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Research Article

Biological parameters of *Trialeurodes vaporariorum* (Hemiptera: Aleyrodidae) exposed to lethal and sublethal concentrations of Calypso®

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Abstract: Efficacy of the neonicotinoid insecticide, Calypso® was studied on eggs, nymphs and adults of *Trialeurodes vaporariorum* Westwood, using a leaf disc bioassay method. Concentrations from 0.15 to 0.8 ml/l were applied by systemic-contact method. Nymphs were more susceptible than eggs and adults, and LC_{50} and LC_{30} values were estimated to be 0.465 and 0.263 ml/l, respectively. Also, the longevity and fecundity of exposed females was reduced compared to control. Moreover, the demographic parameters were adversely influenced compared to control. The intrinsic rate of increase (r_m) was significantly decreased to 0.132 and 0.139 day^{-1} at LC_{50} and LC_{30} level, compared to control (0.152 day^{-1}). Other life table parameters (R_0, λ, T, and DT) were also significantly lower in the treated insects. Sublethal concentrations of Calypso® may reduce the insecticide residuals on greenhouse crops and reduce the resistance development in greenhouse whiteflies. Therefore, these concentrations may be applicable in the management of *T. vaporariorum* after complementary studies.

Keywords: life table parameters, whitefly, Calypso®, sublethal concentrations

Introduction

The greenhouse whitefly (GW), *Trialeurodes vaporariorum* (Westwood) (Hemiptera: Aleyrodidae) is one of the most serious pests of many horticultural and greenhouse crops worldwide (Helgesen and Tauber, 1974; Zabel *et al*., 2001). Large populations of this insect can consume high quantities of plant phloem sap which can result in reduction of plant growth and yield (Johnson *et al*. 1992). Adults can transmit some plant viruses like beet pseudo yellow virus (BPYV), tomato yellow leaf curl virus (TYLCV) and bean golden mosaic virus (BGMV) (Liu *et al*., 1993; Bi *et al*., 2002; Karatolos *et al*., 2010). Also, adults and nymphs cause damage by producing honeydew that encourages the growth of sooty molds and contamination of leaves and fruits (Gerling, 1992; Liu *et al*., 1993; Coffin and Coutts, 1995; Guzman *et al*., 1997). The greenhouse whitefly is a noxious polyphagous pest; so its control is very hard and for a long time has been accomplished by variable success. Use of synthetic insecticides has a long history and is the primary mode of its control; however, there are several reports on the development of genetic resistance in populations of GW against many of the chemicals being used both in the greenhouses and fields (Elhag and Horn, 1984; Omer *et al*., 1992; Sanderson and Rousch, 1992; Gorman *et al*., 2002; Karatolos *et al*., 2010, 2012).

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Indiscriminate and injudicious use of pesticides has posed a major problem of developing insecticidal resistance. This pest had already been reported to have developed resistance to pyrethroids, carbamates and organophosphate including dimethoate (Zheng and Gao, 1995; Rufinger *et al*., 1999; Sood *et al*., 2003).

Neonicotinoid insecticides are compounds acting agonistically on insect nicotinic acetylcholine receptors (nAChR). They are especially important to agriculture because of their activity against not only sucking hemipteran insects such as aphids, whiteflies, and plant-hoppers, but also against many coleopteran and some lepidopteran pest species (Nauen *et al*., 2003; Iwasa *et al*., 2004). Calypso® [(Z)-3-(6-chloro-3-pyridylmethyl)-1, 3-thiazolidin-2-ylidenecyanamide; Calypso®] is a systemic insecticide that like other chloronicotinyl insecticides acts selectively on the insect nervous system as an agonist of the nicotinic acetylcholine receptor. It is a highly active novel insect control agent with broad spectrum efficacy against sucking and biting insects depending on crop, pest and application type (Elbert *et al*., 2008; Saimandir *et al*., 2009).

Sood *et al*. (2006) reported that the insect is also quickly acquiring resistance even to neonicotinoid insecticide imidacloprid and suggested its restricted use. The ongoing introduction of new compounds (e.g., acetamiprid, thiamethoxam, thiacloprid, dinotefuran, and clothianidin), unless carefully regulated and coordinated, seems bound to increase exposure to neonicotinoids and to enhance conditions favoring appearance of resistant phenotypes (Nauen and Denholm, 2005). In order to postpone the resistance development in GW against a specific insecticide, it is important to find an alternative approach which is effective and environmentally compatible (Avery *et al*., 2015).

It has been revealed that the acute mortality of insect pests is not the only determinant of insecticidal efficiency. On the other word, in addition to direct mortality caused by insecticides, some biological traits of insect pests may be also affected by sublethal doses (Jafarbeigi *et al*., 2014). It has been recommended to use demographic toxicology for evaluation of both lethal and sublethal influences of a toxicant on host population because stable population parameters especially r_m take into account not only host survivorship, but also fecundity of targeted females (Stark *et al*., 2004).

In this research, we evaluated the lethal efficiency of Calypso® as chloronicotinyl neonicotinoid insecticide for controlling greenhouse whitefly on common bean. Moreover, sublethal influences of Calypso® were studied on some biological properties and life table parameters of GW. Our results may improve *T. vaporariorum* control efficiency in greenhouses meanwhile using reduced concentrations of this insecticide. These may contribute in hindered host resistance to Calypso® and reduced residuals on greenhouse crops.

Materials and Methods

Insect culture

The population of *T. vaporariorum* was originated from the greenhouse of Urmia University, Iran in summer of 2013. They were collected, using an aspirator, from *Phaseolus vulgaris* L. which was never exposed to any insecticide. After precise determination (Hodges and Evans, 2005), insects were reared in cages (50 × 50 × 35 cm) on young common beans planted in pots (20 cm height and 15 cm diameter) for up to three successive generations and kept at 28 ± 2 °C, 60 ± 10% RH and a photoperiod of 16:8 (L: D) h (air conditioning–equipped glasshouse). To achieve homogeneous nymphal populations in bioassays, newly green bean plants with two or four leaves were placed into large and transparent cylindrical cages (with 30 cm height and 20 cm diameter) with organdy sleeve (300 µm) and then infested by introducing 150 young adult whiteflies (sex ratio ≈ 1: 1). Adults were allowed to oviposit for 24 h on leaves. Then, adults were removed and plants with whitefly eggs were transferred to other insect–free cages. Cages were divided into three groups. The first group was used for

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egg bioassays and next two groups were applied for bioassay of young nymphs, and adults.

Insecticide

The insecticide used in this research was Thiacloprid (Calypso® 480 SC, Bayer CropScience Limited, Germany), applied at various concentrations on different life stages of the pest after preliminary bioassays. Required concentrations were prepared as serial dilutions of the insecticide in distilled water.

Bioassays

The lethal effect of Calypso® was assessed on eggs, nymphs (2nd and 3rd instars), and adults. Based on preliminary bioassays, the experimental concentrations of Calypso® involved 0.15, 0.2, 0.3, 0.4, 0.6 and 0.8 ml/l. For each treatment 14 individuals were used. Control insects were treated with distilled water. A leaf disc (5.5 cm in diameter) with 40 eggs were cut off from fully expanded bean leaves and immersed for 20s in the 20 ml of each given concentration or distilled water. Treated leaves were placed in laboratory conditions for 20–30 min until dry. The leaf discs were placed with their adaxial surface downwards (to simulate the normal feeding orientation of the whiteflies) onto a thin layer of 5% water–agar (Agar–agar, Merck KGaA) in 90 mm diameter plastic Petri dishes. Petri dishes were sealed with Parafilm® and kept in an incubator at 25 ± 2 ºC, 75 ± 5% RH, and 16: 8 (L: D) h. A circular opening (0.5 cm in diameter) covered with thin insect–proof net was opened on the lid of each Petri dish. Mortalities (insect individuals desiccated and/or discolored) were recorded for 5 days (on nymphs) and 8 days (on eggs) in daily intervals.

For adult bioassays, briefly, bean leaf discs (5.5 cm in diameter) dipped in different concentrations of insecticide solution for 20s, and placed on the water–agar medium in Petri dishes with their adaxial surface downwards. CO_2-anaesthetized adult whiteflies (in the same age) were then transferred onto the treated leaf discs using a fine brush. Each Petri dish was then covered with a ventilated lid and stored upside down. Water vapor condensation and static electricity that may hinder the movement of the whiteflies inside the sealed Petri dishes were minimized by covering the internal surface of the lids with a thin layer of absorbent paper (Pappas and Migkou, 2013). Mortalities were scored for the next 8 days. Experiments were replicated four times.

Effect of Calypso® on life table parameters

In this experiment, life table parameters of *T. vaporariorum* were studied under two concentrations of Calypso® including LC_{50} (= 0.465 ml/l) and LC_{30} (= 0.236 ml/l). Ten female adult whiteflies were transferred on untreated and insect-free bean plants (2-4 leaves) with suitable ventilation. After 24 hours, adults were removed leaving just eggs. Adults produced from these eggs were the same age and were used in life table experiments. Newly emerged bean leaves (4-6 cm) were cut and after dipping for 20 s in each concentration, left for 30 minutes to dry. A number of adult insects were released on treated leaves. After 24 hours, twenty of females survivorship were randomly selected and each transferred on a new leaf in a cage (130 mm height and 70 mm diameter). Leaves were replaced every day until death of the last individual. The number of eggs per cage and resulting nymphs were recorded on daily basis. Control insects were treated with sterile distilled water.

Statistical analysis

Mortality data, including four replicates data were handled by probit analysis in SPSS 22 (SPSS Inc., 2013) using the common logarithm (Log_{10}) of the concentration value. Probit regression analysis and x^2 goodness–of–fit tests were used to determine specific lethal concentration (LC_{30} and LC_{50}) values. Analysis of variance and mean comparison (Tukey, $P < 0.01$) of percent mortalities were performed using SPSS (Norusis, 1993). Longevity and fecundity data were used to construct a life table according to age-specific method

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described by Carey (1993). Pseudo-values of the life table parameters were calculated by jackknife procedure to estimate their means and standard errors (Maia *et al*., 2000). All curves were drawn by MS Excel (2013).

Results

Bioassays

Shapiro-Wilk test for normality of mortality data in different developmental stages of whitefly showed a normal distribution of data using the skewness and kurtosis indices (Finney, 1971). All concentrations of insecticides caused mortality on *T. vaporariorum* eggs, nymphs and adults under experimental conditions and mortality percentages were significantly different ($P < 0.01$) within each stage of whitefly. However, nymphs were much more sensitive to insecticide. As, their corrected mortalities varied from 36.87 to 96.87 percent in concentrations ranging from 0.15 to 0.8ml/l of Calypso®, respectively. In the same concentrations of the insecticide, 17.5 and 59.37 percent mortality was recorded for pest eggs. Furthermore, survival of adult insects decreased from 18.75 to 70 percent, respectively in 0.15 and 0.8 ml/l of experimental doses (Table 1).

Probit analysis revealed that the median lethal insecticidal concentration (LC_{50}) of Calypso® was 0.684, 0.186 and 0.465 ml/l on egg, nymph and adults, respectively (Table 2). According to Chi–square values, observed and expected data were homogenous, therefore, no heterogeneity factor was used in calculation of confidence limits. Comparison of confidence limits of LC_{50} values demonstrated that nymphs were remarkably more susceptible to Calypso® than eggs and adults. However, there was no considerable difference in LC_{50} values between pest eggs and adults (Table 2). LC_{30} values were used as sublethal concentrations for further experiments on life table parameters. The estimated values of LC_{30} were 0.275, 0.103 and 0.236 ml/l on whitefly eggs, nymphs and adults, respectively (Table 2).

Life table parameters

Results showed that age-specific survivorship (l_x) and realized fertility ($l_x m_x$) of *T. vaporariorum* were affected by LC_{30} (0.263 ml/l) and LC_{50} (0.465 ml/l) concentrations of Calypso® (Fig. 1) compared to those of control insects. Moreover, the mean longevity of adult whiteflies was considerably ($F = 27.29$, $df = 2, 17$: $P < 0.001$) decreased in the treated compared to control insects (Table 3). Additionally, the number of eggs deposited by each treated female insect in each day ($F = 48.25$; $df = 2, 17$; $P < 0.001$) and the total number of eggs produced by each female whitefly in both Calypso® treatments ($F = 12.39$; $df = 2, 17$; $P < 0.001$) were negatively influenced in comparison with untreated individuals (Table 3).

Table 1 Mean percentage mortalities of different developmental stages of *Trialeurodes vaporariorum*, caused by varying concentrations of Calypso®.

Doses (ml/l)	Mortality (%) (Mean ± SE)[1]		
	Egg	Nymph	Adult
0.8	59.37 ± 0.625[a]	96.87 ± 0.625[a]	70.00 ± 1.020[a]
0.6	46.87 ± 0.625[b]	88.12 ± 0.625[b]	57.75 ± 0.721[b]
0.4	39.37 ± 0.625[c]	80.00 ± 1.020[c]	48.75 ± 0.721[c]
0.3	31.25 ± 0.721[d]	66.87 ± 1.196[d]	34.75 ± 0.625[d]
0.2	23.12 ± 0.625[e]	57.50 ± 1.020[e]	25.62 ± 0.625[e]
0.15	17.50 ± 0.000[f]	36.87 ± 1.196[f]	18.75 ± 0.721[f]

[1] Means in each column followed by the same letter are not significantly different (Tukey HSD test, $P < 0.01$).

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Table 2 Results of probit analysis on mortalities of different stages of *Trialeurodes vaporariorum* exposed to various concentrations of Calypso®.

Stage	n	LC_{50} (CI)[1] (ml/l)	LC_{30} (CI)[1] (ml/l)	Slope ± SE	Intercept ± SE	df	x^2	*P*-value
Egg	160	0.684 (0.571-0.879)	0.275 (0.231-0.319)	1.322 ± 0.151	0.218 ± 0.080	4	2.700	0.609
Nymph	100	0.186 (0.164-0.208)	0.103 (0.084-0.121)	2.042 ± 0.157	1.490 ± 0.096	4	5.388	0.250
Adult	100	0.465 (0.460-0.627)	0.236 (0.199-0.271)	1.500 ± 0.150	0.416 ± 0.081	4	2.248	0.690

[1] Confidence intervals are in parenthesis.

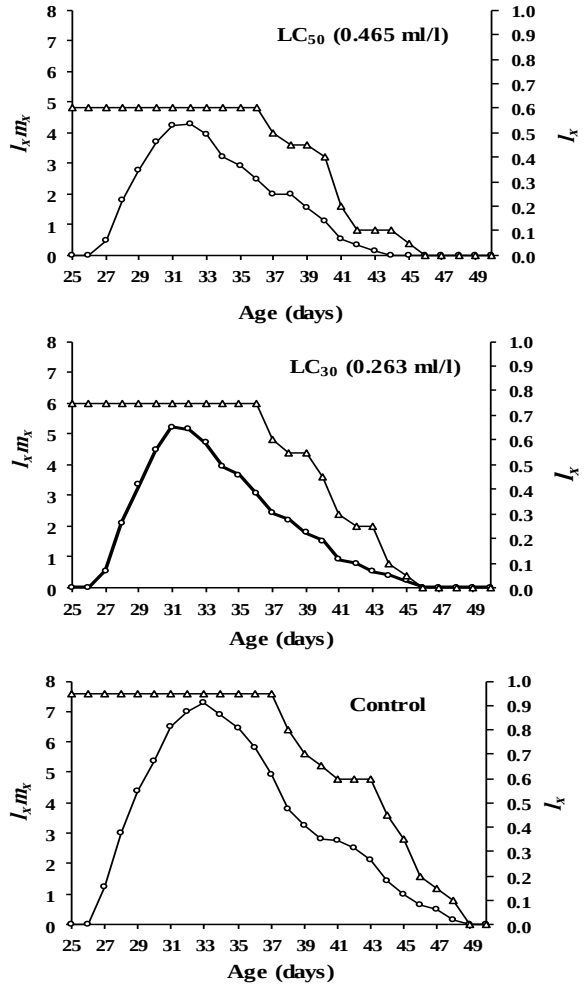

Figure 1 Age-specific survivorship (l_x) and realized fertility ($l_x m_x$) of *T. vaporariorum* females in control and two treatments (LC_{30} and LC_{50}) of Calypso®.

The expected total time for living of an individual of age *x* is explained by life expectancy curves. The expected life span was 18 days for control insects. However, this value was 16.7 and 16.1 days when treated at LC_{30} and LC_{50} doses, respectively (Fig. 2).

Furthermore, there were remarkable differences between life table parameters of control insects and both tested treatments of Calypso®. Net reproductive rate (R_0) of treated insects was remarkably decreased (F = 45.26; df = 2, 17; P < 0.001). Moreover, intrinsic rate of increase (r_m) was 0.152 per day in control insects compared to 0.132 per day for LC_{50} treatment (F = 78.94; df = 2, 17; P < 0.001). Also, the same trend was recorded for the finite rate of increase (λ) (F = 96.07; df = 2, 17; P < 0.001).As expected mean generation time (*T*) was statistically higher in treated females concentration wise and in comparison with control (F = 21.18, df = 2, 17; P < 0.001). Additionally, doubling time (*DT*) was increased in Calypso® treatments compared to control individuals (F = 32.56; df = 2, 17; P < 0.001).

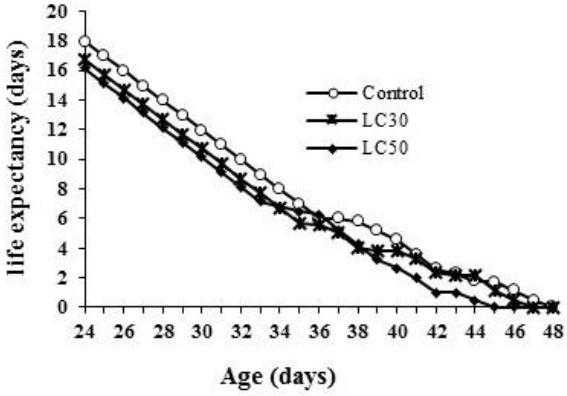

Figure 2 Life expectancy (e_x) of adult *T. vaporariorum* females in control and two treatments (LC_{30} and LC_{50}) of Calypso®.

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Discussion

Insecticides are used extensively in agriculture to reduce the crop losses by pests (Maredia *et al*., 2003). However, they should be used cautiously, because of their persistence, damage to the environment and/or their toxicity to mammals and non-target organisms (van Emden and Service, 2004).

In this research, both lethal and sublethal effects of Calypso® were considered on *T. vaporariorum*. Bioassays showed that eggs, nymphal stages and also adults of greenhouse whitefly were affected markedly by Calypso® concentrations. Eggs were influenced less than other life stages; however, about 59% of them were killed by the highest concentration of Calypso®. Adults suffered more death than eggs when exposed to the same Calypso® concentrations. Our results showed that nymphs were the most susceptible individuals to the insecticide. Similarly, Bi and Toscano (2007) observed that nymphs especially their early instars were the most susceptible individuals to some conventional insecticides such as chlorpyrifos, fenpropathrin and malathion as well as some neonicotinoid insecticides including imidacloprid, thiamethoxam and acetamiprid. Moreover, nymphs of *T. vaporariorum* were highly susceptible to spiromesifen, but moderately to diafenthiuron, buprofezin and chlorfenapyr (Kumar and Singh, 2014). Studies by Wang *et al*. (2003) on the susceptibility of immature and adult stages of greenhouse whitefly to six insecticides showed that abamectin was the most toxic insecticide to eggs and nymphs, followed by neonicotinoids, imidacloprid and acetamiprid. However, imidacloprid was the most toxic insecticide to *T. vaporariorum* adults, followed by acetamiprid, buprofezin, abamectin, fenpropathrin and profenofos.

Neonicotinoids have proved relatively resilient to the development of resistance. However, resistance has been confirmed in some populations of the whitefly, *Bemisia tabaci* (Gennadius) (Hem.: Aleyrodidae) (Nauen and Denholm, 2005). Furthermore, the acute mortality of insect pests is not the only determinant of insecticide efficiency. Therefore, demographic toxicology was considered in this study to combine ecological and toxicological parameters (Sedaratian *et al*., 2013). Sublethal effects are particularly prevalent in some insecticides and may produce higher rates of physiological and behavioral effects rather than acute ones (Studebaker and Kring, 2001; He *et al*., 2013). Sublethal effects of botanical and chemical insecticides have been investigated on *T. vaporariorum* (Omer and Leigh, 1995; Simmods *et al*., 2002; Heidari *et al*., 2005) and *B. tabaci* (He *et al*., 2011; Sohrabi *et al*., 2011; Jafarbeigi *et al*., 2014; Esmaeily *et al*., 2014a; Esmaeily *et al*., 2014b).

Our results showed that longevity of *T. vaporariorum* was significantly affected by LC_{30} and LC_{50} concentrations of Calypso® compared to control. But there were not considerable statistical differences between LC_{50} and LC_{30} concentrations (Table 3). Studies by Omer and Leigh (1995) revealed that sublethal concentration of acephate and biphenate significantly reduced longevity of male (acephate 6.5, biphenate 7.2, control 10.7 days) but not female (acephate 11, biphenate 12.3, control 15.4 days) *T. vaporariorum.* Sohrabi *et al*. (2011) found a significant reduction in the longevity of adult *B. tabaci* exposed to sublethal concentration of buprofezin compared to control, while it was not the case for imidacloprid.

Our results revealed that the daily number of deposited eggs was significantly variable among all treatments; however, total number of eggsdid not differ remarkably between two (LC_{30} and LC_{50}) Calypso® concentrations. But the control adult insects laid statistically more eggs than insecticide treatments (Table 3). Experiments by Omer and Leigh (1995) illustrated that sublethal concentration of acephate and biphenate decreased lifetime fecundity of *T. vaporariorum* by 29% and 37%, respectively. Sohrabi *et al*. (2011) showed that fecundity of *B. tabaci* females considerably decreased by sublethal concentration of buprofezin, whereas imidacloprid did not affect it significantly.

Life table parameters of greenhouse whitefly were considerably affected by Calypso® LC_{30}

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and LC_{50} treatments compared to control insects (Table 4). Net reproductive rate (R_0) of females was statistically varied between control and LC_{50} treated females. In addition, intrinsic rate of increase (r_m) decreased significantly in individuals treated with LC_{50} of Calypso® compared to control insects. Moreover, finite rate of increase (λ) was adversely affected by insecticide treatments. Similar to our results, Heidari *et al*. (2005) showed that pyriproxifen, buprofezin and fenpropathrin decreased r_m and λ values of *T. vaporariorum* females. Our results illustrated the considerable statistical increase in other stable population parameters including *T* and *DT*, following pest exposure to LC_{30} and LC_{50} values of Calypso®. This trend was observed on *T. vaporariorum* females using pyriproxifen, buprofezin and fenpropathrin (Heidari *et al*., 2005). Conversely, life history and biological parameters of *Bemisia tabaci* treated with imidacloprid were not significantly different from control insects; however, buprofezin had great sublethal effects on stable population and biological parameters of *B. tabaci* at the recommended field concentration (Sohrabi *et al*., 2011).

Based on our experiments, it can be concluded that Calypso® decreases longevity and survival of greenhouse whitely and adversely affects other biological parameters specially fecundity of female adults. Therefore, lower concentrations of this insecticide not only cause significant decrease in the number of exposed individuals, but also decrease its progeny. Lowered concentrations of Calypso® are advantageous from some aspects. Our results emphasized that sublethal concentrations of Calypso® are suitable in greenhouse whitefly control and reduce the chemical residuals on greenhouse crops such as cucumber and tomatoes by reduced use of the insecticide. Additionally, the costs of the insecticide application in the greenhouses may be mitigated. Lastly, and more importantly these lowered concentrations of Calypso® may slow the resistance progress in *T. vaporarioum*. More research is however, needed to investigate the resistance development to Calypso® in greenhouse conditions. In addition, side effects of the insecticide on non-target organisms such as *Encarsia formosa* Gahan. (Hymenoptera: Aphelinidae), as the most important parasitoid of the greenhouse whitefly, should be evaluated.

Table 3 Effect of LC_{50} and LC_{30} concentrations of Calypso® on longevity and fecundity of *Trialeurodes vaporariorum* females.

Treatments	Longevity (days) (Mean ± SE)[1]	Total number of eggs/female (Mean ± SE)[1]	Number of eggs/female/day (Mean ± SE)[1]
LC_{50} (0.465 ml/l)	13.67 ± 0.678^b	120.33 ± 6.109^b	8.811 ± 0.158^c
LC_{30} (0.263 ml/l)	14.13 ± 0.780^b	130.47 ± 6.217^b	9.287 ± 0.131^b
Control	16.47 ± 0.833^a	167.84 ± 9.439^a	10.157 ± 0.070^a

[1] Means in each column followed by the same letter are not significantly different (Tukey HSD test, $P < 0.01$).

Table 4 Life table parameters of *T. vaporariorum* females exposed to LC_{50} and LC_{30} concentrations of Calypso®.

Parameters[1]	Control[2]	LC_{30} (= 0.263 ml/l)[2]	LC_{50} (= 0.465 ml/l)[2]
Net reproductive rate (R_0) (offspring)	79.725^a (70.305-89.144)	46.982^b (41.782-52.182)	37.544^c (33.348-41.739)
Intrinsic rate of increase (r_m) (day^{-1})	0.152^a (0.151-0.154)	0.139^b (0.137-0.141)	0.132^c (0.130-0.134)
Finite rate of increase (λ) (day^{-1})	1.165^a (1.163-1.166)	1.149^b (1.147-1.151)	1.141^c (1.138-1.144)
Mean generation time (*T*) (day)	27.391^c (26.900-27.882)	27.679^b (27.065-28.293)	28.661^a (28.054-29.268)
Doubling time (*DT*) (day)	4.535^c (4.495-4.575)	4.981^b (4.911-5.051)	5.234^a (5.142-5.326)

[1] Means in each row followed by the same letter are not significantly different (Tukey HSD test, $P < 0.01$).
[2] Confidence intervals are in parenthesis.

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فراسنجه‌های زیستی سفیدبالک گلخانه *Trialeurodes vaporariorum* (Hemiptera: Aleyrodidae) تیمار شده با غلظت‌های کشنده و زیرکشنده‌ی کالیپسو

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چکیده: کارایی حشره‌کش شبه‌نیکوتینی کالیپسو در کنترل تخم‌ها، پوره‌ها و حشرات کامل سفیدبالک گلخانه Westwood *Trialeurodes vaporariorum* با روش زیست‌سنجی دیسک برگی مطالعه گردید. غلظت‌های مختلف حشره‌کش از ۰/۱۵ تا ۰/۸ میلی‌لیتر بر لیتر به‌صورت تماسی-سیستمیک استفاده شدند. درصد مرگ‌ومیر سفیدبالک گلخانه نشان دهنده‌ی حساسیت بیشتر پوره‌ها در مقایسه با سایر مراحل زیستی بود. مقادیر LC_{50} و LC_{30} به‌ترتیب ۰/۴۶۵ و ۰/۲۶۳ میلی‌لیتر بر لیتر برآورد شدند. تأثیر این غلظت‌ها در پارامترهای جدول زیستی سفیدبالک بررسی گردید. این غلظت‌ها زنده‌مانی و باروری سفیدبالک‌های تیمار شده را در مقایسه با افراد شاهد کاهش دادند. به‌علاوه، نتایج نشان داد که هر دو غلظت اثر نامطلوبی روی فراسنجه‌های دموگرافی *T. vaporariorum* داشتند. نرخ ذاتی افزایش جمعیت (r_m) به‌عنوان مهم‌ترین فراسنجه‌ی جدول زیستی به‌طور معنی‌داری در افراد تیمار شده با مقادیر LC_{50} و LC_{30} (به‌ترتیب ۰/۱۳۲ و ۰/۱۳۹ در روز) در مقایسه با حشرات شاهد (۰/۱۵۲ در روز) پایین‌تر بود. سایر فراسنجه‌های جدول زیستی (R_0, λ, T, DT) نیز به‌طور معنی‌داری در حشرات تیمار شده کم‌تر بودند. غلظت‌های زیرکشنده‌ی تیاکلوپراید, باقی‌مانده سموم در محصولات گلخانه‌ای و توسعه مقاومت در سفید بالک گلخانه را کاهش می‌دهد. بنابراین، چنین غلظت‌هایی ممکن است پس از بررسی‌های تکمیلی در برنامه‌های مدیریت جمعیت *T. vaporariorum* کاربرد داشته باشند.

واژگان کلیدی: فراسنجه‌های جدول زیستی، سفیدبالک گلخانه، تیاکلوپراید، غلظت‌های زیرکشنده

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