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The impact of compounds allowed in organic farming on the above-ground arthropods of the olive ecosystem

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Abstract

The aim of this research was to evaluate the impact of compounds utilised against *Bactrocera oleae* (Rossi) on epigeic arthropod fauna. Rotenone, azadirachtin and copper oxychloride were the tested compounds. Occurrence and abundance of arthropods known for their sensitivity to habitat alterations and environmental perturbations were registered. Results showed that rotenone caused the largest reduction of arthropod abundance in comparison with azadirachtin and copper oxychloride. The impact on non-target arthropods was low for copper oxychloride and high for rotenone. Among surveyed taxa, Isopoda and other Coleoptera were the most reduced by rotenone and azadirachtin spraying. The lowest impact was showed by copper oxychloride which strongly reduces only Coleoptera, while no impact was detected for Araneae and Formicidae. The impact of tested active ingredients was higher on the above-ground arthropods than on canopy ones showed in previous studies. This could be due to the low dispersal ability of above-ground arthropods, mainly walkers, in comparison to canopy ones, mainly fliers. Our findings suggest to promote the use of preventive control strategies in order to reduce the use of any kind of pesticides in organic olive groves enhancing the ecological sustainability of agricultural systems.

Key words: organic farming, sustainable agriculture, biodiversity, coenotic balance, rotenone, azadirachtin, copper oxychloride, *Olea europaea*, Italy.

Introduction

Olive crop is the most widespread agroecosystem in the Mediterranean basin which maintained its ecological stability for thousand years. In the most recent years a strong crop specialisation and an aggressive chemical pest control occurred, determining a destabilisation of natural biological balances between parasitic and beneficial arthropods (Altieri *et al*., 2003). It caused the need of searching for pest control strategies with low environmental impact as suggested by the European Union, Common Agriculture Policy (EU, CAP) and asked by public opinion. The EU has formulated a long-term strategy to dovetail the policies for economically, socially and environmentally sustainable development, its goal being sustainable improvement of the well-being and standard of its citizens. This strategy provides a policy framework to deliver sustainable development by promoting sustainable production and consumption and ensuring biodiversity conservation. Organic farming is considered to be harmless for environmental and human health because only natural-derived pesticides are allowed, but the primary method for pest control is to prevent pest outbreaks by planting disease-resistant plants, using cover crops and crop rotation, and promoting beneficial insects and birds. In fact, very few researches are available in literature concerning risks related to the use of natural-derived pesticides in the field and their impact on non target organisms. Anyway, it is known that the use of compounds allowed in organic farming against the main pests, causes negative environmental impacts on the biocoenosis of the olive ecosystem noticeable by remarkable biodiversity reduction, with special regard to flying insects (Belfiore *et al*., 2006; Iannotta *et al*., 2007a). The side-effects of these active ingredients on the above-ground arthropod of olive groves are unknown. In recent time, the researchers focused their attention on the search of bioindicators able to give information on the environmental health, assessing the presence/absence of arthropods and the whole ecosystem diversity (Cotes *et al*., 2009). In agroecosystems the arthropod fauna is the most abundant and diverse animal component and is sensitive to chemical inputs (Raspi and Malfatti, 1982; Belcari and Dagnino, 1995; Belcari *et al*., 1995; Crovetti *et al*., 1996). Qualitative and quantitative composition of their communities strongly depends on human activities and landscape parameters. Moreover, arthropod fauna is easy to sample and for its sensitivity to environmental changes it has been used for monitoring the ecosystem health (Kremen *et al*., 1993).

The aim of this research, carried out in Calabria, Southern Italy, was to evaluate the impact on above-ground arthropod of some compounds utilised against the olive fly, *Bactrocera oleae* (Rossi) (Diptera Tephritidae). The present study is for completing the research performed by Iannotta *et al*. (2007a) on non-target flying arthropods. *B. oleae* is the key pest of olive ecosystem which determines a serious damage to quali-quantitative production in many olive areas. The active infestation percentages determined by the olive fly very often exceed the economic damage threshold (Iannotta, 2003). Among the compounds allowed in organic farming, in order to assess their environmental impact on non-target arthropods in the present study we evaluated the following compounds: rotenone, azadirachtin and copper oxychloride.

Materials and methods

The study area is located in the municipality of Terranova da Sibari, Cosenza, southern Italy (39°40'14"N 16°23'15"E), and the trials were performed in the Feraudo farm at 60 m above sea level, in a twenty years old, drip irrigated and tilled olive orchard under organic regime as described in Iannotta *et al*. (2007a). Six adjacent plots were established in the experimental olive grove. Two plots of 1.25 ha each were treated with copper oxychloride (Cupravit Blu WG®Bayer Cropscience, Milan, Italy), a fungicide and bacteriostatic agent, one of 0.6 ha was sprayed with rotenone (ROTENA®Serbios, Rovigo, Italy), an unselective insecticide, one of 0.6 ha was sprayed with azadirachtin (DIRACTIN® Serbios, Rovigo, Italy), acting mainly as antifeedant and growth disruptor, and two were untreated and were utilised as control. The active ingredients were sprayed twice (September 24th and October 18th 2005). Characteristics of sampled plots and concentration of active ingredients are summarised in table 1.

Above-ground arthropods were collected by using 5 pit-fall traps per plot usually utilised for the monitoring of Carabid beetles (Brandmayr *et al*., 2005), deployed in a central zone of the plot area to guarantee samples independence, underneath the tree canopy. Inter-trap spacing was higher than 10 metres in order to maximise their efficiency (Ward *et al*., 2001). Data were collected from July to December 2005 every twenty days during drupes ripening and until the harvest. The occurrence and abundance of six taxa (Arachnida: Araneae; Crustacea: Isopoda; Insecta: Coleoptera Carabidae, Coleoptera Staphylinidae, other Coleoptera, Hymenoptera Formicidae) were observed. These taxa were chosen for their sensitivity to habitat alterations and environmental perturbations, and could be considered as good bioindicators (Bohac, 1999; Downie *et al*., 1999; Lobry de Bruyn, 1999; Paoletti *et al*., 1999; Rainio and Niemelä, 2003). We utilised these high taxonomic levels of investigation in order to test a simplified approach, applicable also by non-specialist ecologists. Abundance data were homogenised by computing the Density of Activity (DA) index for each taxon (Brandmayr *et al*., 2005):

$$DA = [n_i / (Tr * d)] * 10$$

where: n_i = number of individuals of the species i; Tr = number of traps; d = days of traps exposure. In order to detect differences in community structure, responses of sampled taxa to treatments, and effects of active ingredients on the efficiency of trophic levels, data were analysed by using analysis of variance, Abbott's formula and index of Coenotic Balance.

Normalised data were submitted to one way analysis of variance (ANOVA) followed by LSD post hoc test to separate the means by using STATISTICA 5.5 (StatSoft, 1999).

We utilised the Abbott's formula in order to evaluate the impact of active ingredients on selected arthropods (Abbott, 1925). This formula was designed for computing the effectiveness of an insecticide on the target insects, but was also utilised for evaluating the impact of active ingredients on non-target insects (Michaud and McKenzie, 2004). Abbott's formula compares the number of individuals belonging to a given taxon found after the treatment in a treated plot with the number of individuals found during the same period in an untreated plot.

An index of Coenotic Balance (*CB*) was computed according to Iannotta *et al*. (2007a) in order to evaluate the efficiency of trophic levels. It is assumed that (1) in natural ecosystems antagonists are less abundant than indifferent insects which represent the major part of their preys, and that (2) the use of pesticides alters this ratio causing a relative higher decreasing of indifferent insects in the short time in respect to antagonist insects. Carabidae, Staphylinidae and Araneae were grouped in the Antagonist category (*A*) while Isopoda, other Coleoptera and Formicidae were grouped in the Indifferent category (*I*). Then, the Coenotic Balance (*CB*) index was computed as follows:

$$CB = n_I/n_A$$

where n_I equals to the number of individuals belonging to indifferent insect, and n_A equals to the number of individuals belonging to antagonist insect. Higher values mean a better coenotic balances.

Table 1. Treatments and plot sizes.

Treatments	Concentration / 100 l of water	Surface (ha)
Copper oxychloride 1	500 g	1.25
Copper oxychloride 2	500 g	1.25
Azadirachtin	200 ml	0.6
Rotenone	150 ml	0.6
Control 1	–	0.6
Control 2	–	1.25

Results and discussion

During this study 16,354 individuals belonging to surveyed arthropod groups were collected. Carabidae (n = 5,953; 36.4%) and Isopoda (n = 4,581; 28.0%) were the most abundant groups, as often occurs in agroecosystems (Kromp, 1999; Paoletti *et al*., 1999). Also Formicidae (n = 2,869; 17.5%) and Araneae (n = 1,815; 11.1%) were well represented, while other Coleoptera (n = 933; 5.7%) and Staphylinidae (n = 203; 1.2%) were scarcely collected. During the pre-treatment period Isopoda was the most abundant group, while Carabidae attained their maximum abundance during the post-treatment period. All taxa were scarcely represented at the end of the study, but all of them are present in the field during treatments (figure 1).

The abundance of arthropods was significantly reduced by treatments (table 2). Among surveyed taxa, only Carabidae and Staphylinidae, holometabolic generalist predators, seem to be unaffected by treatments, while other taxa showed a significant abundance decrease. Isopoda, generalist detritivorous known to be sensitive to pesticide application (Paoletti *et al*., 1999), is the most affected group, probably because of its feeding behaviour. In fact, organic detritus on the soil was covered by pesticides after spraying causing the poisoning of Isopoda pabulum and a consequently rapid reduction of their populations. Other Coleoptera were also strongly reduced because of the high presence among them of Tenebrionidae, mainly detritivorous as Isopoda. Araneae and Formicidae showed a weak reduction of abundance. In azadirachtin and copper oxychloride plots

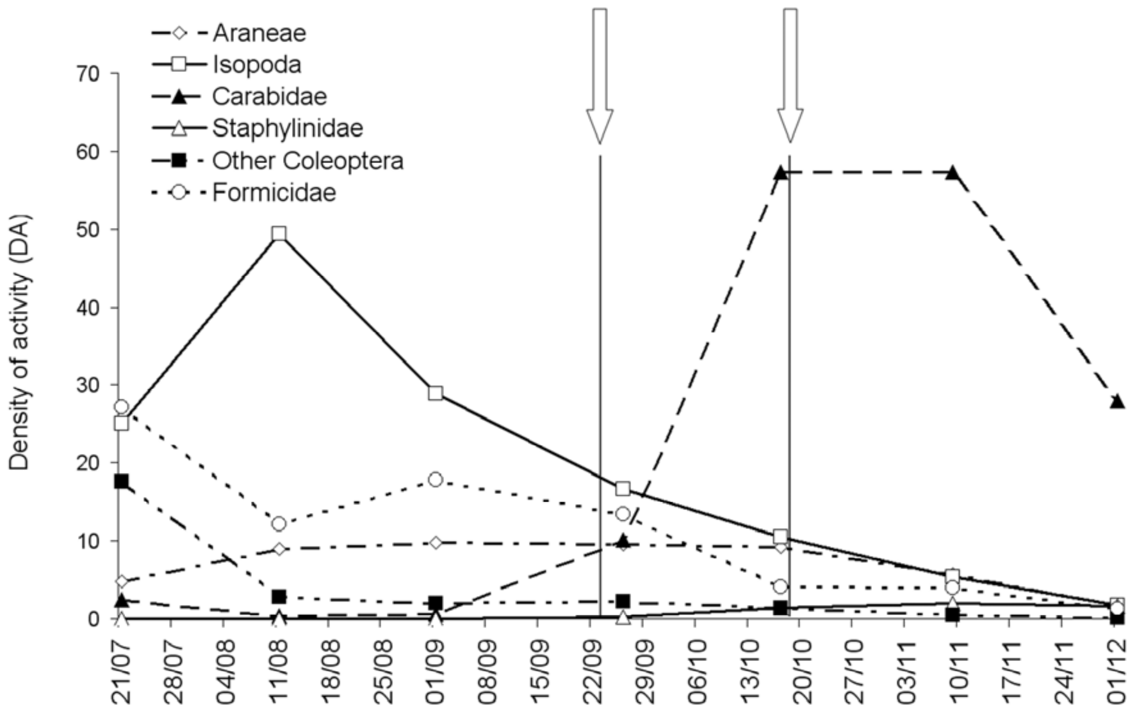

Figure 1. Phenology of surveyed arthropod groups. Arrows indicate treatment dates.

Table 2. Mean density of activity of surveyed taxa and coenosis annual density of activity.

	Control		Copper Oxychloride		Azadirachtin		Rotenone		$F_{3,26}$	*P*-level
	Mean	SD	Mean	SD	Mean	SD	Mean	SD		
Isopoda	52.57a	72.45	10.61b	8.89	1.59b	1.37	0.54b	0.43	2.71	0.06
Carabidae	32.39	39.15	25.89	30.02	23.51	33.48	11.54	16.10	0.46	0.71
Formicidae	17.78a	18.38	8.26ab	6.83	4.59b	2.41	4.69ab	3.37	2.26	0.10
Araneae	11.20a	5.02	8.84ab	3.36	9.83ab	8.06	4.24b	1.94	2.38	0.09
Other Coleoptera	6.05a	3.76	4.04ab	4.01	2.30b	1.32	0.91b	0.94	3.18	0.04
Staphylinidae	0.92	1.14	0.61	0.75	0.97	1.37	0.37	0.43	0.52	0.67
Coenosis	115.21A	65.89	49.56AB	29.96	41.22AB	30.90	20.96B	17.60	7.03	0.001

Different letters indicate significant differences among plots, ANOVA test, LSD post hoc test; small letters: $P = 0.05$; capital letters: $P = 0.01$.

a decrease of the abundance was registered, even if weaker compared with rotenone one, being the latter the only active ingredient having a clear insecticide mechanism of action. The untreated plots showed the highest abundance of arthropods.

The coenotic balance was higher in control plot (*CB* = 1.96), attaining lower values in treated plots. In detail, copper oxychloride (*CB* = 0.57), rotenone (*CB* = 0.36) and azadirachtin (*CB* = 0.28) showed an increasing impact of active ingredients on indifferent arthropods during the weeks after their field application. The *CB* reduction at soil level was higher than those previously observed at canopy level (Iannotta *et al*., 2007a). While at canopy level a decrease of the 71.0-74.0%, 44.6-50.5% and 18.3-52.9% was registered for rotenone, azadirachtin and copper oxychloride respectively (Iannotta *et al*., 2007a), on the ground the decrease reached the 81.6%, 85.7% and 70.9%. This could be in a relevant part due to the low dispersal ability of above-ground arthropods, mainly walkers, in comparison to canopy ones, mainly fliers. These behavioural features give a low resilience to above-ground arthropods which are better bioindicators than canopy ones. Probably the lower degradation dynamics on the ground of active ingredients plays an important role prolonging their life and efficacy.

The computing of Abbott's formula strongly supports the above reported results (table 3). In fact, rotenone showed the highest impact strongly reducing arthropods after its field application. Among surveyed taxa, Abbott's formula showed Isopoda and other Coleoptera as the most reduced by rotenone and azadirachtin spraying. The lowest efficacy was showed by copper oxychloride which strongly reduces only other Coleoptera, while no impact was detected for Araneae and Formicidae.

Table 3. Percentages of impact of tested active ingredients on surveyed arthropods computed by applying the Abbott's formula for each taxon and for the entire coenosis.

	Rotenone	Azadirachtin	Copper oxychloride
Isopoda	97.04	81.41	39.16
Araneae	40.85	51.69	-
Carabidae	72.43	44.98	21.83
Staphylinidae	75.37	32.49	52.55
Other Coleoptera	80.00	77.34	72.57
Formicidae	37.70	56.47	-
Coenosis	72.07	50.69	22.97

Conclusion

Azadirachtin and rotenone have a fast degradation dynamics which is decelerate on the soil because of the reduction of the photodegradation (Cavosky *et al.*, 2007). For these two active ingredients the results here showed must be considered only as short term effects, probably concealed over longer period by above-ground arthropod movements which are in any case slower than for fliers arthropods (Iannotta *et al.*, 2007a). The different dispersal ability between fliers and walkers arthropods can well explain the lower impact of tested active ingredients registered for the former in previous papers (Iannotta *et al.*, 2007a). A different consideration should be done for the copper oxychloride. In fact, it is known that copper residues were accumulated in the environment because of the high persistence of the copper in the soil (Xiaorong *et al.*, 2007). Then, although not so strong negative effects were registered for this compound on arthropods throughout the short duration of this study, its continuous use produces strong undesirable consequences on arthropods as long term effects as proved for several animal taxa. Field studies long more than one year should be able to find this long term effect also in olive groves.

This study is in agreement with the decision of the European Commission 2008/317/EC concerning the withdrawal of rotenone from those active ingredients allowed in organic olive growing, but allowed in Italy until 31 October 2011 on apple, pear, peach, cherry, grape-vine and potato only. This derogation is limited to professional users with appropriate protective equipment.

Although allowed in organic olive farming, all tested active ingredients caused a reduction of arthropods abundance at both canopy (Iannotta *et al.*, 2007a) and ground levels. The uses of appropriate agronomical strategies are known to reduce the negative effects of insect and microbial pests on the olive crop. The anticipate harvesting could reduce application of pesticides utilised for olive fly control (Iannotta, 2003), the soil grassing enhances ecosystem complexity favouring the conservation biological control (Tscharntke *et al.*, 2007), the planting of cultivar with low susceptibility could reduce damages to yield caused by insect and microbial pests (Iannotta *et al.*, 2007b). These preventive control strategies could reduce the use of any kind of pesticides in organic olive groves enhancing the ecological sustainability of agricultural systems.

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