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Long-termed changes in ground beetle (Coleoptera: Carabidae) assemblages in a field treated by organic fertilizers

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Abstract: In 2001–2006, ground beetles were pitfall-trapped in a temperate lowland area of South Slovakia in an experimental field divided in five plots fertilized by four different doses of manure or biosludge (25 t stable manure ha^{-1}, 50 t biosludge ha^{-1}, 50 t stable manure ha^{-1}, 100 t biosludge ha^{-1} and without fertilization). The field was subsequently sown by spring barley, sugar beat, maize, sunflower, sugar beat and maize. The ground beetle assemblage consisted of 31 species, but only five species predominated: *Pseudoophonus rufipes* representing 82.6% of individuals and five species (*Poecilus cupreus, Carabus scheidleri, Calathus fuscipes, Trechus quadristriatus, Pterostichus melanarius, Anchomenus dorsalis, Dolichus halensis*) representing together 14.5% of individuals. *Pseudophonus rufipes* represented 81.7% of dry biomass and three species (*Carabus scheidleri, Poecilus cupreus Pterostichus melanarius)* 15.9% of biomass. There was no significant influence of organic fertilizing on assemblage structure. During the investigation, the number of individuals and their biomass increased in all plots until 2003 and than dropped to the starting values. The culmination of 2003 was preceded by a warmer and more humid season in 2002. After a cold and dry season of 2003 abundance decreased approximately to starting values. Simultaneously, the local maxima and minima of occurrence of ground beetles in individual plots shifted independently on the doses of organic material. At the same time, number of occurring species slightly decreased. The observed changes obviously represent part of long-termed fluctuations in wider surroundings.

Key words: Carabidae; assemblages; organic fertilizers; agriculture; ecology; long-term changes

Introduction

In spite of the fact that the field ecosystems are exposed to strong disturbances repeated even several times a year, composition of ground beetle assemblages in them shows a striking stability and homogeneity in Europe. Their species richness in almost all fields often exceeds species richness of their assemblages in natural or semi-natural ecosystems, especially in the mezohygrophilous or floodplain forests (Jarošík 1983; Šustek & Žuffa 1988; Šustek 1994, 2004a). The cumulative abundance of all ground beetles in the fields reaches huge values. On the other hand, the extensive land consolidation of fields in the countries with collectivized agriculture and reduction of hedges and patches of dispersed shrub vegetation reduced representation of large and wingless species, especially of the genus *Carabus*. In addition, there are only few ground beetle species, first of all *Pseudophonus rufipes* (De Geer, 1774), *Poecilus cupreus* (L., 1758), *Anchomenus dorsalis* (Pontopiddan, 1763), *Brachinus explodens* (Duftschmidt, 1812), *Calathus fuscipes* (Goeze, 1777), which predominate almost in all fields in Central Europe (mesophyticum) and *Dolichus halensis* (Schaller, 1783), which also predominates in fields in warmer parts of Central and Eastern Europe (thermophyticum) (Lővei & Sárospataki 1990). According to local conditions, character of the crop and mutual competition pressure, they just change their rank in an assemblage. Among them *P. rufipes* tends to predominate strongly, as to abundance as to biomass.

The efforts to increase the crop yield on one hand and to harmonize the agriculture with the concept of sustainable development on the other hand leads to searching for optimal modes of fertilizing, melioration of soil conditions and pest control, as well as of reestablishing of the original spatial diversity of agricultural landscape. All these measures also put question of reactions of field fauna on input of different artificial or natural fertilizers, use of different pesticides or changes in landscape structure. Knowledge of such reactions is of crucial practical importance for an effective landscape management and biodiversity protection.

From all these aspects, the field ground beetles have been in focus of attention of an enormous number of authors since mid-1950-ies. Orientation of their studies can bee divided in several directions: (1) study of population and community structure in different

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Table 1. Crop yields in individual study plots and years.

Plot	Crop yield (t ha^{-1})					
	Barley 2001	Sugar beet 2002	Maize 2003	Sunflower 2004	Sugar beet 2005	Maize 2006
1: control	3.73	65.20	39.69	1.84	37.35	14.85
2: 25 t manure	4.30	72.25	64.31	1.76	23.18	56.85
3: 50 t sludges	4.18	85.81	58.78	1.74	76.78	63.18
4: 50 t manure	4.32	61.35	59.76	2.14	80.95	68.36
5: 100 t manure	4.45	82.60	53.01	1.94	64.58	81.75

crops (Skuhravý & Novák 1957; Skuhravý et al. 1959; Štepanovičová & Beláková 1960; Štusák 1962; Petruška 1966, 1971, 1986, 1987, 1988; Obrtel 1969; Novák 1972; Andersen 1999a; Basedow et al. 1976; Sekulić et al. 1973; Ericson 1978; Sharova 1983; Honěk 1997; Petřvalský & Porhajašová 2002, Porhajašová 2002), (2) study of influence of different pest control, fertilization or cultivation practices and pollution (Pauer 1975; Šustek 1985, 1990, 1994a; Lővei 1984; Purvis & Currey 1984; Kabacik-Wasilik 1986; Kromp 1989, 1990; Fadl et al. 1996; Pavuk et al. 1997; Andersen 1999b; Andersen & Eltun 2000) or (3) study of influence of landscape vegetation spatial structure on fauna in neighboring fields (Boháč & Pospíšil 1984; Gruttke 1991; Kromp & Steinberger 1992; Šustek 1992, 1994b, in press.). Influence of input of manure or slurry on field ground beetle fauna was studied by Kabacik-Wasilik (1986), Purvis & Currey (1984), Kromp (1989, 1990), Clark et al. (1997), Irmler (2003), Raworth et al. (2004) and Lövei et al. (2005). Many studies on ground beetles in arable land have contradictory results and lead some authors to considerations about limits and methodology of bioindication of such factors (Thacker & Jepson 1990; Šustek 1998) or to some generalizations (Lővei & Sárospataki 1990).

The aim of this study is to analyze, how abundance, biomass and structure of ground beetle assemblages changed in fields fertilized by different doses of organic material, stable manure and biosludge in course of six years.

Material and methods

The investigations were carried out in the experimental station of the Agriculture University of Nitra in 2001–2006. The station is situated easterly of the Kolíňany village (10 km northeasterly of Nitra, 48°21′49″ N, 18°12′33.28″ E) on a moderate western slope (Fig. 1), at altitude of 160–180 m a.s.l. The geological substrate consists predominantly of eluvial-deluvial sediments of the Tribeč Mts in pleistocenic-holocenic area, locally mixed loess sediments of Žitava Hills (Chlpík & Pospíšil 2004). The soil type is brown soil with the average content of humus (2.149% Hm) and a high acidity (pH 4.59–5.39). The soil is strongly influenced by anthropogenic activity (Šály et al. 2004; Chlpík & Pospíšil 2004). The area is warm, moderately humid, with temperate winters. The average year temperature is 9.7 °C, the average year precipitations 631 mm, while 355 mm fall in the growing season. During 2001–2006 the sunshine lasted 2000–2400 hours, among which 1600 hours during the growing season (Repa & Šiška 2002, 2004; Šiška & Repa 2003.

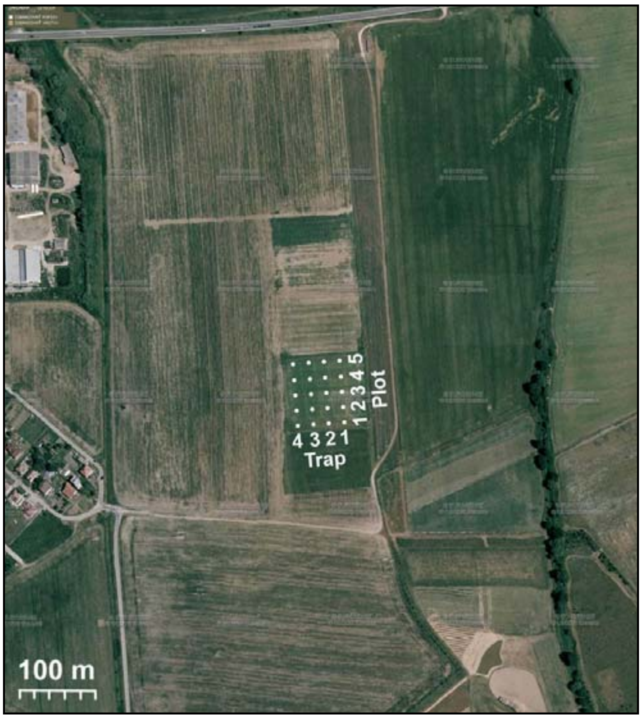

Fig. 1. Position of the plots and individual traps in the experimental field and its immediate surroundings.

The total area of the experimental field was 9000 m^2. It was divided into 5 plots, each of 1800 m^2 (100 × 18 m) treated each year as follows: 1 – non-manure control; 2 – 25 t stable manure ha^{-1}; 3 – 50 t biosludge ha^{-1}; 4 – 50 t stable manure ha^{-1}; 5 – 100 t biosludge ha^{-1}. Biosludge is a residual after biogas production from cattle excrement and other biological material. Each autumn it was applied into the soil as a spray. Sequence of crops over all five plots was spring barley (2001), sugar beet (2002 and 2005), silage maize (2003 and 2006) and (2004). The yield of individual crops (Table 1) showed mostly a positive correlation with increased input of organic matter and was used as an indicator of the crops stand quality influencing the microclimatic conditions in the stand.

The beetles were pitfall-trapped. The glass jars with opening diameter of 95 mm, filled with 4% formalin and protected by iron roofs served as traps. In each plots, four traps were installed in mutual distance 20 m in a line in the plot axis. The traps were exposed from April to October and emptied monthly. In this way 120 one-year samples were obtained. Because of their large numbers, they were mostly further pooled according individual plots or years.

Ground beetles were identified using the key by Hůrka (1996). The ecological properties of species are characterized by Burmeister (1939), Hůrka (1996), Larsson (1939), Lindroth (1949), Thiele (1977), Sharova (1981) and Šustek (1984, 2004b). The biomass of each species was calculated by multiplying its abundance by average dry weight of the species established by Šustek (1984). The index of preference for humidity and vegetation cover was calculated on the base of two semiquantitative scales (1 xerophilic – 8 strongly hygrophilous; 1 heliophilous species of open landscape – 5 species requiring full shadowing by woody vegetation) proposed by Šustek (2004b) as average of preference indices of all species in the sample weighted by their quantitative representation (number of individuals, biomass).

The assemblages were classified by means of average linkage method using the Whitecker's index (proportional similarity) and Canberra metrics (abundance similarity). The DCA method was used for ordination of the data. The diversity was expressed by Shannon-Weaver's index using binary logarithm. All calculations were made by the programs CAP III and PAS. Influence of organic substance input on number of individuals was tested by three-way ANOVA using the Sigma-Plot program.

Results

Community structure

In total 38,795 ground beetle individuals belonging to 31 species were evaluated (Table 2). The average number of individuals in one-year sample from one trap was 323.8 (min. 64, max. 1120, SD 167.1), the average number of species was 9.45 (min. 5, max. 16, SD 2.35), the average Shannon-Weaver's index was 0.79 (min. 0.38, max. 1.86, SD 0.26), average equitability was 0.35 (min. 0.21, max 0.76, SD 0.11).

Six species, *Pseudoophonus rufipes* (82.5%, in individual traps 28.4–92.4%) *Poecilus cupreus* (6.08%, in positive samples 0.6–34.3%), *Carabus scheidleri* (2.6%, in positive samples 0.3–2.8%), *Trechus quadristriatus* (1.3%, in positive samples 0.2–2.2%, *Calathus fuscipes* (1.8%, in positive samples 0.3–1.9%) and *Pterostichus melanarius* (1.2%, in positive samples 0.2–1.6%) were dominant or subdominant. These species moderately changed their position in individual years (Table 2). In 2004, representation of *P. melanarius* and *T. quadristriatus* decreased or they disappeared in some plots. In 2005 their decline or disappearance was also followed by *P. cupreus*, *C. scheidleri* and *C. fuscipes*. This decline was accompanied by a moderate emergence of *Dolichus halensis* and *Anchomenus dorsalis* in 2003/2004, which started to disappear again in 2006, when *P. cupreus*, *C. scheidleri* and *C. fuscipes* restored their initial number of individuals. Similar changes in position of these species also occur in field ecosystems as manifestation of spatial distribution pattern of ground beetles along long transects (Šustek 1994a). Among other species, small local concentrations of *Bembidion lampros, Microlestes minutulus* and *Syntomus obscuroguttatus* are remarkable (Table 2). They indicated places with sparser vegetation and less favorable conditions for other species,

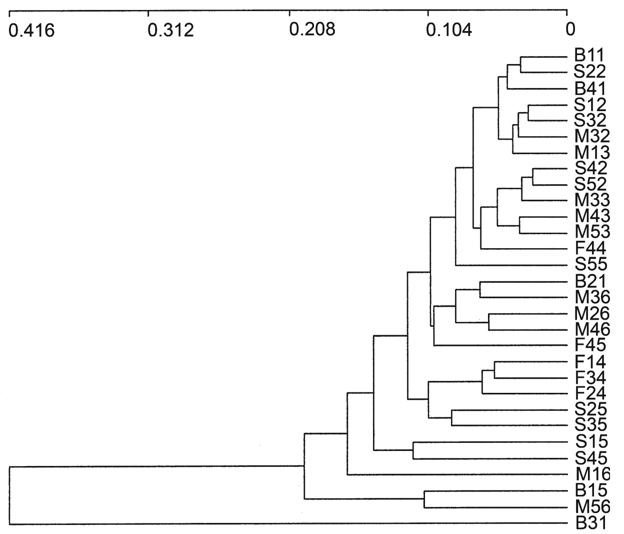

Fig. 2. Classification of one-year samples of ground beetles from each plot according to proportional similarity (Whitecker's index). B – barley, S – sugar beet, M – maize, F – sunflower, first digit – number of plot (1–5), second digit – last digit of the year 2001–2006 (1–6).

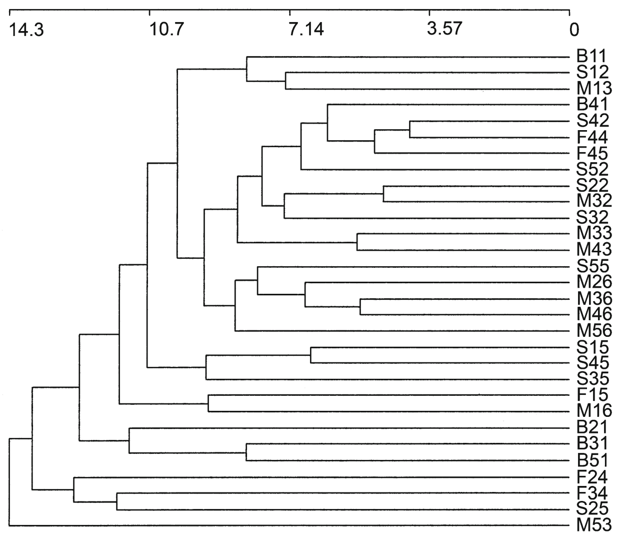

Fig. 3. Classification of one-year samples of ground beetles from each plot according to abundance similarity (Canberra metric), symbols as in Fig. 1.

at least in a part of the season. This fits especially in the plots 3 in 2001, 1 and 5 in 2005.

The above changes in the assemblage are responsible for clustering pattern of one-year samples from each plot (Figs 2, 3). In both dendrograms the clusters are formed predominantly by the samples from 2001, 2002, 2003 and 2006, on one hand, and by those from 2004 and 2005, on other hand. Within these clusters smaller groups of samples from neighboring plots arise. There is not a tendency to clustering after the crop, as manifested especially by splitting of samples from sugar beet and maize sawn twice during the investigation period into many small clusters. The clustering after proportional similarity (Fig. 2) runs on the similarity levels of

Table 2. Survey of ground beetle species, their ecological properties and abundance in individual years, crops and plots.

Species	Ecological properties					Year, crop and plot																													
						2001 Barley					2002 Sugar beat					2003 Maize					2004 Sun flower					2005 Sugar beat					2006 Maize				
	H	V	R	F	DW	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Pseudophonus rufipes (De Geer, 1774)	4	1	a	f	0.4995	915	904	144	802	1002	656	896	681	1021	1628	1453	1468	1403	1495	3228	1824	968	1765	906	884	480	964	848	536	904	740	1196	745	932	648
Poecilus cupreus (L., 1758)	4	1	s	f	0.2710	94	132	76	70	278	54	84	48	44	70	84	68	56	72	122	68	44	63	83	156		16		16	44	69	112	114	8	145
Carabus scheidleri (Panzer, 1799)	5	4	s	n	2.1885	27	32	23	27	32	34	21	41	19	18	67	86	36	70	148	37	28	34	14	8	12	4		8	18	16	52	4	55	7
Calathus fuscipes (Goeze, 1777)	4	1	a	f	0.2236	19	15	7	13	35	11	14	3	9	25	26	31	18	26	84	68	28	700	14		35	53	24	16	16	12	8	7	6	8
Trechus quadristriaus (Schrank, 1781)	4	1	a	f	0.0062	22	14	15	3	27	2	42	21	13	49	64	36	28		52	4				4	45	28	8	9	16	4				
Pterostichus melanarius (Illiger, 1798)	5	2	i	f	0.5336	5	24	17	23	14	13	19	23	20	10	18	53	36	37	52	8		8	7	4	3			8	4		39	14	16	7
Anchomenus dorsalis (Pontopidan, 1810)	3	1	s	f	0.0419	2	2		1	4				2				2	5	36	32	24	71			17	28	24	56		27	8			
Dolichus halensis (Schaller, 1783)	4	1	a	f	0.2319											3				4	91	24	44	7								16			24
Bembidion obtusum (Audimet-Serville, 1821)	3	1	s	f	0.0169		1	1		1	2	1	1				2	2		3	48					8			8	1	84				
Harpalus distinguendus (Duftschmidt, 1812)	3	1	s	f	0.1761	1	2				1					6		4	4	8	4	8					7	24		29		4	14		32
Calosoma auropunctatum (Herbst, 1784)	3	1	a	f	1.6495		2	3		1			1					2		3		12	37				8	16		38		8		6	
Brachinus crepitans (L., 1758)	2	1	i	n	0.1201	3	7	16	19	14		1	5	1		1	2	3	4	4		8	9	13	12		5								
Mirolestes minutulus (Goeze, 1777)	3	1	s	f	0.0042															4							8			5		41	35	5	
Cicindela germanica (L., 1758)	3	1	a	f	0.1170	1	2			1	1				2	6				5	4	12									4	28		21	
Bembidion lampros (Herbst, 1784)	3	1	s	f	0.0172			1	1	21					4			2	3	7							4				8				25
Brachinus explodens (Duftschmidt, 1812)	3	1	s	f	0.0315		2	2		2		1					3						5			4	4				16			11	
Amara aenea (De Geer, 1774)	3	1	a	f	0.1424	1		2			1					2					8	12	5			4	7								8
Anisodactylus signatus (Panz,1797)	5	1	s	f	0.2261		1				1	1				3	6						11			4	4	8	8						
Syntomus obscuroguttatus (Duftschmidt, 1812)	5	2	s	n	0.0043		2	12	4	11					1					4															
Badister sodalis (Duftschmidt, 1812)	7	2	s	f	0.0212			3		2			1								4	4			4						8				

Table 2. Survey of ground beetle species, their ecological properties and abundance in individual years, crops and plots.

Species	Ecological properties					Year, crop and plot																													
						2001 Barley					2002 Sugar beat					2003 Maize					2004 Sun flower					2005 Sugar beat					2006 Maize				
	H	V	R	F	DW	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Harpalus latus (L., 1758)	4	1	s	f	0.1773																4	8	1				4								
Stomis pumicatus (Panzer, 1796)	6	2	s	n	0.0520			1																				8							
Zabrus tenebrioides (Goeze, 1777)	3	1	s	f	0.2522	2	2																				4								
Badister bipustatulus (F., 1792)	5	2	s	f	0.0231		1				2					2	3																		
Pterostichus cylindricus (Herbst, 1784)	4	1	s	n	0.8963																								7						
Pterostichus macer (Marsham, 1802)	4	1	s	f	0.2845														4																
Chlaenius nigricornis (F., 1787)	8	5	s	f	0.4379																											4			
Ophonus azureus (F., 1799)	2	1	a	f	0.1121																	4													
Carabus granulatus (L., 1758)	7	2	s	n	1.1215															4															
Abax parallepipedus (Piller et Mitterbacher, 1783)	3	4	s	n	1.1521																	4													
Amara familiaris (Duftschmidt, 1812)	3	1	s	f	0.0444																		1												
Number of individuals						1092	1145	323	963	1455	778	1080	825	1129	1807	1735	1758	1592	1720	3768	2204	1188	2754	1044	1072	612	1148	960	672	1075	988	1516	933	1060	904
Number of species						12	17	15	10	15	12	10	10	8	9	13	11	12	10	17	14	15	14	7	7	10	16	8	10	10	11	12	7	9	9

Explanations: H – preference for humidity; V – preference for vegetation cover; R – reproduction type, F – flying activity; DW – average dry weight of one individual in g. a – autumnal species;, s – spring species; i – inderminate type; f – able to fly, n – not flying. Scale of humidity preference: 1 – strongly xerophilous, 8 – strongly hydrophilous. Scale of vegetation cover: 1 – without shadowing, 5 – strong shadowing).

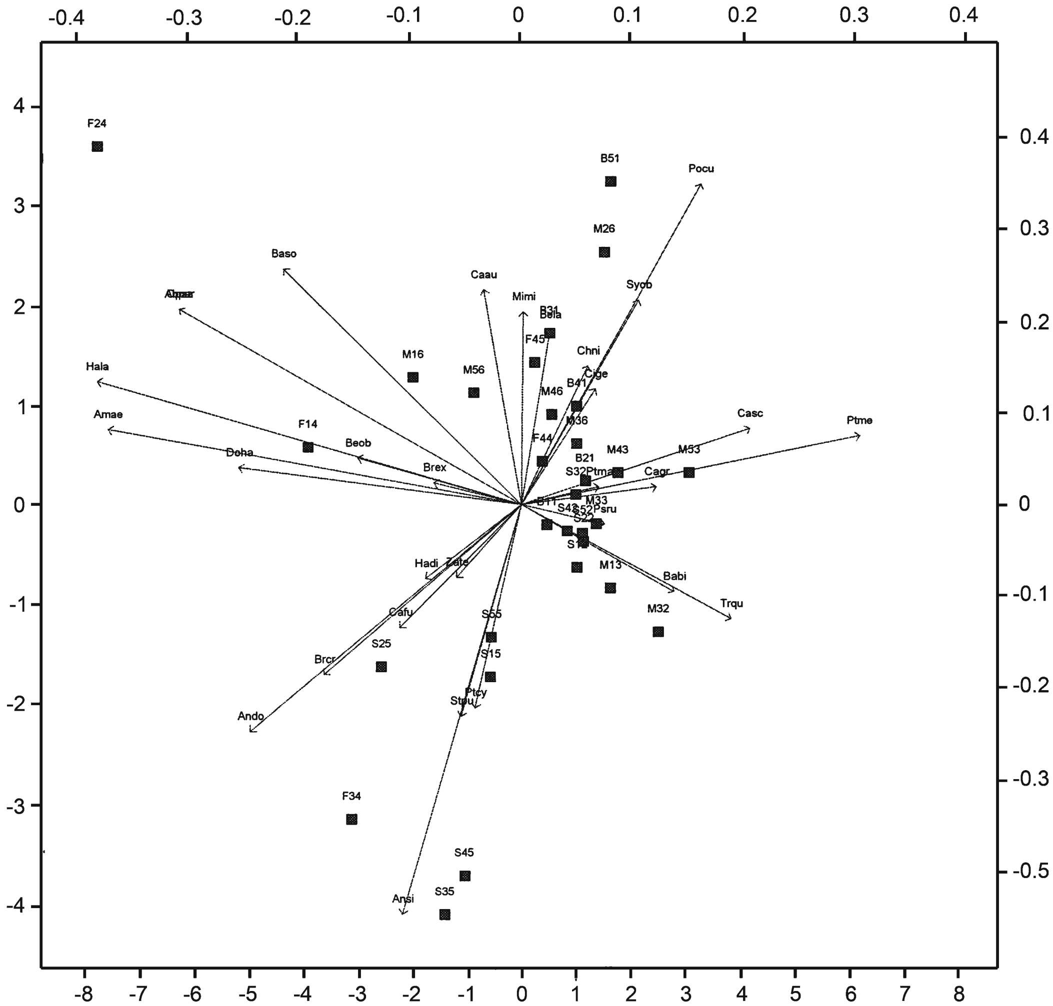

Fig. 4. PCA biplot (1 and 3 axis) of one-year samples of ground beetles from each plot and of all species (encoding of samples as in Fig. 2, abbreviations of species: first two letters generic name, next two letters specific name).

0.80–0.95, which show a high homogeneity of the samples, whereas the clustering on base of abundance similarity (Fig. 3) runs at the distance levels 4–4.5 and indicate large differences in sample size in individual years.

A similar pattern is shown by PCA biplot (Fig. 4). The samples from 2001–2003 and 2006 are concentrated in the upper right quadrant of the diagram and are divided into three groups, one associated with vector of *P. cupreus*, second with *P. melanarius* and *C. scheidleri* and third with *T. quadristriatus.* The samples from 2004 and 2005 are sparsely scattered on the left side, mostly in the lower part of the diagram. Among the more abundant species, they are associated with vectors of *D. halensis, A. dorsale, C. fuscipes* and *B. crepitans.* A remarkable feature of the assemblage was a relatively high representation of *C. scheidleri.* This large, wingless, but relatively eurytopic species was a frequent component of ground beetle assemblages in Central European fields still in 1960-ies (Petruška 1966, 1986, 1987, 1988), but later it almost disappeared (Šustek 1985, 1990) or occurred there only in surroundings of larger islands of shrub or tree vegetation (Šustek 1994a). Its permanent presence in the studied field indicates certain degree of restoration of field fauna in recent period, which was also confirmed in Central Moravia by Krejčová et al. (2000).

Changes in number of species, individuals and dry biomass of samples

Number of species showed generally a decreasing trend in all plots during the whole investigation period (Fig. 5). The highest numbers were recorded in 2001 (10–17, 13.8 on average) and 2003 (10–17, 12.6 on average), after a decline in 2002. Further on, number of species continuously decreased to 7–12 (9.6 on average) in 2006. Whereas there was a relatively balanced number of species in all plots in 2001, in 2002 number of species decreased in the plots fertilized with a dose above 25 t ha^{-1} (plots 3–5), while in 2005–2006 the decrease continued in the plot 3 (50 t ha^{-1} biosludge).

Cumulative abundance and biomass of all species (Fig. 5) was strongly correlated because of enormous predominance of *P. rufipes.* Values of both parameters increased from 2001 until 2003 and then they decreased again to the starting level from 2001. Within this trend, two opposite patterns were also observable. In 2001–

Fig. 5. Number of ground beetle species, cumulative abundance and dry biomass of one-year samples from each plots (encoding of samples as in Fig. 2), left ordinate number of individuals and biomass in g, right ordinate number of species.

2003, the lowest values of both variables were in plot 3 and the local maximums in plots 2 and 5. In addition, in 2003 the maximum values in the plot 5 enormously increased up to 3,768 individuals and 2.1 kg (Fig. 5). However, this increase was only due to *P. rufipes*, which was concentrated only in plot 5. On the contrary, in 2004 the maximum values were observed in plots 1 and 3, while in 2005 and 2006 the maximums shifted to plot 2.

A very illustrative picture gives spatial and temporal distribution of the eudominant *P. rufipes* in each trap, plot and year (Fig. 6). Out of the gradual concentration of most individuals in plot 5 and a general increase of number of individuals in all plots in 2003 and 2004, there is an obvious tendency to concentrations of individuals in plots 1 and 2 in 2005 and 2006, respectively, and simultaneously similar values in near traps or traps situates in similar position on the slope (traps 2 in 2005, traps 1 in 2006).

The plotting of pooled samples from each year and plot (Fig. 7) and of the crop yields (Fig. 8) shows that these values are completely independent and that the crop yield does not indicate the crops stand quality for ground beetles. Similarly the three-way ANOVA ($P > 0.05$) showed that the crop, year and fertilizer dose had not a significant effect on cumulative abundance of ground beetles in 120 one-year samples from each trap.

The increase of number of individuals and number of species in 2001 and 2003 and their culmination in 2003 are delayed one year after increased precipitation in summer 2002 and both, winter and summer average temperatures, in 2002 (Fig. 9). They obviously created more favorable conditions for development of populations of all species, not only in the study plots themselves, but also in a wider surrounding. In 2003 the summer precipitations, as well as the average winter and summer temperature, decreased and a strong drop of number of individuals and a moderate decrease of number of species followed. After an increase of average summer temperatures in 2005, a moderated increase of number of individuals followed, while number on species decreased slightly.

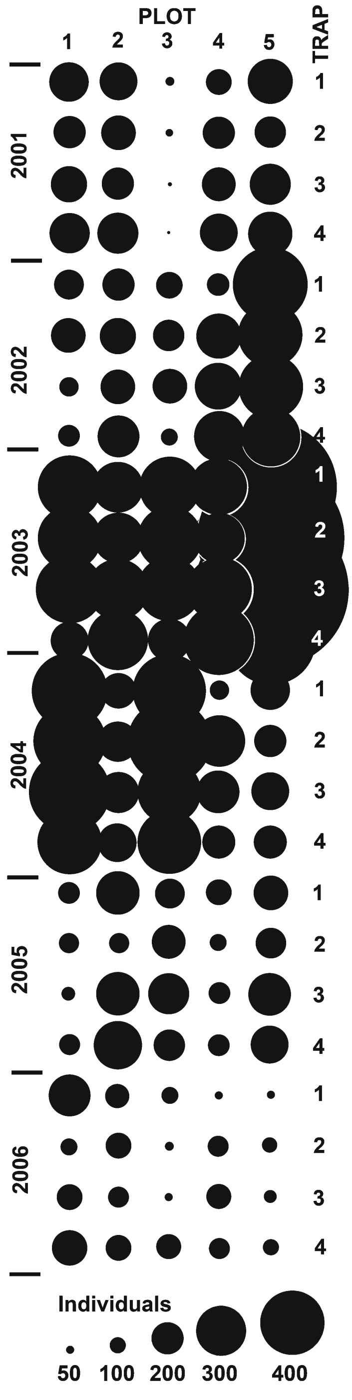

Fig. 6. Spatial and temporal distribution of the number of individuals of *P. rufipes* in each trap, plot and year.

Changes in diversity and equitability

The Shannon's index of diversity (Fig. 10) showed an opposite trend to the trend on number of individuals. Its values decreased from 2001 to 2003 and than they slightly increased up to the end of the investigation period. In all years the values of diversity of individuals and biomass were very similar, only in 2005 the diversity of biomass was much lower because of increased representation of *P. rufipes* and decrease of representation of *P. cupreus*, *C. fuscipes* and *C. scheidleri* (Table 2).

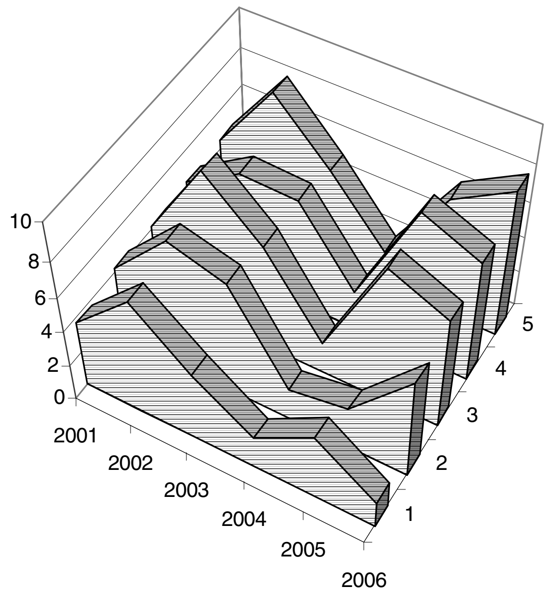

Fig. 7. Spatial and temporal distribution of cumulative abundance of ground beetles in each plot and year.

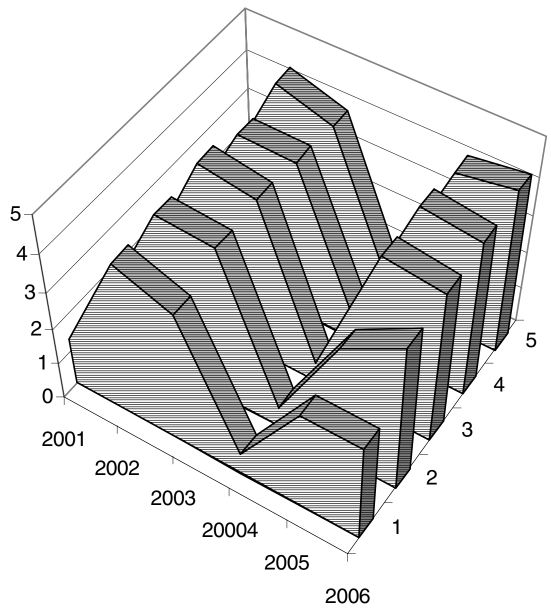

Fig. 8. Crop yield in each plot and year in t ha^{-1} (values expressed in natural logarithm).

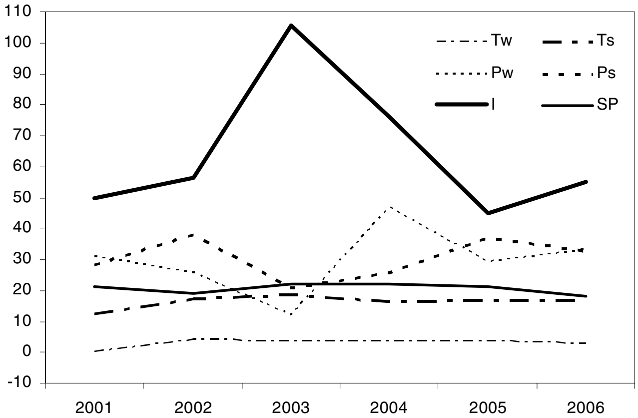

Fig. 9. Annual sums of ground beetle species and individuals (divided by 100) and average temperature [℃] in winter (Tw) and summer (Ts) months and precipitation sums (mm) in winter (Pw) and summer months (Ps) in 2001–2006.

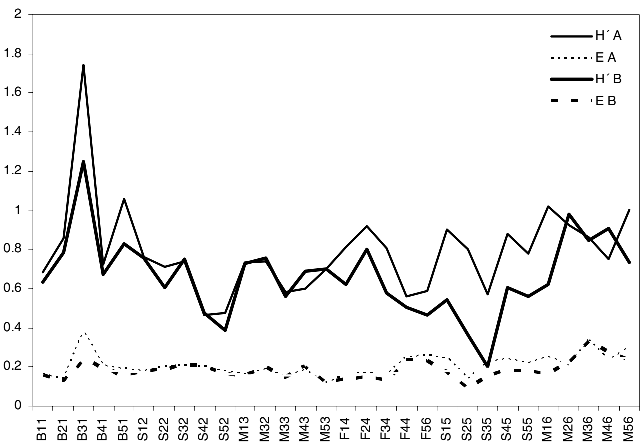

Fig. 10. Diversity H' and equitability (E) of one-year samples of ground beetles and of their biomass from each plot (encoding of samples as in Fig. 2).

Some of the above changes can be explained by occurrence of some, within the studied material, relatively rare, but ecologically specialized species. The low number of individuals in plot 5 in 2001 coincides with increased occurrence of the heliophilous species *Syntomus obscuguttatus, Bembidion lampros* and *Brachinus crepitans* indicating sparse places in the barley (see also above).

The values of Shannon-Weawer's index oscilating between 0.8–1.8 bits and equitability in range of 0.1–1 are typical, in European conditions, of ground beetle assemblages exposed to highest stress of anthropogenic factors.

Relation of assemblages to humidity and vegetation cover

The average humidity index of species (Fig. 11) fluctuated in individual plots and years between the values of 3.6–4.4, which are characteristic for moderately xerophilous to mezohygrophilous species, but did not show a clear trend. The values of humidity index weighted by number of individuals and biomass were strongly correlated and showed a very slight decline from the beginning of investigation to its end. If the values of humidity index weighted by number individuals are plotted against weighted values of vegetation preference index (Fig. 12), the samples from the first part of investigation period showed moderately higher portion of eurytopic and little more hygrophilous species, while those from two last year and increased proportion of expressively open landscapes and more xerophilous species. These changes may be a delayed effect of the decrease of precipitation in 2003 (Fig. 9), but also can reflect the microclimatic properties of interior of the sugar beet and maize growths in 2005–2006.

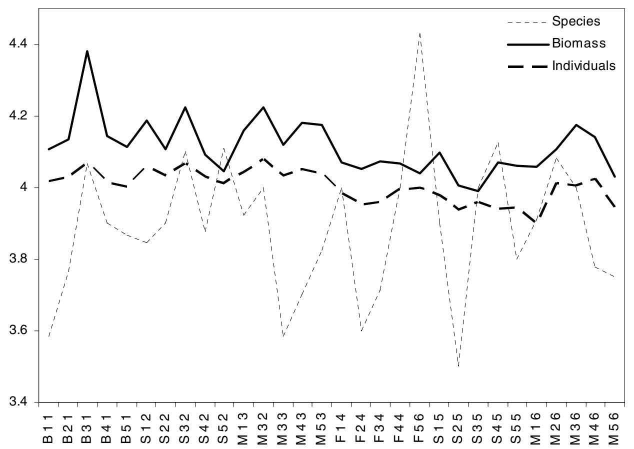

Fig. 11. Average humidity preference of ground beetle species and humidity preference weighted by abundance and biomass one-year samples from each plot (encoding of samples as in Fig. 2).

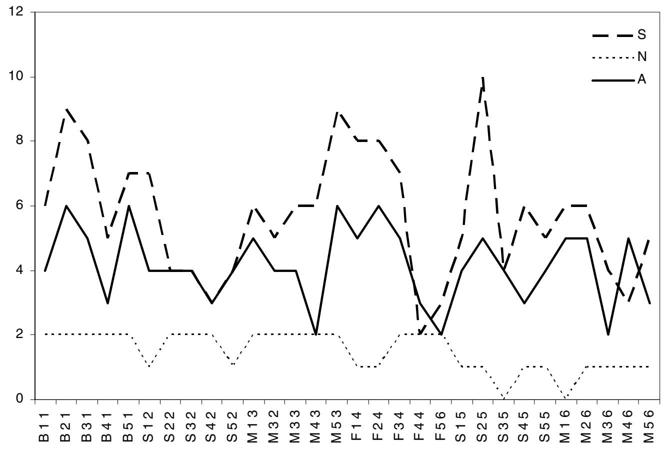

Fig. 14. Number of ground beetle species of spring, autumnal and indeterminate breeders in one-year samples from each plot (encoding of samples as in Fig. 2).

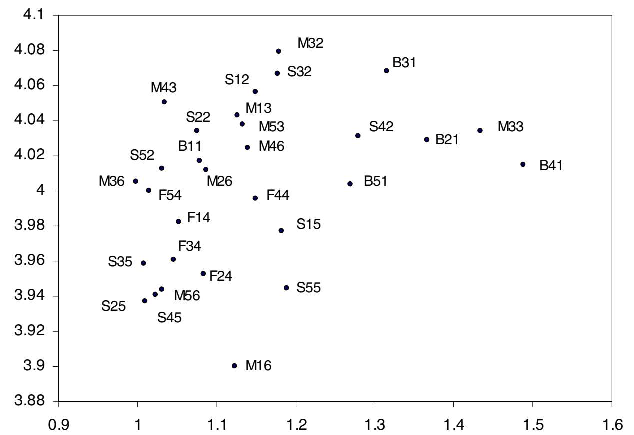

Fig. 12. Humidity and vegetation cover preference index weighted by ground beetle abundance of one-year samples from each plot (encoding of samples as in Fig. 2).

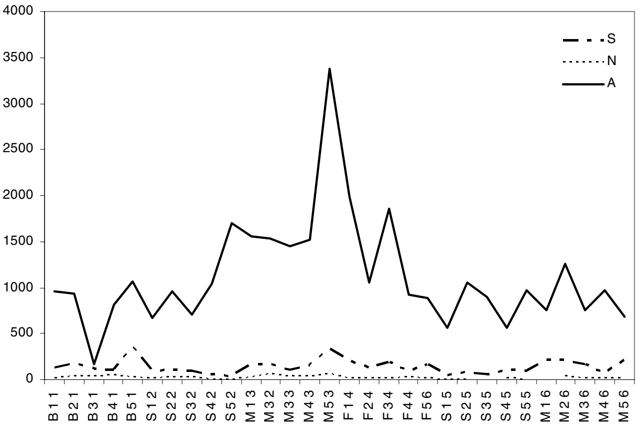

Fig. 13. Cumulative abundance of spring, autumnal and indeterminate breeders in one-year samples from each plot (encoding of samples as in Fig. 2).

Occurrence of species with different reproduction type

Traditionally three basic reproduction types are distinguished within the European ground beetles – spring breeders, autumn breeders and several species with indeterminate reproduction type (Burmeister 1939; Larsson 1939; Thiele 1977). The field crops, the cereals on one hand and maize, potato, sunflower and sugar beat on the other hand, represent more favorable conditions for one or either type of breeders.

Although the first crop in the investigation period was spring barley, which was altered in next years by crops remaining in the field up to late autumn, the cumulative abundance of spring breeders (especially *P. cupreus*) was low during all years (Fig. 13). There were only some indistinct peaks coinciding with the general increase of number of all individuals in 2003 (plot 5) and 2005 (plot 2) (Table 2). Number of autumnal breeders (mainly *P. rufipes*, *C. fuscipes* and *T. quadristriatus*, locally also *D. halensis*) was about 5–8 times higher in both first years of investigation. It strongly increased in 2003, in maize, and again decreased in next two years, with a slight increase in 2006. Number of species with indeterminate reproduction type, in fact *P. melanarius* and *Brachinus crepitans* only, was very low during the whole investigation.

Unlike cumulative abundance of both breeder groups, number of species of spring and autumn breeders was inverse almost during the whole investigation period (Fig. 14). It shows that the spring breeders were in the fields ecologically disfavored. There was, however, no clear difference between spring barley harvested at summer beginning and other crops present on the field until autumn.

Occurrence of species with different ability to fly

Cumulative abundance of non-flying species (Fig. 15) was lower than that of flying species during the whole investigation period, but the number of species of both groups it was moderately decreased due to the general slight decrease of species in 2005–2006 (see above). Number of non-flying species (Fig. 16) was very low, with several very indistinct peaks. Cumulative abundance of flying species was much higher during all six

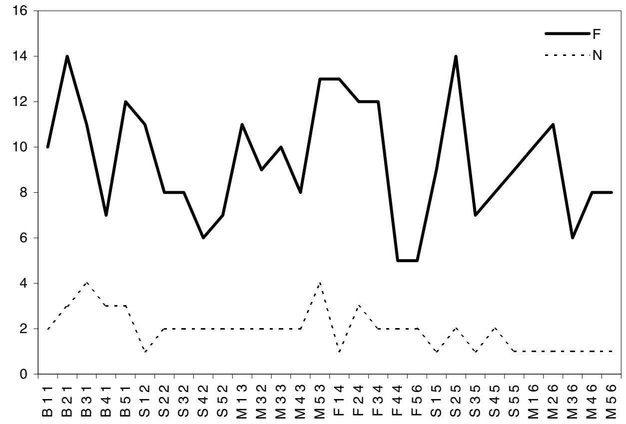

Fig. 15. Number of ground beetle species of flying and non-flying species in one-year samples from each plot (encoding of samples as in Fig. 2).

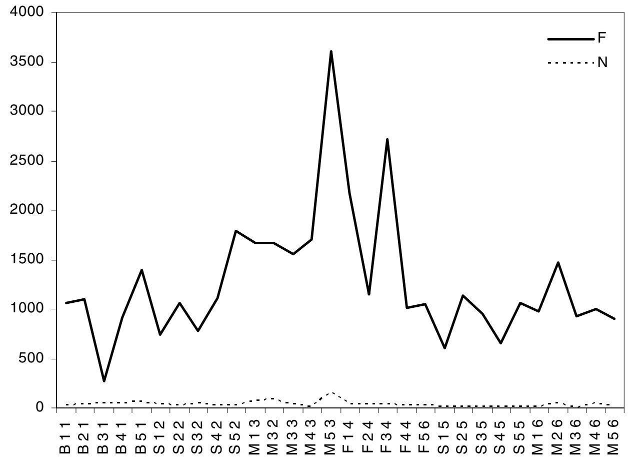

Fig. 16. Cumulative abundance of flying and non-flying ground beetle species in one-year samples from each plot (encoding of samples as in Fig. 2)

years and followed general trend of abundance of all species with a culmination in 2003–2004 (Fig. 5). The strong predominance of flying species is a result of large size of the present days fields in Central Europe, absence of sufficiently large uncultivated areas and large distances to nearest forests or isolated islands of woody vegetation. Ability to fly is an inevitable prerequisite to survive in the frequently disturbed ecosystem.

Discussion and conclusions

Organic fertilizing can be supposed to improve soil structure and increase vitality and density of the crop and to create more favorable microclimatic conditions for ground beetles. In this way it can influence their assemblages indirectly, as it is known that most field ground beetles avoid, in spite of the fact that they are open landscapes species, the open ground or patches with sparse vegetation (Skuhravý et al. 1971; Erichson 1978). In this study, however, differences in cumulative abundance of all species, particularly of the eudominant *P. rufipes*, and other ecological parameters showed that the organic fertilizing had just a partial effect only at a dose of 100 t ha^{-1} of manure. Just in this case a strong increase of number of individuals was observed according to expectations, but only in 2002 and 2003. The lower doses of biosludge or manure had no evident effect or, on the contrary, the dose of 50 t ha^{-1} of biosludge had even an inverse effect in 2001. In next years, cumulative abundance of ground beetles tended to concentrate rather in the unfertilized control plot or in plots with low dose of fertilizer. The observed insignificant effect of organic fertilizing on ground beetles is in accordance with results of Lővei et al. (2005), Rawoth et al. (2004). Similarly, Fadl et al. (1996) stated that effects of spring soil cultivation are rapidly masked by inter-filed migration of beetles. On the contrary Kromp (1990) stated that all ground beetle species preferred the biologically farmed field, except for *P. melanarius*, which preferred the conventionally farmed fields. Kabacyk-Wasylik (1986) found out that an excessive input of liquid manure even degraded the habitat causing increase of dominance of the highly tolerant and expansive *P. rufipes*, while other species disappeared. In accordance with Irmler (2003) the observed changes in ecological parameters of ground beetle assemblage can be taken rather as manifestation of yearly climatic conditions natural and log-term fluctuations.

The community structure and rank of individual species in the assemblage are in accordance with the generalized model of ground beetle assemblages in East European fields compiled by Lővei & Sárospataki (1990). The concrete data are also very similar with results of Petruška (1966, 1971, 1986, 1987, 1988) and in particular with those of Krejčová et al. (2000). In this sense, especially a relatively numerous representation of large predator *C. scheidleri*, they can be taken as an improvement of the body size structure in comparison with the state in different crops in South Slovakia in the 1980-ies (Šustek 1984, 1985, 1987, 1990, 1994a).

The insignificant results can be caused, out of the inter-field migration mentioned above, also by other circumstances. The field ground beetles, especially the autumnal breeders of the genera *Ophonus*, *Pseudoophonus* and *Harpalus*, undertake in July and August intensive night flights on remote distances (Kádár & Szentkirályi 1997; Šustek 1999). During them they can change their local population density in a place rapidly and enormously. If they land in an unsuitable place, they leave it in spite of light attraction within 2–3 hours. Similar waves of migration occur in *T. quadristriatus* in September(Šustek 1999, 2007). Their incidence is, however, irregular. The most intensive flights occur during the second night before or after passing of a cold front (Kádár & Szentkirályi 1997). Other circumstance is, according to Thacker & Jepson(1990), the fact that similar investigations are done on too small plots to may interpret the observed changes in population parameters unambiguously as impact of a studied farming practice. Šustek (1985, 1990, 1998) observed in small plot investigations on influence of input of organomineral substances (zeolit with Vitahum) on ground beetles that the population parameter depended rather on height of wheat stand following obviously a gradient in soil condition running cross the investigation plots. In experiments with herbicides he observed, by means of direction-oriented traps, even influence of intensive sampling and immigration of beetles from surrounding. For interpretation of similar investigations, the work of Hengenveld (1979) is of a great value. By a regular grid of 168 traps on a homogenous pasture, he showed enormous changes in spatial distribution of ground beetles within two months caused by moisture content in the soil connected with minute differences in ground surface altitude. The changes of abundance of *P. rufipes* in our study strongly resemble the patterns described by him. From the investigations of Petruška (1966) also follows that a rich catch in a trap can act as bait and can secondarily increase the catch size and considerably bias the results.

Based on the above facts it can be concluded that the studied doses of biosludge and stable manure had no effect on the ground beetle assemblages and the observed changes resulted primarily from climatic factors, secondarily from migration and long-termed population fluctuations of individual species or their competition. Principally the community returned after six years to the starting state, but with certain decline of number of species which, however, is not to be taken as permanent.

The great similarity with analogous fields in Central Moravia show that the observed state of the community represents a stable result of selection pressure and adaptive changes running in the ground beetle assemblages in a wide supraregional scale and their moderate improvement in comparison with the state from 1980-ies.

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