Studying the Biology of *Carpoglyphus lactis* (L.) Reared on Dried Apricots and Its Control Using Plant Oil Extracts

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ABSTRACT

Carpoglyphus lactis(L.) has been documented as one of the most important pest contaminants of dried fruits during storage. Dried apricots are especially sensitive to the mite infestation, although data concerning bionomics and control of the mite on this subject is rare. In this study, the biological aspects of _C.lactis_ fed on dried apricots were examined under laboratory conditions at 25±2ºC and 85±5% RH in complete darkness. Eggs required an average of 15.2 and 12.2 days to develop into adult females and males, respectively. The oviposition period averaged 10.2 days during which females deposited an average of 31.8 eggs with a daily rate of 3.18 eggs per female. Mean life span of females was longer than that of males being 29.33 and 22.0 days, respectively. The hatch rate was 78.83% and the female to male ratio was 1:0.87. The deutonymph (hypopus) stage was not found in the entire _C.lactis_ life cycle. On the other hand, the acaricidal activity of the three plant oils extracts, cinnamon, chrysanthemum, and eucalyptus oils against _C.lactis_ adults was bio-assayed after a 24h period via direct contact application. As measured by LC_{50} values, the most toxic oil was cinnamon (LC_{50} = 5.6 ppm) followed by chrysanthemum (LC_{50} = 13.9 ppm), and eucalyptus (LC_{50}= 89.2ppm).

Key words: Bionomics, _C.lactis_, Control, Dried apricots, Plant oil extracts.

INTRODUCTION

Investigation of biological contaminants of stored dried fruits revealed their infestation with several arthropod pests. One of the most prominent pests is the dried fruit mite, *Carpoglyphus lactis* (L.) (Acaridida :Carpoglyphidae) (Çobanoğlu, 2009; Hubert *et al*., 2011). This mite mainly infests stored commodities rich in sugar and acids, especially acetic, lactic, and succinic acids which are produced via bacterial activity. Dairy products, honey, jam, rotten fruits, flour, cured ham, wine as well as dry fruits have been documented as the most favorable media for *C. lactis* infestation (Chemielewski, 1971; Arnau and Guerrero, 1994; Marin *et al*., 2009). In a screening survey carried out in Alexandria, Egypt, *C. lactis* was the most frequent and abundant mite species associated with dried apricot and fig with averages of 53.7 and 13.4 mites/g, respectively, recorded in August (Abd El-Razek, 2017). *C. lactis* is pestilential to many stored products, particularly under moist and warm climates as it contributes to their physical damage (Zhan *et al*, 2017) and leads to changes in their chemical composition (Marin *et al*., 2009). It causes allergic reaction in humans as well (Mullen and Oconnor, 2002).

Identification of biological aspects of a pest species is considered a substantial step for understanding the population dynamics of the mite which in turn leads to planning a successful management strategy. Recent storage pests research is focused on the establishment of new pesticides to substitute the prohibited and nonfunctional ones in stored product protection (Coldwell, 2020; Collins, 2006). Plant-derived products are known as potential sources for storage mite pest management with little or no detrimental impact on the human health and environment (Sung *et al*., 2006; Bakr, 2018). Therefore, this study was carried out to obtain more information on the bionomics of the dried fruit mite, *C. lactis* reared on dried apricots. In addition, the toxic effect of some plant oil extracts on *C. lactis* adults was evaluated in comparison to that of the synthetic acaricide, pirimiphos-methyl.

MATERIALS AND METHODS

Biological studies:

Mite rearing

Specimens of *C. lactis* were isolated from infested dried fruit samples obtained from local markets in Alexandria, Egypt. The mite colonies were reared in glass jars containing dried apricots. The stock jars were covered and kept at 25 ± 2 ^{0}C and 80 ± 5% RH in complete darkness.

Biological aspects

Twenty freshly deposited eggs were singly transferred to small glass rearing cells (1 cm diameter X 0.8 cm height) containing 1 mg of dried apricots. The cells were then covered by a nylon mesh and maintained at the optimum rearing conditions described earlier. The developmental times of *C.lactis* stages were observed daily until maturity (Ibrahim, 2006; Bakr, 2018).

In a separate experiment, newly moulted adult females (n=20) were separately transferred with young males to small rearing cells supplied with diet. The number of eggs deposited by each female was

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Table 1 . Tested essential oils and acaricide against the dried fruit mite *C. lactis*

Tested compound	Major components	Tested concentration (ppm)
Cinnamon Bark oil (*Cinnamomum zeylanicum*)	(E).cinnamaldehyde (71.5%), Linalool (7.0%), B-caryophyllene (6.4%),eucalyptol (5.4%), eugenol (4.6%)(Behahani *et al*., 2020)	1-150
Chrysanthemum Leaf oil (*Chrysanthemum trifurcatum*)	Limonene (26.8), T-terpinene(19.6%), ἀ-pinene(9.7%), ἀ-terpenyl acetate (7.2%) (Sassi *et al*., 2014)	4-150
Eucaluptus leaf oil (*Eucalypyus globulus*)	1.8 cineole (eucalyptol) (44.3%), camphene (23.1), B-pinene (12.7), ἀ-pinene (9.5), Globulol (7.3), Limonene (5.1%) (Boukhatem *et al*., 2014).	10-1000
Pirimiphos - methyl		1-100

monitored and the eggs removed daily. Nourishment was provided when needed. The fecundity, longevity, hatchability, and sex ratio were recorded by taking observation every 24h.

Bioassay studies:

Three commercial plant oil extracts (cinnamon, chrysanthemum, and eucalyptus oils) were compared with a synthetic acaricide (pirimiphos-methyl) in the present study. Five concentrations from each compound were prepared (Table 1).

Filter paper discs (1.5 cm diameter) were immersed for 10 sec in oil solutions or in acetone as a control. The discs were allowed to dry for 10 min at room temperature. Each disc was placed at the bottom of a glass microcell (1.5 cm diameter X 2 cm height). Ten mixed adults of *C. lactis* were placed in each microcell using a fine needle then covered. The microcells were held at 25 ± 2 ^{0}C and 80 ± 5% RH in the dark until mortality assessment. Mite mortalities were recorded 24h post treatment and mites were regarded as dead if appendages did not move. Each treatment was represented by three replicates. Mortality data was corrected using Abbott's formula (Abbott, 1925) then subjected to probit analysis (Finney, 1971) to calculate the LC_{50} and their confidence limits.

RESULTS AND DISCUSSION

Mite bionomics

Both sexes of *C. lactis* reared on dried apricots at 25 ± 2 ^{0}C and 80 ± 5% RH passed through egg, larva protonymph, and tritonumph stages before reaching adulthood (Table 2). Our observations confirmed that reproduction in *C. lactis* appears to be mostly sexual where mating happens one or two days after adult emerges. Eggs are laid by females one at a time in a scattered manner. They are globular and whitish in colour. Incubation period lasted 4.2±0.7 & 3.0±0.8 days for females and males, respectively. Concerning the total life cycle duration, it averaged 15.2±1.2 days in females while being shorter in males (12.2±1.4 days). It is of interest to note that males developed earlier than females for each life stage (Table 2).

Comparison of our results with biological data obtained from previous studies shows that the developmental time of *C. lactis* varies according to temperature, relative humidity, and kind of food (Okamoto, 1986; Chmielewski, 1999). Okamoto (1986) observed that the life cycle of *C. lactis* averaged from 6.7 to 36.2 days in females and from 6.8 to 39.0 days in males at temperature ranging between 10 to 35^{0}C and 90-100% RH. Furthermore, our results demonstrate that the deutonymphal stage (hypopus) was not observed in the life cycle of *C. lactis* reared as described above. Our results are in harmony with Okamoto (1986) who reported that hypopus was not found in the entire *C. lactis* life cycle when reared on a mixture of sugar and dried yeast (1:1) at 25 ± 2 ^{0}C and 85 ± 5% RH. On the other hand, Chmielewski (1999) noticed that the deutonymph stage was not observed when *C. lactis* was fed on honey, but it was frequently present when the mite was fed on baker's yeast and pollen at 20^{0}C and 85% RH. In addition, our results showed that *C. lactis* females fed on dried apricots deposited an average of 31.8±0.7 eggs with a daily rate of 3.18±0.4 eggs during the oviposition period which averaged 10.2±1.1 days. The average hatch rate was 78.83% and the female to male ratio was 1:0.87. Apparently, adult longevity was longer for females (14.2±1.31 days) than for males (9.83±0.9 days) (Table 3).

Table 2. Duration in days (Mean±SE) of the immature stage of *C. lactis* reared on dried apricots at 25±2^{0}C and 85±5 % RH in complete dark

Stage	Female	Male
Egg	4.2 ± 0.7	3.0 ± 0.8
Larva	4.3 ± 0.4	3.3 ± 0.6
Protonymph	3.3 ± 0.4	3.2 ± 0.4
Tritonymph	3.5 ± 0.5	2.7 ± 0.4
Life cycle	15.2 ± 1.2	12.2 ± 1.4

Table 3. Some biological aspects (Mean±SE) of *C. lactis* adults reared on dried apricots at 25±2^{0}C and 85±5 % RH in complete dark

Parameter	Female	Male
Preovi.	2.3±0.8	---------
Ovip.	10.2±1.1	---------
Postovi.	1.7±0.5	---------
Longevity	14.2±1.3	9.8±0.9
Life span	29.3±1.8	22.0±1.1
Fecundity	31.8±0.7	---------
Daily rate	3.2± 0.4	---------
Hatchability %	78.8±1.7	
Sex ratio (♀/ ♂)	1♀♀ : 0.87♂♂	

Bionomics of *C. lactis* reared on wheat at 25 ± 2 ^{0}C and 65 ± 5% RH were investigated by Ibrahim (2006) who reported that the oviposition period lasted 12.1 days during which females deposited an average of 55.9 eggs with a daily rate of 4.6 eggs/female. Also, she recorded that males lived shorter than females where females lived around 15.4 days and males around 6.2 days. The variation in results may be due to an array of factors including differences in food, strains, humidity, or the inherent variability of the species (Cunnington, 1985). In addition, Ibrahim (2006) studied the effect of photoperiod on the bionomics of *C. lactis* and it was found that the life cycle duration increased with increasing hours of light in both males and females. However, female fecundity, longevity, as well as mean daily deposited eggs decreased as the photoperiod increased.

Acaricidal activity of essential oils

The acaricidal activities of essential oils extracted from plants against *C. lactis* adults were bio-assayed by impregnated filter paper disc application and compared with the standard pirimiphos-methyl as a synthetic acaricide (Table 4).

Based on the 24-h LC_{50} values, cinnamon bark oil was the most toxic against *C. lactis* adults (LC_{50}=5.6 ppm), its toxicity close to that of pirimiphos-methyl (LC_{50}=4.6), followed by chrysanthemum leaf oil (LC_{50} = 13.9 ppm) and eucalyptus leaf oil (LC_{50}=89.2 ppm) (Table 4).

Direct contact bioassay confirmed that the oil extracted from *C. zeylanicum* bark had a great acaricidal effect on *C. lactis* adults. This is probably due to the action of its major component, (E)-cinnamaldehyde, which constitutes more than 70% of cinnamon bark oil components (Behbahni *et al*., 2020). Similarly, De Assis *et al*., (2011) revealed that *C. zeylanicum* oil has a potent acaricidal activity against the stored product mites, *Tyrophagus putrescentiae* and *Suidasia pontifica*. It was recorded in other investigations done by Kim *et al*., (2004) and Kim *et al*., (2008) that (E)-cinnamaldehyde caused death related to uncoordinated behavior response in *Dermatophagoides farine*, *D. pteronyssinus*, and *T. putrescentiae*. Regarding the acaricidal activity of chrysanthemum leaf oil, our results are consistent with the observations of Haouas *et al*., (2008) who reported that *C. trifurcatum* leaf oil extract caused deterrence and toxicity to the adult confused flour beetle, *Tribolium confusum* through both ingestion and topical applications. Earlier studies have revealed that essential oil toxicities are generally corresponding to their major constituents (Singh *et al*., 2003; Aslan *et al*., 2004) which suggest that the activities of oils shown in this study are probably associated with the main constituents listed in Table (1). Essential oils with their complex chemical composition are more efficient than isolated components as the various components of the oils may have interacted in a synergistic manner increasing and accelerating the toxic effects (Miresmailli *et al*., 2006; Singh *et al*., 2009).

Table 4 . Toxicity of plants essential oils and pirimiphos-methyl towards *C. lactis* via direct contact bioassay after 24 h exposure

Treatment	Slope ± SE	LC_{50} (ppm)	Confidence limits 95%	RT*
Pirimiphos-methyl	0.86±0.01	4.6	3.1-6.5	1.0
Cinnamon bark oil	0.80±0.01	5.6	3.8-8.1	0.80
Chrysanthemum leaf oil	1.01±0.01	13.9	11.8-30.3	0.32
Eucalyptus leaf oil	0.98±0.01	89.2	66.5-120.7	0.05

*relative toxicity = LC_{50} value of pirimiphos-methyl/LC_{50} value of each compound

As a conclusion, under suitable developmental conditions, *C. lactis* can be a serious contaminant to stored dried fruits as their number can grow rapidly which in turn leads to reduction in quality and marketability of dried fruit commodities. Essential oils tested in this study, in particular cinnamon and chrysanthemum oils, hold promising potential for usage as a possible alternative to synthetic products and can be integrated in sustainable stored product pest control strategies. However, further studies should be done on the impact of these compounds on the organoleptic characteristics of dried fruits treated with such compounds.

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الملخص العربي

دراسة بيولوجيا حلم الفواكه المجففة *Carpoglyphus lactis*(L.) المربى على المشمش المجفف ومكافحته باستخدام مستخلصات الزيوت النباتية

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حلم *Carpoglyphus lactis*(L.) تم توثيقه كأحد أهم الأفات الملوثة للفواكه المجففة أثناء التخزين .المشمش المجفف له حساسية خاصة للإصابة بهذا الحلم ,وبألرغم من ذلك المعلومات عن السمات البيولوجية وطرق المكافحة لحلم الفواكه المجففة على هذه المادة تعتبر نادرة .فى هذه الدراسة ,تم دراسة السمات البيولوجية لحلم *C.lactis* المتغذى على المشمش المجفف تحت الظروف المعملية عند حرارة ٢٥±٢°م ورطوبة نسبية ٨٥±٥٪ وتحت الإظلام التام . أوضحت النتائج أن البيض تطلب فى المتوسط ١٥.٢؛ ١٢.٢ يوم ليتطور إلى إناث وذكور بالغة على التوالى .فترة وضع البيض كانت فى المتوسط ١٠.٢يوم وضعت خلالها الأنثى ٣١.٨ بيضة فى المتوسط بمعدل يومى ٣.١٨ بيضة /انثى . متوسط فترة حياة الإناث كانت أطول من الذكور حيث سجلت فى المتوسط ٢٩.٣٣ و٢٢.٠ يوم على التوالى .معدل فقس البيض سجل فى المتوسط ٧٨.٨٣ %ونسبة الإناث /الذكور سجلت ٨٧.٠/١ على الترتيب .طور الحورية الثانى لم يلاحظ خلال دورة حياة هذا الحلم .على الجانب الآخر ,التأثير الإبادى لثلاثة مستخلصات زيوت نباتية تسمى ,زيت القرفة ,الإقحوان والكافور ضد الأفراد البالغة لحلم *C.lactis* تم تقييم السمية لها بعد تطبيقها بالتلامس المباشر لمدة ٢٤ ساعة .بناء على قييم LC_{50} ,الزيت الأكثر سمية كان هو زيت القرفة (LC_{50} = 5.6 ppm) متبوعا بزيت الإقحوان (LC_{50} =13.9ppm) ثم زيت الكافور (LC_{50} = 89.2 ppm)