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# Lethal and Sub-Lethal Effects of Four Insecticides on some parasitoids Associated with the Diaspidid Scale Insects.

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## ABSTRACT

A laboratory experiments had been conducted to study the toxic effect of lethal and sublethal concentrations of four insecticides (chlorpyrifos, spirotetramat, buprofezin and pyriproxifen) on the ectoparasitoid *Aphytis lingnanensis* and the endoparasitoid, *Encarsia citrina.* The obtained results indicated that the residual effect of chlorpyrifos, spirotetramat and buprofezin at the recommended concentration of (675, 40 and 250) ppm, respectively caused more than 90 % mortality to the parasitoid,*A. linganensis*, while, pyriproxifen (50 ppm) was the least toxic product caused 85% mortality. Chlorpyrifos was the most toxic compound to the parasitoid,*E. citrina* female,caused 100% mortality followed by spirotetramat (98.3%), buprofezin (95%) and pyriproxyfen (90%), respectively. Chlorpyrifos, buprofezin, pyriproxifen and spirotetramat at a concentration of 33.75, 12.5, 5 and 2 ppm, respectively had low toxic effect on the parasitoid females with no significant differences between the exposed and non-exposed (control) parasitoid females. The searching rate and mutual interference value of *A. lingnanensis* female treated with buprofezin was affected in comparison with those treated with the other tested compounds. Sublethal concentrations of pyriproxyfen and spirotetramat exhibited a slightly adverse effect on the searching behavior of *E. citrina*. On the contrary, the searching rate of the parasitoid females treated with chlorpyrifos and buprofezin was adversely affected. Reactions of *A. lingnanensis* and *E. citrina* adult females exposed by contact to sub lethal concentrations of the tested insecticides were observed in response to their hosts (*A. aurantii* and *Q.perniciousus*). Pyriproxyfen followed by spirotetramat did not significantly affected the behavior response (host recognition) of *A. lingnanensis* and *E. citrina* adult females to their hosts.

## INTRODUCTION

The diaspidid scale insects, California red scale *Aonidiella aurantii* MaskandSan Jose scale (SJS), *Quadraspidiotus peniciosus* (Comstock) as a new introduced pest to Egypt(Abd El-Kareim,*et al*.,2005) are among the most serious pests of fruit orchards (Claps *et al*., 2001, Kaiser and Sheard, 2006 and Abd-Rabou, 2009).

Parasitoids as bio-control agents provide an opportunity for significant reduction in CRS (Abd El-Kareim, 1998) and SJS(Bayoumy *et al*., 2009). The ectoparasitoid, *Aphytis lingnanensis* Comp. (Abd El-Kareim, 1998) as well as the endoparasitoid, *Encarsia citrina* Craw. (Abd El-Kareim, *et al*, 2004 and Bayoumy, 2010) are among the main mortality factors acting on their host populations.

The indirect effects of pesticides on natural enemies (which are sometimes referred to as sub-lethal or cumulative adverse effects) have not been studied as extensively compared to direct effects, and those studies associated with indirect effects of pesticides have primarily involved evaluating prey searching efficiency and host finding behavior (host-seeking stimulant, kairomene) (Raymond, 2012).

Several insecticides used for crop protection lead to environmental pollution. Native predators and parasitoids provide the essential ecosystem service of conservation biological control (Gardiner *et al*., 2011). The use of pesticides can hamper the effectiveness of natural enemies (Desneux *et al*., 2007). An important behavioral aspect of natural enemies that has not been studied extensively (Martinoua *et al*., 2014) i.e. the time invested to such as prey searching (Candolfi *et al*., 2001 and Delpuech *et al*., 2012).

Studies on how chemicals affect time allocation and the foraging success of beneficial arthropods could be integrated in the evaluation of pesticides during registration procedures (Desneux *et al*., 2007).

So, the present investigation aimed to study the toxic effect of lethal and sub-lethal concentrations of tested insecticides on some searching characteristic of the parasitic wasps, *A. lingnanensis* and *E. citrina*. (Hymenoptera: Aphidiidae), and their orientation behavior in response to odor from treated hosts.

## MATERIALS AND METHODS

**I. The tested insecticides:**

a-Chlorpyrifos-methyl EC 22.5% (Reldan): Organophosphate
b.Buprofezin SC 25% (Applaud): Insect growth regulators (IGR)
c. Pyriproxyfen EC 10% (Admiral): IGR
d. Spirotetramat SC 10% (Movento).

**2. The diaspidid species:**

- San Jose scale (SJS) *Quadraspidiotus perniciosus* (Comstock) and California red scale (CRS), *Aonidiella aurantii* (Maskell).

*Q. perniciosus* and *A. aurantii* were cultured in the laboratory of Economic Entomology Department at Mansoura University. Crawlers of *Q. perniciosus* and, *A. aurantii* were collected from infested apple and navel orange trees in the experimental farm of the Faculty of Agriculture, Mansoura University to start a culture. *Q. perniciosus* was reared on pumpkins (*Cucurbita maxima* Duchesne) and, *A. aurantii* on oleander seedlings (*Nerium oleander* L.).

**3. The parasitoid species:**

The tested parasitoids were the ectoparasitoid, *Aphytis lingnanensis*Comp and the endoparasitoid, *Encarsia citrine* Craw.. *A. lingnanensis* was collected in the pupal stage from infested navel orange trees with *A. aurantii*, while *E. citrina* was collected in the pupal stage from ficus trees (*Ficus nitida*) infested with *Aspidiotus nerii* and maintained in glass tubes until adult emergence. *A. lingnanensis* was reared on*A. aurantii* infesting oleander shrubs (*Nerium oleander*), while, *E. citrina* was reared on pumpkins infested with *Q. perniciosus*. The sex of the emerged *A.*

*lingnanensis*adults was determined according to Rosen and DeBach (1979) method, and pairs of a female and a male were kept separately in tubes for the experiments. The parasitoids were provided with honey streaks as an additional food source.

**4. Lethal and sub-lethal effects of insecticideson the natural enemies.**

Lethal and sub-lethal effects of chlorpyrifos-methyl, spirotetramat, pyriproxyfen and buprofezin on the parasitoids (*A. lingnanensis* and *E. citrina*) were investigated under laboratory conditions.

**A- Insecticide solutions:**

Commercial products of pyriproxyfen (Best WP 25%), buprofezin (Applaud SC 25%), chloropyrifos (Reldan EC 22.5 %) and spirotetramat (Movento® SC 10%) were diluted with tap water to have different concentrations. Tested concentrations were as follows: the recommended field rates of the tested compounds used on scale insects were 50,100, 300 and 40 ml/100 L respectively and reduced rates (80, 60, 40, 20 and 10 and 5) % of recommended rate for each insecticide to mimic lower rates that usually occur in fields during the days/weeks/months following insecticides application.

**B- Toxicity of insecticide residues on glass tube:**

The toxicity of the tested insecticides was estimated by exposing the tested parasitoids (*A. lingnanensis* and *E. citrine*) to the previously mentioned six concentrations of each insecticide.

To get a homogeneous deposit according to He *et al.* (2012), 19.6 ml of the various solutions (or water as control) was put in glass tubes (length: 14.8 cm, diameter: 1.3 cm and internal surface: 19.6 $cm^2$), which allowed a total coverage of the internal surface of the tubes. The tubes were then rotated and the solutions were poured off until no more droplets were seen on the glass tubes. Finally, they were left to allow complete evaporation of solutions at room temperature before introducing the natural enemies.

Exposing ten adult females of (*E. cirina* and *A. linganensis*) to dry residues of the tested insecticides in glass tubes. Then the tubes were closed with fine nylon to prevent insects escaping. Mortality was recorded after 24hrs. of exposure. Each treatment was replicated six times. Individuals that did not react when pushed with a brush were considered dead. According to He *et al.* (2012) surviving females were transferred into glass vials provided with honey streaks as an additional food source and kept under laboratory conditions until the sublethal effect examination.

**C- Sub-lethal effect of the tested compounds on some searching characteristics of the parasitoids:**

**Searching rate and mutual interference value of A. *linganensis* and *E. citrina* in response to *A. aurantii*.**

The searching rate and mutual interference value of exposed and unexposed adult female stage of *A. linganensis*as well as *E. citrina*to sub-lethal concentration of the tested compounds were estimated on oleander shrubs infested with *A. aurantii*.

Four densities consist of 1, 2, 3 and 4 individuals of each parasitoid species, respectively, were examined by confining 50 individuals of 2$^{nd}$ instar (for *E. citrina*) or adult stage of *A. aurantii* on oleander shrub (for *A. linganensis*) with each density in cylinder screen-cage (10 cm in diameter X 30 cm length).

The parasitoid females were left in the cylinder cage (30 cm long x 10 cm diameter) for 48 hrs. with their hosts. Each parasitoid density was replicated five times. After the removal of the parasitoid females, oleander shrubs were kept under laboratory conditions (25 ± 2.5 $^{o}$C and 69 ± 3.9 R.H.) until the parasitoid progenies reached their pupal stage.

The searching rate ($a_t$) was calculated according to Varley *et al.*, (1973) equation as follow:-

$$a_t = (1/p) \log_e (N/S).$$

**Where,** p = number of parasitoid.

N = the number of hosts.

S = number of hosts not parasitized.

The relationships between the search rate ($a_t$) and parasitoid density (log p) are indicated by the slope of the equation:

$$\log a_t = \log Q - m \log p$$

**Where** Q: is the quest value (the search rate when the parasitoid density is one) and m: is the mutual interference value.

**D- Behavioral responses of the parasitoids to host seeking stimulants (kairomone):**

**Behavioral responses of *A. linganensis* and *E. cirina* to their hosts:**

Parasitoid females of (*E. cirina* and *A. linganensis*) treated with the sub-lethal rate of (chloropyrifos, spirotetramat, pyriproxyfen and buprofezin) or with distilled water (as a control were transferred into glass vials provided with honey streaks as an additional food source for the parasitoids and kept under laboratory conditions (Sokal and Rohlf, 1995).

The response of parasitoids to the host kairomone(*A. aurantii* or *Q. perniciousus*) was evaluated by using an experimental Y-tube.The experimental Y-tube consists of three dark cylinder arms (1 cm diameter x 6 cm highest) attached with an exposure plastic cylinder chamber (4.0 cm in diameter x 2.0 cm highest). Each tube (arm) was closed by black plastic cover.The internal wall of each cover was coated by Tangle-Foot as sticky materials (Abd El-Kareim *et al*., 2007).

To estimate host-seeking stimulants (kairomone) for parasitoids, the internal wall of one tube cover was coated with five individuals of the host, (virgin females of *A.aurantii*for *A. linganensis*and 2$^{nd}$ instar nymphsfor *E. cirina*, respectively), while the other two arms of the Y-tube were left empty (control).

Five females of each parasitoid species were introduced within the exposure chamber of the olfactometer for a period of 30 min. The exposure chamber was covered immediately after parasitoid release. The test was replicated five times (by using five parasitoid females each time) for each treatment. After each set of trials, the experimental Y-tube was cleaned with ethanol and distilled water. The parasitoids used in the bioassays were used only once.

## RESULTS

**1. Lethal effects of tested compounds on the tested parasitoids:**

A laboratory experiments had been conducted to study the effect of chlorpyrifos, spirotetramat, buprofezin and pyriproxifen residues on the ectoparasitoid *Aphytis linganensis* and the endoparasitoid, *Encarsia citrina* under laboratory conditions.

**The ectoparasitoid, *Aphytis linganesis*:**

The effect of tested insecticide residues on mortality percentages of the ectoparasitoid female, *A. linganensis* are presented in Table (1). The obtained results indicated that the residual effect of chlorpyrifos, spirotetramat and buprofezin at the recommended concentration of (675, 40 and 250) ppm, respectively caused more than 90 % mortality to the parasitoid, while, pyriproxifen (50 ppm) was the least toxic product caused 85% mortality.Chlorpyrifos (at a concentration of 33.75 ppm), spirotetramat (at a concentration of 4 and 2 ppm), pyriproxifen (at a concentration of 5 and 2.5 ppm) and buprofezin (at a concentration of 25 and 12.5 ppm) had low lethal effect on the parasitoid females with no significant differences between the exposed and non-exposed (control) parasitoid females.

**Table 1. Mortality percentage of *Aphytis linganensis* female after exposure to residues of chlorpyrifos, spirotetramat, pyriproxifen and buprofezin:**

| Chlorpyrifos | | Spirotetramat | | Pyriproxifen | | Buprofezin | |
|---|---|---|---|---|---|---|---|
| **Con. ppm** | **Mortality ± SE** | **Con. ppm** | **Mortality ± SE** | **Con. ppm** | **Mortality ± SE** | **Con. ppm** | **Mortality ± SE** |
| 675 | 98.3 ± 4.4 a | 40 | 95.0 ± 5.5 a | 50 | 85.0 ± 5.5 a | 250 | 98.3 ± 4.1 a |
| 540 | 91.7 ± 5.4 ab | 32 | 90.0 ± 8.9 a | 40 | 73.3 ± 12.1 b | 200 | 86.7 ± 5.2 b |
| 405 | 85.0 ± 7.6 b | 24 | 63.3 ± 8.2 b | 30 | 55.0 ± 10.5 c | 150 | 70.0 ± 8.9 c |
| 270 | 61. 7 ± 8.4 c | 16 | 46.7 ± 8.2 c | 20 | 35.0 ± 10.5 d | 100 | 53.3 ± 8.2 d |
| 135 | 45.0 ± 11.6 d | 8 | 36.7± 8.2 c | 10 | 26.7 ± 50.2 d | 50 | 43.3 ± 8.2 d |
| 67.5 | 26.67 ± 5.6 e | 4 | 16.7 ± 8.2 d | 5 | 13.3 ± 5.5 e | 25 | 20.0 ± 8.9 e |
| 33.75 | 15.0 ± 4.8 f | 2 | 13.3 ± 3.9 d | 2.5 | 10.0 ± 6.3 e | 12.5 | 13.3 ± 6.3 e |
| Control | 13.30 ± 3.5 f | 0 | 10.0 ± 4.1 d | 0 | 8.3 ± 5.5 e | 0 | 8.3 ± 5.5 e |
| L.S.D | 11.60 | | 12.32 | | 9.89 | | 10.64 |

**Values labeled with the same letter in a column are not significantly different at the 5% level, respectively (one way ANOVA).**

**The endoparasitoid, *Encarsia citrina*:**

Mortality percentages of the endoparasitoid female *E. citrina* female after exposure to residues of chlorpyrifos, spirotetramat, pyriproxifen and buprofezin, under laboratory conditions are presented in Table (2). The obtained results indicated that chlorpyrifos was the most toxic compound to *E. citrina* caused 100% mortality followed by spirotetramat (98.3%), buprofezin (95%) and pyriproxyfen (90%), respectively. While, chlorpyrifos, spirotetramat, pyriproxifen and buprofezin at 33.75, 2, 5 and 12.5 ppm, respectively, had low toxic effect on the parasitoid females with no significant differences between the exposed and non-exposed (control) parasitoids to the above-mentioned concentrations.

As shown in Tables (1, and 2) contact toxicity of pyriproxifen on adult female parasitoids (*A. linganensis* and *E. citrina)* was less harmful in comparison with the other tested compounds.

**Table 2. Mortality percentage of *Encarsia citrina* female after exposure to residues of Chlorpyrifos, spirotetramat, pyriproxifen and buprofezin:**

| Chlorpyrifos | | Spirotetramat | | Pyriproxifen | | Buprofezin | |
|---|---|---|---|---|---|---|---|
| **Con. ppm** | **Mortality ± SE** | **Con. ppm** | **Mortality ± SE** | **Con. ppm** | **Mortality ± SE** | **Con. ppm** | **Mortality ± SE** |
| 675 | 100 ± 0.0 a | 40 | 98.3 ± 4.1 a | 50 | 90.0 ± 8.9 a | 250 | 95.0 ± 5.5 a |
| 540 | 91.7± 5.6 ab | 32 | 85.0 ± 4.5 b | 40 | 80.0 ± 12.9a | 200 | 85.0 ± 5.5 a |
| 405 | 86.7 ± 6.8 b | 24 | 60.0 ± 8.9 c | 30 | 58.3 ± 7.5 b | 150 | 70.0 ± 8.9 b |
| 270 | 55.0 ± 8.4 c | 16 | 46.7 ± 8.2 d | 20 | 38.3 ± 9.8 c | 100 | 50.0 ± 8.9 c |
| 135 | 41.7 ± 7.9 d | 8 | 43.3 ± 8.2 d | 10 | 35.0 ± 5.5 c | 50 | 43.3 ± 8.2 cd |
| 67.5 | 30.0 ± 4.6 e | 4 | 30.0 ± 8.9 e | 5 | 15.0 ± 5.5 d | 25 | 33.3± 5.2 d |
| 33.75 | 11.7 ± 3.4 f | 2 | 18.3 ± 7.5 f | 2.5 | 10.0 ± 6.3 d | 12.5 | 13.3 ± 8.3 e |
| Control | 8.3 ± 3.6 f | 0 | 10.0 ± 6.3 f | 0 | 6.7± 5.5 d | 0 | 10.0 ± 7.9 e |
| L.S.D | 9.4 | | 8.6 | | 10.68 | | 10.55 |

**Values labelled with the same letter in a column are not significantly different at the 5% level, respectively (one way ANOVA).**

**2- Sub lethal effect of the tested compounds on the parasitoids.**

**On the searching rate and mutual interference values**

Sublethal effect of four commercial formulations of spirotetramat (at 4 ppm), chlorpyrifos (at 33.75 ppm), pyriproxyfen (at 5 ppm) and buprofezin (at 12.5 ppm) on the searching rate and mutual interference value of *A. lingpanenesis* and*E. citrina* was studied under laboratory conditions.

**The ectoparasitoid, *A. linganenesis***

Data presented in Table (3) and illustrated in Figure (1a) showed that the searching rate ($a_t$) of both treated and untreated with pyriproxyfen *A. linganenesis* females was the same (0.126)), While, treated *A.*

*linganenesis* females with buprofexin exhibited the lowest searching rate (0.094). Parasitoid females treated with spirotetramat or chlorpyrifos showed intermediate searching rate (0.107 and 0.102, respectively).On the other hand, the results indicated that by increasing parasitoid density, the searching rate of treated *A. linganenesis* females was affected in comparison with untreated (control) one. Mutual interference values for treated *A. linganenesis* females with pyriproxyfen, buprofezin, chlorpyrifos and spirotetramat were (0.103, 0.067, 0.057 and 0.052, respectively), respectively). Therefore, by increasing parasitoid density, searching rate per treated *A. linganenesis* female was decreased.

So, it could be concluded that the searching rate and mutual interference value of *A. linganenesis* female treated with buprofezin was affected in comparison with those treated with the other tested compounds.

**The endoparasitoid, *E. citrina***

Data represented in Figure (1b) cleared that; pyriproxyfen had no adverse effect on *E. citrina* female. The regression analysis obviously indicated that, the searching rate (log $a_t$) and mutual interference values (m) of untreated (0.123 and 0.041) and treated female (0.132 and 0.063) with pyriproxyfen were relatively similar (Table, 3). However, by increasing parasitoid density the searching rate of treated and untreated *E. citrina* female was slightly decreased.

In case of *E. citrina* females treated with spirotetramat andchlorpyrifos the searching rate was relatively lower in comparison with control. It was 0.115and 0.105, respectively. The lowest searching rate was recorded by female's trated with buprofezin (0.095). On the other hand, mutual interference values of *E. citrina* female treated with buprofezin, chlorpyrifos and spirotetramat were 0.068, 0.072 and 0.036, respectively (Table, 3).

Generally, it could be concluded that sublethal concentration of pyriproxyfen and spirotetramat exhibited a slightly adverse effect on the searching behavior of the tested natural enemies. However, they induced slight impact on the searching rate and mutual interference of the aphelinids parasitoids (*A. linganenesis* and *E. citrina*). On the contrary, the searching rate of the parasitoid females treated with chlorpyrifos and buprofezin was adversely affected.

a

B

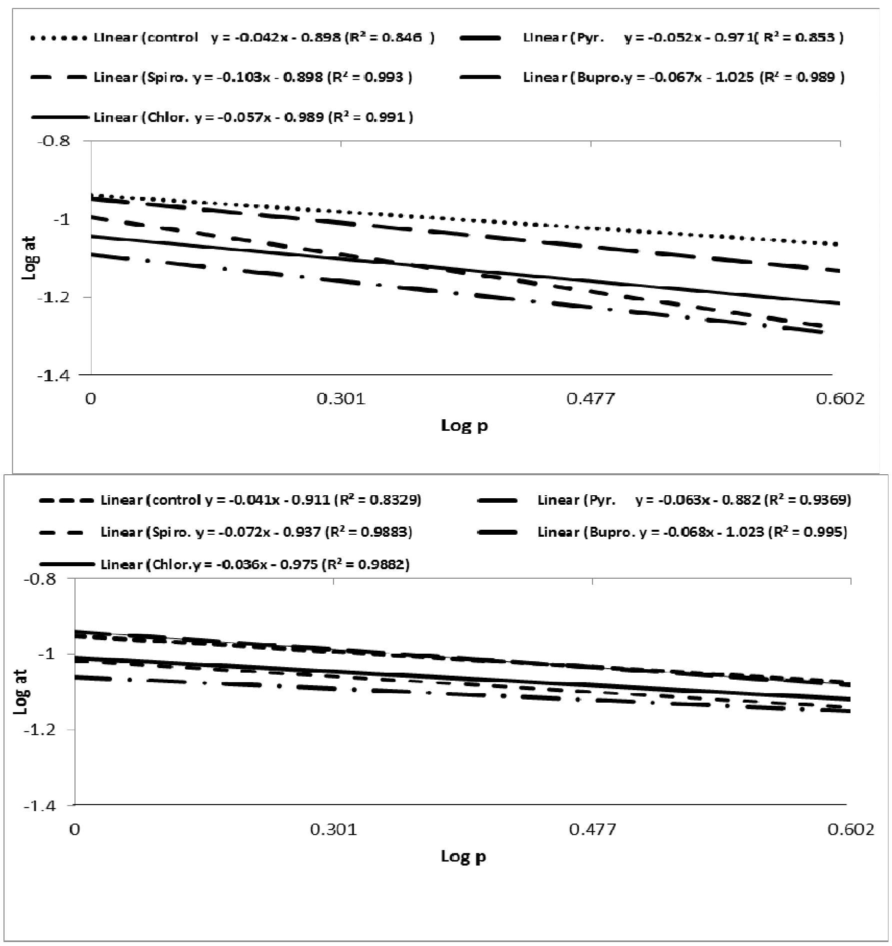


**Figure 1a and b. The relation between the searching rate (log at) and parasitoid density (log P) of treated and untreated parasitoids (a:A. linganenesis and b: Encarsia citrinae females) with the commercial product of (Spirotetramat, Chlorpyrifos, Pyriproxyfen and Buprofezin) under laboratory conditions**

**Table 3.The searching rate (log at) and mutual interference (regression coefficient: m) of treated and untreated parasitoids with sublethal concentration of (spirotetramat, chlorpyrifos, pyriproxyfen and buprofezin) under laboratory conditions.**

| Insecticides | Searching parameters | | | |
|---|---|---|---|---|
| | *A. linganenesis* | | *Encarsia citrina* | |
| | $a_t$ | m | $a_t$ | m |
| Control | 0.126 | 0.042 | 0.123 | 0.041 |
| pyriproxyfen | 0.126 | 0.052 | 0.132 | 0.063 |
| Buprofezin | 0.094 | 0.067 | 0.095 | 0.068 |
| Spirotetramat | 0.107 | 0.103 | 0.115 | 0.072 |
| Chlorpyrifos | 0.102 | 0.057 | 0.105 | 0.036 |

**On the parasitoid host-finding behavior (Kairomone)**

Sublethal effect of four formulations of spirotetramat (at 4 ppm), chlorpyrifos (at 33.75 ppm), pyriproxyfen (at 5 ppm) and buprofezin (at 12.5 ppm) on the parasitoid host-finding behavior of the *A. lingpanenesis* and *E. citrina*was investigated under laboratory conditions.

***A. linganenesis* in response to *A.aurantii*.**

The percentage of *A. linganenesis* adult females attracted to scale bodies of *A. aurantii* female after exposure to sub lethal concentration of the different insecticides (pyriproxyfen, buprofezin, chlorpyrifos and spirotetramat) as well as water (as control) are illustrated in Figure (2). The percent% of attracted *A. linganenesis* females exposed to pyriproxyfen to their host was (76%) comparing with control (88%) with no significant differences. Exposure to, spirotetramat and buprofezin caused a slight decrease in attractiveness (68 % and 60%, respectively). Chlorpyrifos caused a significantly reduction in parasitoid response to its host, only 52% of exposed females showed positive response to their host.

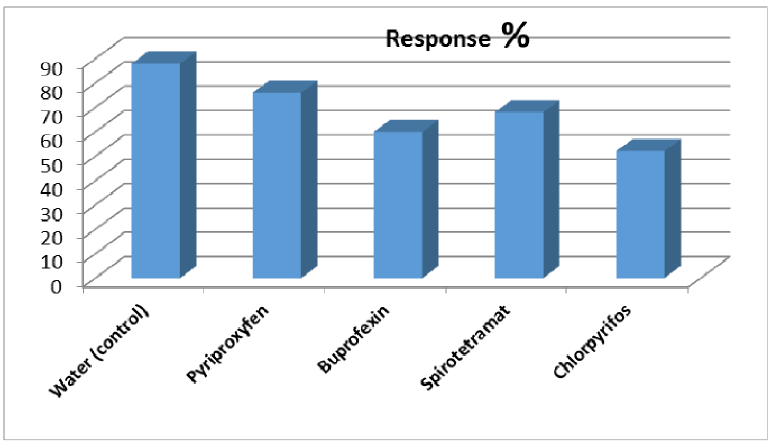


**Figure 2. Percent of attracted *Aphytis linganensis* adult females to *Aonidiella aurantii* female body after exposure to sub lethal concentration of pyriproxyfen, buprofezin, chloripyrifos and spirotetramat (L.S.D., p 5% =18.7- F-test, one way ANOVA).**

***E. citrina*in response to *A.aurantii* and *Q. perniciosus***

Reactions of *E. citrina* females exposed by contact to sub lethal concentration were observed in response to 2nd instar females of CRS,*A. aurantii* and SJS, *Q.perniciousus* by using the experimental Y tube.

As shown in Table (4), exposed *E. citrina* females to sub-lethal concentration of pyriproxyfen recorded a percent response of 80 % with no significant difference with control (84% response), while *E. citrina* females exposed to spirotetramat, and buprofezin showed 68 % and 56% response, respectively. On the other hand, *E. citrina* females exposed to chlorpyrifos, only 44% showed positive response to their host.

Data presented in Table (4),indicated that exposed *E. citrina* adult females to sub-lethal concentration of the tested compounds showed different degrees of their preference for SJS females. However, pyriproxyfen treated *E. citrina* females showed similar percentage of attractance to *SJS* adults (84%) compared with the control (92%), followed by Spirotetramat, buprofezin and chlorpyrifos treatments (64, 64 and 60 %, respectively) which significantly different from the former treatments (pyriproxyfen and control).

It can be concluded that, pyriproxyfen followed by spirotetramat did not significantly affected the behavior response (host recognition) of *A. linganenesis* and *Encarsia citrina* adult females to their hosts.

**Table 4. Percent of attracted *Encarsia citrina* adult females to 2nd instar female of CRS, *A.aurantii* and SJS, *Q. perniciosus* after exposure to sub lethal concentration of pyriproxyfen, buprofezin, chloripyrifos and spirotetramat (under laboratory conditions).**

| Treatment | % Response to their host | |
|---|---|---|
| | CRS | SJS |
| Water (Control) | 84 ± 16.7 a | 92 ± 11.0 a |
| Pyriproxyfen | 80 ± 14.1 a | 84 ± 16.7 a |
| Buprofezin | 56 ± 16.7 bc | 64 ± 14.1 b |
| Spirotetramat | 68 ± 17.9 ab | 64 ± 17.9 b |
| Chloripyrifos | 44 ± 16.7 c | 60 ± 14.1 b |
| L.S.D. (p 5%) | 17.2 | 19.3 |

**Values labeled with the same letter in a column are not significantly different at the 5% level, respectively (one way ANOVA).**

## DISCUSSION

**1. Lethal effects of tested compounds on the tested parasitoids:**

Toxicity bioassays of chlorpyrifos, spirotetramat, pyriproxifen and buprofezin conducted on *A. lingpanenesis,E. citrina* and *Chry.carnea* under laboratory conditions revealed that chlorpyrifos exhibited the highest rate of mortality in comparison with the other tested compounds. It induced approximately 100% mortality on all tested natural enemies. Chlorpyrifos is a organophosphate insecticide. it acts on the nervous system of insects by inhibiting acetylcholinesterase (Yerushalmi and Cohen, 2001). So, the tested natural enemies may more sensitive to chlorpyrifos than the other tested compounds. These results confirmed with those obtained by Morse *et al*. (1987); Michaud (2003); Suma *et al*.,(2009) and Gonzalez-Zamora *et al* (2013) that organophosphate insecticide are highly toxic to parasitoids. In the present study, pyriproxifen had a low toxicity on the adults of the aphelinid parasitoids.These results confirmed with those obtained by(Mendel *et al*., 1994 ; Michaud 2003; Rill *et al*., 2008; Suma *et al*.,2009;Gonzalez-Zamora *et al*.,2013) , while buprofezin, had toxic effect on the tested natural enemies.

**2- Sub lethal effect of the tested compounds on some natural enemies associated with the tested diaspidid scales:**

Insecticides at sublethal levels can influence insect behavior (Haynes, 1988). Several insecticides interfere with the normally well-orchestrated behavioral patterns of insects (Haynes, 1988 and Delpuech *et al.,* 1998). Also, the progeny production of each the ectoparasitoid*, Aphytis melinus*(Rosenheim & Hoy, 1988; Grafton-Cardwell & Reagan, 1995 and Yerushalmi & Cohen, 2001) and endoparasitoid, *Encarsia perniciosi*(Navrozidis *et al.,* 1999) females exposed by contact to sublethal concentration of the organophosphorus, chlorpyrifos or buprofezin (Rosenheim and Hoy, 1988) temporarily depressed progeny production. While, the IGR, pyriproxifen (Suma *et al*., 2009 and Salman *et al.,* 2014) and the Ketoenole (Carbonate0, spirotetramat (Garcera *et al.,* 2013) slightly harmful on *A. melinus*. Chlorpyrifos is an organophosphate insecticide. it acts on the nervous system of insects by inhibiting acetylcholinesterase .while the carbamates, was two orders of magnitude less effective on acetylcholinesterase (Yerushalmi and Cohen, 2001). So, pyriproxifen and spirotetramat are itegrated pest management compatible insecticides, effective in reducing the scale insects and allowing survival of its primary parasitoids (i.e. *A. linganenesis* and *E. citrina*).

**3. Sub lethal effect of the tested compounds on the parasitoid host-finding behavior (Kairomone)**

The sub-lethal rates of deltamethrin altered the response of the parasitoid *Trissolcus basalis* (Wollaston) to patches contaminated by a contact kairomone from its host (Salerno *et al.,* 2002). However, treated females showed a significantly lower residence time compared with untreated females. Untreated *Aphidius ervi* females were innately attracted to the odour of their hosts. This response was decreased by exposure to LC 0.1 of the pyrethroid lambda-cyhalothrine (Desneux *et al.,* 2000). On contrary, none of the doses of lambda-cyhalothrin, chlorpyriphos and pirimicarb had any effect on *A. ervi* responses to the odour from the aphid-infested plant (*Myzus persicae* on oilseed rape) (Desneux *et al.,* 2004).

*Leptopilina heterotoma* females exposed to chlorpyrifos at $LD_{20}$ found its host larvae more quickly than control females. They exhibited higher increase of their probing response to the odor than control. These sub-lethal effects, that stimulate host searching by parasitoids without impairing odormemorization, could increase their parasitic efficiency (Rafalimanana *et al.,* 2002). On contrary, in the present study *A. linganenesis* and *Encarsia citrina* adult females exposed to chlorpyrifos at 33.75 ppm induced adversely influenced host finding behavior. These differences may be attributed to chlorpyrifos molecules altered the functions necessary for olfactory responses, or surviving parasitoids were more susceptible (Desneux *et al.,* 2004).

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## النأثير المميت والغير مميت لأربعة مبيدات على بعض الطفيليات المرتبطة بالحشرات القشرية الصلبة

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تم اجراء بعض التجارب المعملية بهدف دراسة التأثير المميت وتحت المميت لكل من مبيد الاسبيروتيترامات والكلوربيريفوس و البيريبروكسيفين والبيبروفيزين على اناث كلا من الطفيل *Aphytis linganensis* والطفيل *Encarsia citrina*. واوضحت النتائج ان نسبة الموت فى اناث الطفيل *A. linganensis* المعاملة بكلا من الكلوربيريفوس والاسبيروتيترامات والبيبروفيزين (بالتركيزات الموصى بها وهى ٦٧٥- ٤٠.- ٢٥٠ جزء فى المليون.على التوالى) قد بلغت اكثر من ٩٠% بينما سجل البيريبروكسيفين اقل سمية ٨٥%. اما بالنسبة للطفيل *E. citrine* فقد كان مبيد الكلوربيريفوس الاكثر سمية حيث بلغت نسبة الموت ١٠٠% يليها الاسبيروتيترامات (٩٨,٣%) والبيبروفيزين (٩٥%) و البيريبروكسيفين (٩٠%). كما اوضح التحليل الاحصائى عدم وجود فروق معنوية فى نسب الموت بين لاناث المعاملة بالتركيزات المنخفضة للمبيدات (الكلوربيريفوس والبيبروفيزين والبيريبروكسيفين والاسبيروتيترامات بتركيز ٣٣,٧٥ و ١٢,٥ و ٥ و ٢ جزء فى المليون على التوالى) والغير معاملة. وبدراسة تأثير التركيزات تحت المميتة على المعدل البحثى وقيم التداخل التبادلى لكلا الطفيليين – فقد كان لمبيد البيبروفيزين تأثير سلبى المعدل البحثى والتداخل التبادلى لاناث الطفيل *A. linganensis* مقارنة بالمعاملات الاخري. بينما ابدى التركيز تحت المميت لكلا من والبيريبروكسيفين والاسبيروتيترامات تأثير طفيف على المعدل البحثى وقيم التداخل التبادلى للطفيل *E. citrina* بينما انخفض المعدل البحثى لاناث الطفيل المعاملة بميد الكلوربيريفوس والبيبروفيزين. كما وجد ان التركيز تحت المميت لكلا من البريبروكسيفين والاسبيروتيترامات لم يؤثر معنويا على سلوك اناث الطفيليات فى التعرف على عوائلها (الحشرة القشرية الحمراء وحشرة سان جوزية القشرية).