich wariantach doświadczenia to *Pseudoophonus rufipes, Anchomenus dorsalis, Poecilus cupres* oraz gatunki z rodzaju *Bembidion*.