Efficacy of cinnamon oil and its active ingredient (cinnamaldehyde) on the cotton mealy bug *Phenacoccus solenopsis* Tinsley and the predator *Chrysoperla carnea*

Abd-Allah E. Ghada¹* and Youssef M. Naglaa²

**Abstract**

**Background:** The importance of *Chrysoperla carnea* (Steph.) (Neuroptera: Chrysopidae) as a predator is due to nourishing this predator on some dangerous pests as the cotton mealybug, *Phenacoccus solenopsis* Tinsley, belongs to Hemiptera: Pseudococcidae. So the predator *C. carnea* was used in the management of various pests. The basic aim of this study was the indirect effect of some natural materials against some stages of *C. carnea* through feeding of the predator on the treated prey, *Phenacoccus solenopsis* Tinsley (Hemiptera: Pseudococcidae).

**Results:** The results showed the comparison between the effectiveness of cinnamaldehyde and cinnamic oil in controlling the pest as soon as ineffectiveness on the predator. Cinnamaldehyde was very safe against *C. carnea* which did not effect on the biology of it and the predator completed its life cycle as control (water + tween 80). Thus, the results suggested that cinnamaldehyde could be included in the Integrated Pest Management (IPM) Program without any adverse effect on bio-control agents used in an IPM.

**Conclusion:** This study may be a great alternative to chemical pesticides in controlling cotton mealybug, *P. solenopsis*, and at the same time, this material is saving to the predator *C. carnea*. This alternative is cinnamaldehyde (the active ingredient of cinnamon oil).

**Keywords:** *Chrysoperla carnea*, *Phenacoccus solenopsis*, Cinnamic oil, cinnamaldehyde

---

**Background**

The cotton mealybug, *Phenacoccus solenopsis* Tinsley (Hemiptera: Pseudococcidae), is considered one of the most recent invasive sap-sucking insects in Egypt that is attacking cotton (El-Zahi et al. 2016; Mostafa et al. 2018), vegetables (Ibrahim et al. 2015), and many other field crops of economic importance. This pest feeds on all the green parts of the infested plants which become stunted, weak with distorted and yellow leaves, and die in severe infestations (Culik and Gullan 2005).

Natural products have been recently attracting the attention of some scientists to avoid the problems caused by synthetic compounds (Abou-Yousef et al. 2010; Mostafa et al. 2018).

The application of predators for a successful biological control program could be controversial, due to their potential to prey on other biological control agents and non-target species (Symondson et al. 2002).
Green lacewing, *Chrysoperla carnea* (Stephens), is a polyphagous predator that is released for pest control in greenhouses and is also very common in many agricultural systems. The previous studies indicate that five larvae *C. carnea* per 100 nymphs of the pest can be used as a biological control against *P. solenopsis* during the management program (Ibrahim 2018). This species is a powerful agent in biological control programs because of an expanded geographical distribution, high compatibility to different systems, high searching ability, and an easy way to rear (Golmohammadi et al. 2009). *C. carnea* larvae are extremely effective predators in the protected or enclosed areas such as greenhouses (Nayar et al. 1976).

The aim of this study was to determine the effect of cinnamon oil and its active ingredient, Cinnamaldehyde, on the cotton mealybug, *Phenacoccus solenopsis*, and apply LC50 on *P. solenopsis* individuals to feed the prey *C. carnea* and show the indirect effect of these materials on the control agent.

**Methods**

**Insect rearing**
The cotton mealybug, *Phenacoccus solenopsis* Tinsley (Hemiptera: Pseudococcidae), was collected from infested cotton plants (*Gossypium barbadense var. Giza 86*) at the field of Aga district, Dakahalia governorate, Egypt. The mealybug was transferred to the laboratory, and sprouting potato tubers were used as a host plant for its rearing. Gravid females of *P. solenopsis* were inserted in sprouting potatoes. Each sprouted potato was infested with an adult female and observed daily (Attia and Ebrahim 2015). From the reared culture, newly hatched crawlers of *P. solenopsis* were placed on each sprouted potato before being confined in a carton cylindrical box of 8-cm long and 12-cm diameter. The carton boxes were kept at 30 °C and 60 ± 5% R.H. Daily examination for the morphological changes were recorded and monitored until adult emergence (Attia and Ebrahim 2015).

**Natural enemy culture maintenance**
Larvae of *C. carnea* were obtained from the Bio-Control Laboratory of Plant Protection Research Institute, Dokki, Egypt. They were maintained on *P. solenopsis* at 27 ± 2 °C, 65 ± 5% RH, and 16:8 L:D.

**Natural products**
Cinnamon oil and its active ingredient, cinnamaldehyde, were used in this study and were bought from Essential oil Extracts Center, National Research Center. Jun-Ran et al. (2015) proved that cinnamaldehyde is the active ingredient of cinnamon oil.

---

**Preparing the stock solution of the tested materials**
The stock concentrations of each tested material (cinnamon oil or cinnamaldehyde powder) were prepared on basis of weight and the volume of the distilled water (w/v) in the presence of tween 80 (0.1%) as emulsifier. Four diluted concentrations for each material were used to draw the LC-P lines. Three replicates were used for each concentration.

**Toxicity test**

**Direct experiment**
Toxicity of cinnamon oil and cinnamaldehyde powder was evaluated against adult of *P. solenopsis*. Thirty newly emerged adults, 10 individuals in each replicate, were placed on okra leaves in each Petri dish. Each material had four concentrations, 500, 1000, 5000, and 10,000 ppm, which were sprayed on the individuals. Mortality was recorded for 7 days after treatment. The mortality percentage was estimated and corrected according to Abbott (1925). LC50 values were determined using probit analysis statistical method of Finney (1971).

Equation: Sun (1950) (to determine LC50 index)

\[ \text{Toxicity index for LC50} = \left( \frac{\text{LC50 of the most effective compound}}{\text{LC50 of the least effective compound}} \right) \times 100 \]

**Indirect experiment**
After calculating LC50 for each material, each LC50 was sprayed on 30 adults of *P. solenopsis*, 10 individuals for each replicate; these individuals were introduced to one larva of the predator, *C. carnea*, after 24 h of direct spraying. Four replicates were used, one prey in each. The results were corrected by control, and the mortality percentage was estimated and corrected according to the analysis of variance (ANOVA) (Analytical software 2005).

**Results**

**Direct experiment**
Toxicity studies:

Effect and toxicity index of cinnamon oil and cinnamaldehyde on mortality rate of cotton mealybug, *Phenacoccus solenopsis*
Results obtained in Table 1 showed that mortality rate of the active ingredient, cinnamaldehyde, was high against *P. solenopsis* and more effective than cinnamon oil for all concentrations used. The total mortality was 43.33, 56.67, 60, and 66.67% for 500, 1000, 5000, and 10,000 ppm, respectively for cinnamon oil, while the total mortality for cinnamaldehyde was 50, 60, 73.33, and 76.67% for 500, 1000, 5000, and 10,000 ppm, respectively.

In addition, LC$_{50}$ of the active ingredient, cinnamaldehyde, was 423.33 ppm and LC$_{90}$ 86,181.21 ppm, while cinnamon oil had LC$_{50}$ 802.14 ppm and LC$_{90}$ 1,737,321.67 ppm. The toxicity index was 100% for cinnamaldehyde, but it was 52.78% for cinnamon oil.

The slope values indicated that cinnamaldehyde had a higher value which was 0.555 while cinnamon oil slope value was 0.384.

LC$_{90}$/LC$_{50}$ value confirmed that cinnamaldehyde had a lower value, 203.58, than cinnamon oil, 2165.86. Thus, the highest slope value or the lowest ratio LC$_{90}$/LC$_{50}$ means the steepest toxicity line.

**Indirect experiment**

In Table 2, the active ingredient, cinnamaldehyde, proved that it was a safety material against the predator *C. carnea* which completed its larval and pupal stages until adult emergence (*C. carnea* feed on *P. solenopsis* individuals sprayed only with water and tween 80), while using cinnamon oil completed the larval stage only of *C. carnea*. Also, the predation efficiency of the predator was higher by using active ingredient cinnamaldehyde than using cinnamon oil. Table 2 also demonstrated the efficiency of *C. carnea* female in laying eggs by percentage 100% in control as soon as in cinnamaldehyde.

**Discussion**

The active ingredient, cinnamaldehyde, proved its toxicity effect against *P. solenopsis* than cinnamon oil. Similar results were observed by Jun-Ran et al. (2015) who proved effectiveness of cinnamaldehyde and illustrated that cinnamaldehyde was a more active ingredient than other compounds of cinnamic acid which were used in controlling *P. solenopsis*.

Also, cinnamaldehyde is very a useful material for controlling the cotton mealy bug pest, *P. solenopsis*; as soon as it did not cause any harm for the predator, *C. carnea*. Hafiz et al. (2012) proved the effectiveness of *C. carnea* against *P. solenopsis*. Sana et al. (2015) showed that emamectin benzoate had no residual effect on the predator *C. carnea* than neem oil. Pilar et al. (2005) demonstrated that the natural plant extracts, *Trichilia havanensis* (Meliaceae) extracts and *Teucrium viscidum* (Lamiaceae), are nearly innocuous for both natural insects at the conditions tested. El-Wakeil et al. (2006) proved that the chemical products were harmless to adults of *C. carnea*. Kim et al. (2013) and Isman (2000, 2006) illustrated that plant essential oils are potential products for the control of *M. pruinosa* because some of them are selective, biodegrade into nontoxic products, and have less harmful effects on non-target organisms.

**Table 1** Efficiency of cinnamon oil and cinnamaldehyde against *Phenacoccus solenopsis* under laboratory conditions 27 ± 2 °C and 65 ± 5% RH

| Treatments         | Conc. | Total mortality% | LC$_{50}$  | LC$_{90}$ | Slope ± S.D. | Toxicity index LC$_{50}$/LC$_{50}$ |
|--------------------|-------|------------------|------------|-----------|--------------|----------------------------------|
| Cinnamic oil       | 500   | 43.33            | 802.14     | 1,737,321.67 | 0.384 ± 0.122 | 52.78                            |
|                    | 1000  | 56.67            |            |           |              | 2165.86                          |
|                    | 5000  | 60               |            |           |              |                                  |
|                    | 10,000| 66.67            |            |           |              |                                  |
| Cinnamaldehyde     | 500   | 50               | 423.33     | 86,181.21 | 0.555 ± 0.126 | 100                              |
|                    | 1000  | 60               |            |           |              | 203.58                           |
|                    | 5000  | 73.33            |            |           |              |                                  |
|                    | 10,000| 76.67            |            |           |              |                                  |

**Table 2** Effect of different tested materials indirectly on the biological aspects of *Chrysoperla carnea*

| Tested materials  | Average period of different developmental larval instars (in days) | Total larval stage | Pupal stage | Egg laying % |
|-------------------|---------------------------------------------------------------|---------------------|-------------|--------------|
|                   | 1st               | 2nd               | 3rd         |              |              |
| Cinnamon oil      | 3.17 ± 0.2        | 2.96 ± 0.2        | 3.67 ± 0.2  | 9.8 ± 0.2    | ------       |
| Cinnamaldehyde    | 3.33 ± 0.3        | 2.98 ± 0.2        | 3.83 ± 0.4  | 10.14 ± 0.2  | 11.67 ± 0.3  | 100       |
| Control           | 3.26 ± 0.2        | 2.83 ± 0.2        | 3.33 ± 0.2  | 9.42 ± 0.2   | 9.67 ± 0.3   | 100       |
Conclusion
The cotton mealy bug, *Phenacoccus solenopsis*, is a destructive pest for cotton and some host plants, and one of ways of controlling this pest is biological control. *Chrysoperla carnea* was used for predation of *P. solenopsis* but it dies from using the chemical pesticides, so this study is concerned mainly with maintenance of the predator, *C. carnea*, and at the same time controlling the pest, *P. solenopsis*.

Acknowledgements
Authors would like to express their gratitude for the biological control department, plant protection research institute for providing the predator, *C. carnea*.

Authors' contributions
This work was carried out in collaboration between the two authors. GEA designed the study, wrote the protocol, made the statistical analysis, and reviewed the manuscript. NMY applied the whole laboratory work. The two authors read and approved the final version.

Authors' information
Dr. Ghada E. Abd-Allah is an associate professor at the Vegetable Pests Department, Plant Protection Research Institute, Agriculture Research Center, Dokki, Giza, Egypt.
Dr. Naglaa M. Youssef is an associate professor at the Scale Insects and Mealybug Department, Plant Protection Research Center, Agriculture Research Center, Dokki, Giza, Egypt.

Funding
There was no funding for this work.

Availability of data and materials
All data generated during this study are included in this published article.

Ethics approval and consent to participate
The manuscript does not contain any studies involving human participants, human data, or human tissue.

Consent for publication
Not applicable.

Competing interests
The authors declare that there are no competing interests.

Author details
1Vegetable Pests Department, Plant Protection Research Institute, Agriculture Research Center, Dokki, Giza, Egypt. 2Scale Insects and Mealybug Department, Plant Protection Research Institute, Agriculture Research Center, Dokki, Giza, Egypt.

Received: 14 April 2020 Accepted: 18 August 2020
Published online: 09 September 2020

References
Abbott WS (1925) A method of computing the effectiveness of an insecticide. J. Econ. Entomol. 18:265–267
Abou-Yousef HM, Farghaly FS, Torkey HM (2010) Insecticidal activity of some plant extracts against some sap-sucking insects under laboratory conditions. World J. Agric. Sci. 6(4):434–439
Analytical Software (2005). Statistix version 8.1: user's manual. Analytical Software. Atta AR, Ibrahim AM (2015) Biological studies on the predator *Dicrodiplosis manihotis* Harris (Diptera, Cecidomyiidae) on the mealybug *Phenacoccus solenopsis* Tinsley (Hemiptera, Pseudococcidae). Egypt. J. Biol. Pest Control 25(3):565–568
Cullik MP, Gullan PJ (2005) *A new pest of tomato and other records of mealybugs (Hemiptera: Pseudococcidae) from Espirio Santo, Brazil*. Zootaxa 964:1–8
El-Wakeel NE, Gaafar NM, Vidal S (2006) Side effect of some neem products on natural enemies of Helicoverpa (Trichogramma spp.) and Chrysopera carnea. J. Arch. Phytopathol. Plant Protect 39(6):445–455
El-Zahi ES, Aref SA, Korish SKM (2016) The cotton mealybug, *Phenacoccus solenopsis* Tinsley (Hemiptera: Pseudococcidae) as a new menace to cotton in Egypt and its chemical control. J. Plant Protect. Res 56(2):111–115
Finney DJ (1971) Probit analysis. Cambridge univ, London, p 333.
Golmohammad GH, Hejazi M, Iranpour SH, Mohammadi SA (2009) Lethal and sublethal effects of endosulfan, imidacloprid and indoxacarb on first instar larvae of *Chrysopera carnea* (Neuroptera: Chrysopidae) under laboratory conditions. J. Entomol. Soc 28(2):37–47
Hafiz AK, Ali HS, Waseem A, Sabtain R, Muhammad A (2012) Predatory potential of *Chrysoperla carnea* and *Cryptolaemus montrouzieri* larvae on different stages of the mealybug, *Phenacoccus solenopsis*: a threat to cotton in South Asia. J. Insect Sci. 12:197–202
Ibrahim SS (2018) Study on cotton host plants of mealybug *Phenacoccus Solenopsis* (Tinsley) and efficiency release the predator *Chrysoperla Carnea* (Stephens) for its controlling on cotton plants in Egypt. J. Plant Prot Path Mansoura Univ 93(3):247–252
Ibrahim SS, Moharum FA, Abd El-Ghany NM (2015) The cotton mealybug, *Phenacoccus solenopsis* Tinsley (Hemiptera: Pseudococcidae) as a new insect pest on tomato plants in Egypt. J. Plant Protect Res 55(1):48–51
Isman MB (2000) Plant essential oils for pest and disease management. Crop Prot 19:693–608
Isman MB (2006) Botanical insecticides, deterrents, and repellents in modern agriculture in and increasingly regulated world. Annu Rev Entomol 51:45–66
Jun-Ran K, In-Hong J, Young-Su L, Sang-Guei L (2015) Insecticidal activity of cinnamon essential oils, constituents, and (e)-cinnamaldehyde analogues against *Metzalca prunosus* Say (Hemiptera: Flatidae) nympha and adults. Korean J Appl Entomol. 54(4):375–382
Kim JR, Ji CW, Seo BY, Park CG, Lee GS, Lee SG (2013) Toxicity of plant essential oils and their spray formulations against the citrus flatid plant hopper *Metzalca prunosus* Say (Hemiptera: Flatidae). Korean J. Pest Sci. 17:419–427
Mostafa ME, Youssef NM, Abaza AM (2018) Insecticidal activity and chemical composition of plant essential oils against cotton mealybug, *Phenacoccus solenopsis* (Tinsley) (Hemiptera: Pseudococcidae). J. Entomol. Zool Stud 6(2):539–543
Nayar K., T.N. Ananthak and B.V. David (1976). General and applied entomology Tata McGraw Hill publishing company limited, 28(2):37–47.
Pilar M, Flor B, Manuel G, Benjamin R, Aurelio D, Arturo H, Nelson Z, Elisa V (2005) Effects of botanical insecticides on two natural enemies of importance in Spain: *Chrysoperla carnea* (Stephens) and *Psyltolca cincaria* (Szépligeti). IBOC/ wprs Bull. 29(10):85–99
Sana ZK, Farman U, Saed K, Muhammad AK, Muhammad AK (2015) Residual effect of insecticides against different stages of green lacewing, *Chrysopera Carnea* (Neuroptera: Chrysopidae). J. Entomol. & Zool. Studies 3(4):119–125
Symondson WOC, Sunderland KD, Greenstone MH (2002) Can generalist predators be effective biocontrol agents? Ann Rev Entomol. 47:561–594
Vogt T (2010) Phenylpropanoid biosynthesis. Mol Plant.2–20. https://doi.org/10.1093/mp/ssp106

Publisher's Note
Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.