Spanish Journal of Agricultural Research
16 (2), e0301, 13 pages (2018)
eISSN: 2171-9292
https://doi.org/10.5424/sjar/2018162-12385
Instituto Nacional de Investigación y Tecnología Agraria y Alimentaria, O.A, M.P. (INIA)

RESEARCH ARTICLE

OPEN ACCESS

Arthropod communities within the olive canopy as bioindicators of different management systems

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Abstract

Arthropods, within the olive tree canopy, which can act as bioindicators of different management systems (conventional, integrated and organic), were collected in costal Croatia during 2007-2009. The aim of the research was to determine the arthropod orders present in each of the observed olive groves, to identify the number of individuals in each order, and to set potential bioindicators of different management systems. In order to do that, arthropods were collected from the olive canopies at three locations (Supetar, Kaštel Stari and Duilovo). After the samples were sorted according to orders, and determined according to arthropods determination keys. Olive groves were characterised by the same growth conditions and environment, with differences in agricultural management systems. In this investigation, 7882 arthropods were collected, belonging to 17 orders. It was found that Diptera, Heteroptera and other Hemiptera individuals, excluded Cicadidae and Psyllidae family individuals, could be defined as potential bioindicators of olive groves under different management systems. The number of Araneae and Coleoptera individuals significantly differed in all researched olive groves. So, these orders can be considered as bioindicators of different management systems. The knowledge obtained in this research can potentially be exploited in olive production in the future. Obtained results represent an important contribution to the inventory of arthropods in olive canopy. Also, this research significantly improves understanding of both harmful and beneficial entomofauna in olive groves and consequently contributes to better understanding of the total entomofauna in Croatia.

Additional keywords: conventional olive grove; integrated olive grove; *Olea europaea*; orders abundance; organic olive grove.

Abbreviations used: COG (conventional olive grove); GAP (good agricultural practice); IOG (integrated olive grove); OOG (organic olive grove).

Authors' contributions: Conceived and designed the experiments, interpretation of data, and performed the experiments: EV, SK, MK, PD and JIB. Wrote the paper: EV. Statistical analyses: MK and EV. Critical revision of the manuscript for important intellectual content, supervising the work: JIB and MI. Coordinating the research project: MK. Obtaining funding: SK.

Citation: Vitanović, E.; Ivezić, M.; Kačić, S.; Katalinić, M.; Durbešić, P.; Igrc Barčić, J. (2018). Arthropod communities within the olive canopy as bioindicators of different management systems. Spanish Journal of Agricultural Research, Volume 16, Issue 2, e0301. https://doi.org/10.5424/sjar/2018162-12385

Received: 04 Oct 2017. **Accepted:** 22 May 2018.

Funding: Croatian Ministry of Science and Education (project 'Research & Development of Environmentally-Friendly Methods in Olive Pest Control', 091-0910468-0364).

Competing interests: The authors have declared that no competing interests exist.

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Introduction

Olive (*Olea europaea* L.) is the most widespread agricultural plant in the whole Mediterranean, including Croatia. For many years the pest management has been based only on the use of pesticides, of which the result was negative affect on the environment (Heim, 1985; Cirio, 1997; Civantos, 1999). The preservation of biological balance and the entire agroecosystem is the biggest challenge of today. Intensive agriculture is responsible for imbalance of olive grove biocoenosis by reducing diversity between the harmful and beneficial species, and by destroying their natural habitat (Brnetić, 1978; Lacroix & Abbadie, 1998). The excessive use of agrochemicals has triggered the need for development of different plant protection models with minimum negative effect to biodiversity. For that reason integrated and organic management is widely applied nowadays since they limit the use of pesticides. Olive is a host to many pests, the most numerous among which are insects with 110 species, followed by 90 species of pathogenic fungi, 13 species of mites, 11 nematodes, 5 bacteria and 5 species of birds (Cirio, 1997). Numerous investigations by international scientists show that the most numerous arthropods in the olive groves are spiders (Araneae) with about 50 species, followed by beetles (Coleoptera) with 30 species, ants (Hymenoptera, family Formicidae) with 23 species, Hemiptera with 11 species, Neuroptera with 13 species, and Diptera with one species (Morris, 1997; Morris *et al.*, 1999; Campos & Civantos, 2000). Many of these arthropod species belong to the group of phytophagous insects, but also many belong to the group of predators and parasitoids, which are the natural enemies for the most important olive pests. This interaction of phytophagous species, predators and parasitoids is important for the sustainability and preservation of biological balance of an ecosystem (Andrewartha & Birch, 1984; Rodriguez *et al.*, 2003; Garratt *et al.*, 2011).

Integrated or organic plant protection is recommended in order to preserve diversity of arthropod community in olive grove. The analysis of soil, plant material and oil can determine the levels and types of used pesticides, and potentially confirm their overuse. Overuse of pesticides can also be determined by using arthropods, as members of the olive tree canopy. Such bioindication is a valuable tool, as it permits the evaluation of the overall state of conservation for a particular ecosystem, based on the living organisms that it contains (Burel *et al.*, 2004; Jerez-Valle *et al.*, 2014). For many arthropods, survival in agrosystems depends on the suitability of the habitat, which is strongly influenced by agricultural management systems (Jenneret *et al.*, 2003; Jerez-Valle *et al.*, 2014). The use of bioindicators as the reference point for different agricultural management systems does not have a long tradition (Van Straalen & Verhoef, 1997; Markert & Wunschmann, 2011), especially of arthropod communities, which have been used since the beginning of 20th century (Cairns & Pratt, 1993; Brown, 1997). Bioindicators are defined as organisms or groups of organisms that react in a measurable way to environmental stress, especially to the use of pesticides (Meffe & Carroll, 1994; McGeoch, 1998; Igrc Barčić & Maceljski, 2001). Olive tree canopy is abundant in various species (Arambourg, 1986; De Andres, 1991; Varela & Gonzales, 1999; Campos & Civantos, 2000; Ruiz & Montiel, 2000) that can act as bioindicators of different management system (Cairns & Pratt, 1993; Brown, 1997; Cotes *et al.*, 2011; Jerez-Valle *et al.*, 2015; Gkisakis *et al.*, 2016). These are numerous phytophagous species, among which a large number are olive pests, and many parasitoids and predators. Parasitoids are the most numerous, with about 300-400 different species of Hymenoptera (Arambourg, 1986). Predators comprise mostly the orders of Araneae, Coleoptera and Hymenoptera (family of Formicidae), which are the most diverse (Churchill, 1997; Morris, 1997; Peck *et al.*, 1998; Morris *et al.*, 1999; Marc *et al.*, 1999; Holland & Luff, 2000; New, 2000). Excessive use of pesticides disrupts the balance of the olive tree canopy, which reflects on the number of species in Arthropoda phylum. The use of olive canopy arthropods at the level of order proved to be useful in discriminating between management systems, especially among organic and non-organic practice (Biaggini *et al.*, 2007; Jerez-Valle *et al.*, 2015). Depending on the management systems (conventional, integrated or organic) applied in olive groves, the presence of orders of arthropod and the number of their families and species is different in the canopy, so they can be used as bioindicators of changes caused by the applied management systems.

Negative effect of the use of pesticides on arthropod communities has been investigated by many authors (Heim, 1985; Cirio, 1997; Civantos, 1999; Ruano *et al.*, 2001, 2004, 2010; Scalercio *et al.*, 2009; Santos *et al.*, 2010; Cardenas *et al.*, 2015), who confirmed that the lowest number of arthropods is found in the conventional olive groves (COG). According to research by Ruano *et al.* (2004), the arthropods collected in the olive canopy are more reliable bioindicators of different management systems than those collected in the soil using pitfall soil traps. These authors point out that the obtained results are likely to be directly affected by pesticide spraying of olive tree canopies. Orders of Coleoptera, Diptera, Heteroptera, Lepidoptera and Thysanoptera can be used as bioindicators of different pesticide treatments in olive groves. These authors especially mention Coleoptera and Lepidoptera as bioindicators of organic plant protection in olives. The claims of these authors are aligned with the selection criteria of bioindicators according to Cilgi (1994). Mentioned insect orders are also determined as sustainability bioindicators of many other agricultural crops (Fauvel, 1999; Kevan, 1999).

In Croatia, diversity of the arthropod fauna in the olive grove has not been investigated until this research, neither were arthropods so far investigated as bioindicators of different management systems. Having in mind the lack of research on this matter in Croatia, and the importance of arthropod communities in olive growing, their role as bioindicators has been selected as the topic of this research. The aim of the research was to determine the orders of arthropod present in each of the observed olive groves and to identify the number of individuals in each order. Based on the obtained results, the final goal was to determine the bioindicators of different management systems. This was the first project of this kind in Croatia, so the obtained results have brought important contribution to the inventory of arthropod communities in olive tree canopies. On top of that the results are setting a whole new direction in using arthropod communities as bioindicators of various agricultural management systems in a particular olive grove. It is important to mention that these results are also contributing to better understanding of harmful and beneficial entomofauna in olive orchards.

Material and methods

Study area and agricultural management systems

The research was done in three experimental olive groves in costal Croatia. First experimental olive grove (conventional - COG) is located in Supetar (43°22'38.6"N 16°32'15.8"E), second (integrated olive grove - IOG) is located in Kaštel Stari (43°33'25.8"N 16°20'56.3"E) and third (organic olive grove - OOG) is located in Duilovo (43°30'20.1"N 16°19'55.5"E). The selected olive groves have been characterised by similar growth and environmental conditions, as well as the variety; the only difference was the applied agricultural management system in each of them. Each experimental grove covers the area of approx. 0.5 ha, comprising about 125 trees of the autochthonous variety 'Oblica'. COG is ten years old, while IOG and OOG are twenty five years old. Good agricultural practices (GAP) were applied in all olive groves. According to Köppen Climate Classification System, observed olive groves are located in the region with Mediterranean or dry summer climate – Csa (Koppen & Geiger, 1954). It is usually characterized by rainy winters and dry, warm to hot summers.

The soil tillage was done twice each year of the research in the COG. Mechanical tillage has been done only in the ground plan projection of canopy at the end of April and in mid-May. Vegetation in the grove between the rows was maintained by mechanical mowing. In March or April, spring fertilisation was applied during shallow mechanical soil tillage in all three years of the research. Each olive tree was fertilised with 1 kg of nitrogen fertiliser KAN N 27 (INA, Kutina, Croatia). During autumn fertilisation in November 1 kg of complex fertiliser N-P-K (7:14:21; INA, Kutina, Croatia) per tree was applied. Treatments against *Bactrocera oleae* Gmel. and the anthophagous generation of *Prays oleae* Bern. were applied every year during research. In July and September, treatment with systemic organophosphate insecticide (dimethoate) at the concentration of 0.15 % was applied against *B. oleae*, while for the anthophagous generation of *P. oleae*, a synthetic pyrethroid (deltamethrin) at the concentration of 0.03 % was used. It was applied in each year of the research at the beginning of flowering (phenophase F) in May.

In the IOG soil was managed the same as in the COG. During shallow mechanical treatment in the spring, fertilisation with 1.5 kg of inorganic fertiliser Hortyflor (Cedar agro d.o.o., Novi Marof, Croatia) per olive tree was applied. For autumn fertilisation of olive trees, 1 kg per tree of complex fertiliser N-P-K (7:14:21; INA, Kutina, Croatia) was used. In this grove, *B. oleae* and *P. oleae* were also treated each year of the research. Poisoned baits were used for *B. oleae*. In the first two years, a poisoned protein bait consisting protein hydrolysates as a food attractant and insecticide (spinosad) at the concentration of 3 % was used, while in the third year a bait containing 0.07 % of sexual attractant Polycore™ SKl (AgriSense BCS Ltd., Pontypridd, UK) and synthetic pyrethroid (deltamethrin), was used. Each year 1 dL of poisoned baits was used, applied five times according to *B. oleae* control programme (Katalinić, 1998). Against the anthophagous generation of *P. oleae*, a growth inhibitor based on the active substance diflubenzuron at 0.02 % concentration was used.

The soil in the OOG was managed in the same way as in the other two groves. Spring and autumn fertilisations were done during shallow mechanical tillage in three years of the research using 1 kg per tree of Hortyflor fertiliser (Cedar agro d.o.o., Novi Marof, Croatia). Against *B. oleae*, attract-and-kill method was applied using Eco-trap (Vioryl S.A., Afidnes, Greece). A microbiological insecticide containing *Bacillus thuringiensis* Berliner spores at the concentration of 0.1 % was used against the anthophagous generation of *P. oleae*. It was applied at the beginning of flowering (phenophase F).

Experimental design and arthropod collection

The samples were taken monthly from April to November during the years 2007-2009, as the time when the largest differences in composition of the arthropod communities are observed between applied management systems in olive groves and which has the highest arthropod abundance (Ruano *et al.*, 2004; Jerez-Valle *et al.*, 2014; 2015). One sample contained fauna collected from the canopies of three olive trees of a smaller size or three branches of larger trees was randomly selected and put into linen bags of 4×2 m dimensions. Each sample was collected in three repetitions in three olive groves under different management systems (conventional, integrated and organic), in daytime between 8 am and 2 pm. The bags were firmly tied with a rope to keep the tree fauna inside. The fauna were collected by fogging through an opening in the bag with the solution of 9 mL of dichlorvos in 5 L of water using IGEBA TF 35 thermal fogger (IGEBA, Weitnau, Germany). The pipe was inserted through an opening in the bag and after fogging pulled out and the opening tightly closed with a rope. Ten minutes after the treatment, the bags were shaken well so that as many insects as possible would fall from the branches into the bag. Then the bags were carefully removed and taken to the laboratory for further examination. The contents of the bags were emptied on a large plastic foil to separate the fauna samples from the leftovers of the trees and other impurities. Each sample was examined with a binocular microscope and those of the Arthropoda phylum were separated and placed into 200 mL plastic bottles containing the solution of ethanol/water 70% (v/v) for further examination. The arthropods were further sorted according to orders, and each order was placed in a 1.5 mL Eppendorf tube containing the solution of ethanol/water 70% (v/v) and determined according to arthropods determination keys (Reitter, 1908; 1909; 1910; 1911; Kuhnt, 1911; Winkler, 1932; Freude *et al.*, 1964-1974; Schmidt, 1970; Durbešić, 1988). The identification was confirmed at the University of Zagreb Faculty of Science and Faculty of Agriculture, Croatia.

The family Formicidae (Hymentoptera) was separated from the other Hymenoptera, and was considered as an independent group due to its abundance. Further, suborder Heteroptera was separated from the other Hemiptera individuals, as well as individuals of Cicadidae and Psyllidae families. They were also considered as three independent groups due to their abundance.

Data analysis

The Shannon-Weiner (H') and Simpson (1-lambda) diversity indexes were calculated at the order level for each olive grove (COG, IOG and OOG) using PRIMER 6 (Plymouth Routines In Multivariate Ecological Research) software.

For statistical analysis, SPSS 11.0.0 software (SPSS Inc., Chicago, IL, USA) was used. Descriptive parameters (arithmetic mean and standard deviation) were used to describe continuous variables. Shapiro-Wilk test was used to determine normality. The differences among the olive grove locations were examined with one-way variance analysis. Variance homogeneity was assessed by using Levene's test and Bonferroni post hoc test. In the case of significant differences, further tests were applied that are usually used when homogeneity or equality of variances are not found.

A discriminant analysis was performed using the groups that showed significant differences in abundant to establish whether differences among the management systems would arise. The discriminant analysis was performed in different ways, either considering each year separately or grouping them, and also grouping samples in different sizes.

Results

Presence and abundance of arthropods in the olive groves under different management systems

All arthropod fauna collected from the olive groves under different management systems were representatives of two classes, Arachnida and Insecta. In the COG, 15 different orders were found, among which two belong to the Arachnida class, and 13 to Insecta class. In the IOG, 14 orders were found, two of Arachnida and 12 of Insecta class, while in the OOG 14 orders were found, three belonging to Arachnida and 11 to Insecta class (Fig. 1). In the same Fig. 1 the percentages of each order collected in the olive groves with different management systems during 2007-2009, are shown.

In the research a total of 7882 arthropods were collected. The highest number (3433) was collected in COG, followed by IOG where 2569 arthropods were collected. The lowest number (1880) was collected in OOG (Table 1). In the same Table the total number of arthropods collected in all researched olive groves during three years of the research, is shown. The majority of collected arthropods in the COG belong to order of Hemiptera, followed consecutively by Hymenoptera and Araneae. The majority of individuals in Hemiptera order belonged to Cicadidae and Psyllidae families, and the majority of individuals in Hymenoptera order belonged to Formicidae family. In IOG and OOG, the majority of the collected arthropods belong to the order of Hemiptera, largely influenced by the high number of Cicadidae and Psyllidae individuals, followed by orders of Araneae and Coleoptera.

These finding indicates great diversity of arthropods in olive groves. According to the results of Shannon-Weiner (H') and Simpson (1-lambda) diversity indexes (Table 2), great diversity of arthropods between the olive groves under different applied management systems was detected. The greatest diversity of arthropods was found in the IOG, followed by OOG. The lowest diversity of arthropods was found in the COG.

The total number of each order of arthropods collected in the three years of research according to the observed olive groves is shown in Table 3. In the same Table also the arithmetic mean values and standard deviations of each order of arthropods in the

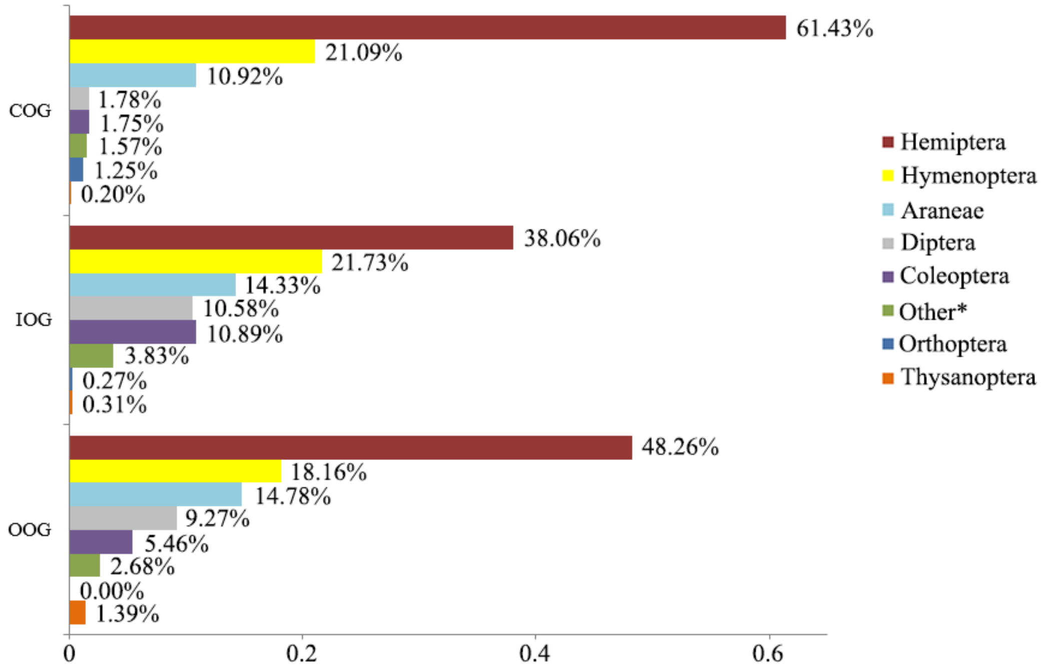

Figure 1. Percentage of orders of arthropods in COG (conventional olive grove), IOG (integrated olive grove) and OOG (organic olive grove) during 2007-2009. *Other: Trichoptera, Psocoptera, Collembola, Pseudoscorpiones, Mantodea, Neuroptera, Blattodea, Psocoptera, Acari, Dermaptera, Lepidoptera (all less then 1%).

olive groves under different management systems during 2007-2009, are shown. The differences between the years were investigated using the analysis of variance (ANOVA), and when the number of individual samples was not sufficient, ANOVA was not used. Table 3 also show that there were no statistically significant differences in number of Araneae individuals between 2008 and 2009 (p>0.05). Significantly more samples were collected in the first than in the second year of research (p=0.012). Statistically significant difference can be seen in the number of Psyllidae individuals (Hemiptera), between years 2007 and 2008. Significantly lower number of Psyllidae family individuals was determined in the second year of the research. Also, there were no significant differences in the number of Coleoptera individuals between second and third year of the research in IOG. It can be seen that relatively higher number of Coleoptera individuals was collected in 2007 comparing to 2008 (p=0.05). There were no statistically significant differences in the number of arthropods in OOG among the observed years (Table 3). According to the results, the orders of Araneae, Coleoptera and family of Psyllidae (Hemiptera) showed statistically significant differences; therefore, their mean values were used in the discriminant analysis.

Arthropods as bioindicators of different management systems

Discriminant analysis (Fig. 2) was used to determine differentiating functions of each olive grove under different management systems during the three years of research. Comparison among different management systems showed no significant differences except two orders and one family. Only the significant variables (orders of Araneae and Coleoptera, and family of Psyllidae) were used as potential ones, which can discriminate the researched groves. The other groups did not differ statistically or there were lack of some specimens depending on the management system considered. The dependent variable was each of the researched olive groves.

Significance of the individual functions is visible in the eigenvalues shown in Table 4, while Table 5 contains standardised coefficients that show which variables contribute most to discrimination among the groups. In 2008, none of the canonical functions was statistically significant (Table 4). In 2007 and 2009, there was only one discriminant function that statistically significantly differentiated the dependent variables. Orders of Araneae and Coleoptera contributed most to the discriminant function in 2007. The percentage of correctly classified cases was high (80%). In 2009, Coleoptera contributed

Table 1. Total number of arthropods in the olive groves with different agricultural management systems during three years of the research

Arthropods	N_{COG}	N_{IOG}	N_{OOG}	N_{tot}
Araneae	375	326	288	989
Pseudoscorpiones	2	3	1	6
Acari	0	0	4	4
Collembola	3	10	2	15
Hymenoptera	46	135	57	238
Hymenoptera/ Formicidae	678	432	282	1392
Hemiptera	55	210	103	368
Hemiptera/Cicadidae	989	374	315	1678
Hemiptera/ Psyllidae	1043	341	426	1810
Hemiptera/ Heteroptera	22	70	57	149
Dermaptera	21	15	13	49
Lepidoptera	13	10	8	31
Orthoptera	43	7	0	50
Coleoptera	60	284	102	446
Neuroptera	6	13	15	34
Diptera	56	276	173	505
Thysanoptera	14	8	26	48
Psocoptera	5	54	0	59
Blattodea	0	1	7	8
Mantodea	2	0	1	3

N_{COG}= number of arthropods in conventional olive grove; N_{IOG}= number of arthropods in integrated olive grove; N_{OOG}= number of arthropods in organic olive grove; N_{tot} = total number of arthropods in all researched olive groves

most to the discriminant function, and the percentage of correct classifications was also high (73%). None of the canonical functions was statistically significant in 2008, while in both 2007 and 2009, there was one function that statistically significantly discriminated the dependent variables (the researched olive groves). Total number of Araneae and Coleoptera individuals contributed the most to the discriminant function in 2007. The highest standardised beta coefficient for order of Araneae was positive, and for Coleoptera it was negative. The percentage of correctly classified cases was high (80%). Arithmetic mean values of discriminant points were significantly different among the three groups, and the most outstanding separated olive grove was COG. It was characterised by a higher number of Araneae individuals, and a lower number of Coleoptera individuals than the other two researched olive groves. In 2009, the number of Coleoptera individuals contributed the most to the discriminant function. The percentage of correct classifications was high (73%). Arithmetic mean values of discriminant points were significantly different among the three groups, and the most outstanding separated olive grove was IOG. It had higher number of Coleoptera individuals than olive groves with conventional and organic management systems.

Table 2. Shannon-Weiner (H') and Simpson (1-lambda') diversity indexes between the olive groves with different management systems in the three years of research

Olive groves	H′(loge)	1-lambda′
COG	1.742	0.7727
IOG	2.277	0.8827
OOG	2.161	0.8585

Discussion

Olive tree canopy is abundant in various orders of arthropods (Arambourg, 1986; De Andres, 1991; Varela & Gonzales, 1999; Campos & Civantos, 2000; Ruiz & Montiel, 2000), which can be bioindicators of different management systems (Cairns & Pratt, 1993; Brown, 1997; Jerez-Valle *et al.*, 2015). Intensive use of pesticides disturbs the balance of the biocoenosis, which reflects in the number and diversity of arthropods. Therefore, they can serve as bioindicators of changes in the olive grove caused by different management systems. The less abundance of arthropods in the COG than in the groves with other management systems was expected as a consequence of negative effects of pesticide use. Namely, the negative effect of pesticide use on the arthropods has been researched by many authors (Heim, 1985; Cirio, 1997; Civantos, 1999; Ruano *et al.*, 2004, 2010; Scalercio *et al.*, 2009; Santos *et al.*, 2010; Porcel *et al.*, 2013; Cardenas *et al.*, 2015; Jerez-Valle *et al.*, 2015), who confirmed that the least number of arthropods was found in the COGs. Ruano *et al.* (2004) pointed out that the highest number of arthropods after two years of research was collected in the IOG. The second highest number of arthropods was collected in the COG. On the contrary, the results of this research show that the highest number or arthropods was collected in the COG, followed by IOG. The lowest number or arthropods was collected in OOG. In all researched olive groves, and especially in conventional, a large number of Cicadidae, Psyllidae and Formicidae was collected. One of the reasons for their high abundance is their ability to adapt to changes, which are consequence of the pesticide use. Ruano *et al.* (2004) stated that the family of Formicidae is less sensitive to the pesticide use. One of the reasons that explain high numbers in some of the samples is that they are eusocial insects (Morris *et al.*, 2002). Their number can be related to the presence of numerous species that excrete honeydew, on which they feed. If the number of arthropods in the researched olive tree canopies is compared excluding the individuals of Cicadidae, Psyllidae and Formicidae families, different results are obtained. In that case, the most abundant of arthropods was IOG (1422), followed by the OOG (857). COG had the least number of arthropods (723).

In this work, the highest number of arthropods was collected in the first year of the research. The reason that may explain this is the extremely high temperature recorded during the sampling period in 2007. High temperatures, especially in the beginning of vegetation, have probably caused the sudden appearance of a large number of arthropods.

In the first two years of research, the highest number of Araneae individuals was collected in the COG, while in the third year of the research it was collected in the IOG. The lowest number of Araneae individuals, on average, was collected in the OOG. The results of this research are aligned with those of Mansour (1984) and Van Den Berg *et al.* (1990), but are contrary to those of Cardenas *et al.* (2006) and Morris *et al.* (2002). The same authors reported the highest number of Araneae in OOG, where 114.6% more samples were collected than in conventional grove. The results of this research can be affected by diversity of Araneae, as Cardenas *et al.* (2006) mentioned in the research. Also, Marc *et al.* (1999) stated that the species within order of Araneae behave differently depending on their exposure to pesticides used in the agriculture with conventional management system. It is well known that Araneae is more resistant to organophosphorus pesticides, carbamates (Mansour, 1984) and pyrethroids (Van Den Berg *et al.*, 1990) than to chlorinated carbohydrates. Mansour (1984) confirmed that some of the species of Araneae developed resistance.

In 2007 the highest number of Formicidae individuals was collected in the COG, which can be explained with proportionally high abundance of Cicadidae and Psyllidae individuals, as it is mention before. In other years of the research, the highest number of Formicidae individuals was collected from the IOG. Santos *et al.* (2007) investigated the arthropods in olive groves with integrated and organic management systems. The number of Formicidae individuals was the highest

Table 3. Total number of order of arthropods in olive groves under different management systems (COG= conventional olive grove; IOG= integrated olive grove; OOG= organic olive grove) during 2007-2009.

Arthropods	COG									IOG								
	N	2007		2008		2009				*N*	2007		2008		2009			
		M	SD	M	SD	M	SD	$F_{(2,14)}$*	*p*		M	SD	M	SD	M	SD	$F_{(2,14)}$*	*p*
Araneae	375	38.20	13.61	18.80	3.96	18.00	4.90	8.727	0.005	326	30.80	18.27	13.20	8.70	21.20	5.76	2.632	0.113
Pseudoscorpiones	2	0.40	0.55	0.00	0.00	0.00	0.00	-	-	3	0.40	0.89	0.20	0.45	0.00	0.00	-	-
Acari	0	0.00	0.00	0.00	0.00	0.00	0.00	-	-	0	0.00	0.00	0.00	0.00	0.00	0.00	-	-
Collembola	3	0.20	0.45	0.00	0.00	0.40	0.89	-	-	10	0.40	0.89	1.60	3.58	0.00	0.00	-	-
Hymenoptera	46	4.00	7.38	1.00	1.00	4.20	2.39	0.788	0.477	135	12.40	12.76	4.40	4.62	10.20	8.67	0.988	0.401
Hymenoptera/ Formicidae	678	114.80	247.21	17.00	21.42	3.80	2.28	0.896	0.434	432	20.80	24.91	27.60	34.57	380.00	23.08	0.479	0.631
Hemiptera	55	7.60	15.88	.80	1.79	2.60	3.65	0.693	0.519	210	260.00	52.05	10.80	12.30	5.20	4.60	0.603	0.563
Hemiptera/ Cicadidae	989	87.00	135.55	29.40	10.83	81.40	30.94	0.778	0.481	374	31.60	42.38	6.60	6.88	36.60	42.85	1.053	0.379
Hemiptera/ Psyllidae	1043	162.80	139.12	19.40	12.12	26.40	41.48	4.620	0.033	341	51.40	48.74	9.80	17.33	70.00	6.63	3.410	0.067
Hemiptera/ Heteroptera	22	1.20	1.79	2.80	3.11	0.40	0.89	1.635	0.236	70	5.80	6.69	3.40	3.21	4.80	2.05	0.368	0.700
Dermaptera	21	1.60	2.51	0.60	0.89	2.00	2.92	0.500	0.619	15	1.60	2.51	0.00	0.00	1.40	1.67	-	-
Lepidoptera	13	1.60	2.51	1.00	0.71	0.00	0.00	-	-	10	1.20	1.10	0.80	1.10	0.00	0.00	-	-
Orthoptera	43	4.80	6.53	3.40	7.06	0.40	0.55	0.817	0.465	7	0.80	1.10	0.40	0.89	0.20	0.45	0.636	0.546
Coleoptera	60	5.80	5.26	3.20	1.79	3.00	1.58	1.096	0.366	284	38.20	30.01	8.80	8.23	9.80	4.32	4.234	0.041
Neuroptera	6	0.00	0.00	1.00	2.24	0.20	0.45	-	-	13	0.20	0.45	0.60	0.89	1.80	2.17	1.825	0.203
Diptera	56	4.00	5.83	0.20	0.45	7.00	12.41	0.926	0.423	276	11.80	18.67	140.00	10.12	29.40	34.80	0.830	0.460
Thysanoptera	14	1.20	1.64	1.00	2.24	.60	1.34	0.147	0.865	8	0.00	0.00	0.60	1.34	10.00	0.71	-	-
Psocoptera	5	1.00	2.24	0.00	0.00	0.00	0.00	-	-	54	10.80	17.80	0.00	0.00	0.00	0.00	-	-
Balttodea	0	0.00	0.00	0.00	0.00	0.00	0.00	-	-	1	0.00	0.00	0.00	0.00	0.20	0.45	-	-
Mantodea	2	0.40	0.55	0.00	0.00	0.00	0.00	-	-	0	0.00	0.00	0.00	0.00	0.00	0.00	-	-

Table 3. Continued

Arthropods	*N*	OOG							
		2007		2008		2009			
		M	SD	M	SD	M	SD	$F_{(2,14)}$*	*p*
Araneae	288	260.00	10.32	15.40	9.94	16.20	8.79	1.850	0.199
Pseudoscorpiones	1	0.20	0.45	0.00	0.00	0.00	0.00	-	-
Acari	4	0.80	1.30	0.00	0.00	0.00	0.00	-	-
Collembola	2	0.00	0.00	0.00	0.00	0.40	0.89	-	-
Hymenoptera	57	4.60	4.04	2.60	1.82	4.20	3.42	0.537	0.0598
Hymenoptera/ Formicidae	282	29.80	36.89	150.00	12.51	11.60	14.38	0.814	0.466
Hemiptera	103	16.80	27.86	1.80	2.49	20.00	1.58	1.141	0.281
Hemiptera/ Cicadidae	315	33.40	33.52	18.20	17.68	11.40	4.93	1.303	0.307
Hemiptera/ Psyllidae	426	57.20	65.40	22.60	18.19	5.40	6.19	2.247	0.148
Hemiptera/ Heteroptera	57	5.20	9.47	0.60	0.89	5.60	11.41	0.524	0.605
Dermaptera	13	1.60	3.05	10.00	1.41	0.00	0.00	0.867	0.445
Lepidoptera	8	10.00	10.00	0.20	0.45	0.40	0.55	1.733	0.218
Orthoptera	0	0.00	0.00	0.00	0.00	0.00	0.00	-	-
Coleoptera	102	11.40	7.77	3.60	1.67	5.40	2.51	3.605	0.059
Neuroptera	15	0.20	0.45	1.20	1.64	1.60	1.67	1.368	0.292
Diptera	173	8.20	10.50	9.40	8.85	170.00	16.03	0.767	0.486
Thysanoptera	26	2.60	4.22	20.00	2.74	0.60	0.89	0.605	0.562
Psocoptera	0	0.00	0.00	0.00	0.00	0.00	0.00	-	-
Balttodea	7	0.20	0.45	0.00	0.00	1.20	1.10	-	-
Mantodea	1	0.00	0.00	0.20	0.45	0.00	0.00	-	-

N= number of arthropods collected in each olive grove (COG, IOG and OOG) during 2007-2009. M= average number of arthropods collected each year of the research in COG, IOG and OOG. SD= standard deviation

in both investigated olive groves. The same authors pointed out that Formicidae individual's presence in the IOG accounted for 36.8%, while in that with OOG for 17.4%. The highest number of other Hymenoptera was collected in the IOG and the lowest number was collected in the COG. Results lead us to conclude that pesticide use in COG reduces their abundance. The absence of Hymenoptera is important, especially in the integrated or organic olive groves, because most of them are significant predators in various ecosystems, as many authors have indicated (Finnegan, 1974; El Haidri, 1981; Arambourg, 1986; Gotwald, 1986; Sato & Higashi, 1987; Paulson & Akre, 1992; Way & Khoo, 1992; Majer & Delabie, 1993; Weseloh, 1993).

In this work, the highest number of order of Hemiptera was collected in the COG. The lowest number of same arthropods was collected in OOG. Individually, the most numerous families of Hemiptera were Cicadidae and Psyllidae. On the contrary, the highest number of all other individuals from order of Hemiptera was in IOG and the lowest in COG. It is important to emphasise that all collected samples of Psyllidae belong to the same species, *Euphyllura olivina* Costa. Ruano *et al.* (2004) also mentioned this species as the most numerous within the family. The same authors pointed out that *E. olivina* was the most numerous species in the canopies of the olive groves with integrated (95%) and organic (79.3%) management systems. Suborder of Heteroptera is the most numerous in IOG and OOG. In the first two years of the research, the highest number of Heteroptera individuals was collected in the IOG, while in 2009 it was collected in the OOG. Many authors emphasise the sensitivity of Heteroptera to insecticides used in olive groves (Zeletzki & Rinnhofer, 1966; Paternotte *et al.*, 1986). Severin *et al.* (1984) and Ruano *et al.* (2004) claimed that the species of this suborder can serve as bioindicators of different management systems.

In all years of research, the highest number of Coleoptera was collected from the IOG, followed by COG. Coleoptera is one of the most diverse orders in IOG, with the greatest diversity observed in the olive groves with integrated management systems. Many

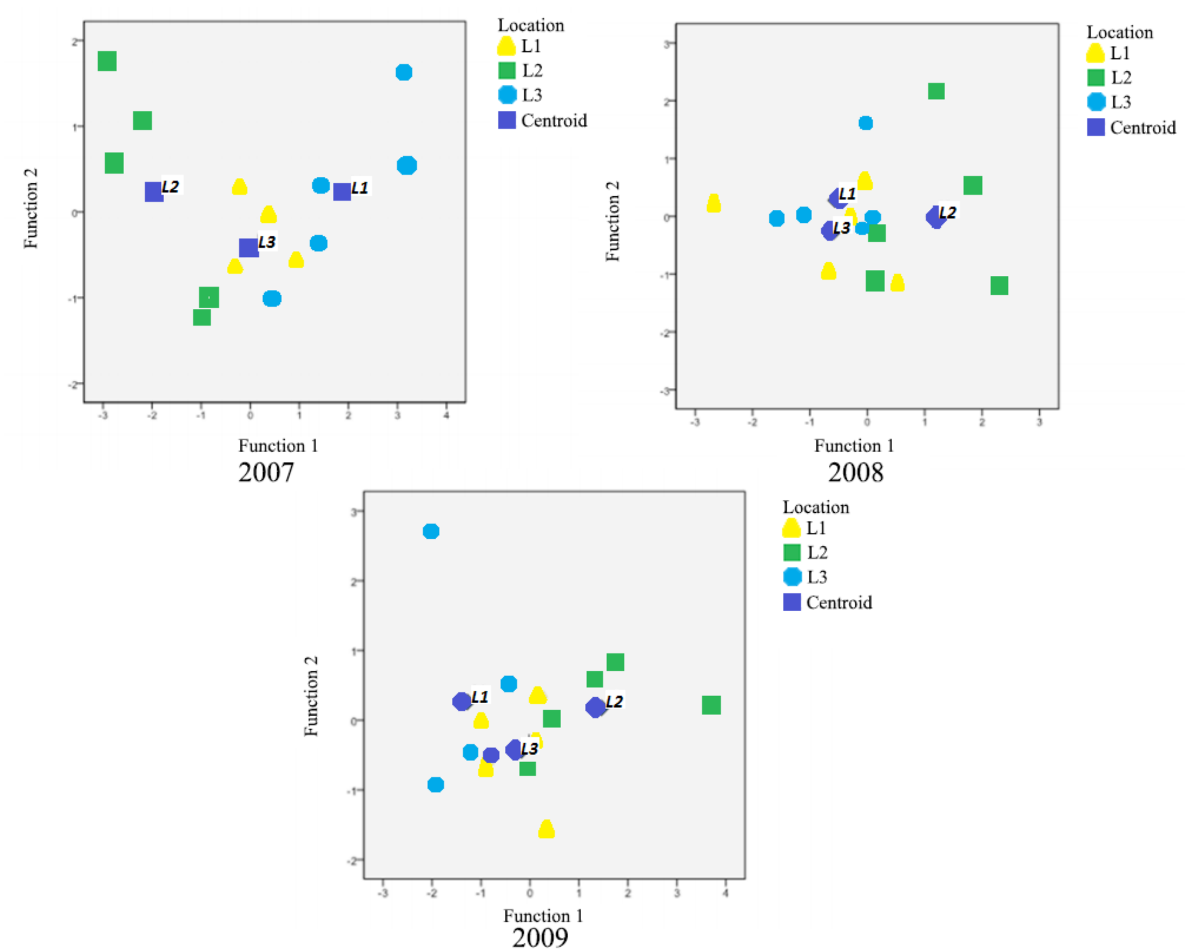

Figure 2. Distribution of the total number of arthropods in 2007, 2008 and 2009 (discriminant points of individual functions) and the corresponding centroids. L1= conventional olive grove; L2= integrated olive grove; L3= organic olive grove

Table 4. Values of eigenvalue, variance percentages, canonical correlation, significance function indicator and the percentage of correctly classified cases

Year	Function	Eigenvalue	Variance (%)	Canonical correlation	Wilks' Lambda	*p*-value	Classified cases (%)
2007	1	3.042	96.1	0.868	0.220	0.011	80.0
	2	0.123	3.9	0.331	0.890	0.528	
2008	1	0.832	92.9	0.674	0.513	0.291	46.7
	2	0.064	7.1	0.245	0.940	0.711	
2009	1	1.583	92.9	0.783	0.346	0.069*	73.3
	2	0.120	7.1	0.328	0.893	0.536	

*Relatively close to statistically significant

Table 5. Standardised coefficients for the variables of the arthropod orders included in the discriminant analysis (two canonical functions) depending on the year of investigation.

Order	2007		2008		2009	
	1	2	1	2	1	2
Araneae	1.050	0.353	-0.127	0.992	0.364	0.595
Hemiptera/Psyllidae	0.484	0.431	-0.817	-0.661	-0.513	0.703
Coleoptera	-1.515	0.389	1.010	0.018	0.961	0.083

researchers highlight its presence in the IOG and their importance, because it belongs to the group of predators (Churchill, 1997; Morris, 1997; Peck *et al.*, 1998; Morris *et al.*, 1999; Marc *et al.*, 1999; Holland & Luff, 2000; New, 2000; Ruano *et al.*, 2004).

The highest number of Diptera individuals was collected in the IOG, followed by organic grove. In COG, the number of Diptera individuals was the lowest, which was also indicated by other authors. Sol & Sanders (1959) and Sommaggio (1999) pointed out that the use of pesticides in agriculture significantly reduces the number of Diptera. Apart from them, Speight & Castella (2001), Ruano *et al.* (2004) and many others investigated the order of Diptera as potential bioindicator. According to them, the presence of Diptera in the olive grove and other agricultural crops indicates different management systems, as we can also conclude according to our results.

According to values of Shannon-Weiner and Simpson diversity indexes IOG was the most diverse that was due to fact that integrated management positively affects the abundance and diversity of arthropods, while conventional management negatively affects it. The results of arthropod diversity obtained in this research are aligned with those of Cardenas *et al.* (2006).

The olive biocenosis is stable and characteristic for a particular growth area and the environmental conditions typical for the olive grove. It responds in a measureable way to stress changes in the environment, especially to those caused by the pesticide use (Meffe & Carroll, 1994; McGeoch, 1998; Igrc Barčić & Maceljski, 2001). Diptera and suborder Heteroptera as part of olive tree canopy are potential bioindicators of different management systems. The number of Araneae and Coleoptera individuals differentiates significantly the olive groves under different management systems, so they can be considered as their bioindicators. Cardenas *et al.* (2006) also investigated the order of Araneae as bioindicators of different management systems. Similar results as ours were obtained by Ruano *et al.* (2004), according to whom the orders of Coleoptera, Diptera, Lepidoptera, Thysanoptera, and suborder of Heteroptera are potential bioindicators of different management systems. Orders of Coleoptera and Diptera are pointed out as bioindicators of the olive grove with organic management system. The findings of the above authors, as well as of the present research, match almost completely the criteria for the selection of bioindicators; they are extremely widespread, constant inhabitants of olive biocoenosis, always in great abundance, easy to collect and to determine, and are sensitive to pesticides. They are very important part of olive tree canopy because many of them are predators and parasitoids. The mentioned orders of insects have also been determined as bioindicators of sustainability in other agricultural crops (Fauvel, 1999; Iperti, 1999; Kevan, 1999).

In conclusion, the use of arthropod communities within the olive canopy could be useful in distinguishing between agricultural management systems, especially integrated and conventional. Diptera, Heteroptera and other Hemiptera individuals, excluded Cicadidae and Psyllidae family individuals, are potential bioindicators of olive groves under different management systems. The number of Araneae and Coleoptera individuals significantly differed all researched olive groves, so they can be considered as bioindicators of different agricultural management systems. According to the number of their individuals collected from the olive canopy, it is possible to determine, with great certainty, which management system was applied in particular olive grove. In the future, these two orders could potentially be used as bioindicators to determine the particular management system applied in a particular olive grove. In order to prove this we will expand investigation on more locations and on other Mediterranean crops.

References

Andrewartha HG, Birch LC, 1984. The ecological web: More on the distribution and abundance of animals. University of Chicago Press, Chicago, USA. 506 pp.

Arambourg Y, 1986. Traite d'entomologie oleicole. Ed. International Olive Oil Council, Madrid, Spain. 360 pp.

Biaggini M, Consorti R, Dapporto L, Dellacasa M, Paggeti E, Corti C, 2007. The taxonomic level order as a possible tool for rapid assessment of arthropod diversity in agricultural landscape. Agr Ecosyst Environ 122 (2): 183-191. https://doi.org/10.1016/j.agee.2006.12.032

Brnetić D, 1978. Štetne posljedice narušavanja biološke ravnoteže u maslininoj ekocenozi i nastojanju da se te štete ublaže u skladu s interesima čovjekovog zdravlja i ekonomične proizvodnje. Agronomski glasnik 5-6: 915-927.

Brown KS, 1997. Diversity, disturbance and sustainable use of Neotropical forest: insects as bioindicators for conservation monitoring. J Insect Conserv 1: 25-42. https://doi.org/10.1023/A:1018422807610

Burel F, Butet A, Delettre YR, Millan N, 2004. Differential response of selected taxa to landscape contex and agricultural intensification. Landscape Urban Plann 67: 195-204. https://doi.org/10.1016/S0169-2046(03)00039-2

Cairns J, Pratt JR, 1993. A history of biological monitoring using benthic macroinvertebrates. In: Freshwater biomonitoring and benthic macroinvertebrates; Rosenberg DM, Resh, VH (eds). pp: 10-27. Chapman & Hall, NY.

Campos M, Civantos M, 2000. Tecnicas de cultivo del olivo y su incidencia sobre las plagas. Olivae 84: 40-46.

Cardenas M, Ruano F, Garcia P, Pascual F, Campos M, 2006. Impact of agricultural management on spider populations in the canopy of olive trees. Biol Control 38: 188-195. https://doi.org/10.1016/j.biocontrol.2006.02.004

Cardenas M, Pascual F, Campos m, Pekar S, 2015. The spider assemblage of olive groves under three management systems. Environ Entomol 44 (3): 509-518. https://doi.org/10.1093/ee/nvv030

Churchill TB, 1997. Spiders as ecological indicators: An overview or Australia. Memoirs of the National Museum of Victoria 56: 331-337. https://doi.org/10.24199/j.mmv.1997.56.21

Cilgi T, 1994. Selecting arthropod 'indicator species' for environmental impact assessment of pesticides in field studies. Aspect Appl Biol 37: 131-140.

Cirio U, 1997. Agrichemicals and environmental impact in olive farming. Olivae 65: 32-39.

Civantos M, 1999. Control de plagas y enfermedades del olivar. Consejo Oleicola International, Madrid. 207 pp.

Cotes B, Campos M, Garcia PA, Pasual F, Ruano F, 2011. Testing the suitability of insect orders as indicators for olive farming systems. Agr Forest Entomol 13 (4): 357-364. https://doi.org/10.1111/j.1461-9563.2011.00526.x

De Andres F, 1991. Enfermedades y plagas del olivo. Riquelme y Vargas, Jaen, Spain. 646 pp.

Durbešić P, 1988. Upoznavanje i istraživanje kopnenih člankonošaca. Mala ekološka biblioteka 4, Zagreb, Hrvatska. 77 pp.

El Haidri HS, 1981. The use of predator ants for the control of date palm insect pests in the Yemen Arab Republic. Date Palm J 1: 129-132.

Fauvel G, 1999. Diversity of Heteroptera in agroecosystems: role of sustainability and bioindication. Agr Ecosyst Environ 74: 275-303. https://doi.org/10.1016/S0167-8809(99)00039-0

Finnegan RJ, 1974. Ants as predators of forest pests. Entomophaga Mémoire Hors Série 7: 53-59.

Freude H, Harde KW, Lohse GA, 1964-1974. Die Käfer Mitteleuropas Band I-XI. Goecke & Evers. Krefeld.

Garratt MPD, Wright DJ, Leather SR, 2011. The effects of farming system and fertilisers on pests and natural enemies: A synthesis of current research. Agr Ecosyst Environ 141: 261-270. https://doi.org/10.1016/j.agee.2011.03.014

Gkisakis V, Volakakis N, Kollaros D, Barberi P, Kabourakis EM, 2016. Agriculture ecosystems & environment. Agr Ecosyst Environ 218: 178-189. https://doi.org/10.1016/j.agee.2015.11.026

Gotwald WH, 1986. The beneficial economic role of ants. In: Economic impact: Control of Social Insect. Vinson SB (eds). pp 290-313. NY, USA.

Heim G, 1985. Effect of insecticidal sprays on predators and indifferent arthropods found in olives trees on the north of Lebanon. In: Integrated pest control in olive groves; Cavalloro R, Crovetti A (eds). pp: 456-465. CEC/FAO/IOBC/IJMP, Italy.

Holland JM, Luff ML, 2000. The effects of agricultural practices on Carabidae in temperate agroecosystems. Integr Pest Manage Rev 5: 109-129. https://doi.org/10.1023/A:1009619309424

Igrc Barčić J, Maceljski M, 2001. Ekološki prihvatljiva zaštita bilja od štetnika. Zrinski, Čakovec, Hrvatska. 247 pp.

Iperti G, 1999. Biodiversity of predaceous coccinellidae in relation to bioindication and economic importance. Agr Ecosyst Environ 74: 323-342. https://doi.org/10.1016/S0167-8809(99)00041-9

Jenneret P, Schupbach B, Pfiffner L, Walter T, 2003. Arthropod reaction to landscape and habitat features in agricultural landscapes. Landscape Ecol 18: 253-263. https://doi.org/10.1023/A:1024496712579

Jerez-Valle C, Garcia PA, Campos M, Pascual F, 2014. A simple bioindication method to discriminate olive orchard management types using the soil arthropod fauna. Appl Soil Ecol 76: 42-51. https://doi.org/10.1016/j.apsoil.2013.12.007

Jerez-Valle C, Garcia-Lopez PA, Campos M, Pascual F, 2015. Methodological considerations in discriminating olive-orchard management type using olive-canopy arthropod fauna at the level of order. Span J Agric Res 13 (4): 1-14. https://doi.org/10.5424/sjar/2015134-6588

Katalinić M, 1998. Zaštita masline od štetnika, bolesti i korova. Mediteranska poljoprivredna biblioteka. Zadružni savez Dalmacije - Zadrugar, Split, Hrvatska. 64 pp.

Kevan PG, 1999. Pollinators as bioindicators of the environment: species, activity and divesity. Agr Ecosyst Environ 74: 373-393. https://doi.org/10.1016/S0167-8809(99)00044-4

Köppen W, Geiger R, 1954. Klima der Erde (Climate of the earth). Wall Map 1:16 Mill. Klett-Perthes, Gotha.

Kuhnt P, 1911. Käfer Deutschlands. E. Schweizerbartsche, Verlagsbuchhandlung. Stuttgart. 1138 pp.

Lacroix G, Abbadie L, 1998. Linking biodiversity and ecosystem function: An introduction. Acta Oecologica 19 (3): 189-193. https://doi.org/10.1016/S1146-609X(98)80023-4

Majer JD, Delabie JHC, 1993. An evaluation of Brasilian cocoa farm ants as potential biological control agents. J Plant Protect Trop 10: 43-49.

Mansour F, 1984. A malathion-tolerant strain of the spider Chiracanthium mildei and its response to Chlorpyrifos. Phytoparasitica 12 (3-4): 163-166. https://doi.org/10.1007/BF02981168

Marc P, Canard A, Ysnel F, 1999. Spiders (Araneae) useful for pest limitation and bioindication. Agr Ecosyst Environ 74: 229-273. https://doi.org/10.1016/S0167-8809(99)00038-9

Markert B, Wunschmann S, 2011. Bioindicators and biomonitors: Use of organisms to observe the influence of chemicals on the environment. In: Organic xenobiotics and plants: from mode of action to ecophysiology; Schroder

P, Collins CD (eds.). pp: 217-236. Springer, Netherlands. https://doi.org/10.1007/978-90-481-9852-8_10

McGeoch MA, 1998. The selection, testing, and application of terrestrial insects as bioindicators. Biol Rev Cambridge Philos Soc 73: 181-201. https://doi.org/10.1017/S000632319700515X

Meffe GK, Carroll CR, 1994. Principles of conservation biology. Sinauer, Sunderland, MA, USA. 600 pp.

Morris TI, 1997. Interrelaciones entre olivos, plagas y depredadores. Doctoral thesis. University Granada, Spain.

Morris TI, Campos M, Kidd NAC, Jervis M, Symondos WOC, 1999. Dynamics of the predatory arthropod community in Spain olive groves. Agr Forest Entomol 1: 219-228. https://doi.org/10.1046/j.1461-9563.1999.00030.x

Morris TI, Symondson WOC, Kidd NAC, Campos M, 2002. The effect of different ant species on teh olive moth, *Prays oleae* (Bern.), in Spanish olive orchard. J Appl Entomol 126: 224-230. https://doi.org/10.1046/j.1439-0418.2002.00647.x

New TR, 2000. How useful are ant assemblages for monitoring habitat disturbance on grass land in South Eastern Australia? J Insect Conserv 4: 153-159. https://doi.org/10.1023/A:1009668817271

Paternotte E, Sterk G, Schmidt H, 1986. Etude de l'action de defferents fongicides et insecticides sur la faune des arbres frutiers. IOBC/WPRS Bull. IX (3): 15-28.

Paulson GS, Akre RD, 1992. Evaluating the effectivness of ants as biological control agents of pear psylla (Homoptera: Psyllidae). J Econ Entomol 85: 70-73. https://doi.org/10.1093/jee/85.1.70

Peck SI, McQuaid B, Campbell CL, 1998. Using ant species (Hymenoptera: Formicidae) as biological indicators of agrosystem condition. Environ Entomol 27: 1102-1110. https://doi.org/10.1093/ee/27.5.1102

Porcel M, Ruano F, Cotes B, Pena A, Campos M, 2013. Agricultural management systems affect the green lacewing community (Neuroptera: Chrysopidae) in olive orchards in Southern Spain. Environ Entomol 42 (1): 97-106. https://doi.org/10.1603/EN11338

Reitter E, 1908. Die Käfer des Deutschen Reiches. Band I. K. G. Lutz Stuttgart. 248 pp.

Reitter E, 1909. Die Käfer des Deutschen Reiches. Band II. K. G. Lutz Stuttgart. 392 pp.

Reitter E, 1910. Die Käfer des Deutschen Reiches. Band III. K. G. Lutz Stuttgart. 436 pp.

Reitter E, 1911. Die Käfer des Deutschen Reiches. Band IV. K. G. Lutz Stuttgart. 236 pp.

Rodriguez E, Pena A, Raya AJS, Campos M, 2003. Evaluation of the effect on arthropod populations by using deltamethrin to control *Phloeotribus scarabaeoides* Bern. (Coleoptera: Scolytidae) in olive orchards. Chemosphere 52 (1): 127-134. https://doi.org/10.1016/S0045-6535(03)00184-X

Ruano F, Lozano C, Tinaut A, Pena A, Pascual F, Garcia P, Campos M, 2001. Impact of pesticides on beneficial arthropod fauna of olive groves. IOBC/WPRS Bull. 24: 113-120.

Ruano F, Lozano C, Garcia P, Pena A, Tinaut A, Pascual F, Campos M, 2004. Use of arthropods for the evaluation of the olive-orchard management regimes. Agr Forest Entomol 6: 111-120. https://doi.org/10.1111/j.1461-9555.2004.00210.x

Ruano F, Campos M, Sanchez-Raya AJ, Pena A, 2010. Olive trees protected from the olive bark beetle, *Phloeotribus scarabaeoides* (Bernard 1788) (Coleoptera, Curculionidae, Scolytinae) with a pyrethroid insecticide: Effect on the insect community of the olive grove. Chemosphere 80 (1): 35-40. https://doi.org/10.1016/j.chemosphere.2010.03.039

Ruiz M, Montiel A, 2000. Introducción al conocimiento de la entomofauna del olivar en la provincia de Jaen. Aspectos cualitativos. Bol San Veg Plagas 26: 129-147.

Santos SAP, Pereira JA, Torres LM, Nogueira AJA, 2007. Evaluation of the effects, on canopy arthropods, of two agricultural management systems to control pest sin olive groves from north - east of Portugal. Chemosphere 67: 131-139. https://doi.org/10.1016/j.chemosphere.2006.09.014

Santos SAP, Pereira JA, Raimundo A, Torres LM, Nogueira AJA, 2010. Response of coccinellid community to the dimethoate application in olive groves in northeastern Portugal. Span J Agric Res 8 (1): 126-134. https://doi.org/10.5424/sjar/2010081-1151

Sato H, Higashi S, 1987. Bionomics of Phyllonorycter (Lepidoptera, Gracillaridae) on Quercus. II. Effects of ants. Ecol Res 2: 53-80. https://doi.org/10.1007/BF02348619

Scalercio S, Belfiore T, Noce ME, Vizzarri V, Iannotta N, 2009. The impact of compounds allowed in organic farming on the above-ground arthropods of the olive ecosystem. Bull Insectol 62 (2): 137-141.

Schmidt L, 1970. Tablice za determinaciju insekata. Poljoprivredni fakultet Sveučilišta u Zagrebu. 256 pp.

Severin F, Bassino JP, Blanc M, Boni D, Gendrier JP, Reboulet JN, Tisseur M, 1984. Importance des heteropteres predateurs des psylles du poirier dans le sud-est de la France. IOBC/WPRS Bull VII (5): 140-147.

Sol R, Sanders W, 1959. Uber die Empfindlichkeit von Syrphiden-larven gegen Pflanzenschutzmittel. Anzeiger für Schädlingskunde 32: 169-172.

Sommaggio D, 1999. Syrphidae: can they be used as environmental bioindicators? Agr Ecosyst Environ 74: 343-356. https://doi.org/10.1016/S0167-8809(99)00042-0

Speight MCD, Castella E, 2001. An approach to interpretation of lists of insects using digitised biological information about the species. J Insect Conserv 5: 139-1139. https://doi.org/10.1023/A:1011399800825

Van Den Berg AM, Dippenaar-Schoeman AS, Schoonbee HJ, 1990. The effect of two pesticides on spiders in South Africa cotton fields. Phytoparasitica 22: 435-441.

Van Straalen NM, Verhoef HA, 1997. The development of a bioindicator system for soil acidity based on arthropod pH preferences. J Appl Ecol 34: 217-232. https://doi.org/10.2307/2404860

Varela JL, Gonzales R, 1999. Estudio sobre la entomofauna de un olivar en la provincia de Granada, durante el periodo de vuelo de la generación antofaga de Prays oleae (Lep., Yponomeutidae). Phytoma-España 111: 42-55.

Way MJ, Khoo KC, 1992. Role of ants in pest management. Ann Rev Entomol 37: 479-503. https://doi.org/10.1146/annurev.en.37.010192.002403

Weseloh RM, 1993. Manipulation of the forest ants (Hymenoptera: Formicidae) abundance and resulting impact on gypsy moth (Lepidoptera: Lymantriidae) populations. Environ Entomol 22: 587-594. https://doi.org/10.1093/ee/22.3.587

Winkler A, 1932. Catalogus Coleopterorum Regionis Pallaearticae. Wien. 1687 pp.

Zeletzki C, Rinnhofer G, 1966. Über Vorkommen und Wirksamkeit von Praedatoren in Obstanlagen I. Eine Mitteilung über Ergebnisse zweijähriger Klopffänge an Apfelbäumen. Beiträge zur Entomologie 16: 713-72.