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Populations, longevity, mortality and fecundity of *Chrysoperla carnea* (Neuroptera, Chrysopidae) from olive-orchards with different agricultural management systems

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Abstract

The influence that different styles of olive-orchard management (conventional, integrated, and organic) exert on the predator *Chrysoperla carnea* has been studied to strengthen this insect's role in the integrated management against pests. For this, the adult chrysopid populations were determined by McPhail traps, and laboratory examinations were made of certain biological characteristics of the first generation of adults captured in each of the olive orchards studied. The chrysopid populations increasing significantly during some months in the integrated and organic olive orchard. The most abundant species in all the zones was *C. carnea*, representing 95% of all captures in the conventional olive orchard. It was found that the larvae from the integrated olive orchard took longer to develop, while the pupae from the organic orchard evolved most rapidly to adulthood. The highest mortality rate was for larvae in the conventional olive orchard. The fecundity of the females from the organic orchards was significantly greater, presumably due to their greater longevity and shorter pre-oviposition period. These results can be used to improve conservation strategies and to increase *C. carnea* populations and their predatory activity.

Keywords: *Chrysoperla carnea*; Fecundity; Mortality; Longevity; Integrated pest control; Organic agriculture; Pesticides

1. Introduction

Natural enemies play an important role in agroecosystems, offering a valid alternative to, or integration with, other control methods (Salerno et al., 2002). Thus, the development of integrated management of pests seeks to increase natural control by the attraction and preservation of entomophagous arthropods (Szentkirályi, 2001). For this, it is fundamental to improve knowledge on the influence that different agricultural practices exert over such beneficial organisms.

Chrysoperla carnea Stephens is a widespread predator in agroecosystems, with great potential in integrated pest management (Hassan, 1974; Stelzl and Devetak, 1999; Duelli, 2001). In olive orchards, this insect is a major predator of two of the main phytophagous pests in this crop, *Prays oleae* Bernard (Lepidoptera, Plutellidae) with three

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generations and *Saissetia oleae* Olivier (Hemiptera, Coccidae) with one generation (Alrouedchi, 1980; Campos and Ramos, 1984; Sacchetti, 1990; Pantaleoni et al., 2001), and therefore it is of great importance to conserve and increase its populations (McEwen et al., 1994).

Many laboratory and semi-field studies have shown the sensitivity or tolerance of *C. carnea* to insecticides (New, 1975; Bigler, 1984; Grafton-Cardwell and Hoy, 1985a; Hassan et al., 1985; Vogt et al., 1992; Vogt, 1994; Elzen et al., 1998). In the olive orchard, the treatments applied reportedly diminished not only the effectiveness of its larvae against *P. oleae* (Ramos et al., 1978) and *S. oleae* (Delrio, 1983), but also the diversity of the species of chrysopids present (Pantaleoni and Curto, 1990; Ruano et al., 2001), and even the stability of forewing development in *C. carnea* adults (Lorenz, 2002). On the other hand, the beneficial effect of vegetation on the chrysopid populations has been shown in this crop as this insect lays its eggs on plants (Canard and Laudého, 1980; McEwen and Ruiz, 1994).

Currently, the integrated approach to olive-orchard management is being promoted because of the undesirable alterations that are becoming apparent with the growing indiscriminate use of chemical treatments (Heim, 1994; Cirio, 1997). In addition, organic management is growing in this culture due to market demand as well as environmental advantages (Civantos, 1999), reaching 17.8% of the total organic surface area of Spain (Alonso Mielgo, 2001).

Since agronomic factors incising *C. carnea* are numerous, the aim of the present work is to study the populations and behaviour of this chrysopid in olive orchards with different agricultural management systems.

2. Materials and methods

2.1. Study zones

The study was conducted in 2000 in commercial olive orchards (two conventional, two integrated and two organic) 20 km north of Granada (southern Spain). These sites, in an area of large olive orchards (ranging between 100 and 250 ha), lie some 4 km apart from each other and are located at similar altitudes, have similar environmental characteristics, but are under different management systems, which are being used at least for the last 10 years.

Conventional orchards were drip irrigated every 15 days and frequently ploughed deeply and, according to farmers' information, received three annual treatments of different insecticides and herbicides:

1. In March–April, a dimethoate spray (150 cc/ha of the EC formulation at 40%) against the phytophagous generation of *Prays oleae* Bern., and a soil treatment with the herbicide simazine (4 l/ha of the formulation at 50%).
2. In June, an alpha-cypermethrin spray (37.5 cc/hl of the SC formulation at 4%) against anthophagous generation of *P. oleae*.
3. In October, a dimethoate spray against the main important pest of this culture, *Bactrocera oleae* Gmelin (Diptera, Tephritidae) and a second treatment with simazine.

Integrated orchards were flood irrigated twice per summer and ploughed deeply from the end of May to the beginning of June. The application of pesticides is based on the economic threshold and using products authorised for integrated pests management, so only one treatment with dimethoate, in June 2000, was applied against the anthophagous generation of *P. oleae* and, during the study year, two soil treatments were made with simazine (in March and September).

Finally, the organic olive orchard, were drip irrigated bi-weekly in summer, ploughed only to a shallow depth (10 cm) from the end of May to the beginning of June and neither *Bacilllus thuringiensis* Berliner nor permitted insecticides were applied during our study.

2.2. Field trials

1. Adult chrysopid populations. In each olive orchard, three McPhail traps some 20 m apart were baited with ammonium phosphate plus borax, and were examined weekly from June to October.
2. The presence of possible prey of *C. carnea*. Taking into account the polyphagic characteristics of this chrysopid it is well known that it is fed from *P. oleae* eggs present in the fruits, the larvae stages of *S. oleae* and *Euphyllura olivina* Costa (Hemiptera, Psyllidae), and the honeydew from latter (Alrouedchi, 1980).

A total of 800 shoots from each type of olive orchard were collected over three samplings (May, July and November) and the presence of *Euphyllura olivina* Costa (Hemiptera, Psyllidae) and *Saissetia oleae* was recorded.

For a quantification of the incidence of *P. oleae*, 500 olive fruits were collected from each type of olive orchard at middle July and the total number of egg was counted.

2.3. Laboratory tests

In each plot, during August and September, adults of *C. carnea* were collected with butterfly nets. The specimens were placed in glass jars of some 2000 ml with food (50% beer yeast and 50% sugar) and were maintained at 22 ± 1 °C, 60(±5)% RH and a photoperiod of 16:8 h (L:D). The newly laid eggs were removed and were separated into individual jars at the same conditions, where the different developmental stages were examined daily to determine the duration, mortality and reproductive characteristics. The larvae were fed on eggs of *Ephestia kuehniella* Zeller (Lepidoptera, Pyralidae). The study of the duration of the different stages was made with 200 eggs, 180 larvae, 140 pupae and 100 adults from each type of olive orchard. The mortality of the different stages was studied beginning with 80 eggs and the study of reproductive characteristics was made with 100 females, from each type of olive orchards.

2.4. Statistical analysis

The data were submitted to an Analysis of Variance (ANOVA) and Multiple Range Test.

3. Results and discussion

3.1. Adult chrysopid populations

A total of 257, 630 and 365 adults were captured by trapping in the conventional, integrated and organic orchards, respectively. In those months where the chrysopids population were the lowest (July and October), the mean number of adults captured in the three olive orchards was similar; however, when the density increased the number of chrysopids captured was significantly higher ($p > 0.05$) in the integrated and organic olive orchard (Fig. 1).

These differences could be determined by different factors, although it is known that pesticide use (both for its direct toxicity as well a its sub-lethal effects) and soil management interfere most with the populations of natural enemies (Menalled et al., 1999). The impact of pesticides on natural enemies can occur by direct toxicity, repellent action, and host elimination (DeBach and Barlett, 1951). In the grape, *C. carnea* is more abundant in plots where mating disruption is used to control pests than in conventional ones where deltamethrin is used, because this technique with pheromones may lower the pesticide load of the environment (Schirra, 1990; Stockel et al., 1997). With respect to soil management, vegetation in the olive orchard can have a positive effect on chrysopid populations, as this insect uses plants to lay its eggs (McEwen and Ruiz, 1994). In this respect, it has been determined in apple orchards that the presence of plants such as *Melilotus alba* (Papilionaceae), *Lagopsis supina* (Labiatae) or *Medicago sativa* (Papilionaceae), favour *C. carnea* populations by offering pollen and alternative prey (Wyss, 1995; Yan et al., 1997).

Prey availability is another factor to take into account, as it can determine the attraction or displacement of individuals towards other zones in search of food (Croft and Strickler, 1983; Reddy, 2002). In the olive orchard, the main prey of chrysopids includes *P. oleae*, *S. oleae*, *E. olivina*, and psocids (Pantaleoni et al., 2001), with a relationship among the populations of *S. oleae* and *C. carnea* (Alrouedchi, 1980). Under our study conditions, the conventional olive orchard registered the lowest prey availability (Table 1), as the *P. oleae* egg populations on the fruits were six-fold lower than in the other olive orchards. The hemipteran *E. olivina* was found primarily in the integrated olive orchard, while *S. oleae* was found mostly in the organically managed orchard.

The most abundant chrysopid species in the olive orchards in study was *C. carnea*, as reported in other olive-growing zones (Alrouedchi, 1980; Neuenschwander and Michelakis, 1980; Campos and Ramos, 1983; Sacchetti, 1990; Bento, 1994; Pantaleoni et al., 2001). In the conventional orchards, this species reached 95% of the adults captured, while in organic and integrated orchards, the percentages fell to 79.3% and 61.3%, respectively, in agreement with Ruano et al. (2001) who reported, with a different sampling system, that *C.*

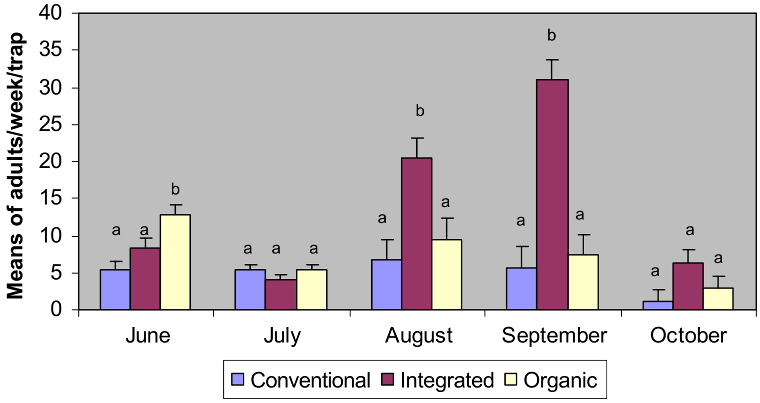

Fig. 1. Captures of adult chrysopids in olive orchards under different management systems.

Table 1
Eggs laid by *Prays oleae* on fruits and the presence of *Saissetia oleae* and *Euphyllura olivina* in olive shoots (between bracket the number of fruits and shoots observed)

Orchard	No. of *P. oleae* eggs	Shoots with *E. olivina*		Shoots with *S. oleae*	
		No.	%	No.	%
Conventional	138 (500)	2 (800)	0.3	24 (800)	3.0
Integrated	946 (500)	269 (800)	33.6	46 (800)	5.8
Organic	832 (500)	28 (800)	3.5	211 (800)	26.4

carnea was more abundant and constant in olive orchards under conventional management. *C. carnea* is more tolerant to the treatments than are other chrysopids present in the crop perhaps because it is constantly found in the crop (Campos and Ramos, 1983) and its populations are larger and therefore the pressure exerted by pesticides is greater. In this sense, Vogt et al. (2001) indicated that the populations most subjected to insecticide treatments were usually more tolerant than those from zones of less frequent applications. Other authors (Pree et al., 1989) have determined that *C. carnea* is more tolerant because it can metabolise certain pesticides by oxidative and esteratic pathways.

3.2. Duration and mortality of the different pre-imaginal stages

Under the study conditions, the eggs had a duration of four days, with no significant differences between the values corresponding to the different management methods. The larvae from the integrated olive orchard needed the most time to develop ($p > 0.05$), while the pupae of the organic olive orchard developed most rapidly to adulthood ($p > 0.05$) (Table 2). In general, the duration of the pre-imaginal stages of *C. carnea* depends on many factors (temperature, photoperiod, light intensity, food quality, sex of the specimen) (Canard and Principi, 1984), and thus it is difficult to distinguish the cause for the differences found.

The highest mortality rate was among the individuals from the conventional olive orchard, affecting mainly eggs and larvae, of which 25.75% did not reach the pupal stage (Table 3). These results suggest that the adults have been affected by the chemicals used in this type of management. In relation to the direct effects, it is known (Vogt et al., 2001) that in general the eggs and pupae of *C. carnea* are the most resistant stages, although oils (Bartlett, 1964) and a juvenile hormone analogue (Chen and Liu, 2002) cause significant mortality among eggs in this species. The adults are more sensitive than are larvae, and under the field conditions the insecticide can reach the insects by different avenues, given its entry into the food chain (Vogt et al., 2001). In this sense, Hamilton and Lashomb (1997) showed in the laboratory that the ingestion of prey treated with rotenone affected the feeding and survival of *C. carnea* larvae. However, in general, the effects observed in the field were less severe than those determined in the laboratory (Vogt, 1994; Vogt et al., 1998), given, among other factors, the lower exposure to the possibility of escape, or a more rapid degradation of the insecticide. On the other hand, the percentages of mortality in the field depend on the type of insecticide used and, despite the insect's tolerance to many pesticides, it has been noted that *C. carnea* is highly susceptible to the application rates in the field of most carbamates and organophosphorates, although different responses observed may be due to the test used and the variation of the response according to the geographic situation (Grafton-Cardwell and Hoy, 1985b).

3.3. Reproductive characteristics

Many laboratory studies have shown the impact of pesticides on the oviposition of *C. carnea*, reflecting different effects according to the exposure time, although many of the tests made were not adequate to verify the consequences of the use of pesticides in the field (Grafton-Cardwell and Hoy, 1985a).

Table 2
Duration of the different developmental stages of *C. carnea*

Orchards	Eggs		Larvae		Pupae	
	No.	Duration	No.	Duration	No.	Duration
Conventional	200	4.18 ± 0.10 a	180	9.77 ± 0.26 a	140	9.76 ± 0.21 a
Integrated	200	4.64 ± 0.10 a	180	11.48 ± 0.25 b	140	9.86 ± 0.19 a
Organic	200	4.55 ± 0.10 a	180	9.90 ± 0.24 a	140	8.36 ± 0.17 b

Different letters indicate significant differences ($p < 0.05$).

Table 3
Percentages of mortality of the different stages of *C. carnea*

Orchard	Eggs		Larvae		Pupae		Adults
	No.	%	No.	%	No.	%	No.
Conventional	80	17.50	66	25.75	49	8.16	45
Integrated	80	7.50	74	5.40	70	11.42	62
Organic	80	11.25	71	1.41	70	17.14	58

Table 4
Reproductive characteristics of females of *C. carnea* under controlled conditions, expressed in mean values (±SD)

Orchard	Total fecundity	Number of eggs/female/day	Longevity	Pre-oviposition period	No. of females observed
Conventional	124 ± 81 a	8 ± 4 a	19 ± 9 a	5 ± 2 a	100
Integrated	168 ± 139 a	9 ± 6 a	22 ± 10 ab	6 ± 3 a	100
Organic	316 ± 228 b	11 ± 6 a	30 ± 13 b	2 ± 2 b	100

Different letters indicate significant differences ($p < 0.05$).

Under the study conditions, no significant differences were found between female fecundity from adults collected in the conventional and integrated olive orchards. However, the females from the organically managed orchards presented significantly greater fecundity ($p < 0.05$) (Table 4). The number of eggs laid per day did not differ between orchards, although the value rose as the aggressiveness of the management style diminished (Table 4).

With respect to longevity, significant differences ($p < 0.05$) were found in the females from adults of the conventional and organic olive orchards, where the highest values were reached at 42 days in the former and 61 days in the latter. The females of the integrated orchard had intermediate longevity, with no significant differences with respect to the other two orchards. These results suggest that the different values related to fecundity may have resulted because the females of the organic orchards live longer and their pre-oviposition period is significantly shorter ($p < 0.05$) (Table 4).

Given that reproduction involves a series of physical, physiological, and hormonal factors leading to oviposition (Haynes, 1988), it is difficult to determine the specific components that determined the different values registered. That is, fecundity and longevity in *C. carnea* are related not only to feeding habits of the adults, which feed on honeydew, but also on the larvae (Canard and Principi, 1984; Zheng et al., 1993). Also, an agroecosystem with ecological management probably offers this species the best conditions to find adequate food, as occurs with other predators (Norris and Kogan, 2000).

To date, the few studies related to the sublethal effects of insecticide application indicate that in only some cases was there a non-significant reduction in the fecundity and fertility of adults (Vogt et al., 2001) or alteration in enzyme activity (Rumpf et al., 1997). Grafton-Cardwell and Hoy (1985a,b) reported a temporal effect, as *C. carnea* females exposed to pyrethroid laid fewer eggs, depending on the exposure time, their values returning to normal after exposure. Other authors (Shour and Crowder, 1980) have reported that the topical application of pyrethroids on third-stage larvae shortened longevity of the females and caused a post-treatment effect through one generation.

The results of the present study show the sensitivity of chrysopids to the different management methods and can thereby help improve conservation strategies and increase *C. carnea* populations as well as its predatory activity. This information can be of use in developing integrated management programmes for pests in this crop.

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References

Alonso Mielgo, A.M., 2001. El olivar ecológico en la comarca de los Pedroches (Córdoba). En: La práctica de la agricultura y ganadería ecológicas. Ed. Comité Andaluz de Agricultura Ecológica, Sevilla, 245–250.

Alrouedchi, K., 1980. Les chrysopides en verger d'oliviers. Bioecologie de *Chrysoperla carnea* (Stephens) (Neuroptera:

Chrysopidae), relations comportamentales et trophiques avec certaines espèces phytophages. PhD thesis, Université, Paris.

Bartlett, B.R., 1964. Toxicity of some pesticides to eggs, larvae and adults of the green lacewing, *Chrysopa carnea*. J. Econ. Entomol. 57, 366–369.

Bento, A., 1994. Studo sobre a traça da oliveira (*Prays oleae* Bern.) na terra quente transmontana na óptica da protecçao integrada. MSc thesis, Universidade Lisboa.

Bigler, F., 1984. Biological control by chrysopids: integration with pesticides. In: Canard, M., Semeria, Y., New, T.R. (Eds.), Biology of Chrysopidae, pp. 233–245.

Campos, Ramos, 1983. Chrisópidos (Neuroptera) capturados en un olivar del sur de España. Neuropt. Int. 2, 219–227.

Campos, M., Ramos, P., 1984. Some relationship between the number of *Prays oleae* eggs laid on olive fruits and their depredation by *Chrysoperla carnea*. In: Proceeding of International Joint Meeting CEC/FAO/IOBC, pp. 237–242.

Canard, M., Laudého, Y., 1980. Les néuroptéres captures au piège de McPhail dans les oliviers en Grèce. 2 : La région d'Akrefnion. Biologia Gallo-Hellenica 9, 139–146.

Canard, M., Principi, M.M., 1984. Life histories and behaviour. Development of chrysopidae. In: Canard, M., Semeria, Y., New, T.R., (Eds.), Biology of Chrysopidae. pp.57–75.

Chen, T.Y., Liu, T.X., 2002. Susceptibility of immature stages of *Chrysoperla carnea* (Neurop., Chrysopidae) to pyriproxyfen, a juvenile hormone analog. J. Appl. Entomol. 126 (2-3), 125–129.

Cirio, U., 1997. Productos agroquímicos e impacto ambiental en olivicultura. Olivae 65, 32–39.

Civantos, M., 1999. Control de plagas y enfermedades del olivar. Ed. Consejo Oleícola Internacional, Madrid, 207 pp.

Croft, B.A., Strickler, K., 1983. Natural enemy resistance to pesticides: documentation, characterization, theory and application. In: Georfhiou, G.P., Saito, T. (Eds.), Pest Resistence to Pesticides. Plenum Press, New York, pp. 669–702.

DeBach, P., Barlett, B., 1951. Effects of insecticides on biological control of insect pests of citrus. J. Econ. Entomol. 41, 1188–1191.

Delrio, G., 1983. The entomophagous insects of *Saissetia oleae* (Oliv.) in Sardinia. In etomphagous insects and biotechnologies against olive pests. In: Cavalloro, R., Piavaux, A. (Eds.), Proceeding of the European Commission Expert Meeting on Entomophages and Biological Methods in Integrated Control in Olive orchards, Chania, Greece, pp. 15–23.

Duelli, P., 2001. Lacewing in field crops. In: McEwen, P.M., New, T.R., Whittington, A.E. (Eds.), Lacewing in the Crop Environment. Cambridge, UK, pp. 158–171.

Elzen, G.W., Elzen, P.J., King, E.G., 1998. Laboratory toxicity of insecticides residues to *Orius insidiosus*, *Geocoris punctipes*, *Hippodamia convergens* and *Chrysoperla carnea*. Southw. Entomol. 23 (4), 335–341.

Grafton-Cardwell, E.E., Hoy, M.A., 1985a. Short-term effects of permethrin and fenvalerate on oviposition by *Chrysoperla carnea* (Neuroptera:Chrysopidae). J. Econ. Entomol. 78, 955–959.

Grafton-Cardwell, E.E., Hoy, M.A., 1985b. Intraspecific variability in response to pesticides in the common green lacewing, *Chrysoperla carnea* (Stephens) (Neuroptera: Chrysopidae). Hilgardia 53 (6), 1–31.

Hamilton, G.C., Lashomb, J.H., 1997. Effect of insecticides on two predators of the Colorado potato beetle (Coleoptera: Chrysomelidae). Florida Entomol. 80 (1), 10–23.

Hassan, S.A., 1974. Mass-culturing and utilization of *Chrysopa* spp. (Neuroptera, Chrysopidae) in the control of insect pests. Pflanz. Krank. 10, 620–635.

Hassan, S.A., klinganf, f., Shalin, F., 1985. Role of *Chrysopa carnea* as an aphid predator on sugar beet and the effect of pesticides. Z. ang. Entomol. 100, 163–174.

Haynes, K.F., 1988. Sublethal effects of neurotoxic insecticides on insect behavior. Ann. Rev. Entomol. 33, 149–168.

Heim, G., 1994. Effect of insecticidal sprays on predators and different arthropods found on olive trees in the north of Libanon. In: Cavalloro, S., Crovetti, S., (Eds.), Integrated Pest Control in Olive Groves. 456–465.

Lorenz, C., 2002. Changes in fluctuating asymmetry of *Chrysopa carnea* as a response to pesticides use in olive tree crops. Tesina Unv. Zaragoza, 36.

McEwen, P., Ruiz, J., 1994. Relationship between non-olive vegetation and green lacewing eggs in spanish olive orchard. Anntena 13, 148–150.

McEwen, P.K., Jervis, M.A., Kidd, N.A.C., 1994. Use of a sprayed L-tryptophan solution to concentrate numbers of the green lacewing *C. carnea* in olive tree canopy. Entomol. Exp. Appl. 70, 94–97.

Menalled, F.D., Lee, J.C., Landis, A., 1999. Manipulating carabid beetle abundance alters prey removal rates in corn fields. Biocontrol 43, 441–456.

Neuenschwander, P., Michelakis, S., 1980. The seasonal and spatial distribution of adults and larva chrysopids on olive-trees in Crete. Act. Oecol. Oecol. Appl. 1, 93–102.

New, T.R., 1975. The biology of chrysopidae and Hemerobiidae (Neuroptera) with reference to their usage as biocontrol agents: a review. Trans. Royal Entomol. Soc. London. 127, 115–140.

Norris, R.F., Kogan, M., 2000. Interaction between weeds, arthropod pests, and their natural enemies in managed ecosystems. Weed Sci. 48, 94–158.

Pantaleoni, R.A., Curto, G.M., 1990. Neurotteri delle colture agrarie: Crisopidi in oliveti del Salerno (Italia meridionale). Boll. Insti. Entomol. Univ. Bologna 45, 167–179.

Pantaleoni, R.A., Lentini, A., Delrio, G., 2001. Lacewing in Sardinia olive groves. In: McEwen, P.M., New, T.R., Whittington, A.E. (Eds.), Lacewing in the Crop Environment. Cambridge, UK, pp. 435–446.

Pree, D., Archibald, D.E., Morrison, R.K., 1989. Resistance to insecticides in the Common Green Lacewing *Chrysoperla carnea* (Neuroptera: Chrysopidae) in southern Ontario. J. Econ. Entomol. 82 (1), 29–34.

Ramos, P., Campos, M., Ramos, J.M., 1978. Osservazioni biologiche sui tratamenti contro la tignola dell'olivo (*Prays oleae* Bern., Lep. Plutellidae). Boll. Lab. Entomol. Agrar. Portici 35, 16–24.

Reddy, G.V.P., 2002. Plant volatiles mediate orientation and plant preferente by the predator *Chrysoperla carnea* Stephens (Neuroptera: Chrysopidae). Biol. Control. 25, 49–55.

Ruano, F., Lozano, C., Tinaut, A., Peña, A., Pascual, P., García, P., Campos, M., 2001. Impact of pesticides on beneficial arthropod fauna of olive groves. IOBC/WPRS Bull. 24 (4), 113–120.

Rumpf, S., Hetzel, F., Frampton, C., 1997. Lacewing (Neuroptera: Hemerobiidae and Chrysopidae) and integrated pest management. Enzyme activity as biomarker of sublethal insecticide exposure. J. Econ. Entomol. 90 (1), 102–108.

Sacchetti, P., 1990. Osservazioni sull'activitá e sulla bioetologia degli entomofagi di *Prays oleae* (Bern.) in Toscana I. I predatori. Redia 73, 243–259.

Salerno, G., Colazza, S., Conti, E., 2002. Sub-lethal effects of deltamethrin on walking behaviour and response to host kairomone of the eggs parasitoid *Trissolcus basalis*. Pest Mang. Sci. 58, 663–668.

Schirra, K.J., 1990. Effects of applications through several years without using insecticides on beneficial arthropods in viticulture. IOBC/WPRS Bull. 13, 282–285.

Shour, M.H., Crowder, L.A., 1980. Effects of pyrethroid. Insecticides on the common green lacewing. J. Econ. Entomol. 73, 306–309.

Stelzl, M., Devetak, D., 1999. Neuroptera in agricultural ecosystems. Agr. Ecosys. Environ. 74, 305–321.

Stockel, J.P., Lecharpentier, P., Fos, A., Delbac, L., Witzgall, P., Arn, H., 1997. Effects de la confusion sexuelle contre l'eudemis *Lobesia botrana* sur les populations d'autres ravageurs et auxiliaries dans le vignoble Bordelais. OILB/WPRS Bull. 20, 89–94.

Szentkirályi, F., 2001. Lacewing in fruit and nut crops. In: McEwen, P.M., New, T.R., Whittington, A.E. (Eds.), Lacewing in the Crop Environment. Cambridge, UK, pp. 172–220.

Vogt, H., Rumpf, S., Wetzel, C., Hassan, S., 1992. A field method for testing effects of pesticides on larvae of the green lacewing *Chrysoperla carnea* Steph. (Neuroptera, Chrysopidae). IOBC/WPRS Bull. 15, 176–182.

Vogt, H., 1994. Effects of pesticides on *Chrysoperla carnea* Steph. (Neuroptera, Chrysopidae) in the field and comparison with laboratory and semi-field results. OILB/WPRS Bull. 17 (10), 71–82.

Vogt, H., Gonzalez, M., Adan, A., Smagghe, G., Viñuela, E., 1998. Efectos secundarios de la azadiractina, via contacto residual, en larvas de jóvenes del depredador *Chrysoperla carnea* (Stephens) (Neuroptera, Chrysopidae). Bol. San. Veg. Plagas 24, 67–78.

Vogt, H., Viñuela, E., Bozsik, A., Hilbeck, A., Bigler, F., 2001. Interations with plant management strategies. In: McEwen, P.M., New, T.R., Whittington, A.E. (Eds.), Lacewing in the Crop Environment. Cambridge, UK, pp. 357–379.

Wyss, E., 1995. The effects of weed strips on aphids and aphidophagous predators in an apple orchard. Entomol. Exp. Appl. 75, 43–49.

Yan, Y., Yu, Y., Du, X., Zhao, B., 1997. Conservation and augmentation of natural enemies in pest management of Chinese apple orchards. Agr. Ecosys. Environ. 62, 253–260.

Zheng, Y., Daane, K.M., Hagen, K.S., Mittler, T.E., 1993. Influence of larval food consumption on the fecundity of the lacewing *Chrysoperla carnea*. Entomol. Exp. Appl. 67, 9–14.