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ROVE BEETLES (*COLEOPTERA*: *STAPHYLINIDAE*) IN CENTRAL EUROPEAN APPLE AND PEAR ORCHARDS – COMPARATIVE STUDIES OF SPECIES RICHNESS, ABUNDANCE AND DIVERSITY

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Abstract: The dominance, diversity and activity density of rove beetles were studied in Central European apple and pear orchards. Altogether 6877 individuals, belonging to 271 species and 11 subfamilies were collected. Thirteen species presented a relative abundance from 9 to 2% and amounted to almost 56% of all staphylinids recorded. In dominance order they were: *Dinaraea angustula* (Gyllenhal), *Omalium caesum* Gravenhorst, *Drusilla canaliculata* (F.), *Sphenoma abdominale* Mannerheim, *Palporus nitidulus* (F.), *Xantholinus linearis* (Olivier), *Dexiogya corticina* (Erichson), *Coprochara bipustulata* L., *Mocyta orbata* (Erichson), *Oligota pumilio* Kiessenwetter, *Xanthlinus longiventris* (Olivier), *Tachyporus hypnorum* (F.) and *Pycnota vicina* (Kraatz). The alpha diversity of staphylinids for different environmental conditions was relatively similar but the Shannon-Weiner Index (H) was higher than of other similar studies. However, the activity density was higher in pear, in sand and in abandoned plantations; under different environmental conditions this could not be considered uniform in time. After the cumulative studies on the population dynamics, one can conclude that the highest number of species can be found in spring and in summer. Species *D. canaliculata* and *P. nitidulus* presented the similar seasonal dynamics in orchards located in different environmental areas, while *O. caesum* had the same activity density both in apple and pear orchards.

Key words: habitat, orchards, rove beetles, soil structure, treatment

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INTRODUCTION

Staphyilinidae is one of the largest families of Coleoptera with species that are mostly predacious. Although many authors studied the European staphylinid fauna (Galli 1985; Reede 1985; Dennis *et al.* 1990; Majzlan and Holecová 1993; Wardle *et al.* 1993; Heyer 1994; Krooss and Schaefer 1998; Andersen 1991, 2000; Perner and Malt 2002), it is still little known about their community structure in agro-ecosystems. Andersen (1991) presented a list of staphylinid beetles occurring in spring barley, cabbage, carrot, potato, strawberries and grassland fields in Norway. The author described 103 000 specimens belonging to 226 species. *Aloconota gregaria* (Erichson), *Anotylus rugosus* (F.) *Atheta fungi* (Gravenhorst), *Amischa analis* (Gravenhorst), *Tachinus signatus* (Gravenhorst) and *Philonthus cognatus* (Stephens) were most often found. Data about Staphylinid beetles from cereal ecosystems in Europe are frequent (Dennis *et al.* 1990; Krooss and Schaefer 1998; Andersen 2000; Perner and 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.).

The response to prey spatial heterogeneity, the aggregation, aphid and mildew preferences were studied by many authors (Bryen and Wratten 1985; Sunderland *et al.* 1987; Dennis *et al.* 1991; Good and Giller 1991). Several species aggregated in patches of aphids, and they presented a positive numerical response to the high aphid densities (Bryen and Wratten 1985). Under laboratory conditions the average aphid consumption was 1 mg daily for many of the species, which is more than 34% of their 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, rusts and non-rust fungi. Dennis *et al.* (1991) showed that these species presented a positive numerical response to a high density of rusts and non rust-fungi, while aphid predation decreased significantly at the same time. Other species like *Philonthus* spp. fed on a wide range of arthropod prey, aphid predation averaged 200 aphid specimens daily and there is no record of mycophagy (Good and Giller 1991).

In Central Europe more than 2000 arthropod species have been recorded since 1976 in apple and pear orchards, but there is still little known about the staphylinid beetles (Kutasi *et al.* 2001; Balog *et al.* 2003).

MATERIALS AND METHODS

Studies were carried out for five years, from 1998 to 2002, on nine farms and thirteen plantations in Hungary. The structure of presented studies is given in Table 1. The investigated sites were situated in three geographical regions with different environmental conditions. They were agricultural lowland environments (ALE), regularly flooded areas (RFA) and woodland areas of medium height mountains (WAM). Five farms were located on sand, whereas four on clay.

Eleven plantations were treated with mainly organophosphate insecticides (methidation, fosalon, fosfamidon) during the study period. There were applied on average ten times during the vegetation period (CON – conventionally treated). Two apple plantations were untreated and neither pesticides nor fertilizers had been used for five years before we started our investigation (ABA – abandoned).

Ten covered pitfall traps (300 cm^3 of capacity, 8 cm in diameter, half-filled with 30% ethylene glycol solution) were placed in transect from a field margin towards the field centre at 10 m intervals within each plantation. Five traps were placed in the middle of the plantation and five on the inner edges. Samples were collected fortnightly from April to October.

Pitfall traps were considered a useful method to study community assemblages of epigeal arthropods (Luff and Eyre 1988).

On five farms and seven plantations staphylinids were also collected from canopy level using trunk traps. They consisted of a plastic cylinder with 1000 cm^3 of capacity attached to the tree trunk. A 1:3 mixture of ethylene glycol and tap water were used as killing and preservative solution. Trunk traps (v/v) were used to measure the activity of staphylinids from canopy level to soil surface. The traps used in our assessment measured activity density. It was dependent not only on the population density of the species, but also its activity on the ground and canopy level. As traps were the only method used in the surveys, our results concerned mainly the activity density of species. All staphylinids from traps were sorted and identified up to species level using a stereo microscope. For identification, the works of Freude *et al.* (1964, 1974) and Tóth (1982, 1984) were used. The material was deposited at Entomology Museum of the Corvinus University.

The most common species in Hungarian orchards were considered by investigating their relative abundance (%) and their distribution (presence-absence) on the thirteen investigated plantations.

The Shannon-Weiner (H') and the log series Fisher alpha ($\acute{\alpha}$) diversity index were computed as a measure of biodiversity (Fisher *et al.* 1943; Pielou 1984). The alpha diversity index is considered to be superior to commonly used indices because the sensitivity to sample size is low and uses high discriminate ability (Fisher *et al.* 1943; Shah *et al.* 2003). The maximum likelihood estimate $\acute{\alpha}$ can be devided from the following formula:

$$S = \acute{\alpha} \log (1+N/\acute{\alpha})$$

where: S – number of species in the sample,
N – number of individuals in the sample.

Values of $\acute{\alpha}$ were computed using the Past Program 1.18. Distribution of the data followed the log-series distribution and fitted using one-way parametric ANOVA to make comparisons between farms for the staphylinid species recorded. All these distributions are indicated in the text.

The analyses of variance were performed and similarities were compared with O'Brien and Levene test (Pielou 1984) to determine whether there were any differences in species richness and abundance between the management systems (CON, ABA) and soil composition for staphylinids. Values of *F* and *P* were computed using Nucosa Program (Tóthmérész 1996). The following standardizations were used for the test: for treatment orchards from farm 5 and 6 (ABA) for ABA, were compared with apple orchards from farm 8 and 6 (CON) for CON. In soil composition studies, orchards from ALE were compared first and were used as replicate orchards from farm 3 and 7 (apple) for clay, and 6 (CON), 8 (apple) for sand. From WAM apple plantation from farm 1 on clay was compared with apple plantation from farm 4 on sand (Table 1).

Table 1. Characteristics of the investigated orchards

Farms	1	2	3	4	5	6	7	8	9
Plantation	apple	apple	apple	apple	apple	apple, apple	apple, pear	apple, pear	apple, pear
Soil	clay	clay	clay	sand	sand	sand sand	clay clay	sand sand	sand sand
Environmental	WAM	WAM	ALE	WAM	ALE	ALE ALE	ALE ALE	ALE ALE	RFA RFA
Treatment	CON	CON	CON	CON	ABA	CON ABA	CON CON	CON CON	CON CON
Traps used	P-t, T-t	P-t, T-t	P-t	P-t	P-t, T-t	P-t P-t	P-t P-t	P-t P-t T-t T-t	P-t P-t T-t T-t

Explanation: WAM – woodland areas of medium height mountains, ALE – agricultural lowland environments, RFA – regularly flooded area, CON – conventionally treated orchards, ABA – abandoned orchards, P-t – pitfall trap, T-t – trunk trap

Table 2. Number of species, individuals and diversity of staphylinid fauna in Hungarian apple and pear orchards. The Shannon-Weiner (H) and the log series Fisher alpha ($\acute{\alpha}$) diversity index were used as a measure of biodiversity

Farms	1	2	3	4	5	6	7	8	9
Plantation	apple	apple	apple	apple	apple	apple, apple	apple, pear	apple, pear	apple, pear
Taxa	57	31	80	104	66	54 31	45 38	58 73	54 81
Individuals	1044	179	567	989	971	519 159	233 180	611 675	182 568
Fisher (α)	1.11	1.03	1.40	1.46	1.20	1.18 1.06	1.22 1.16	1.19 1.31	1.41 1.41
Shannon H`	2.84	2.40	3.57	3.19	2.77	2.62 2.52	3.03 2.99	2.52 3.02	2.96 3.32

The activity density of the staphylinid fauna was computed for different environments (ALE, WAM, RFA) and tree species (apple and pear), and were performed the number of specimens caught in each pitfall traps. Values of F and P were also computed using a Nucosa Program (Tóthmérész 1996). For environmental studies orchards from farms 3, 7 (apple, ALE) were compared with farms 1 and 2 for WAM, all situated on clay. Apple orchard from farm 4 (WAM), was compared with apple orchards from farm 8 (ALE) and 9 (RFA) all on sandy soil. Staphylinid fauna on different tree species were compared separately in farms 7, 8 and 9. Back-transformed means and $p < 99\%$ confidence limits are considered as statistically significant differences. For similarity and activity density studies, orchards used as replicates differed from each other in only one parameter (tree species, soil, treatment or environment).

Seasonal dynamics were calculated only for dominant species with relative abundance higher than 10% in at least one of the investigated orchards and all individuals were considered from the whole investigation period.

RESULTS

Dominance and diversity

All in all 6877 individuals, belonging to 271 species and 11 subfamilies were collected. *Aleocharinae* were also identified up to species level, 81 species and 1/3 of the specimens (2327) were members of the subfamily. Other subfamilies with high species and specimen's number caught in investigated orchards were *Staphylininae, Tachyporinae, Paederinae, Oxytelinae* and *Xantholininae*. The trap catches of the staphylinids differed and were high in pitfall traps where 259 species and 6706 individuals were captured, while in trunk traps only 69 species and 171 individuals were collected. Twelve species [*Alianta incana* (Erichson), *Baptolinus affinis* (Paykull), *Brachyusa concolor* (Eirchson), *Conosoma testaceum* (Eirchson), *Gabrius splendidulus* (Gravenhorst), *Philonthus rectangulus* (Eirchson), *Plathystethus capito* (Erichson), *Nestus excubitor* (Erichson), *Nudobius lentus* (Gravenhorst), *Ocypus biharicus* (J. Müller), *Ocypus nitens* (Schrank) and *Hypnogyra glabra* (Nordman)] were present sporadically only at canopy level and were absent in pitfall traps.

After the cumulative studies on the communities, we identified the most widely occurring species in Hungarian apple and pear orchard. Altogether 13 species presented a relative abundance from 9 to 2% and amounted to almost 56% of all individuals recorded. In dominance order they were: *D. angustula*, *O. caesum*, *D. canaliculata*, *S. abdominale*, *P. nitidulus*, *X. linearis*, *D. corticina*, *C. bipustulata*, *M. orbata*, *O. pumilio*, *X. longiventris*, *T. hypnorum* and *P. vicina*.

The pooled value of $\acute{\alpha}$ diversity varied between 1.64 for farm 4 and 1.03 for farm 2. Considering different tree species (apple and pear from farms 7, 8 and 9), the species number varied between 45–58 in apple and 38–81 in pear orchards. Although pooled value of $\acute{\alpha}$ diversity was higher for apple orchards' farm 7 ($\acute{\alpha} = 1.22$ for apple and $\acute{\alpha} = 1.16$ for pear) and lower for farm 8 ($\acute{\alpha} = 1.19$ for apple and $\acute{\alpha} = 1.31$ for pear). The above values were statistically insignificant ($F_{7a,\,p} = 1.76$, $P = 0.53$; $F_{8a,\,p} = 1.33$, $P = 0.84$) and a common value of 1.41 was computed for $\acute{\alpha}$ by comparing apple and pear plantations for farm 9 (Table 2).

Using the analysis of variance (ANOVA) to determine the effect of insecticides and the soil composition the richness of species caught in each trap, we observed that the richness was higher in abandoned orchards than in the conventionally treated ones, but the differences were statistically insignificant (F = 1.86, P = 0.17). Similarly, the species richness in sandy soil was higher than in clay soil but this values were insignificant (F = 1.35, P = 0.59). The interaction of high input of insecticides and the soil composition had a significant effect the species richness (F = 5.17, P = 0.01).

Activity density

The soil composition had no effect, but the insecticide overtaking had significant effect (F = 18.09, P = 0.01) the activity density of staphylinids in orchards.

The activity density of the staphylinid fauna for different fruit species (apple and pear) was similar for farms 7 and 8 ($F_{7a,\ p}$ = 1.44, P = 0.66; $F_{8a,\ p}$ = 2.3, P = 0.84), and differed significantly from farm 9 where the activity density was 2.7-fold greater in pear than in apple orchards ($F_{9a,\ p}$ = 15.77, P = 0.002) (Fig. 1).

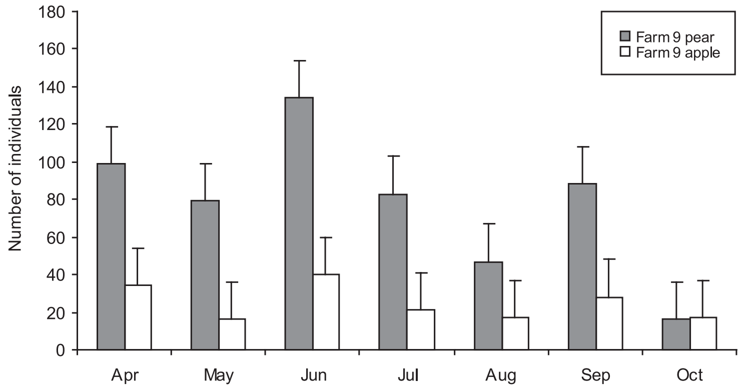
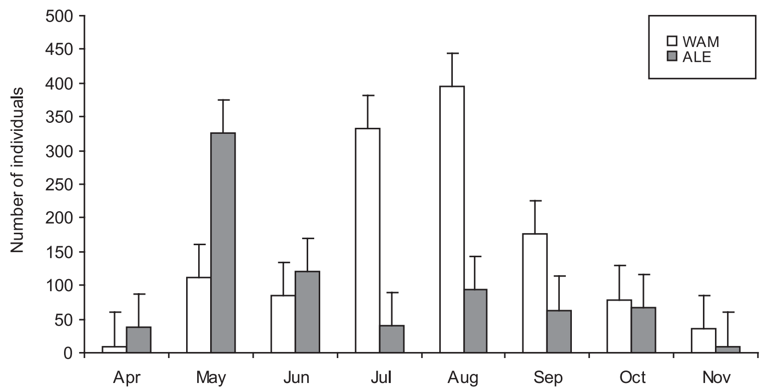


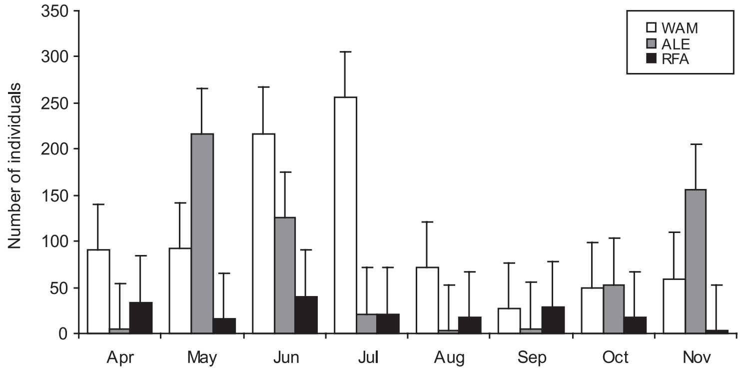
Fig. 1. Activity density of the soil inhabiting staphylinid fauna in orchards with different tree species from farm 9



WAM – Woodland areas of medium height mountains
ALE – agricultural lowland environments

Fig. 2. Activity density of the soil inhabiting staphylinid fauna in orchards with different environmental conditions situated on clay. Were considered as replicates orchards from farms 3 and 7 for ALE and compared with orchards from farms 1 and 2 for WAM

On all farms staphylinids were active throughout the year, maximum catches took place mostly in April, May, June and July but sometimes reached high values in autumn. Considering the activity density of the soil inhabiting staphylinid fauna in orchards with different environmental conditions situated on clay (orchards from farms 3 and 7 for ALE compared with orchards from farms 1 and 2 for WAM), we observed that for ALE the highest activity density occurred in May, while for WAM in July and August however the difference was statistically insignificant ($F_{\text{clay ALE, WAM}} = 1.99$, $P = 0{,}51$) (Fig. 2). Comparing orchards from farms situated on sand (apple orchards from farm 4 (WAM) with 8 (ALE) and 9 (RFA)) the highest activity for ALE was observed in May, June and November while for WAM in June and July. The difference was statistically insignificant ($F_{\text{sand ALE, WAM}} = 1.10$, $P = 0.31$). Low activity density was observed for RFA during the whole period of vegetation and differed significantly for WAM ($F_{\text{sand RFA, WAM}} = 54.84$, $P = 0.001$) and ALE ($F_{\text{sand RFA,ALE}} = 49.82$, $P = 0.01$) (Fig. 3).



WAM – woodland areas of medium height mountains
ALE – agricultural lowland environments
RFA – regularly flooded areas

Fig. 3. Activity density of the soil inhabiting staphylinid fauna in orchards with different environmental conditions situated on sand. Were compared apple orchards from farm 4 (WAM) with 8 (ALE) and 9 (RFA)

Seasonal dynamics

Seasonal dynamics were calculated only for dominant species with relative abundance higher than 10% in at least one of the investigated orchards. These species were *Dinaraea angustula, Omalium caesum, Drusilla canaliculata, Palporus nitidulus, Xantholinus linearis* and *X. longiventris.*

The greatest number of *D. angustula* occurred in apple orchards in WAM, where its abundance was the highest in the latter half of the vegetation period (Fig. 4).

O. caesum was common in apple and pear orchards in ALE, with the highest abundance in the first period of the vegetation (Fig. 5).

As for *D. c.,* most individuals were caught in apple orchards in WAM and ALE. In all of the orchards the greatest abundance occurred in the latter half of July and in the first half of August (Fig. 6).

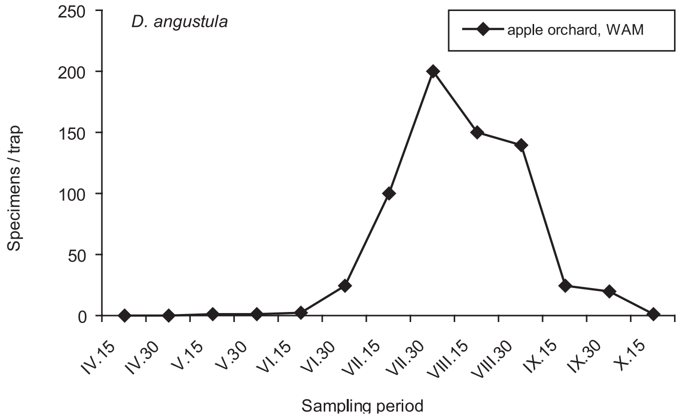


Fig. 4. Seasonal dynamics of *D. angustula* in conventionally treated apple orchards in woodland areas of medium height mountains (WAM)

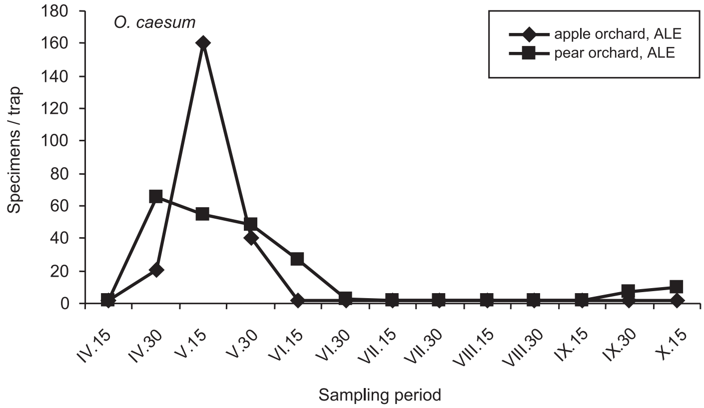


Fig. 5. Seasonal dynamics of *O. caesum* in conventionally treated apple and pear orchards in agricultural lowland environments (ALE)

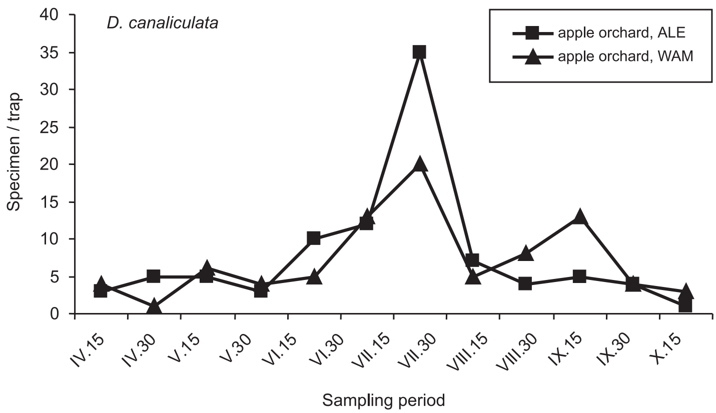


Fig. 6. Seasonal dynamics of *D. canaliculata* in conventionally treated apple orchards in agricultural lowland environments (ALE), and in woodland areas of medium height mountains (WAM)

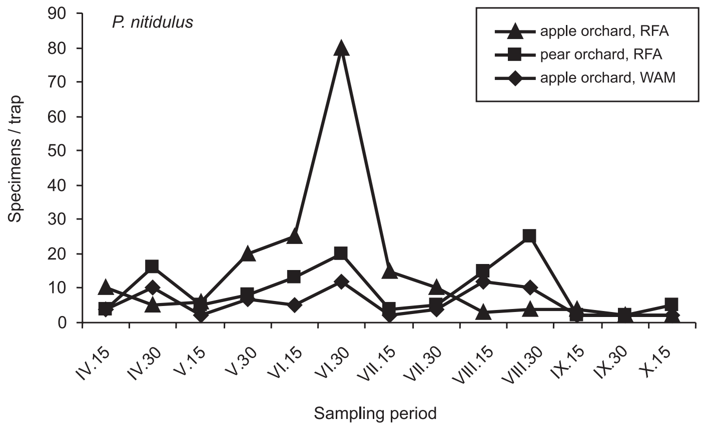


Fig. 7. Seasonal dynamics of *P. nitidulus* in conventionally treated apple and pear orchards in regularly flooded areas (RFA) and in woodland areas of medium height mountains (WAM)

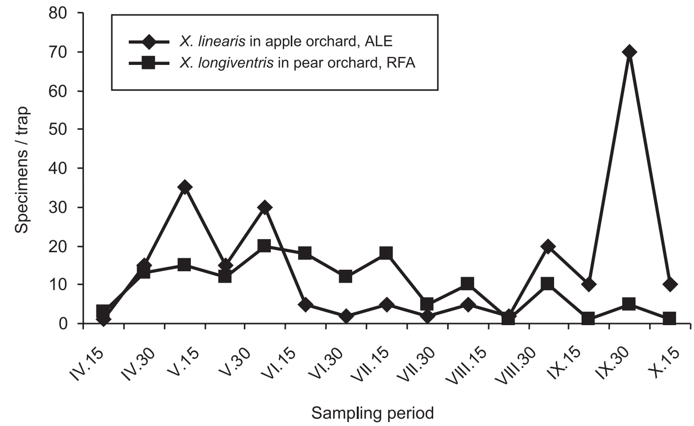


Fig. 8. Seasonal dynamics of *X. linearis* and *X. longiventris* in conventionally treated apple orchards in agricultural lowland environments (ALE) and in per orchards in regularly flooded areas (RFA)

Pitfall trap catches of *P. nitidulus* were the highest in conventionally treated apple and pear orchards in RFA and in apple orchards in WAM. The species occurred from spring to autumn, with high number in summer in RFA (Fig. 7).

The greatest abundance of *X. linearis* occurred in apple orchards in ALE, with a relative high number in spring and in autumn, while *X. longiventris* were dominant in pear orchards in RFA, and occurred during the whole period of the vegetation (Fig. 8).

DISCUSSION

In the percentage terms, 23% of the Hungarian and 15% of the Central European staphylinid fauna were represented in orchards. We identified the most common – and perhaps functionally important – species of Staphylinidae in the Hungarian apple and pear orchards. However, few of these species were recorded as frequent in agricultural fields by other authors throughout Western Europe (Galli 1985; Reede 1985; Dennis *et al.* 1990; Majzlan and Holecová 1993; Kollát and Basedow 1995; Basedow and Kollát 1997). In the same studies *Aleocharinae* were not considered, although they represent at least half of the Staphylinid fauna in agro ecosystems (Andersen 1991; Krooss and Schaefer 1998). We consider that species of *Aleocharinae* represent a substantial part of staphylinids in apple and pear orchards, and they could not be ignored. The vertical migration of staphylinids from canopy level to soil surface is low probably because of the flying ability of the species. The alpha diversity indices of staphylinids for different fruit species, soils, management system and environment were relatively similar. Shannon-Weiner Index (H') was computed in order to facilitate direct comparisons with other studies that have not used the alpha index (Table 4). We found that H`was relatively high compared to other studies and varied between 2.40 and 3.57. Other authors reported lower value for different agricultural fields (conventional winter wheat 2.2–2.4 reported by Lubke 1991 in Austria; 1.6 in organic and 1.5 in conventional winter cereals in southern England reported by Shah *et al.* 2003). There is no similar report about the diversity from Central European apple and pear orchards under different structural and environmental conditions.

Comparing the structure of the orchards (soil compositions, tree species), the activity density of staphylinids was higher in sandy soil and in pear. These could be explained with different soil-texture, microclimatic and wetness tolerance of species. Other studies need to be carried out to confirm these preferences. Considering the pest management control (conventional) or the absence of it (abandoned orchards) the higher number of species was observed in abandoned orchards while in conventionally treated orchards there were fewer individuals. Our findings are consistent with other studies, which have shown higher species number with abandoned systems. The greater mobility of staphylinids, which fly more readily than the most Coleoptera, may enable them to avoid pesticide applications in individual fields. Such ability has been observed with *Tachyporus* spp. The activity density of the staphylinid fauna in Central European apple and pear orchards under the different environmental conditions could not be considered uniform in time, and probably the climate conditions, especially the lowest temperature in WAM promote the staphylinid fauna in different ways. The seasonal dynamics for some of the dominant staphylinid species in Central European apple and pear orchards are presented for the first time. After the cumulative studies on the population dynamics, may reach the conclusion that the highest number of species can be found in spring and summer. Further research is needed to identify the ecological and physiological background of the microclimatic, environmental and insecticide tolerance of the staphylinids in orchards.

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POLISH SUMMARY

CHRZĄSZCZE Z RODZINY KUSAKOWATYCH (*COLOPTERA: STAPHYLINIDAE*) W SADACH JABŁONIOWYCH I GRUSZOWYCH EUROPY ŚRODKOWEJ – BADANIA PORÓWNAWCZE NAD BOGACTWEM GATUNKÓW, ROZPOWSZECHNIENIEM I RÓŻNORODNOŚCIĄ

W sadach jabłoniowych i gruszowych Europy Środkowej przeprowadzono badania nad dominacją, różnorodnością i aktywnością chrząszczy z rodziny kusakowatych. Zebrano w sumie 6877 osobników, które należą do 271 gatunków i 11 podrodzin. Względne rozpowszechnienie trzynastu gatunków wynosiło od 9% do 2% i stanowiło do 56% wszystkich zarejestrowanych kusakowatych. Co do ich dominacji, były to w kolejności: *Dinaraea angustula* (Gyllenhal), *Omalium caseum* (Gravenhorst), *Drusilla canaliculata* (F.), *Sphenoma abdominale* (Mannerheim), *Palporus nitidulus* (F.), *Xantholinus linearis* (Olivier), *Dexigogya corticina* (Erichson), *Coprochara bipustulata* (L.), *Mocyta orbata* (Erichson), *Oligota pumilio* (Kissenwetter), *Xanthilinus longiventris* (Olivier), *Tachyporus hypnorum* (F.) i *Pycnota vicina* (Kraatz).

Indeks różnorodności alfa (α) dla kusakowatych w różnych warunkach środowiska był względnie podobny, lecz indeks Shannon-Weinera (H) był wyższy niż w innych, podobnych badaniach. Aktywność owadów była wyższa na gruszach, piaskach i plantacjach opuszczonych; jednak w różnych warunkach środowiska, a więc nie można wziąć takich kalkulacji pod uwagę. Ze zbiorczych badań nad dynamiką populacji można wywnioskować, że największą ilość gatunków można spotkać wiosną i latem. Takie gatunki jak *D. canaliculata* i *P. nitidulus* wykazują podobną dynamikę sezonową w sadach położonych na obszarach o różnych warunkach środowiskowych, natomiast *O. caseum* wykazuje tę samą aktywność zarówno w sadach jabłoniowych jak i w gruszowych.