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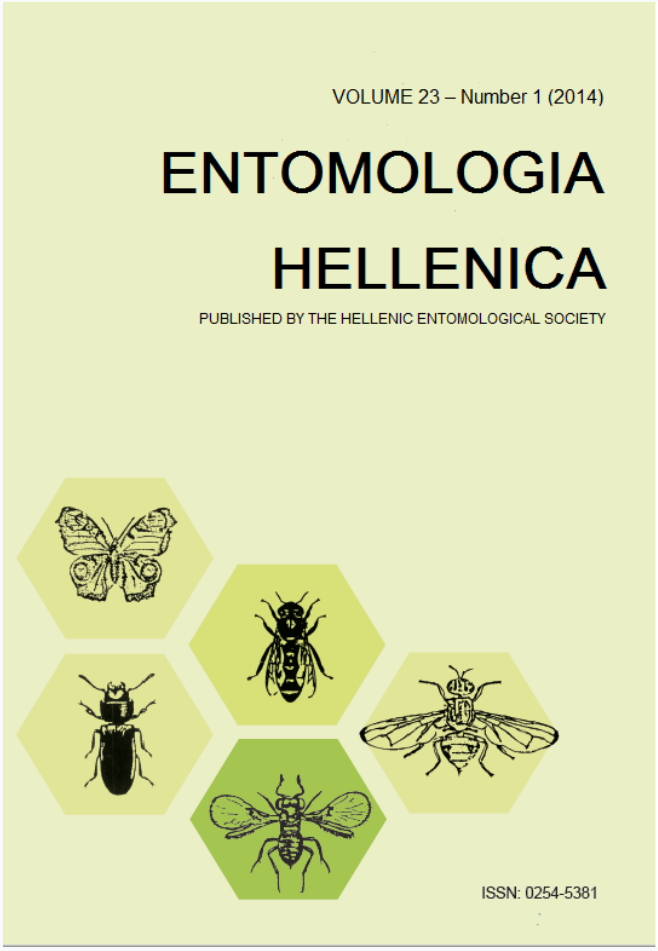

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Comparison of coleopteran fauna in olive orchards under different production systems in the Messara's valley, on Crete island, Greece

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ABSTRACT

In this study the results of the captured Coleoptera in pitfall traps in nine olive orchards in the valley of Messara, on Crete Island, were compared. The liquid used for killing and preservation in the pitfall traps, was propylene glycol. The nine olive orchards were distributed in four areas in the valley. In each area there were at least two olive orchards under different agricultural management system, organic and conventional. The experiments were conducted from October 2004 to April 2005. The number of captured Coleoptera specimens was 4,937. The specimens were identified to the family level. Coleoptera from 25 families were found, but the analysis was focused at eleven of them, the richest in specimens. These were: Anthicidae, Carabidae, Chrysomelidae, Curculionidae, Histeridae, Leiodidae, Scarabaeidae, Silphidae, Silvanidae, Staphylinidae and Tenebrionidae. Staphylinidae were the most abundant in all olive orchards independently of the agricultural management (production system). In the other families instead of differences amongst the different systems of agricultural management, more prominent were the differences amongst areas.

KEY WORDS: Olive orchards, coleopteran families, biodiversity, pitfall traps, Staphylinidae.

Introduction

Coleoptera is an order of insects very plentiful in species and heterogeneous. Thus, in many biotopes Coleoptera fill many ecological niches, as grazers e.g. Curculionidae (Murray et al. 2006), predators e.g. Carabidae, Staphylinidae (Brunke et al. 2009), detritivores e.g. Scarabaeidae (Teixeira et al. 2009) and scavengers e.g. Silphidae (Gibbs and Stanton 2001). The beetle's families were studied as indicators in organic and conventional Mediterranean vineyards and olive orchards, in the study of Hadjicharalampous et al. (2002), but only during fall (October).

The aim of our study was the investigation about the synthesis of Coleopteran fauna in Messara's olive orchards and to investigate differences between conventional and organic olive orchards, and also amongst four different sites - villages.

To carry out our study we have used a reticule of pitfall traps for an extended period (about six months).

Materials and Methods

In the experiments pitfall traps were used having as liquid propylene glycol. The collection of specimens and the renewal of liquid were made three or four times monthly from 20 October 2004 to 17 April 2005.

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In this study two types of olive orchards were mainly compared: The conventional and the organic ones. In the organic olive orchards, the farmers were using drip irrigation, manure as fertilizer, traps for olive fruit flies and grazing or mild treatment of soil against the weeds (superficial tillage). In the conventional olive orchards the farmers were using bait spraying to control olive fruit flies, both manure and chemical fertilizers, intense soil treatment against weeds (deep plowing) and drip irrigation similar or identical with the organic farmers. For this comparison one conventional and one organic orchard were selected in each of four areas (villages): Roufas, Kouses, Peri and Petrokefali. In the case of Petrokefali, the olive orchard is completely aligned to the standards of Integrated Management System as they are described by ISO 9001.

Apart of these orchards, traps established in an additional abandoned olive orchard close to the village Roufas. The data of this olive orchard were used to search differences among the four regions, but the abandoned as unique is not appropriate to be compared with the other types.

The specimens were separated at the family level. The analysis was focused at eleven of them, which were the most abundant ones. The rest 14 families, from which there were collected very few specimens, were unified in a separate category and named as "Others".

For the measurement of biodiversity Shannon index (H′) was used.

$$H' = -\sum_{i=1}^{R} p_i \ln p_i$$

where p_i is percentage of species i, $\ln p_i$ Neperian logarithm of the same species and R the number of species.

The results were analyzed using ANOVA (Analysis of Variance) and the post hoc indices Tukey, Duncan, Scheffe and LSD For the data analysis Excel 2003 and the software SPSS 17.0 were used.

Results

During the study totally 4,937 coleopteran individuals were captured belonging to 25 families. Among them the 11 most abundant families were Anthicidae, Carabidae, Chrysomelidae, Curculionidae, Histeridae, Leiodidae, Scarabaeidae, Silphidae, Silvanidae, Staphylinidae and Tenebrionidae (Fig. 1). The rest 14 ones were unified as "Others".

As a consequence of the trapping method, the catches of specimens were mainly species from epigeous, totally or partly, families (e.g. Carabidae, Histeridae, Scarabaeidae, Silphidae, Tenebrionidae). At a second level, our traps collected specimens from flying species, as the members of the family Anthicidae and the majority of Staphylinidae species, but also specimens from Curculionidae and Chrysomelidae, families with species mainly roaming on plants.

The staphylinids were the most abundant family, with statistical level of confidence 99% and are grouped separately from the rest of families according all the used post hoc indices. The family Staphylinidae occupied 50% of our specimens (2,481 in the total of 4,937, Fig. 2). The captures in 8 of the 11 families were comparable. By searching more divisions on families' separation, except the easily discriminated Staphylinidae which occupy its own division, we can remark that the Duncan index presented the families Carabidae and Leiodidae in a different level from Anthicidae and Silphidae. All the other families weren't put in a clear position by this index (Table 1).

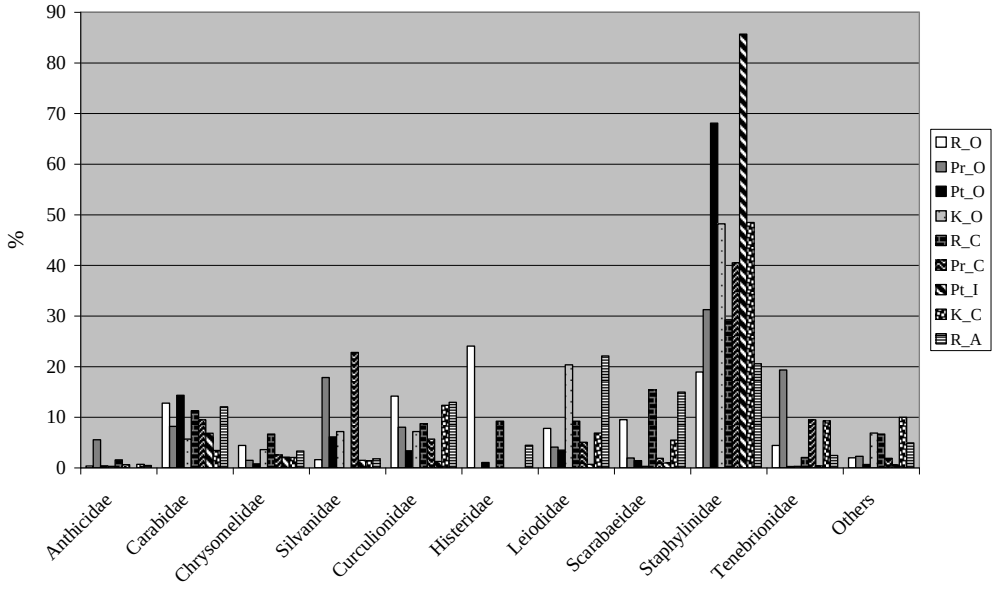

FIG. 1. The percentages of the main families in the nine olive orchards, during the experimental period. In the legend the first symbol indicate villages (R for Roufas, Pr for Peri, Pt for Petrokefali, K for Kouses) and the second, after dash, the management system (O for organic, C for Conventional, I of Integrated Management and A for abandoned).

TABLE 1. Grouping of percentages for Coleopteran's main families according to Duncan post hoc index (Index uses harmonic mean sample size, N=number of samplings)

Percentages	Subset for alpha = 0.05				
		N	1	2	3
Duncan	Anthicidae	27	1.0474		
	Silphidae	27	1.2549		
	Others	27	3.3547	3.3547	
	Chrysomelidae	27	3.4178	3.4178	
	Histeridae	27	3.6801	3.6801	
	Tenebrionidae	27	4.5305	4.5305	
	Scarabaeidae	27	6.3268	6.3268	
	Silvanidae	27	7.2700	7.2700	
	Curculionidae	27	8.0686	8.0686	
	Carabidae	27		10.2554	
	Leiodidae	27		10.3373	
	Staphylinidae	**27**			**40.4565**
	Sig.		.052	.054	1.000

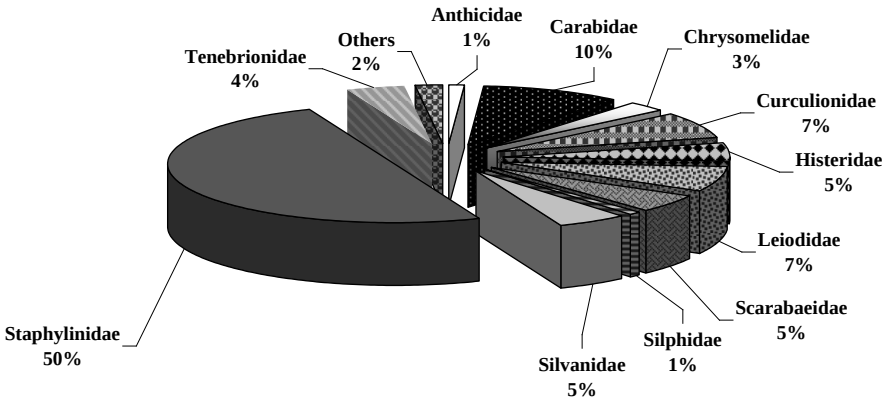

FIG. 2. Percentages of total captured beetles, during all the experimental period, for the main families.

In general, the family Staphylinidae is clearly the most abundant, independently of the agricultural management systems, followed by Carabidae in the organic olive orchards and by Curculionidae in the conventional ones.

By comparing according to the regions (i.e. the four villages), Staphylinidae occupied the first place everywhere, but the families following Staphylinidae were different depending on the region: in Peri were Silvanidae and Tenebrionidae, in Petrokefali Carabidae, in Kouses Leiodidae and in Roufas Histeridae.

Many families have statistically significant differences between different olive orchards. These differences are presented synoptically in Table 2. There is a slight indication of difference that in the organic olive orchards the second place in percentages is occupied by Carabidae and in the conventional ones by Curculionidae.

After the unification of the olive orchards, according to the region, we have made the abundances' comparison of the main families, in these new groups of olive orchards. The results of this new process with statistically significant differences are giving separately (Table 3). The families Anthicidae, Curculionidae, Histeridae, Leiodidae, Silphidae, Chrysomelidae and the group of "Others" have not significant differences among the four regions.

TABLE 2. Main families of Coleoptera, which present statistically significant differences among the olive orchards of the study, according to the indices Duncan, Tukey and LSD.

Families	**Post hoc**	**Higher Percentages**	**Lower Percentages**
Staphylinidae	Duncan	Petrokefali organic	Peri conventional Roufas conventional Roufas abandoned
Tenebrionidae	Duncan	Peri organic	All the others
Anthicidae	Duncan	Peri organic	All the others
Chrysomelidae	Duncan	Roufas organic	Peri conventional Petrokefali organic Kouses conventional
Silvanidae	Duncan	Peri organic	Roufas conventional Kouses conventional Roufas abandoned
Curculionidae	Duncan	Roufas organic	All except Peri organic and Roufas abandoned
Leiodidae	Duncan	Roufas abandoned	Peri conventional Petrokefali organic
Scarabaeidae	Duncan	Roufas organic	All except Roufas abandoned
Scarabaeidae	Duncan	Roufas abandoned	All except Roufas conventional
Scarabaeidae	Tukey	Roufas organic	Peri organic Petrokefali organic Kouses organic Peri conventional Petrokefali organic
Histeridae	LSD	Roufas organic	Peri organic, Petrokefali organic Kouses organic Peri conventional, Kouses conventional, Petrokefali organic

TABLE 3. Main families of Coleoptera, which present statistically significant differences among the regions of the study, according to ANOVA and the post hoc indices.

Families	**ANOVA & Post hoc**	**Higher Percentages**	**Lower Percentages**
Staphylinidae	ANOVA 95% & Duncan	Petrokefali	All the others
Tenebrionidae	Duncan	Peri	Petrokefali
Carabidae	Duncan	Petrokefali	Kouses
Sylvanidae	Duncan	Peri	Roufas
Scarabaeidae	ANOVA 99% and all the used post hoc	Roufas	All the others

In regard to the biodiversity per region, Petrokefali was grouping separately from the other regions in a level of probability 99% (F=17.68, df=3, 5, *P*<0.004). The olive orchards of Petrokefali had values of 0.65 & 1.17 (Shannon), which were very lower than the other ones (1.62 – 2.12) which belong to the other three locations. The Roufas region had the highest biodiversity values (Fig. 3).

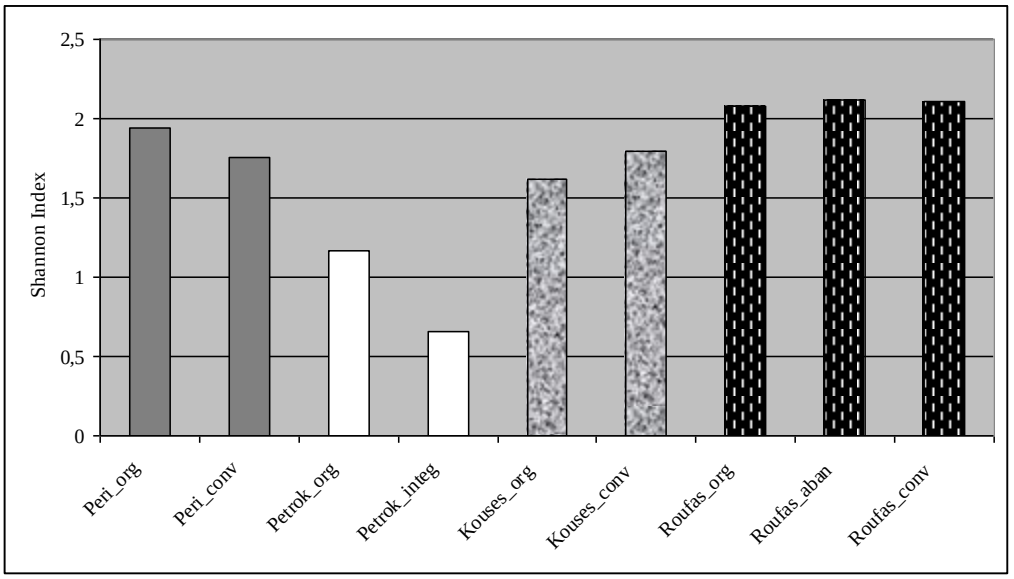

FIG 3. Values of biodiversity of the different olive orchards, according to the Shannon index. (Petrok= Petrokefali, org= organic, conv= conventional, integ= integrated and aban= abandoned).

Discussion

From a total of 25 families, which were recorded in this study, Staphylinidae is by far the most abundant in captures followed by Carabidae. The families Carabidae and Staphylinidae were amongst the seven prominent ones in olive orchards in Granada Spain, but in very lower percentages (4% and 1% respectively of the Coleoptera total) than in this work (Cotes et al. 2009b). The same families plus two (Tenebrionidae, Anthicidae) were the most abundant in olive groves in Granada and Cordova (Cotes et al. 2009a). In Petrokefali region these families are especially dominant and for this reason its olive orchards have the lowest biodiversity, as Staphylinidae plus Carabidae reach percentages of 82.4% in the organic olive orchard of Petrokefali.

In contradiction, Roufas' olive orchards have the lowest percentages of Staphylinidae (about 10-30%). In Roufas there are more families with pronounced percentages such as Scarabaeidae and Histeridae. Likely this is due to a slightly milder soil treatment in all the olive orchards and/or to more intense combined use of manure and chemical fertilizers in the conventional one. There is the hypothesis that species of these families are attracted in debris from sheep and goats, as also from the other fertilizers. These two families, together with Chrysomelidae, only in Roufas, from all the four regions, reached percentages higher than 10%. This contributed to the highest values of biodiversity (about 2.1) found in Roufas.

Despite this, these values don't have statistically significant difference from the other olive orchards except Petrokefali.

At the other hand, families as Anthicidae and Silphidae, have the lowest percentages. This probably can be attributed, partially, to their way of life. As it is known, the members of the first family are not soil dwellers and these of the second one depend on special diet (dead small animals).

The abandoned olive orchard was used for a total view of Roufas village but as unique is not comparable with the other treatments. For this reason we compare only organic with conventional olive orchards.

May be the only important indication of difference, which is given by the beetle families' percentages between organic and conventional olive orchards is the second place in percentages, occupied in organic by Carabidae and in conventional by Curculionidae.

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Σύγκριση πανίδας κολεοπτέρων σε ελαιώνες της Μεσαράς, με διαφορετικά καθεστώτα διαχείρισης

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ΠΕΡΙΛΗΨΗ

Σε αυτήν την εργασία συγκρίνονται τα αποτελέσματα από τις συλλήψεις κολεοπτέρων σε παγίδες εδάφους (pitfall traps) με προπυλενογλυκόλη, σε εννέα ελαιώνες της Μεσαράς σε τέσσερις τοποθεσίες από τον Οκτώβριο έως και τον Απρίλιο του 2005. Η ανανέωσή τους πραγματοποιείτο τρεις έως τέσσερις φορές ανά μήνα. Στη μελέτη συγκρίνονται κατά βάση δύο τύποι ελαιώνων, οι ελαιώνες συμβατικής και οι ελαιώνες βιολογικής καλλιέργειας. Εκτός αυτών υπήρχε ένας ελαιώνας σε καθεστώς ολοκληρωμένης διαχείρισης και ένας εγκαταλειμμένος. Επίσης μπορούν να ομαδοποιηθούν σύμφωνα με τις τέσσερις περιοχές δειγματοληψίας (Ρουφάς, Κουσές, Πέρι, Πετροκεφάλι). Καθ' όλη τη διάρκεια της μελέτης συνελήφθησαν, περίπου 5000 κολεόπτερα από 25 οικογένειες. Οι ένδεκα αφθονότερες ήταν: Anthicidae, Carabidae, Chrysomelidae, Curculionidae, Histeridae, Leiodidae, Scarabaeidae, Silphidae, Silvanidae, Staphylinidae και Tenebrionidae. Οι υπόλοιπες 14 ομαδοποιήθηκαν σε μια χωριστή κατηγορία. Γενικά, τα Staphylinidae ήταν τα αφθονότερα, με μεγάλη διαφορά, κοιτώντας είτε απόλυτους αριθμούς, είτε ποσοστά, σε όλες τις επιμέρους καλλιεργητικές διαχειρίσεις. Σε ότι αφορά στη δεύτερη οικογένεια, στους βιολογικής γεωργίας ελαιώνες βρίσκονται τα Carabidae, ενώ στους συμβατικής καλλιέργειας τα Curculionidae. Σε αφθονία, μετά τα Staphylinidae, που είναι πρώτα σε ποσοστά, οι οικογένειες που ακολουθούν διαφέρουν από περιοχή σε περιοχή. Στο Πέρι είναι οι οικογένειες Silvanidae και Tenebrionidae, στο Πετροκεφάλι η οικογένεια Carabidae, στον Κουσέ η Leiodidae και στο Ρουφά η Histeridae. Στο Ρουφά, συναντάμε διψήφια ποσοστά σε έξι οικογένειες (Leiodidae, Staphylinidae, Scarabaeidae, Curculionidae, Carabidae, Histeridae). Στα Tenebrionidae και τα Anthicidae, ο ελαιώνας βιολογικής διαχείρισης (Β.δ.) στο Πέρι διαφοροποιείται από όλους τους υπόλοιπους. Στα Curculionidae το Ρουφάς Β.δ. διαφοροποιείται από όλους τους ελαιώνες εκτός του Πέρι Β.δ. Πραγματοποιώντας ομαδοποίηση ανά περιοχή για τις κύριες οικογένειες προέκυψαν ότι στα Staphylinidae διαφέρει το Πετροκεφάλι από όλα τα υπόλοιπα και στα Scarabaeidae διαφέρει ο Ρουφάς από τα υπόλοιπα (και στη βιοποικιλότητα οικογενειών κολεοπτέρων ανά περιοχή, το Πετροκεφάλι ομαδοποιείται ξεχωριστά). Τα ιδιαίτερα άφθονα Staphylinidae και Carabidae στην περιοχή Πετροκεφάλι, ευθύνονται για τη χαμηλή βιοποικιλότητα κολεοπτέρων σ' αυτό. Η περιοχή του Ρουφά, με τα χαμηλότερα ποσοστά Staphylinidae, εμφανίζει τις υψηλότερες βιοποικιλότητες κολεοπτέρων (γύρω στο 2,1). Τα στοιχεία αυτά φανερώνουν ότι η περιοχή διαδραματίζει πολύ σημαντικότερο ρόλο από το καθεστώς διαχείρισης σε ότι αφορά τις ομαδοποιήσεις των ελαιώνων και η βιοποικιλότητα εμφανίζεται αυξημένη, όπου αποτρέπεται η σχεδόν παντελής επικράτηση μιας ή δύο οικογενειών.