Baltic J. Coleopterol. 12(1) 2012
ISSN 1407 - 8619

Epigeic carabid beetles (Coleoptera: Carabidae) in strawberry plantations in northeastern Poland

Agnieszka Kosewska, Mariusz Nietupski, Bożena Kordan, Krzysztof Mech

Kosewska A., Nietupski M., Kordan B., Mech K. 2012. Epigeic carabid beetles (Coleoptera: Carabidae) in strawberry plantations in northeastern Poland. *Baltic J. Coleopterol., 12(1): 77 – 90.*

The aim of this research was to determine the species composition and structure of ground beetle (Coleoptera: Carabidae) assemblages found in strawberry plantations grown for a different number of years. The study was carried out on a farm near Bartoszyce, in northeastern Poland. It covered 4 plantations of cv. Senga Sengana strawberries. The youngest plantation was set up in September 2007, and each preceding plantation was a year older, so the oldest one was set up in 2004. The investigations on carabid beetles inhabiting these fields lasted from May to the end of October 2008. Beetles were collected by modified Barber traps. Samples were taken in bi-weekly intervals. In total, 5,682 individuals of the family Carabidae, representing 60 species, were caught. The most numerous ones were *Harpalus rufipes* (26.8%), *Calathus fuscipes* (23.7%), and *Nebria brevicollis* (17.5%). The dominant species belonged to the autumn-type of development, open-area, and eurytopic beetles. The results showed that the strawberry plantations differed from each other in the composition of Carabidae depending on their surroundings and age.

Key words: Ground beetles, natural enemy, predators, strawberry fields, surroundings

Agnieszka Kosewska, Mariusz Nietupski, Bożena Kordan. University of Warmia and Mazury, Department of Phytopatology and Entomology, Prawocheńskiego 17, 10-719 Olsztyn, Poland

Krzysztof Mech. Main Inspectorate of Plant Health and Seed Inspection, Regional Inspectorate in Olsztyn, Border Inspection Post in Bezledy, 12-222 Bezledy, Poland

INTRODUCTION

The research on ground beetles (Carabidae) dwelling on arable fields in Europe covers a wide range of questions. The effect of particular crops, type of soil, adjacent plantations, agronomic treatments, plant protection chemicals, crop systems, etc., on Carabidae assemblages has been investigated for a long time (Tischler 1955, Kabacik-Wasylik 1970, Górny 1971, Basedow *et al*. 1976, Thiele 1977, Aleksandrowicz 1979, Scheu 2001, Holland 2002, Kosewska *et al*. 2009, Kotze *et al*. 2011). However, less attention has been paid to carabids inhabiting strawberry plantations (Luff 1980, Huruk 2002a, Huruk 2002b, Luik *et al*. 2000, Tuovinen *et al*. 2006). This may be due to the fact that strawberry plantations cover only a small percentage of the total cropped area. However, in strawberry-growing regions they are the dominant crop and turn into the major source of income for plantation owners (Cross *et al*. 2001, Huruk 2002b).

Strawberries are an important plantation crop in temperate areas, which unfortunately can be plagued by aphids, mites, root weevils and slugs (Lee and Edwards 2011). It is normal commercial practice to use plant protection chemicals to control pests and diseases, which would otherwise cause serious economic loss. However, application of broad-spectrum insecticides, even when occasional, affects both pests and beneficial arthropods in strawberry crops (Easterbrook 1997, Cross *et al.* 2001). Most ground beetles can be classified as predatory polyphagous insects, thus natural enemies of many pests and weeds which are a threat to strawberry plantations (Kromp 1989, Moorhouse *et al*. 1992, South 1992, Bohan *et al*. 2000, Cowles 2003).

The objective of the present research has been to determine the species composition and to examine the structure of carabid communities (Coleoptera: Carabidae) occurring in northeastern Poland, in strawberry plantations grown for a different number of years. An attempt has also been made to evaluate the influence of immediate surroundings of the strawberry fields on carabid beetles.

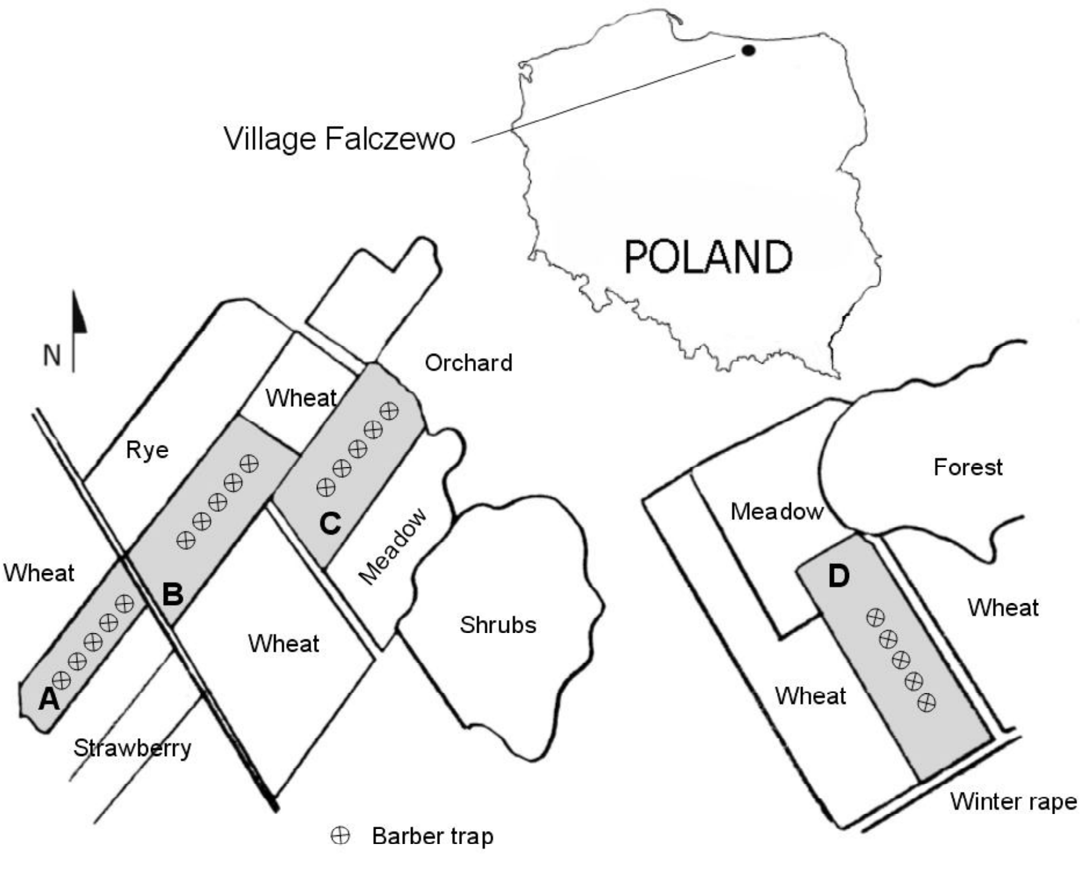

Fig. 1. Map of strawberry fields (A, B, C, D) and their environs

MATERIAL AND METHODS

Study area

The study was carried out in 2008, on strawberry plantations in the village of Falczewo in northeastern Poland (Fig. 1). The examinations covered four fields on which the same strawberry cultivar (cv. Senga Sengana) was grown for a different number of years. The youngest plantation was started in September 2007, and each preceding plantation was a year older, so the oldest one was set up four years prior to the study. The first site (A) was a field of strawberries planted a year before the study. To the southwest, it bordered with a four-meter wide belt of trees and shrubs as well as some single houses. To the south, it lay next to a plantation of strawberries of the same cultivar, but grown for seven years. The fields to the northeast were covered by another, two-year-old strawberry plantation or cropped with rye, while a field to the north was seeded with wheat. Site A covered 0.5 ha. The second site (B) consisted of a two-year-old strawberry plantation. It bordered with site A to the southwest and – partly – site C to the east. Apart from that, site B was surrounded by cereal fields and covered 0.85 ha. The strawberry plantation which made up the third site (C) neighboured to the east with an orchard and a meadow, both used extensively. To the west, the plantation bordered with a wheat field and – for a short distance – with the second site. Site C had a size of 0.9 ha. The soil of sites A, B, and C was classified as strong fodder cereal complex with light and medium-weight loam soils (class IIIb). The fourth site (D) was located near a forest. To the north, it bordered with a peat meadow and, to the south, with a field of oilseed rape. The other two sides ran along wheat fields. Site D covered 1.1 ha. The soil of this strawberry plantation belonged to good wheat complex. Like the soil of the other sites it consisted of light and medium-weight loam. All analyzed fields underwent the same agronomic treatments, except for the one-year-old plantation of strawberries, which was additionally weeded by mechanical tools.

Carabid sampling

Our study on the carabid beetles of the above strawberry plantations ran from May 5th, 2008, to October 20th, 2008. The beetles were captured by modified Barber traps filled up to 1/3 of their capacity with ethylene glycol solution with a few drops of detergent, which was added to decrease the surface tension. Plastic containers, 500 ml in capacity, 130 mm high and 90 mm in diameter, were used as traps. The traps were dug into the ground so that the upper edge was level with the soil surface. A canopy was placed above each trap to mask it as well as to prevent dilution and spill of the liquid due to rainfall. Five traps were placed on each plantation, at a distance of 10 meters from one another, along a middle row of strawberry plants. The traps were emptied every two weeks.

Data analysis

The collected material was identified to the species according to the key provided by Watała (1995) and Hůrka (1996), using the nomenclature of Aleksandrowicz (2004). Besides species composition and catchability (number of individuals caught in one trap per day), the Carabidae were analyzed with respect to their number of individuals and dominance structure. The following dominance classes were adapted: eudominants (>10% of the individuals in an assemblage), dominants (5.1-10%), subdominants (2.1-5%), recedents (1.1-2%), and subrecendents (<1%) (Górny and Grüm 1981). The carabid species were characterized in terms of their ecology, including foraging, habitat and moisture requirements, as well as the type of development. In order to elaborate the ecological characteristics of the Carabidae, we referred to the following papers: Larsson (1939), Sharova (1974), Thiele (1977) Lindroth (1985, 1986), and Aleksandrowicz (2004). For processing the results we used the Shannon-Weaver index of species diversity (H'), Pielou's evenness index (J'), and Simpson's index of species richness (D). Similarities between carabid assemblages from the analyzed strawberry fields were illustrated by a dendrogram based on Bray-Curtis' values. Differences between the means were assessed by a one-factor analysis-of-variance (ANOVA) test. In addition, Duncan's test, which combines means of similar values into ordered homogenous groups, was applied. The relations between the sites are demonstrated by a dendrogram calculated by a cluster analysis. Ordination methods were applied to visualize the data. The main directions of dissimilarities between the ecological groups of Carabidae were illustrated by principal component analysis (PCA). Connections between the Carabidae species and habitat-related conditions (age of a plantation, neighborhood: forest, shrubs, meadows, cereals, other strawberry fields) (Fig. 1) were assessed by redundancy analysis (RDA). The RDA method was chosen following an analysis of the data distribution, which proved to be linear. Statistical significance of canonical axes was determined according to the Monte-Carlo test. All statistical calculations and their graphic interpretation were performed with the software packages Statistica 9.0 PL and Canoco 4.5 (Ter Braak and Smilauer 1998).

RESULTS

In total, 5,682 specimens representing 60 species of the family Carabidae were captured from the study fields (Tab. 1). Statistically significant differences were observed in the average number of individuals, catchability, as well as the number of captured species between the analyzed fields (Tab. 2). An increasing trend in the average catchability and number of captured carabid specimens was observed in subsequent years of maintaining the plantations. The oldest, four-year-old strawberry field (D) was characterized by the highest number of caught specimens and species of carabid beetles (2,201 individuals belonging to 52 species). Comparison of the mean values of the indices of diversity, evenness, and species richness revealed significant differences between the individual fields (Tab. 2). The Shannon-Weaver species diversity index H' and, closely connected, the Pielou evenness index J' attained the highest scores for the most stabilized, four-year plantation. The Simpson species richness index D, also known as the dominance concentration index, which recognizes commonly present species but attributes less importance to rare ones, reached the highest values for the carabid community inhabiting the three-year plantation (C). This assemblage was also notable for large disparities in shares of particular dominance classes. The group of eudominants, which comprised 3 species, made up nearly 90% of all individuals in this assemblage (Tab. 3). On the other strawberry fields, the percentage of eudominant species was likewise very high and always exceeded 50%. The eudominant species which were present in all analyzed fields, were *Harpalus rufipes* and *Calathus fuscipes*.

Carabidae have extremely different feeding requirements. In our study, carabid beetles were divided into five trophic groups: large zoophages (over 12 mm in body length), medium zoophages (12-5 mm in body length), small zoophages (less than 5 mm in body length), hemizoophages, and phytophages. When analyzing the occurrence of Carabidae in the experimental fields, as classified according to the above trophic groups, in both quantitative and qualitative aspects, large proportions of hemizoophages and medium zoophages were found. The group of large zoophages dominated in just one, three-year-old strawberry plantation (C), owing to the presence of the beetle *Nebria brevicollis*, which on that field made up almost 50% of all captured beetles (Tab. 4). Ground beetles can be encountered in different habitats. In the analyzed material, four habitat groups were distinguished: forest, open-area, eurytopic, and peatbog species. Both quantitatively and qualitatively, the open- area species were evidently dominant. In respect of their moisture demands, the ground beetles caught on the analyzed strawberry plantations were similar (Tab. 4). Most of the assemblages consisted of mesophiles, highly tolerant to different moisture levels. Analysis of the presence of ground beetles representing two types of development (spring and autumn breeders) revealed that autumn breeders were much more numerous. However, in the qualitative context, the proportions of both types were similar.

Table 1. Species composition and abundance of Carabidae caught in strawberry plantations

Species / Abbreviation	Strawberry plantation			
	A	B	C	D
Agonum sexpunctatum (Linnaeus, 1758) / Ag_sex	-	-	-	1
Amara aenea (DeGeer, 1774) / A_aene	-	4	-	10
Amara apricaria (Paykull, 1790) / A_apr	-	1	1	-
Amara bifrons (Gyllenhal, 1810) / A_bifr	1	-	-	2
Amara communis (Panzer, 1797) / A_com	-	3	-	9
Amara convexior (Stephens, 1828) / A_conv	-	4	-	2
Amara equestris (Duftschmid, 1812) / A_equ	-	-	-	1
Amara eurynota (Panzer, 1797) / A_eur	-	-	-	1
Amara familiaris (Duftschmid, 1812) / A_fami	-	2	-	4
Amara fulva (DeGeer, 1774) / A_fulv	10	1	-	-
Amara majuscula (Chaudoir, 1850) / A_maj	1	-	1	-
Amara ovata (Fabricius, 1792) / A_ova	-	1	-	1
Amara plebeja (Gyllenhal, 1810) / A_pleb	2	-	-	23
Amara similata (Gyllenhal, 1810) / A_simi	2	2	-	3
Anchomenus dorsalis (Pontoppidan, 1763) / Anch_dor	7	9	3	1
Anisodactylus binotatus (Fabricius, 1787) / Ani_bin	-	1	-	3
Asaphidion flavipes (Linnaeus, 1761) / Asa_flavi	-	1	1	4
Bembidion guttula (Fabricius, 1792) / Be_gutt	-	-	-	2
Bembidion lampros (Herbst, 1784) / Be_lamp	10	52	8	360
Bembidion properans (Stephens, 1828) / Be_prop	5	29	8	123
Bembidion quadrimaculatum (Linnaeus, 1761) / Be_quadm	16	4	1	1
Broscus cephalotes (Linnaeus, 1758) / Br_ceph	-	-	-	6
Calathus ambiguus (Paykull, 1790) / Cal_ambi	27	11	4	5
Calathus cinctus (Motschulsky, 1850) / Cal_cin	-	-	-	1
Calathus erratus (Sahlberg, 1827) / Cal_erra	-	-	2	22
Calathus fuscipes (Goeze, 1777) / Cal_fusc	269	510	347	220
Calathus halensis (Schaller, 1783) / Cal_hal	1	-	-	3
Calathus melanocephalus (Linnaeus, 1758) / Cal_mela	-	-	1	2
Carabus cancellatus (Illiger, 1798) / Ca_canc	-	1	-	6
Clivina fossor (Linnaeus, 1758) / Cl_foss	1	1	-	-
Curtonotus aulicus (Panzer, 1797) / Cur_aul	-	1	-	1
Harpalus affinis (Schrank, 1781) / H_affi	74	45	15	31
Harpalus griseus (Duftschmid, 1812) / H_gri	15	4	5	40
Harpalus latus (Linnaeus, 1758) / H_lat	4	6	-	-
Harpalus luteicornis (Duftschmid, 1812) / H_lute	-	5	4	82
Harpalus quadripunctatus (Dejean, 1829) / H_quad	-	-	-	3
Harpalus rubripes (Duftschmid, 1812) / H_rub	-	1	1	1
Harpalus rufipes (DeGeer, 1774) / H_ruf	350	220	214	740
Harpalus signaticornis (Duftschmid, 1812) / H_sign	-	-	-	1
Harpalus tardus (Panzer, 1797) / H_tard	1	2	1	6
Harpalus xanthopus winkleri (Schauberger, 1923) / H_xan	-	1	-	6
Leistus ferrugineus (Linnaeus, 1758) / Lei_ferr	-	-	2	2
Loricera pilicornis (Fabricius, 1775) / Lo_pil	-	2	2	-
Microlestes maurus (Sturm, 1827) / Mic_maur	-	-	1	1
Nebria brevicollis (Fabricius, 1792) / Ne_brevi	82	189	596	127
Notiophilus palustris (Duftschmid, 1812) / N_pal	-	4	1	2
Olistopus rotundatus (Paykull, 1790) / Oli_rot	-	-	2	1
Oxypselaphus obscurus (Herbst, 1784) / Oxy_obs	-	-	-	1
Panagaeus bipustulatus (Fabricius, 1775) / Pan_bipu	-	-	-	1
Patrobus atrorufus (Strom, 1768) / Pat_atr	-	2	-	-
Platynus assimilis (Paykull, 1790) / Platyn_as	-	1	-	-
Poecilus cupreus (Linnaeus, 1758) / Po_cupr	9	9	5	131
Poecilus lepidus (Leske, 1785) / Po_lepi	1	3	-	81
Poecilus versicolor (Sturm, 1824) / Po_ver	-	1	-	33
Pterostichus melanarius (Illiger, 1798) / Pt_ mela	30	74	50	36
Pterostichus niger (Schaller, 1783) / Pt_ nig	-	7	1	31
Pterostichus oblongopunctatus (Fabricius, 1787) / Pt_ oblo	-	-	-	1
Pterostichus vernalis (Panzer, 1796) / Pt_ vern	-	-	-	8
Stomis pumicatus (Panzer, 1796) / Sto_pum	2	8	6	2
Trechus quadristriatus (Schrank, 1781) / Tre_qua	17	24	13	16
Number of individuals	937	1248	1296	2201
	5682			
Number of species	24	40	28	52
	60			

In order to demonstrate the differentiation of the above ecological groups within the analyzed habitats, PCA analysis was run, which showed the ecological types of ground beetles arranging distinctly along the age gradient of the strawberry plantations (Fig. 2). Cluster analysis showed that the oldest, four-year-old plantation was distinctly different from all other fields (Fig. 3). The assemblage of ground beetles which had colonized that field was in less than 50% similar to those living on younger plantations.

The diagram of redundancy analysis (RDA), illustrating changes in the analyzed fields caused by various factors, suggests that the major variables responsible for the variability among ground beetles are the age of a plantation and its most immediate surroundings (Fig. 4).

Table 2. Mean number of individuals and number of species, species richness, and indices describing Carabidae assemblages in strawberry plantations (mean/trap).

Indices	Strawberry plantation			
	A	B	C	D
Shannon H' (log Base 2.718)	1.78 ± 0.05 b	1.87± 0.10 b	1.45 ± 0.05 a	2.29± 0.07 c
	F=24.86; p<0.01			
Pielou J'	0.65 ± 0.02 b	0.63 ± 0.01 b	0.55 ± 0.03 a	0.68± 0.02 b
	F=7.44; p<0.01			
Simpson D	0.25 ± 0.02 b	0.24± 0.02 b	0.32 ± 0.02 c	0.17± 0.02 a
	F=9.59; p<0.01			
Mean number of individuals	187.4± 2.18 a	249.6 ± 23.13 a	259.2 ± 37.41 a	440.2 ± 53.67 b
	F=9.83; p<0.01			
Mean number of species	15.6± 0.87 ab	19.4 ± 1.69 b	13.8 ± 0.58 a	29.6 ± 2.04 c
	F=24.58; p<0.01			
Catchability	1.11 ± 0.01 a	1.48 ± 0.14 a	1.53 ± 0.22 a	2.60 ± 0.32 b
	F=9.83; p<0.01			

± standard error of the mean (SEM)

a, b, c - homogenous groups (Duncan's test)

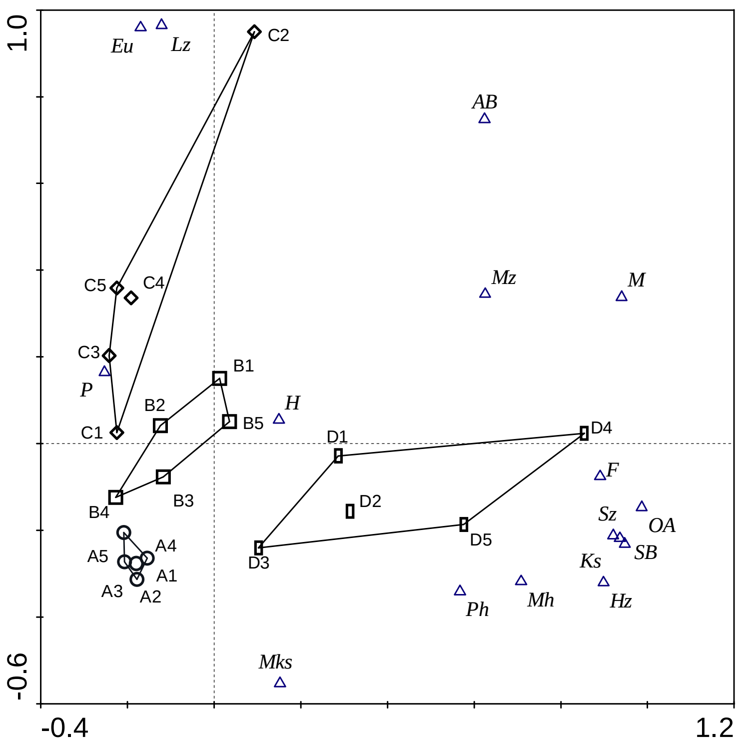

Fig. 2. Diagram of principal component analysis (PCA) presenting the variability of the ecological groups of Carabidae depending on the study sites A – D, each with traps 1-5. (The key to abbreviations of ecological groups used in the diagram is given in Table 4.)

Table 3. Dominant and recedent carabid beetles in strawberry plantations

Dominance class	Strawberry plantation							
	A	D [%]	B	D [%]	C	D [%]	D	D [%]
Eudominant species (>10%)	*Harpalus rufipes* *Calathus fuscipes*	37.4 28.7	*Calathus fuscipes* *Harpalus rufipes* *Nebria brevicollis*	40.9 17.6 15.1	*Nebria brevicollis* *Calathus fuscipes* *Harpalus rufipes*	46.0 26.8 16.5	*Harpalus rufipes* *Bembidion lampros* *Calathus fuscipes*	33.6 16.4 10.0
Dominant species (5 - 10%)	*Nebria brevicollis* *Harpalus affinis*	8.8 7.9	*Pterostichus melanarius*	5.9			*Poecilus cupreus* *Nebria brevicollis* *Bembidion properans*	6.0 5.8 5.6
Sub-dominant species (2 - 5%)	*Pterostichus melanarius* *Calathus ambiguus*	3.2 2.9	*Bembidion lampros* *Harpalus affinis* *Bembidion properans*	4.2 3.6 2.3	*Pterostichus melanarius*	3.9	*Harpalus luteicornis* *Poecilus lepidus*	3.7 3.7
Recedent species (1 - 2%)	*Trechus quadristriatus* *Bembidion quadrimaculatum* *Harpalus griseus* *Amara fulva* *Bembidion lampros*	1.8 1.7 1.6 1.1 1.1	*Trechus quadristriatus*	1.9	*Harpalus affinis* *Trechus quadristriatus*	1.2 1.0	*Harpalus griseus* *Pterostichus melanarius* *Poecilus versicolor* *Harpalus affinis* *Pterostichus niger* *Amara plebeja* *Calathus erratus*	1.8 1.6 1.5 1.4 1.4 1.0 1.0
Sub-recedent species (< 1%)	13 species	4.0	32 species	8.4	22 species	4.7	37 species	5.5

The variables with which most of the carabid beetles captured in the strawberry plantations correlated were the adjacent forest or fields cropped with cereals. These variables were strongly correlated with ordination axis I, which describes 71.1% of the variance. Ordination axis II, which describes the variability of assemblages at the level of 22.8%, was positively correlated with the close proximity to meadows and the age of plantations.

DISCUSSION

Cropped fields create habitats in which ground beetles are abundant, in terms of the number of

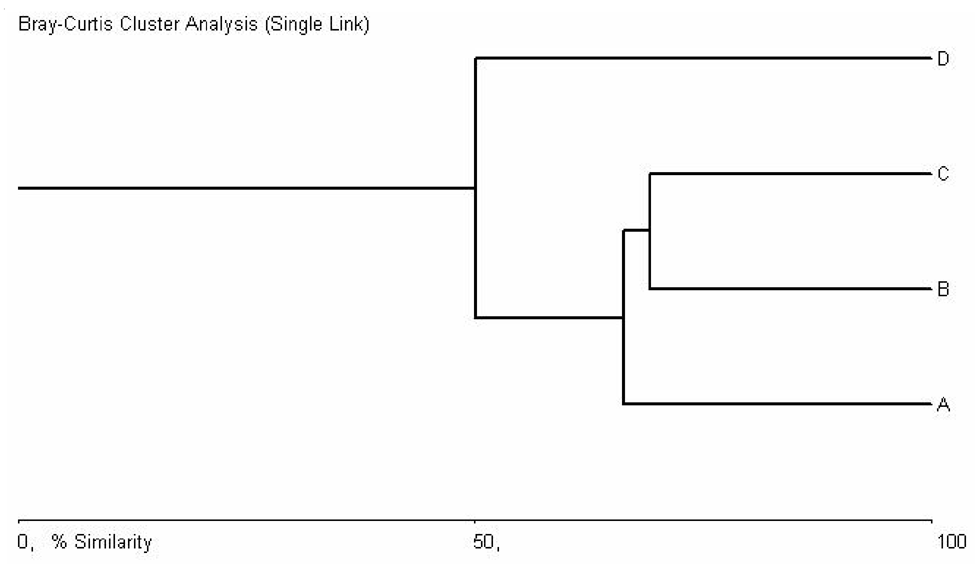

Figure 3. Cluster analysis based on the Bray-Curtis index

Table 4. Ecological description of the carabid beetles caught in strawberry plantations

Ecological description	Strawberry plantation							
	A		B		C		D	
	[%] Ql*	[%]Qn**	[%] Ql *	[%] Qn**	[%] Ql *	[%] Qn**	[%] Ql *	[%] Qn**
Trophic structure								
Large zoophages (Lz)	12.5	12.1	10.0	21.7	10.7	49.9	11.5	9.5
Medium zoophages (Mz)	29.2	33.7	30.0	44.8	35.7	28.9	28.9	22.9
Small zoophages (Sz)	16.7	5.1	15.0	9.1	25.0	2.6	19.2	23.5
Hemizoophages (Hz)	33.3	48.7	40.0	23.9	28.6	18.7	34.6	42.4
Phytophages (Ph)	8.3	0.4	5.0	0.5	0.0	0.0	5.8	1.6
Habitat preferences								
Forest species (F)	4.2	0.2	12.5	1.5	17.9	1.0	19.2	3.2
Open area species (OA)	83.3	87.4	65.0	76.3	67.9	48.9	71.2	88.8
Eurytopic species (Eu)	12.5	12.4	17.5	21.9	10.7	49.9	9.6	8.0
Peatbog species (P)	0.0	0.0	5.0	0.3	3.6	0.2	0.0	0.0
Hygropreferences								
Xerophilic species (Ks)	8.3	1.7	7.5	0.9	3.6	0.4	7.7	6.2
Mesoxerophilic species (Mks)	25.0	13.9	17.5	6.9	28.6	3.0	25.0	4.0
Mesophilic species (M)	58.3	83.5	60.0	91.0	57.1	96.1	51.9	87.8
Mesohygrophilic species (Mh)	8.3	1.0	10.0	1.0	7.1	0.3	11.5	1.8
Hygrophilic species (H)	0.0	0.0	5.0	0.3	3.6	0.2	3.9	0.1
Breeding type								
Spring species (SB)	45.8	13.7	65.0	15.2	50.0	4.1	63.5	42.8
Autumn species (AB)	54.2	86.3	35.0	84.8	50.0	95.9	36.5	57.2

* Ql - Qualitative aspect ** Qn Quantitative aspect

both individuals and species. Although they are constantly exposed to human interference (many of these beneficial beetles are killed during agronomic treatments), ground beetles readily settle on arable fields. This is where they find excellent food resources (Cross *et al.* 2001). Strawberry plantations receive extremely high quantities of plant protection chemicals, but this does not diminish their value as a habitat colonized by ground beetles. Flohre *et al.* (2011) claim that agricultural intensification does not have adverse influence on the richness of ground beetles. In the present study, as many as 60 species of carabids were captured in strawberry fields. This is a high number of species since the number of ground beetle species observed by Aleksandrowicz *et al.* (2008) in one year of research, depending on the type of crop and soil, was lower. In long-term observations, the number of determined species is typically much higher, up to 175 (Aleksandrowicz 1982). As a result of a four-year study completed by Huruk (2002b) on strawberry plantations in central Poland, 61 species were captured. In turn, one-year observations of strawberry fields in southeastern Poland yielded 45 species (Olbrycht 2007). In comparison, in Finland, 67 species of Carabidae were caught during two years of study (Touvinen *et al.* 2006). In view of the above, it can be concluded that strawberry fields are a specific type of plantations, where ground beetles appear in very high numbers.

While characterizing Carabidae assemblages it is very important to analyze their dominance structure. In our study, the dominance structure shows the group of eudominants to make up over 70% of the assemblages of ground beetles in strawberry plantations. This is quite a common phenomenon in fields exposed to unfavorable factors, such as agronomic treatment measures or application of plant protection chemicals. Analogously to the results published by other authors (Huruk 2002a, Huruk 2002b, Czerniakowski and Olbrycht 2004, Olbrycht 2007) who studied ground beetles living on strawberry plantations in Poland, the most numerous species was *Harpalus rufipes*. Some authors point

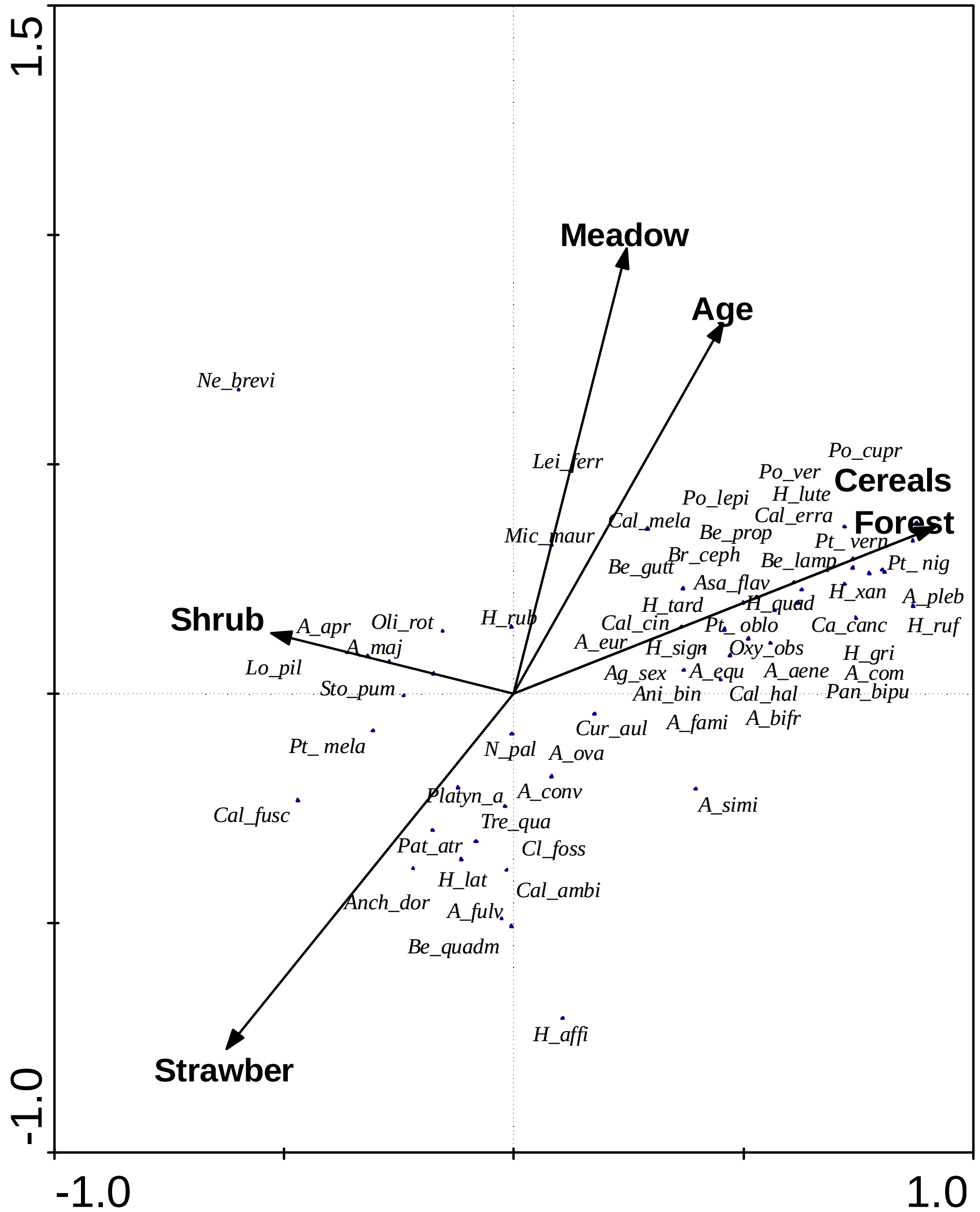

Fig. 4. Diagram of redundancy analysis (RDA) demonstrating the relationships between the analyzed environmental variables and Carabidae species.

Statistical significance of canonical axes was established according to the Monte-Carlo test ($p<0.1$). (The key to abbreviations used in the diagram is given in Table 1.)

to certain damage to strawberries caused by *Harpalus rufipes* and other species of the genera *Harpalus* and *Pterostichus* (Luff 1974, Luik *et al*. 2000, Fitzgerald and Solomon 2001, Kikas and Luik 2002), which nonetheless does not belittle the positive role of these beetles in strawberry plantations.

Our ecological analysis of the examined assemblages of ground beetles indicates certain disorders, typical of Carabidae assemblages found on arable fields. In respect of the trophic structure, the highest proportions in whole assemblages were attained by hemizoophages and medium zoophages. This is characteristic for assemblages subjected to stress factors, e.g. agronomic treatment. The same is reflected by the analysis of habitat types, where the majority of the beetles belonged to open-area species. According to Czechowski (1982), it is a typical development that open-area beetles supersede other habitat types of Carabidae when agronomic practice intensifies. In open areas, autumn ground beetles, better suited to living in fields, are found to prevail. In the spring, when many agronomic treatment measures are carried out, they are still in the pupal stage, thus more likely to survive (Thiele 1977, Huruk 2006). This observation is fully supported by the quantitative results of our study. The analysis-of-similarities dendrogram and principal component analysis (PCA) show that on each plantation separate assemblages of ground beetles were formed. Some authors suggest that some increase in insect species diversity may be expected as the habitat ages (Brown and Hyman 1986, Frank *et al*. 2007). Carabids can colonize agroecosystems rapidly (Kromp 1999, Eskelson *et al*. 2010), but the first to arrive are common species, easily adaptable to a given crop, e.g. *Harpalus rufipes*, or *Calathus fuscipes* on strawberry fields. In our study the youngest plantations (A, B) are characterized by the least stabilized assemblage of Carabidae, which on the one-year-old plantation (A) – apart from the age of plants – may have been additionally affected by the mechanical weeding, which either drove away or destroyed some of the insects. In older plantations, larger numbers of ground beetles, including the ones less commonly associated with fields, were noticed. The three-year-old plantation (C) favored the development of large zoophages. Most of the ecological groups of carabid beetles were observed in the oldest plantation (D). According to Eskelson *et al*. (2010), we can predict that abundance, diversity, and stabilization of Carabidae assemblages will increase as the strawberry crop becomes more strongly established. In order to obtain a more complete image of the Carabidae assemblages, we should also look at the immediate surroundings of strawberry fields. Carabid beetles migrate between fields and adjacent sources of natural habitats in response to changing field conditions (Varchola and Dunn 1999). These are also areas where carabids could migrate from, e.g. in search for food. Skłodowski (2002) reports that the spatial differentiation of the environment largely determines the species composition of carabid assemblages. Likewise, Duelli *et al*. (1999) conclude that the species richness of a given area depends, e.g., on the biodiversity of its environs. The redundancy analysis diagram obtained in our study supports this conclusion. Here, the occurrence of most carabid beetle species was positively correlated with the close proximity of cereal fields and a forest. It is well known that cereal crops are an excellent foraging base for ground beetles (Hurej and Twardowski 2006). Moreover, forest is a very stable habitat and as such it is chosen by many Carabidae as a place for overwintering and breeding (Skłodowski 2002) or as a refuge to hide away from agronomic treatment measures carried out on fields, which are fatal for these beetles.

CONCLUSIONS

Ground beetles very readily colonize strawberry plantations. With respect to ecological requirements, the dominant species represented mesophilic, open-area beetles with the autumn type of development, either hemizoophages or medium zoophages.

The variables which differentiated the examined strawberry plantations significantly, were their surroundings and the age of plantations. Most species and individuals of Carabidae were determined on the oldest plantation, bordering with a forest and a wheat field, which contained an assemblage of ground beetles distinctly different from the other analyzed assemblages.

REFERENCES

Aleksandrowicz O. R. 1979. Żużelicy (*Coleoptera, Carabidae*) v polevych agrocenozach Belorussii. Sb. nauć. tr. BelNII zaśćity rastenij. Mińsk. 4: 27-35. [In Belarusian].

Aleksandrowicz O. R. 1982. Ekologićeskaja struktura fauny żużelic zernovych polej Belorussii u ee izmenenie pod vlijaniem intensifikacii selskochozjajstvennogo proizvodstva. Avtoreferat dissertacii na soiskanie ućenoj stepeni kandidata biologiceskich nauk. Leningrad-Puskin. 19c. [In Russian].

Aleksandrowicz O. R., 2004. Biegaczowate (Carabidae). [in:] Fauna Polski: charakterystyka i wykaz gatunków (Bogdanowicz W., Chudziaka E., Pilipiuk I. i Skibińska E., red.). Muzeum i Instytut Zoologii PAN. Warszawa. I: 28 [In Polish].

Aleksandrowicz O., Pakuła B., Mazur J. 2008. Biegaczowate (Coleoptera: Carabidae) w uprawie pszenicy w okolicy Lęborka [Carabid beetles (Coleoptera: Carabidae) in the wheat field near Lębork]. Słupskie Prace Biologiczne. 5: 15-25. [In Polish; abstract in English].

Basedow Th., Borg A., De Clercq R., Nyveldt W., Scherney F. 1976. Untersuchungen tber das Vorkommen der Laufkafer (*Col.: Carabidae*) auf europaischen Getreidefeldern. Entomophaga. 21: 59-72.

Bohan D. A., Bohan A. C., Glen D. M., Symondson W. O., Wiltshire C. W., Hughes L. 2000. Spatial dynamics of predation by carabid species on slugs. J. Anim. Ecol. 69: 367-379.

Brown V. K., Hyman P. S. 1986. Successional communities of plants and phytophagous Coleoptera. J. Ecol. 74: 963-975.

Cowles R. S. 2003. Practical vine weevil management. J. Am. Rhododendron. Soc. 57: 219-222.

Cross J. V., Easterbrook M. A., Crook A. M., Crook D., Fitzgerald J. D., Innocenzi P., J. Jay C. N., Solomon M. G. 2001. Review: Natural Enemies and Biocontrol of Pests of Strawberry in Northern and Central Europe. Biocontr. Sc. and Tech. 11: 165-216.

Czechowski W. 1982. Occurrence of Carabids (*Coleoptera, Carabidae*) in the urban greenery of Warsaw according to the land utilization and cultivation. Memorabilia Zool. 39: 3-108.

Czerniakowski Z.W., Olbrycht T. 2004. Różnorodność gatunkowa biegaczowatych (Col., Carabidae) w wybranych biotopach południowo-wschodniej Polski [Species diversity of ground beetles (Col., Carabidae) in different biotopes of S-E Poland]. Prog. Plant Protect. 44: 22–27. [In Polish; abstract in English]

Duelli P., Obrist M.K, Schmatz D.R. 1999. Biodiversity evaluation in agricultural landscapes: above-ground insects. Agric. Ecosyst. Environ. 74: 33–64.

Easterbrook M. A. 1997. A field assessment of the effects of insecticides on the beneficial fauna of strawberry. Crop Protection. 16. 2: 147-152.

Eskelson M. J., Chapman E. G., Archbold D. D., Obrycki J. J., Harwood J. D. 2010. Molecular identification of predation by carabid beetles on exotic and native slugs in a strawberry agroecosystem. Biol. Contr. 56: 245-253.

Fitzgerald J., Solomon M. 2001. Ground dwelling predatory carabid beetles as biocontrol agents of pests in fruit production in UK. Bull. OILB/SROP 24: 155-159.

Flohre A., Fischer C., Aavik T., Bengtsson J., Berendse F., Bommarco R., Ceryngier P., Clement L. W., Dennis C., Eggers S., Emmerson M., Geiger F., Guerrero I., Hawro V., Inchausti P., Liira J., Morales M. B., Onate J. J., Pärt T., Weisser W. W., Winqvist C., Thies C., Tscharntke T. 2011. Agricultural intensification and biodiversity partitioning in European landscapes comparing plants, carabids and birds. Ecol. Appl.. 21 (5): 1772-1781.

Frank T., Kehrli P., Germann K. 2007. Density and nutritional condition of carabid beetles in wildflower areas of different age. Agric. Ecosyst. Environ. 120: 377-383.

Górny M. 1971. Z badań nad biegaczowatymi (*Col. Carabidae*) zadrzewienia śródpolnego i pól. Pol. Pismo Ent. 41: 386-415. [In Polish]

Górny M., Grüm L. 1981. Metody stosowane w zoologii gleby. PWN. Warszawa. 482. [In Polish]

Holland J. M. (Ed) 2002. The Agroecology of Carabid Beetles. Intercept Ltd. Hampshire. UK: 356 pp.

Hurej M., Twardowski J. P. 2006. The influence of yellow lupin intercropped with spring triticale on predatory carabid beetles (Coleoptera: Carabidae). Eur. J. Entomol. 103: 259-261.

Hůrka K. 1996. Carabidae of the Czech and Slovak Republics. Kabournek – Zlin: 565 pp.

Huruk S. 2002a. Carabids (Coleoptera, Carabidae) in strawberry plantations on brown soils. Baltic J. Coleopterol. 2: 105-116.

Huruk S. 2002b. Biegaczowate (*Coleoptera, Carabidae*) w uprawach truskawek na glebach bielicowych [Carabid beetles (*Coleoptera, Carabidae*) in strawberry crops on podsolic soils]. Rocz. Świętokrzyski. Ser. B - Nauki Przyr. 28: 53-66. [In Polish; abstract in English]

Huruk S. 2006. Porównanie struktur zgrupowań biegaczowatych (Coleoptera: Carabidae) łąk kośnych oraz przylegających do nich pól uprawnych. Wiad. Entomol. 25, Supl. 1: 9-32. [In Polish, abstract in English]

Kabacik-Wasylik D. 1970. Ökologische Analyse der Laufkäfer (Carabidae) einiger Agrikulturen. Ekol. Pol. 18: 137-209.

Kikas A., Luik A. 2002. The influence of different mulches on strawberry yield and beneficial entomofauna. Acta Hort. 567: 701-704.

Kosewska A., Nietupski M., Ciepielewska D., Słomka W. 2009 Czynniki wpływające na struktury zgrupowań naziemnych biegaczowatych (Col., Carabidae) w wybranych uprawach zbóż [Factors which influence structures of assemblages of epigeic carabids (Col. Carabidae) populating some cereal plantations]. Prog. Plant Protect. 49 (3):1035 – 1046. [In Polish; abstract in English]

Kotze J. D., Brandmayr, P., Casale, A., Dauffy-Richard E., Dekoninck W., Koivula M.J., Lövei G.L., Mossakowski D., Noordijk J., Paarmann W., Pizzolotto R., Saska P., Schwerk A., Serrano J., Szyszko J., Taboada A., Turin H., Venn S., Vermeulen R., Zetto T. 2011. Forty years of carabid beetle research in Europe - from taxonomy, biology, ecology and population studies to bioindication, habitat assessment and conservation. Zookeys. 100: 55-148.

Kromp B. 1989. Carabid beetle communities (Carabidae, Coleoptera) in biologically and conventionally farmed agroecosystems. Agriculture, Ecosystems and Environment. 27: 241–251.

Larsson S. G. 1939: Entwicklungstypen und Entwicklungszeiten der dän Carabiden. Entom. Meddelels. 20: 270 – 560.

Lee J. C., Edwards D. L. 2011. Impact of predatory carabids on below- and above-ground pests and yield in strawberry. BioControl, pp. 1-8, article in press.

Lindroth C. H. 1985: The Carabidae (Coleoptera) of Fennoscandia and Denmark. Fauna Entomol. Scandinavica. Vol. 15: 1 – 225.

Lindroth C. H. 1986: The Carabidae (Coleoptera) of Fennoscandia and Denmark. Fauna Entomol. Scandinavica. Vol. 15: 230 – 497.

Luff M. 1974. Aspects of damage by strawberry ground beetle (*Pterostichus madidus* (F)). Plant Pathol. 23: 101-104.

Luff M. 1980. The biology of the ground beetle *Harpalus rufipes* of a strawberry field in Northumberland. Ann. Appl. Biol. 94: 153-164

Luik A., Eenpuu R., Heidemaa M., Arus L., Tarang T., Vares A. 2000. Carabids in different agrocenosis of Estonia. Trans. Estonian Agric. Univ. Agron. 209: 114-117.

Moorhouse E. R., Charnley A. K., Gillespie A. T. 1992. A review of the biology and control of the vine weevil, *Otiorhynchus sulcatus* (Coleoptera: Curculionidae). Ann. Appl. Biol. 121: 431-454.

Olbrycht T. 2007. Biegaczowate wybranych ekotopów (Col., Carabidae) południowo wschodniej Polski [Ground beetles (Col., Carabidae) in selected ecotops of south eastern Poland]. Prog. Plant Protect. 47 (4): 193-196. [In Polish; abstract in English]

Scheu S. 2001. Plants and generalist predators as links between the below-ground and above-ground system. Basic Appl. Ecol. 2: 3-13.

Sharova I. H. 1974. Zhiznennye formy imago zhuzhelits (Coleoptera, Carabidae). Zool. Zhurn. 53(5): 692 – 709. [In Russian].

Skłodowski J. W. 2002: System kolonizacji zrębu zupełnego przez biegaczowate oraz możliwości jego doskonalenia [System of colonization clear-cut area by carabid beetles and possibility of its improving]. Rozprawy naukowe i monografie. Treatises and Monographs. SGGW, Warszawa: 1 – 134. [In Polish; summary in English]

South A. 1992. Terrestrial Slugs: Biology and Control. Chapman and Hall. 428 pp.

Ter Braak C.J.F., Smilauer P. 1998: CANOCO Reference Manual and User's Guide to Canoco for Windows. Microcomputer Power, Ithaca, USA. 352 pp.

Thiele H. U. 1977: Carabid beetles in their environments. Springer – Verlag, pp. 329.

Tischler W. 1955. Influence of soil types on the epigeic fauna of agricultural land. In: Soil Zoology. Kevan D. K. (red.). London: 125-137.

Tuovinen T., Kikas A., Tolonen T., Kivijärvi P. 2006. Organic mulches vs. black plastic in organic strawberry: does it make a difference for ground beetles (Col., Carabidae)? J. Appl. Entomol. 130 (9-10): 495-503.

Varchola J. M., Dunn J. P. 1999. Changes in ground beetle (Coleoptera: Carabidae) assemblages in farming systems bordered by complex or simple roadside vegetation. Agric. Ecosys. Environ. 73: 41-49.

Watała C. 1995: Przegląd Carabidae Polski. Cz. I. Wstęp oraz plemię Carabini. Folia Zoologica. 3: 1-75. [In Polish].

Received: 12.06.2012.
Accepted: 25.08.2012.