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Dominance, activity density and prey preferences of rove beetles (*Coleoptera*: *Staphylinidae*) in conventionally treated Hungarian agro-ecosystems

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Abstract

Field experiments were conducted to investigate the mechanism underlying patterns of the rove beetle populations in apple and pear orchards (1998–2002) and winter wheat (2006–2007) in Hungary following treatment with broad-spectrum insecticide. The capacity of predatory staphylinid species to feed on cereal pests was measured, with six species tested in petri dishes, in the laboratory at room temperature. Almost 23% of the Hungarian and 13% of the European staphylinid fauna are represented in the investigated agro-ecosystems. In orchards, 5236 individuals, belonging to 253 species, were collected. The most widely occurring were *Omalium caesum* Gravenhorst, *Drusilla canaliculata* (F.), *Dinaraea angustula* (Gyllenhal), *Palporus nitidulus* (F.), *Xantholinus. longiventris* (Olivier), *X. linearis* (Olivier) and *Aleochara bipustulata* (L.). In winter wheat, 798 individuals and 20 species were collected, the most frequent were *Staphylinus caesareus* Cederh, *Tachyporus hypnorum* (F.), *Philonthus cognatus* (Stephens), *Aloconota gregaria* (Erichson), *Tachyporus chrysomelinus* (L.) and *T. obtusus* (L.). Species composition differed by crop (apple, pear and wheat), soil composition and surrounding habitat. Species diversity was also influenced by these parameters. In wheat, one acute change in species composition was observed with the decline of *Tachyporus* spp., which occurred equally across all farms. The consumption rate of prey by the dominant species occurring in wheat ecosystems was relatively high; however, we did not offer any fungal food to compare with insects' prey.

Keywords: hedgerows, orchards, soil structure, surrounding habitat, wheat

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Introduction

Altogether, many authors have studied the staphyilinid fauna (Galli, 1985; Reede, 1985; Dennis *et al*., 1990, 1991; Majzlan & Holecová, 1993; Wardle *et al*., 1993; Heyer, 1994; Knopp, 1997; Krooss & Schaefer, 1998; Andersen, 1991, 2000; Perner & Malt, 2002) but their community structure in conventionally treated agro-ecosystems are still

Table 1. Geographical localization and characteristics of the investigated orchards.

Farms	1	2	3	4	5	6		7		8	
UTM	46°6′ N, 16°6′ E	48° N, 18°52′ E	46°3′ N, 17°6′ E	47°2′ N, 17°5′ E	47°5′ N, 21°3′ E	48°12′ N, 21°4′ E		47°36′ N, 19°36′ E		47°16′ N, 18°6′ E	
Plantation	apple	apple	apple	apple	apple	apple	pear	apple	pear	apple	pear
Soil	clay	clay	clay	sand	sand	clay	clay	sand	sand	sand	sand
Environ.	WAM	WAM	ALE	WAM	ALE	ALE	ALE	ALE	ALE	RFA	RFA

WAM, woodland area of medium height mountains; ALE, agricultural lowland environment; RFA, regularly flooded area.

little known. From Europe, Andersen (1991) presented a list of staphylinid beetles occurring in spring barley, cabbage, carrot, potato, strawberries and grassland fields in Norway. The author found 103,000 specimens belonging to 226 species. The most frequent were: *Aloconota gregaria* (Erichson), *Anotylus rugosus* (F.), *Athena fungi* (Gravenhorst), *Amischa analis* (Gravenhorst), *Tachinus signatus* (Gravenhorst) and *Philonthus cognatus* (Stephens). From Canada Levesque and Levesque (1995, 1996) presented a species list occurring in raspberry plantations. The authors presented 81 species and 16,074 specimens (without species of the *Aleocharinae* subfamily). The most abundant species were *Gyrohypnus angustatus* Stephens and *Tachinus corticinus* Gravenhorst. Staphylinid beetles reported from conventionally treated cereal ecosystems in Europe are frequent (Dennis *et al*., 1990, 1991; Krooss & Schaefer, 1998; Andersen, 2000; Perner & Malt, 2002). In wheat, the most abundant species were *Philonthus cognatus* (Stephens), *Tachyporus hypnorum* (F.), *T. chrysomelinus* (L.), *T. obtusus* (L.) and *Stenus biguttatus* (L.). For the past 20 years, the Game Conservancy has monitored abundances of cereal invertebrates in over 100 fields in Sussex, UK. The total number of invertebrates (excluding *Acari*, *Collembola* and *Thysanoptera*) recorded per sample has dropped by almost half in the course of the study, corresponding to a quarter of what was present in pre-pesticide times. This overall change was the result of widespread decline in *Araneae*, *Lepidoptera*, *Aphididae* (*Hemiptera*), *Symphyta* (*Hymenoptera*), *Staphylinidae*, *Cryptophagidae*, *Lathridiidae* and *Lonchopteridae* (*Diptera*); these groups constituted 72%, on average, of the total by number (Aebischer & Potts, 1990). Hedgerows act as a corridor of movement and dispersal for many forest species, such as carabids, staphylinids or even small mammals (Burel, 1996). Crop field surroundings influence the abundance of pests in several ways. The climatic conditions created by the presence of a forest edge or a hedgerow, for example, gives opportunities for several species to reproduce, especially those that benefit from high humidity and low wind speed. Some insect species also benefit from their winter host being present along hedgerows, such as *Rhopalosiphum padi* (L.) (Ravn & Holm, 1997; Magura & Tóthmérész, 1997; Magura *et al*., 1997).

The functional role of rove beetles in agro-ecosystems, the response to prey spatial heterogeneity, the aggregation and the aphid and mildew preferences were studied by other authors (Bryan & Wratten, 1984; Sunderland *et al*., 1987; Dennis *et al*., 1991; Good & Giller, 1991). Bryan & Wratten (1984) demonstrated that several species of rove beetles aggregated in patches of aphids and presented a positive numerical response to high aphid densities. Under laboratory conditions, aphid predation was 1 mg day^{-1} for many of the staphylinid species, which is more than 34% of the body weight. In gut-dissection work carried out by Sunderland *et al*. (1987), three categories of food, other than aphids, were identified in the diet of the *Tachyporus* spp.: non-aphid arthropods, rust and non rust fungi. Dennis *et al*. (1991) showed that these species have a positive numerical response to high density of rusts and non-rust fungi, while aphid predation decreased significantly at the same time. Other species, such as *Philonthus* spp., fed only with arthropods, their aphid predation was on average 20 aphid specimens day^{-1}, and there is no record of mycophagy (Good & Giller, 1991).

As part of a greater project (Apple Ecosystem Research), faunistic studies have been carried out since 1976 to describe the species composition of arthropod assemblages in conventionally treated apple orchards in Hungary. Mészáros *et al*. (1984) examined apple orchards in five localities; Markó *et al*. (1995) investigated the *Coleoptera* communities in apple and pear orchards in three localities, while Bogya *et al*. (1999) present data about species composition of apple and pear orchard inhabiting Araneae. Altogether, more than 2000 arthropod species were recorded; there is still little known about the staphylinid beetles in apple and pear orchards; and there are no records about the staphylinids occurring in conventionally treated winter wheat (Kutasi *et al*., 2001; Balog *et al*., 2003).

In this study, our aim was to make a thorough survey of species composition of staphylinid fauna occurring in economically important agricultural fields in Hungary.

Materials and methods

Characterization of the investigated ecosystems and sampling procedures

Investigations in orchards took place over five years (1998–2002) in 11 plantations situated in eight farms. Five farms consisted of one apple orchard each, while three consisted of one apple and one pear orchard (table 1). The investigated farms were in three geographical regions with different environmental conditions. These were agricultural lowland environments (ALE), regularly flooded areas (RFA) and woodland area of medium height mountains (WAM). Four farms were located on sand and four on clay (table 1). Plantations were treated with organophosphate insecticides during the study period. These were applied on average ten times each year.

Studies in wheat were performed in 2006 and 2007 in four conventionally farmed plots (10 ha each) all surrounded by hedgerows of different sizes. The soil structure was sandy-loam and the treatments consisted of foliar fungicides during

Table 2. Geographical localization and characteristics of the investigated winter wheat farms.

Farms	A1	A2	B1	B2
UTM	47°33′ N, 21°33′ E	47°33′ N, 21°34′ E	47°34′ N, 21°33′ E	47°31′ N, 21°32′ E
Hedgerows	20 m	20 m	40 m	40 m
Soil	sandy-loam	sandy-loam	sandy-loam	sandy-loam
Environment	ALE	ALE	ALE	ALE

A1 & A2, Farms surrounded by 20-m-wide hedgerows; B1 & B2, Farms surrounded by 40-m-wide hedgerows.

the vegetation period. The crop rotation was with sugar-pea (table 2).

Ten covered pitfall traps (300 cm^3 in size, 8 cm in diameter, half-filled with ethylene glycol 30% solution) were placed from the field margins towards the field centre at 10 m intervals within each orchard. Five traps were placed in the middle of the plantation and five in the inner edges. In wheat, 14 traps were used in two replicates for each farm. The first trap was placed in the middle of the hedge, the second at the field margin, while the others towards the field centre at 5 m intervals. Pitfall traps are considered a useful method to study community assemblages of epigeal arthropods (Luff & Eyre, 1988). Samples were collected fortnightly from April until October in orchards and from April until August in wheat. All staphylinids, even species from *Aleocharinae*, were sorted and identified up to species level. Species identification was based on the works of Freude *et al*. (1964, 1974), Tóth (1982, 1984) and Zerche (1996a,b).

Laboratory studies of prey preferences

Under laboratory conditions at room temperature, the prey preferences of the dominant species in wheat were studied. In the first experiment, five living individuals of each species (*Aloconota gregaria*, *Philonthus cognatus*, *Tachyporus hypnorum*, *T. chrysomelinus* and *T. obtusus*) were placed in 90 mm diameter petri dishes and each was offered 20 adult individuals of *Ropalosiphum padi* every day for a week. In a second experiment, five individuals of species *Staphylinnus caesareus* and *T. hypnorum* were used and each was offered five types of prey daily (eggs of *Lema melanopus* L., larvae of *Apomyza* sp., and *Phorbia secures* Tiensuu, and adults of *Haplothryps* sp. and *Sitobion avenae* (F.)) in four exemplars. The partially and/or fully consumed individuals for both experiments, two replications each, were counted and the $\log_{10}$ transformed prey numbers were computed.

Data analyses

The most common species in orchards were determined by investigating their relative abundance and distribution in the cumulative sample and comparing their position in the dominance order in each of the investigated orchards (sum of the rank scores). The most abundant species in each orchard got a rank score of '7', the following species got a rank score of '6', etc. The seventh species in the dominance order got a rank score of '1' and the species with lower abundance than that got a score of '0' (Balog *et al*., 2003). The percentage of species in different fruit, soil and environment were also considered. The Jaccard similarity and diversity between the species collected in different plantations, soil compositions and surrounding habitats were computed. The Jaccard's coefficient is used to compare the species composition of two communities using binary dates and registered only the presence and the absence of the species (Pielou, 1984). The log series Fisher's alpha (ά) index was used as a measure of biodiversity (Krebs, 1989). The alpha diversity index is considered to be superior to commonly used indices because the sensitivity to sample size is low and it uses high discriminate ability (Tóthmérész, 1995; Shah *et al*., 2003). The analyses of variance (ANOVA) were performed and similarities were compared with O'Brien and Levene tests to compare the activity density of rove beetles and ground beetles in wheat, and the prey preferences of dominant species under laboratory conditions. Back-transformed means and $P < 99\%$ confidence limits were considered as statistically significant differences (Tóthmérész, 1995). The following standardizations were used for the test: different fruit species were used as replicate dates from orchards 6, 7 and 8 (apple and pear); soil compositions were used as replicate orchards from farm 3 and 6 (apple) for clay, 7 and 8 (apple) for sand; environmental conditions from farms 3 and 6 were compared with farms 1 and 2, all situated on clay; the apple orchard from farm 4 was compared with apple orchards from farm 7 and 8 all on sandy soil.

Results

Dominance in orchards

Altogether, 5236 individuals were collected belonging to 253 species and 11 subfamilies. Almost 23% of the Hungarian and 13% of the European staphylinid fauna were represented in the orchards. The compositions of the dominant species were similar in all of the orchards; however, species with relative abundance of less than 2% differed from apple to pear. In eight apple orchards, 3859 specimens, belonging to 191 species, were captured; while in three pear orchards, 121 species and 1377 specimens were collected.

Considering different plantations (apple and pear) from the same localities (loc. 6, 7 and 8), the Jaccard similarity was 51.7%. Under different soil compositions, the number of species recorded in sand was 203 species represented by 2724 specimens; while, in clay, it was 146 species with a total number of 2512 specimens, and the similarity was 39.4%.

For species composition in different surrounding habitats, we observed that, in woodland areas of medium height mountains (WAM), there were 141 species and 2340 specimens collected; in agriculture lowland environments (ALE), there were 156 species and 2191 specimens collected; while, in regularly flooded areas (RFA), there were 90 species and 705 specimens collected. The similarities were 22.5% between ALE and RFA, 23.9% between ALE and WAM, and 28.8% between RFA and WAM.

Table 3. Number of species, individuals and diversity of rove beetles fauna in Hungarian agro-ecosystems.

	apple	pear	clay	sand	ALE	RFA	WAM	wheat $A_{1,2}$	wheat $B_{1,2}$
Species	191	121	146	203	156	90	141	13	18
Individuals	3859	1357	2512	2724	2191	705	2340	288	510
Fisher ά	1.18	1.45	1.29	1.23	1.24	1.63	1.35	1.03	1.59

$A_{1,2}$, Cumulative samples from farms surrounded by 20-m-wide hedgerows; $B_{1,2}$, Cumulative samples from farms surrounded by 40-m-wide hedgerows.

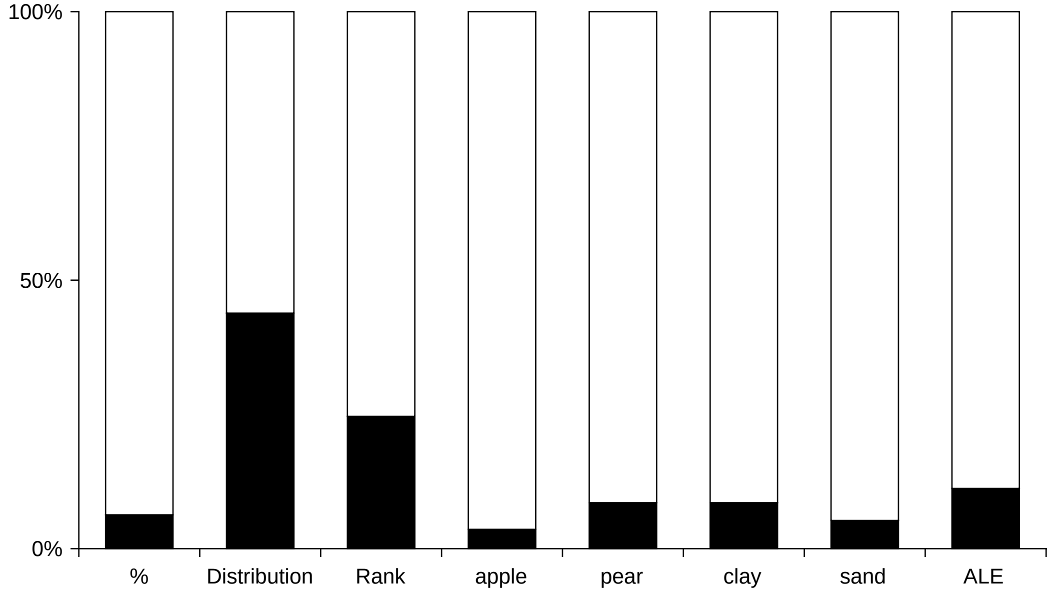

Fig. 1. The relative abundance, distribution by orchards, total rank score and percentage in different fruit, soil and environment of *Omalium caesum* in Hungarian agro-ecosystems.

After cumulative assay studies of the communities, we identified the most widely occurring species in conventionally treated agro-ecosystems from Hungary. In orchards, seven species presented a relative abundance of 40%. In dominant order, these were *Omalium caesum* Gravenhorst, *Drusilla canaliculata* (F.), *Dinaraea angustula* (Gyllenhal), *Palporus nitidulus* (F.), *Xantholinus longiventris* (Olivier), *Xantholinus linearis* (Olivier) and *Aleochara bipustulata* (L.).

For different tree species (apple and pear from farms 6, 7 and 8), the ά diversity was lower for apple and higher for pear orchards but the differences were not statistically significant ($F = 1.54$; $P < 0.68$). The ά diversity was also higher on clay and lower on sand, the difference being not significant ($F = 1.35$; $P < 0.59$). The pooled value of ά diversity was high for RFA and low for ALE with statistically significant differences ($F_{\mathrm{RFA,\,WAM}} = 54.84$; $P < 0.01$; $F_{\mathrm{RFA,\,ALE}} = 49.82$; $P < 0.01$) (table 3).

Dominance in wheat

In wheat, a total number of 798 individuals belonging to 20 species of rove beetles were collected. The width of the hedgerows surrounding the farms affected the number of species and individuals representing them. In farms surrounded by 20-m-wide hedgerows, 288 individuals and 13 species were recorded; while, in farms surrounded by 40-m-wide hedgerows, 510 individuals and 18 species were recorded.

Six species were dominant with a relative abundance of 65%. These were *Staphylinus caesareus* Cederh, *Tachyporus hypnorum* (F.), *Philonthus cognatus* (Stephens), *Aloconota gregaria* (Erichson), *Tachyporus chrysomelinus* (L.) and *T. obtusus* (L.). Although species from *Tachyporus* spp. were dominant in cumulative samples, the activity density decreased considerably for the second half of the vegetation period. Species with bigger body size (*S. caesareus* and *P. cognatus*) preferred hedgerows, while small species (*A. gregaria* and *Tachyporus* spp.) were frequent in wheat. The pooled value of ά diversity was higher for farms surrounded by 40-m-wide hedgerows and differed significantly from farms with 20-m-wide hedgerows ($F = 6.05$; $P < 0.001$) (table 3).

Activity density in orchards

Omalium caesum was common in many of the orchards, and its relative abundance in the total sample was high. The distribution and the sum of the rank scores for this species were also high. Its activity density was higher in pear than in apple and also in orchards on clay in ALE (fig. 1). Similarly, *Drusilla canaliculata* was common in conventionally treated apple orchards. It was dominant and its distribution and total rank scores were high. Its activity density was higher

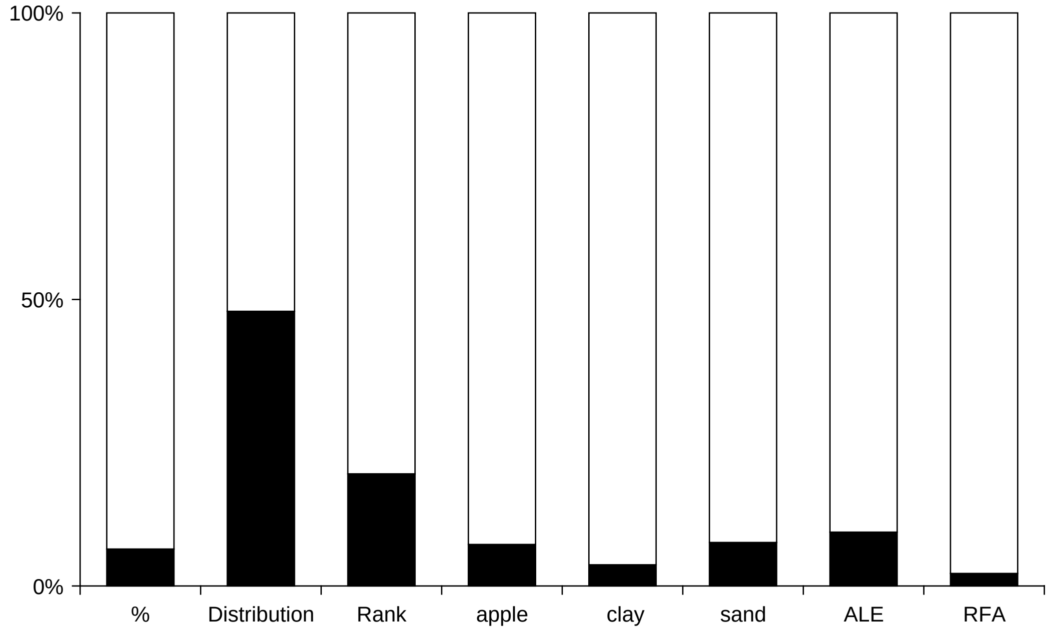

Fig. 2. The relative abundance, distribution by orchards, total rank score and percentage in different fruit, soil and environment of *Drusilla canaliculata* in Hungarian agro-ecosystems.

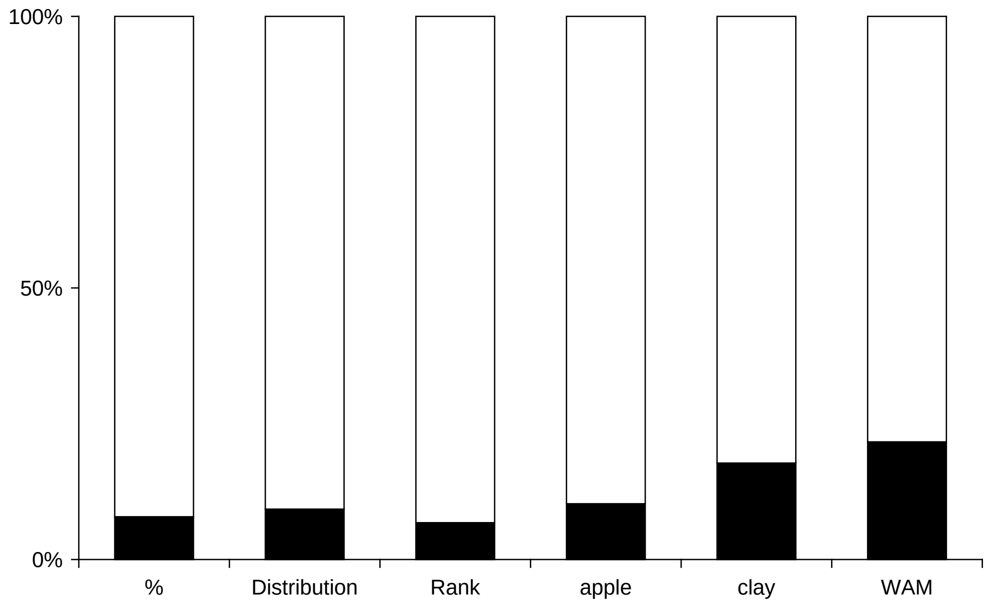

Fig. 3. The relative abundance, distribution by orchards, total rank score and percentage in different fruit, soil and environment of *Dinaraea angustula* in Hungarian agro-ecosystems.

in apple and in sand in ALE. It can also be found in RFA in relatively low numbers (fig. 2). *Dinaraea angustula* was present in high numbers in only one commercial apple orchard situated on clay in WAM. Its high number can be explained by irrigation in this orchard. In the cumulative samples, it was dominant, but its distribution was narrow, and its total rank score was, therefore, low (fig. 3). Pitfall trap catches of *Palporus nitidulus* were high in apple and pear orchards in RFA and in WAM. The species occurred in all of the investigated orchards situated on sand with a high rank sum (fig. 4). *Xantholinus longiventris* was dominant in pear orchards situated on sand in RFA and occurred in the whole period of vegetation with wide distribution but low rank sum (fig. 5). The greatest number of *Xantholinus linearis* occurred in apple orchards on sand in ALE with a relatively high distribution and a medium rank sum (fig. 6). The parasitoid species, *Aleochara bipustulata*, distribution by orchards was high with a relatively low rank sum. It was

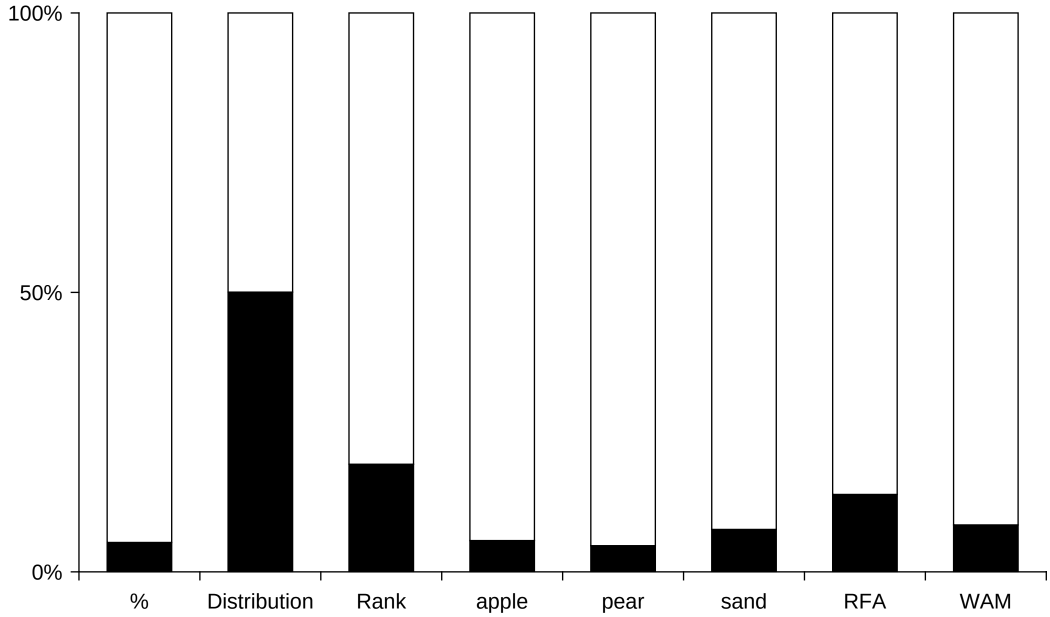

Fig. 4. The relative abundance, distribution by orchards, total rank score and percentage in different fruit, soil and environment of *Palporus nitidulus* in Hungarian agro-ecosystems.

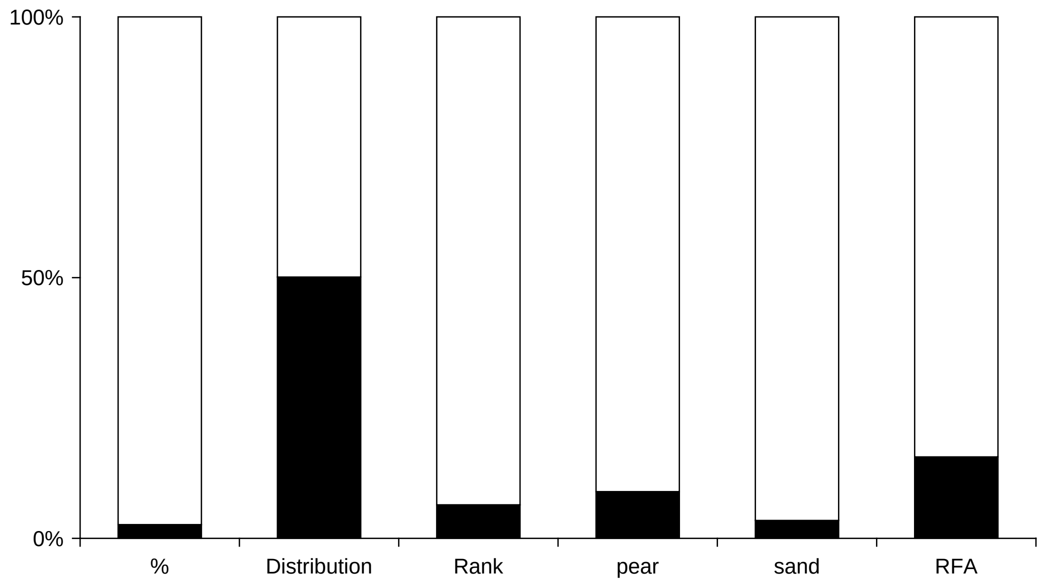

Fig. 5. The relative abundance, distribution by orchards, total rank score and percentage in different fruit, soil and environment of *Xantholinus longiventris* in Hungarian agro-ecosystems.

captured for the duration of the vegetation period in apple orchards on sand in WAM (fig. 7).

Activity density in wheat

In wheat surrounded by 20-m-wide hedges, the activity density of rove beetles was significantly lower compared with ground beetles ($F = 10.22$; $P < 0.01$). For both groups, the activity density was high in wheat with a 40-m-wide hedges (fig. 8). Comparing the two groups, the activity density was higher for rove beetles towards 5 m, while from 10 m toward the centre of the field, ground beetles presented higher activity. The difference was significant only at 10 m intervals ($F = 2.02$; $P < 0.01$) (fig. 9).

Prey preferences

The acceptance of *R. padi* by rove beetles was high and almost all individuals of prey were partially or totally consumed in 24 h. Comparing different species, a significantly higher number ($F = 5.2$; $P < 0.01$) were consumed by *A. gregaria* and *P. cognatus*. Between *Tachyporinae*, the highest

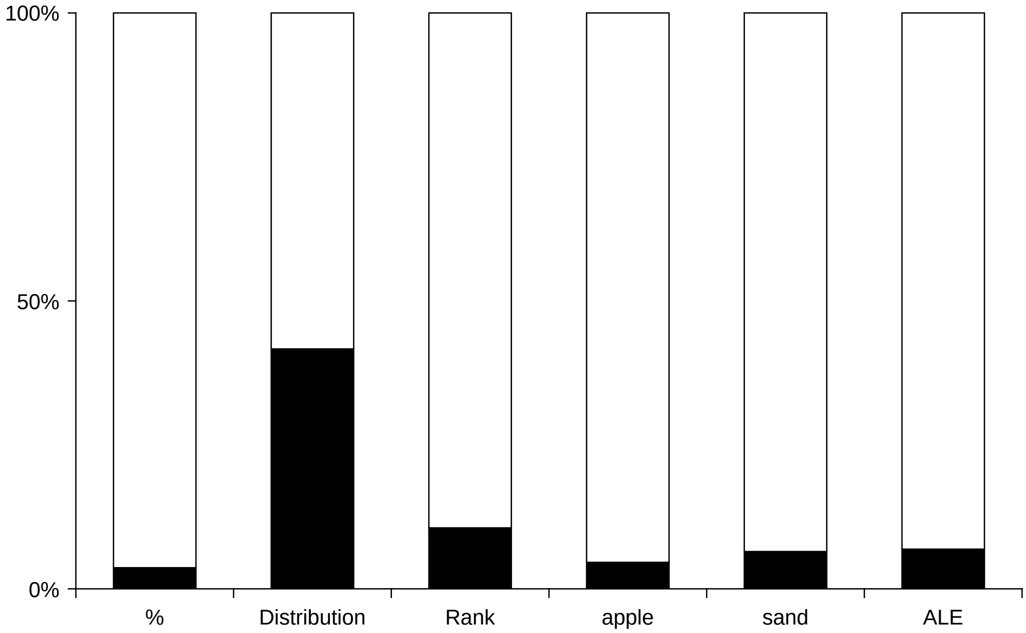

Fig. 6. The relative abundance, distribution by orchards, total rank score and percentage in different fruit, soil and environment of *Xantholinus linearis* in Hungarian agro-ecosystems.

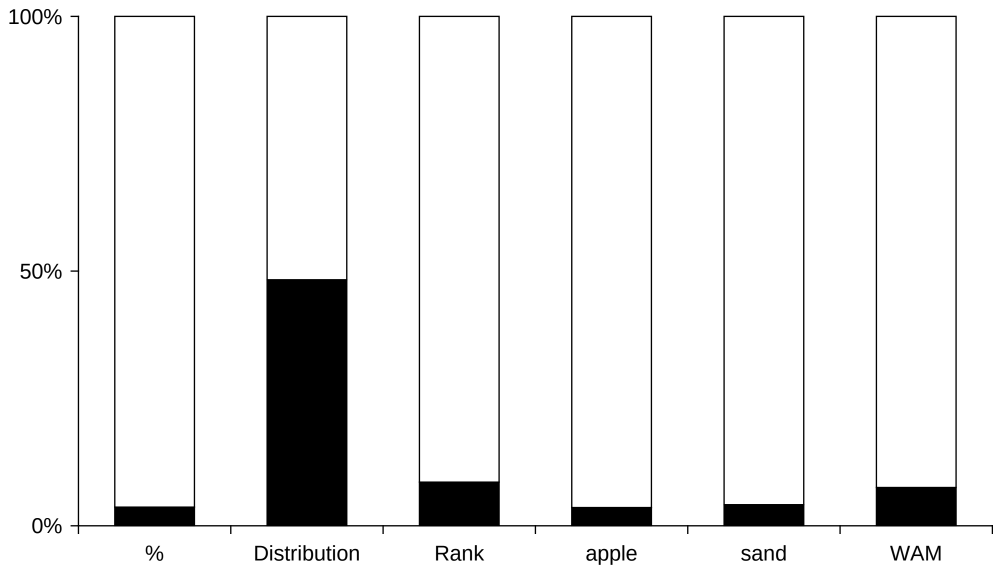

Fig. 7. The relative abundance, distribution by orchards, total rank score and percentage in different fruit, soil and environment of *Aleochara bipustulata* in Hungarian agro-ecosystems.

prey preference was observed for *T. hypnorum* and the least for *T. obtusus* (fig. 10). For different prey species, the consumption rate of eggs (*L. melanopus*) and adults (*Haplothryps* sp. and *S. avenae*) was high for *S. caesareus*, but the consumption of larvae (*Apomyza* sp. and *Phorbia secures*) was not observed. For *T. hypnorus*, the consumption rate of eggs (*L. melanopus*) and adults (*S. avenae*) was significantly higher ($F=4.7$; $P<0.01$) than the consumption of larvae (*Apomyza* sp. and *P. securis*); while, for adults, feeding on *Haplothryps* sp. was not observed (fig. 11).

Discussion

We identified the most common and perhaps functionally important species in conventionally treated Hungarian agro-ecosystems. Most of the species mentioned in this study have been recorded as frequent in agricultural fields by other authors throughout western Europe (Galli, 1985; Reede, 1985; Dennis *et al*., 1990, 1991; Majzlan & Holecová, 1993; Wardle *et al*., 1993; Heyer, 1994; Knopp, 1997; Krooss & Schaefer, 1998; Andersen, 2000; Perner & Malt, 2002).

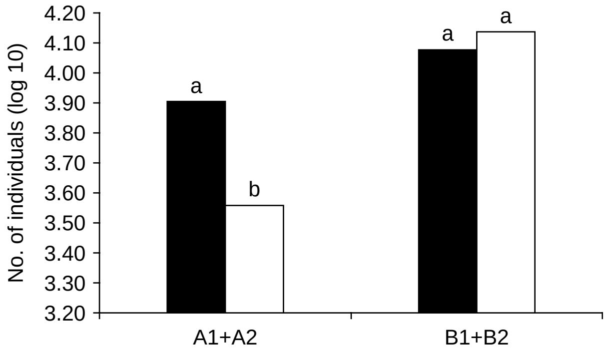

Fig. 8. The activity density of ground and rove beetles in winter wheat with different size of hedgerows. A1 + A2, cumulative data of farms surrounded by 20-m-wide hedgerows; B1 + B2, cumulative data of farms surrounded by 40-m-wide hedgerows; different letters: $P < 0.01$ (■, Carabidae; □, Staphylinidae).

We can conclude that the structure of the orchards (defined as the fruit species, the soil compositions and the surrounding habitats) promote the staphylinid fauna in different ways, and all these factors regulate populations. The species composition differed by crop (apple, pear and wheat), soil composition and surrounding habitat. Species diversity is also influenced by these parameters. In wheat, one acute change in species composition was observed during the vegetation period with the decline of *Tachyporus* spp. occurring equally across all farms. A possible cause was a drop in the availability of fungal food, as the level of mildew and rusts infecting crops dropped in line with the increasing use of foliar fungicides (Aebischer & Potts, 1990). As these species have a positive numerical response to the high density of rust and non-rust fungi, the main population regulatory factor in winter wheat is the fungal food density. The high activity density of *S. caesareus* can certainly be explained with hedgerows, offering similar microclimates as forests.

The dominance and activity density of the staphylinid species in conventionally treated apple and pear orchards are presented for the first time in Hungarian agro-ecosystems. These results can be generalized for the whole central European region. After the cumulative assay studies of the population, we can conclude that the most frequent and functionally important species in conventionally treated apple and pear orchards on clay surrounded by ALE may be *Omalium caesum* and *Drusilla canaliculata*. In irrigated orchards on clay surrounded by WAM, *Dimaraea angustula* may have this functional role. In orchards situated on sand surrounded by ALE, species *O. caesum*, *D. canaliculata* and *Xantholinus linearis* are frequent; while, in WAM, the parasitoid species *Aleochara bipustulata* can play an important role in *Delia* spp. pest control. *Palporus nitidulus* presented high activity density in apple and pear orchards on sand surrounded by WAM and RFA, while *Xantholinus longiventris* preferred pear orchards on sand surrounded only by RFA.

The consumption rate of prey by the dominant species occurring in conventionally treated winter wheat was relatively high; however, we did not offer any fungal food to compare with insect prey, as mentioned by other authors (Dennis *et al*., 1990). The preferences of *R. padi* were significantly higher for *Aloconota gregaria* and *Philonthus cognatus* compared with *Tachyporus* spp. This can be explained with high fungal preferences of *Tachyporus* spp., which means that the offered prey was not its essential food. The prey preferences differed between the two dominant species in wheat (*S. caesareus* and *T. hypnorus*). This led us to think that they had not met the prey before; and, over a longer period of time, they could learn to eat the unknown insects. Because these species are generalist predators, their response to prey density and diversity can be described as Type III functional response (Holling, 1966). The functional response can determine if a predator is able to regulate the

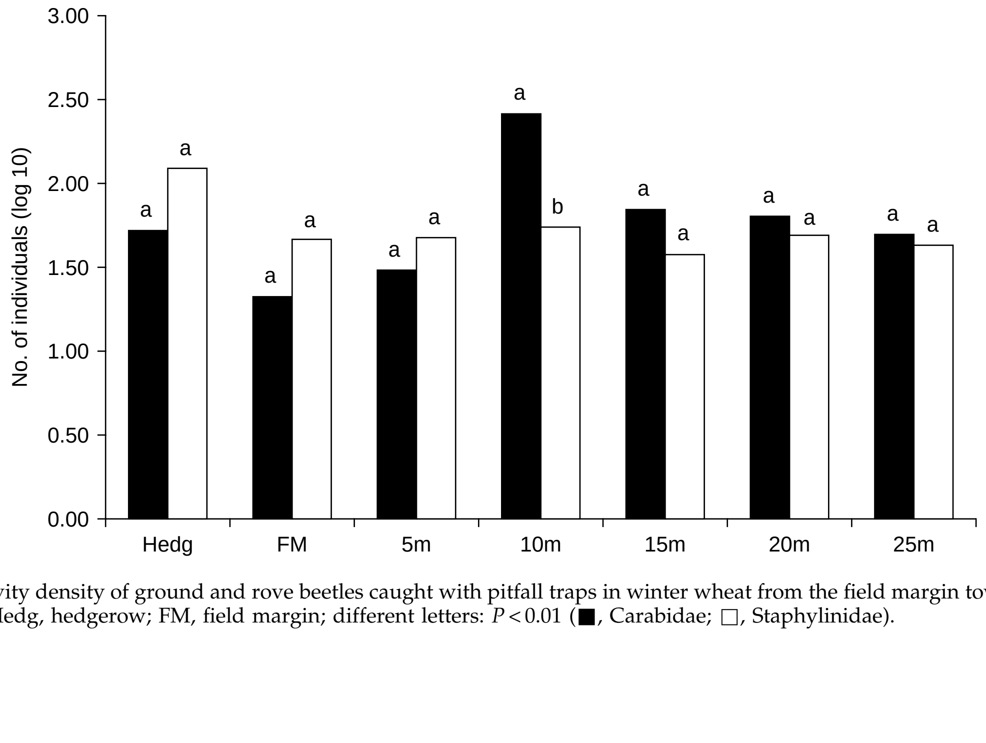

Fig. 9. The activity density of ground and rove beetles caught with pitfall traps in winter wheat from the field margin toward interior at 5 m intervals. Hedg, hedgerow; FM, field margin; different letters: $P < 0.01$ (■, Carabidae; □, Staphylinidae).

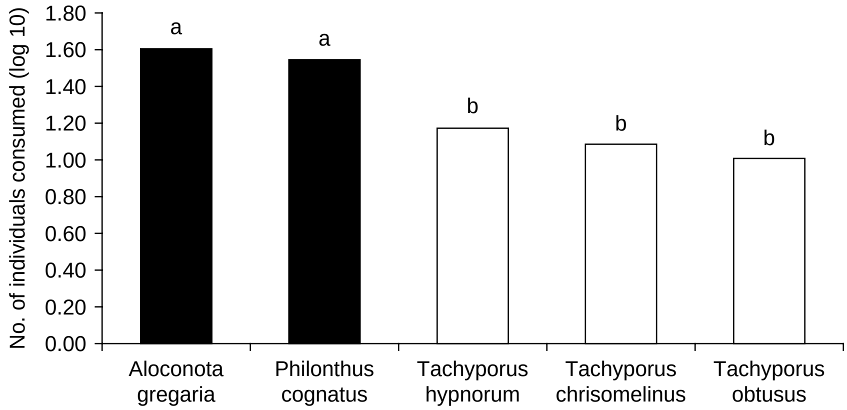

Fig. 10. The consumption rate under laboratory conditions of *Ropalosiphum padi* adult by dominant rove beetles in wheat. Different letters: $P < 0.01$.

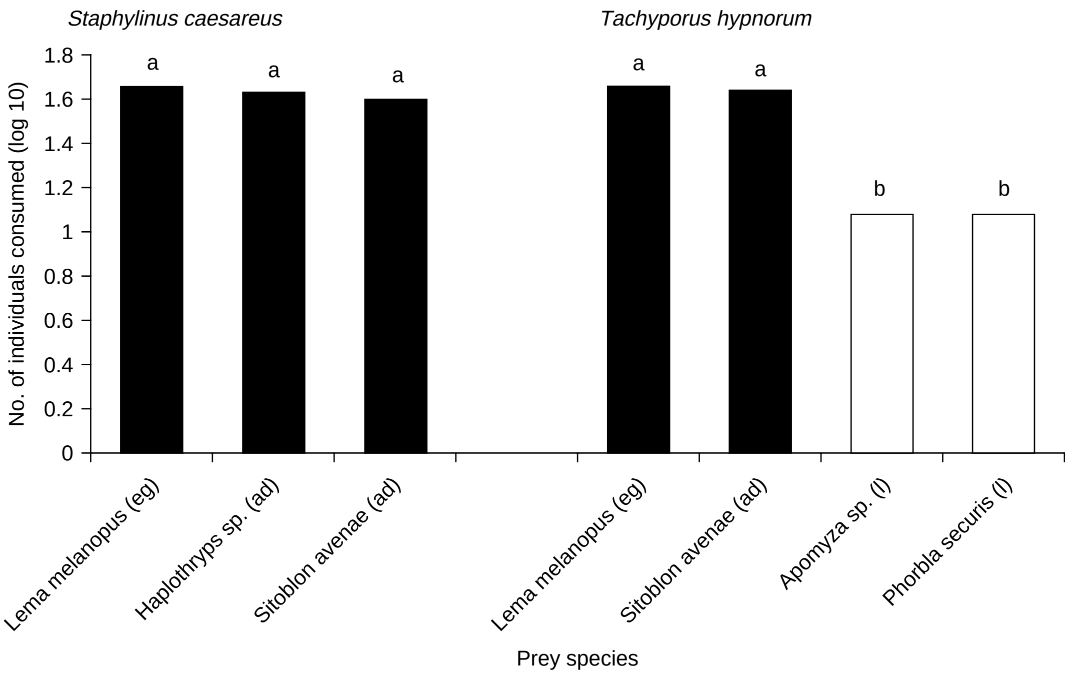

Fig. 11. The most widely consumed prey species under laboratory conditions by rove beetles *Staphylinus caesareus* and *Tachyporus hypnorum*. Different letters: $P < 0.01$.

density of its prey, described also by other authors (Schenk & Bacher, 2002).

Further research is needed to compare the community structure in plantations with different husbandry techniques and the prey preferences in field of staphylinids.

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References

Aebischer, N.J. & Potts, G.R. (1990) Long-term changes in numbers of cereal invertebrates assessed by monitoring. *Pests and Diseases* **1**, 163–172.

Andersen, A. (1991) Carabidae and Staphylinidae (Col.) frequently found in Norwegian agricultural fields. New data and review. *Fauna Norvegica Seria B* **38**, 65–76.

Andersen, A. (2000) Long term developments in the Carabid and Staphylinid (Col. Carabidae and Staphylinidae) fauna during the conversion from conventional to biological farming. *Journal of Applied Entomology* **124**, 51–56.

Balog, A., Markó, V., Kutasi, Cs. & Ádám, L. (2003) Species Composition of Ground Dwelling Staphylinid (Coleoptera: Staphylinidae) Communities in Apple and Pear Orchards in Hungary. *Acta Phytopathologica et Entomologica Hungarica* **38**(1–2), 181–198.

Bogya, S., Szinetár, Cs. & Markó, V. (1999) Species composition of spider (Araneae) communities in apple and pear orchards in the Carpathian basin. *Acta Phytopathologica et Entomologica Hungarica* **34**(1–2), 99–121.

Bryan, K. & Wratten, S.D. (1984) The responses of polyphagous predators to prey spatial heterogenity: aggregation by carabid and staphylinid beetles to their cereal aphid prey. *Ecological Entomology* **9**(3), 251–259.

Burel, F. (1996) Hedgerows and their role in agricultural landscapes. *Critical Reviews in Plant Sciences* **15**(2), 169–190.

Dennis, P., Wratten, S.D. & Sotherton, N.W. (1990) Feeding behaviour of the Staphylinid beetle *Tachyporus hypnorum* in relation to its potential for reducing aphid numbers in wheat. *Annales of Applied Biology* **117**, 267–276.

Dennis, P., Wratten, S.W. & Sotherton, N.W. (1991) Mycophagy as a factor limiting predation of aphids (Hemiptera: Aphididae) by Staphylinid beetles (Coleoptera: Staphylinidae) in cereals. *Bulletin of Entomological Research* **81**, 25–31.

Freude, H., Harde, W.K. & Lohse, G.A. (1964) *Die Käfer Mitteleuropas. Band 4 Staphylinidae I.* 264 pp. Krefeld, Germany, Goecke & Evers Verlag.

Freude, H., Harde, W.K. & Lohse, G.A. (1974) *Die Käfer Mitteleuropas. Band 5 Staphylinidae II.* 381 pp. Krefeld, Germany, Goecke & Evers Verlag.

Galli, P. (1985) Integrated plant protection in Baden-Wurttemberg apple growing. Training, advisory services and experiments within the framework of a model plan for introducing an integrated procedure into commercial fruit growing. *Schriftenreihe des Bundesministers fur Ernahrung, Landwirtschaft und Forsten, Angewandte Wissenschaft* **319**, 54–65.

Good, J.A. & Giller, P.S. (1991) The diet of predatory Staphylinid beetles – a review of records. *Entomologist's Monthly Magazine* **127**, 77–89.

Heyer, W. (1994) Occurrence of epigeal predatory arthropods in apple orchards – a basic approach to a risk assessment. *Planzenschutzdienstes* **2**, 15–18.

Holling, C.S. (1966) The functional response of invertebrate predators to prey density. *Memoirs of the Entomological Society of Canada* **48**, 1–86.

Knopp, M. (1997) Research on integrated pest management of apple and peaches in the highlands of Yemen. *Institut für Pflanzenproduction in den Tropen und Subteran* **3**, 25–29.

Krebs, C.J. (1989) *Ecological Methodology*. 250 pp. New York, Harper & Row.

Krooss, S. & Schaefer, M. (1998) The effect of different farming systems on epigeic arthropods: a five-year study on the rove beetles fauna (Coleoptera: Staphylinidae) of winter wheat. *Agriculture, Ecosystems and Environment* **69**, 121–133.

Kutasi, Cs., Balog, A. & Markó, V. (2001) Ground dwelling Coleoptera fauna of commercial apple orchards. Integrated Fruit Production. *IOBC/wprs Bulletin* **24**(5), 215–219.

Levesque, C. & Levesque, D.I. (1995) Abundance, diversity and dispersal power of rove beetles (Col: Staphylinidae) in a raspberry plantation and adjacent sites in Eastern Canada. *Journal of Kansas Entomological Society* **3**, 355–370.

Levesque, C. & Levesque, D.I. (1996) Seasonal dynamics of rove beetles (Col: Staphylinidae) in a raspberry plantation and adjacent sites in Eastern Canada. *Journal of Kansas Entomological Society* **4**, 285–301.

Luff, M.L. & Eyre, M.D. (1988) Soil-surface activity of weevils (Coleoptera: Curculionidae) in grassland. *Pedobiologia* **32**, 39–46.

Magura, T. & Tóthmérész, B. (1997) Testing edge effect on carabid assemblages in an oak-hornbeam forest. *Acta Zoologica Academiae Scientiarum Hungaricae* **43**(4), 303–312.

Magura, T., Téthmérész, B. & Bordan, Z. (1997) Comparison of the carabid communities of a zonal oak-hornbeam forest and pine plantations. *Acta Zoologica Academiae Scientiarum Hungaricae* **43**(3), 173–180.

Majzlan, O. & Holecová, M. (1993) Arthropodocoenoses of an orchards ecosystem in urban agglomeration. *Ecologia* (*Bratislava*) **12**(2), 121–129.

Markó, V., Merkl, O., Podlussány, A., Víg, K., Kutasi, Cs. & Bogya, S. (1995) Species composition of Coleoptera assemblages in the canopies of Hungarian apple and pear orchards. *Acta Phytopathologica et Entomologica Hungarica* **30**(3–4), 221–245.

Mészáros, Z., Ádám, L., Balázs, K., Benedek, M.I., Csikai, Cs., Draskovits, D.Á., Kozár, F., Lővei, G., Mahunka, S., Meszleny, A., Mihályi, F., Mihályi, K., Nagy, L., Oláh, B., Papp, J., Polgár, L., Radwan, Z., Rácz, V., Ronkay, L., Solymai, P., Soós, Á., Szabó, S., Szabóky, Cs., Szalay-Marzsó, L., Sarukán, I., Szelényi, G., Szentkirályi, F., Sziráki, Gy., Szeőke, L. & Török, L. (1984) Results of faunistical and floristical studies in Hungarian apple orchards (Apple Ecosystem Research No. 26.). *Acta Phytopathologica et Entomologica Hungarica* **19**(1–2), 91–176.

Perner, J. & Malt, S. (2002) Zur epigäischen Arthropodenfauna von landwirtschaflichen Nutzflachen im Thüringen Becken Teil 2. *Käfer* (*Insecta: Coleoptera*) **16**(22), 267–271.

Pielou, E.C. (1984) *The Interpretation of Ecological Data: A Primer on Classification and Ordination*. 288 pp. New York, Wiley-IEEE.

Ravn, H.P. & Holm, S. (1997) On the importance of the surroundings for insect pests in fields. *14th Danish Plant Protection Conference. Pests and Diseases. SP Rapport Statens Planteavlsforsog* **8**, 179–188.

Reede, R.H. (1985) Integrated pest management in apple orchards in the Netherlands: a solution for selective control of tortricids. *Mededeling Laboratorium voor Entomologie Wageningen* **493**, 105.

Schenk, D. & Bacher, S. (2002) Functional response of a generalist insect predator to one of its prey species in the field. *Journal of Animal Ecology* **71**, 524–531.

Shah, P.A., Brooks, D.R., Ashby, J.E., Perry, J.N. & Woiwod, I.P. (2003) Diversity and abundance of the coleopteran fauna from organic and conventional management system in southern England. *Agricultural and Forest Entomology* **5**, 51–60.

Sunderland, K.D., Crook, N.E., Staccy, D.L. & Fuller, B.J. (1987) Study of feeding by polyphagous predators on cereal aphids using ELISA and gut dissection. *Journal of Applied Ecology* **24**, 907–933.

Tóth, L. (1982) *Magyarország Állatvilága – Fauna Hungariae, Holyvák II. – Staphylinidae II*. VII (6). 110 pp. Budapest, Akadémiai Kiadó.

Tóth, L. (1984) *Magyarország Állatvilága – Fauna Hungariae, Holyvák III. – Staphylinidae III*. VII (11). 142 pp. Budapest, Akadémiai Kiadó.

Tóthmérész, B. (1995) Comparison of different methods for diversity ordering. *Journal of Vegetation Science* **6**(2), 283–290.

Wardle, D.A., Nicholson, K.S. & Yeates, G.W. (1993) Effect of weed management strategies on some soil-associated arthropods in maize and asparagus ecosystems. *Pedobiologia* **37**, 257–269.

Zerche, L. (1996a) Studien alpiner und montaner Oxypoda-Arten (Coleoptera: Staphylinidae, Aleocharinae). *Beiträge zur Entomologie* **46**(1), 25–33.

Zerche, L. (1996b) Die Oxypoda-Arten der Kanarischen Inseln (Coleoptera: Staphylinidae, Aleocharinae). Taxonomie, Bionomie, Phylogenie und Biogeographie. *Beiträge zur Entomologie* **46**(2), 277–372.