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Article

Sublethal effects of cyflumetofen and spiroadiclofen on biological parameters of citrus red mite, *Panonychus citri* McGregor (Acari: Tetranychidae)

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ABSTRACT

The citrus red mite, *Panonychus citri* McGregor (Acari: Tetranychidae) whose control is largely based on the use of acaricides, is a key citrus pest in the world. The lethal and sublethal values of cyflumetofen and spiroadiclofen were estimated on citrus red mite. LC₂₀ and LC₅₀ values of cyflumetofen and spiroadiclofen were 2.79 and 10.23 ppm, and 2.30 and 7.28 ppm, respectively. LC₂₀ concentration effects of cyflumetofen and spiroadiclofen were studied on life table parameters of *P. citri* females. These two acaricides had significant effects on *P. citri* biological parameters including developmental time, survival rate, and fecundity. Also, the exposure of females to LC₂₀ considerably reduced net reproductive rate (R_0), finite rate of increase (λ) and intrinsic rate of increase (r). The intrinsic rate of increase in females treated with cyflumetofen and spiroadiclofen was 0.156 and 0.153 day⁻¹, respectively, and it was 0.183 day⁻¹ for untreated females. The sublethal concentrations affected the citrus red mite life table parameters and consequently may influence the population growth of its future generations. These results provide a baseline for the response of *P. citri* to cyflumetofen and spiroadiclofen pesticides that will aid mite control management in citrus.

KEYWORDS: Acaricides; citrus red mite; LC₂₀; LC₅₀; life-table parameters.

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INTRODUCTION

The citrus red mite, *Panonychus citri* McGregor (Acari: Tetranychidae) one of the major citrus pests worldwide, is usually controlled by pesticide. It develops resistance to acaricides used for its control repetitively. Therefore, it is imperative to search for new acaricides with new modes of action, as some pests rapidly develop resistance to several chemical compounds (Dekeyser 2005). Nervous system of mites has long been the target for most chemicals used for their control, but recently many compounds have been introduced acting on respiration, growth or development (Dekeyser 2005; Marcic 2012; Van Leeuwen *et al.* 2015).

Cyflumetofen was launched in 2007 and used around the world for only spider mites. It is a novel benzoyl acetonitrile acaricide (Hayashi *et al.* 2013). It has been shown to be effective against several spider mites including the two-spotted spider mite, *Tetranychus urticae* Koch, citrus red mite *P. citri*

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and the European red mite, *Panonychus ulmi* Koch. Besides, it is safer for non-targeted organisms including predators (Takahashi *et al.* 2012). Hence, it has been recognized as a suitable acaricide for integrated pest management (IPM) to control spider mites while using predatory mites (Hayashi *et al.* 2013).

Spirodiclofen, a tectonic acid derivative, has recently been introduced as a compound that inhibits lipid biosynthesis and is commercially available as an acaricide used effectively against many phytophagous species of mites. Spirodiclofen is effective in controlling mites which are specifically resistant to other acaricides (Nauen *et al.* 2000; Elbert *et al.* 2002; Dekeyser 2005; Marcic 2007).

Acaricides usually affect life-history parameters (fertility, fecundity, developmental time, longevity, sex ratio, etc.), consequently, they affect mite's population growth rates (Stark and Rangus 1994; Stark and Banks 2003; Teodoro *et al.* 2005). Many studies indicate that pesticides tend to have adverse effects on life table traits of tetranychid mites (Landeros *et al.* 2002; Marcic 2007; Marcic *et al.* 2010; Li *et al.* 2017). Cyflumetofen showed considerable negative effects on *T. urticae* life table parameters but it had moderate effects on *Phytoseiulus persimilis* Athias-Henriot (Abdel-Rahman and Ahmed 2018). This acaricide is more efficient against *P. citri* than *T. urticae*; this may be due to AB-1 inhibition of mitochondrial complex II in *P. citri* at lower concentrations than that in *T. urticae* (Hayashi *et al.* 2013).

The effects of pesticides on life table parameters have been suggested as a more reliable approach to evaluate pesticide toxicity. Thus, the evaluation of acaricides' effects could be achieved by analyzing the life table (Kim *et al.* 2006; Li *et al.* 2017). The effects of pesticides on survivors provide a measure of the impact on the established population growth rate (Robertson and Worner 1990; Robertson and Preisler 1992; Stark and Banks 2003). Bioassays addressing potential effects of pesticides deliver information needed in IPM programs (Beers and Schmidt 2014).

Therefore, the present study aimed to determine the biological parameters of *P. citri* under the low-lethal (LC₂₀) concentrations of cyflumetofen and spirodiclofen. Based on the information provided from the results of this study on the effects of the two acaricides on life table parameters of *P. citri*, mite management programs in citrus orchards could be improved.

MATERIALS AND METHODS

Culture of mite

Panonychus citri specimens were collected from citrus orchards from Tanta, Gharbia Governorate, that were not treated with pesticides three months prior to collection.

The citrus red mite was transferred and reared on the adaxial surface of sweet orange leaves (*Citrus sinensis* (L.) Osbeck). Leaves were placed on water-saturated cotton pads in dishes, and a water-saturated, absorbent cotton strip was placed around the edge of the leaves to prevent mites from escaping. The rearing was maintained in an incubator at 25 ± 2 °C, 60 ± 5 % R.H and L14: D10 h photoperiod to maintain a continuous source of mite being used during experiment. The cotton bed was soaked with water daily. The colony was left for at least three generations before starting the experiment. Leaves were replaced every seven days. A thin paint brush was used to transfer the mites from old leaves to the new ones.

Chemicals tested

Cyflumetofen was used in a commercial formulation as Danisaraba 20% SC, OAT Agrico. Co., Japan, application rate 40 ml/100 L., obtained from Shoura Chemicals Co., Egypt.

Spirodiclofen was used in a commercial formulation as Envidor 24% SC, application rate 25 ml/100 L, Bayer Crop Science, obtained from Samtrade Co., Egypt.

These acaricides were chosen because they are commercial pesticides against citrus red mite in Egypt and many other countries and belong to different classes of chemicals with different modes of action on *P. citri*.

Toxicity bioassay

In the toxicity bioassay, five different concentrations of cyflumetofen 20% SC (80, 40, 20, 10 and 5 ppm) and spiroticlofen 24% EC (60, 30, 15, 7.5 and 3.75 ppm) active ingredient were used. The recommended dose was chosen to be the highest concentration for each pesticide. Pre-ovipositing females (< 1 day old) of *P. citri* were sprayed with five different concentrations of each pesticide and distilled water (control). Five replicates/concentration with 75 female individuals were used per concentration. The leaves of sweet orange were placed without cutting on moist cotton pads in Petri dishes. Water-saturated, absorbent cotton strip was placed around the edge of the leaves to prevent mites from escaping. Fifteen adult females of *P. citri* were transferred from the stock culture to each leaf as a replicate and sprayed with the pesticide concentrations or distilled water (control). Spraying was made using a hand sprayer as described by Ribeiro *et al.* (2014).

The experiment was conducted in a climate-controlled room (25 ± 5 °C, $60 \pm 10\%$ RH and L14:D10 h photoperiod). Mite mortality was assessed after 24 hours following the exposure. Natural mortality was estimated using Abbott's formula (Abbott 1925).

The effect of LC₂₀ sublethal concentration of acaricides on biological parameters of P. citri

The influence of LC₂₀ concentration for the selected pesticides (cyflumetofen and spiroticlofen) on the biology and life table parameters of *P. citri* was evaluated under laboratory conditions. Mated females were sprayed with the tested pesticides while distilled water was used in the control. After pesticide treatment, one live mated female/replicate was transferred on the leaf of sweet orange which was placed on wet cotton pads in dishes and left for 24h for oviposition. All Petri dishes were maintained in an incubator at 25 ± 2 °C, $60 \pm 5\%$ RH and L14:D10 h photoperiod. After oviposition, female and all eggs except one were removed from every replicate. Forty eggs as replications/pesticide and the control (n = 120 eggs) were used. The eggs were observed daily until the larvae hatched. The period of each developmental stage was observed till all larvae became adults. During the experiment, leaves of replications were replaced every seven days. Newly emerged adults were separated by sex, paired into couples, and transferred to new leaves for evaluating the pre-ovipositional and ovipositional periods, fecundity, and adult longevity. In leaves where males died before females, new males were added from stock colony to the relevant experimental units. However, the data from these males were not used in the analysis. The dead mites and the eggs laid by female individuals in each disc were counted and removed daily until the end of the experiment. The analysis was done when all mites were dead.

The life tables were developed based on the data for all individuals tested (including females, males, and individuals that died during the development of the immature stage) as proposed by Chi (1988).

Statistical analysis

The lethal (LC₉₀, LC₅₀), sublethal (LC₂₀) and slope values for *P. citri* adult females with cyflumetofen and spiroticlofen were estimated by Probit-MSChart Program (Chi 2021) devoted to calculating the probit analyses according to Finney (1971).

The raw data of the life table parameters were analyzed according to the theory of age-stage, two-sex life table using the TWSEX MSChart program (Chi 2020). The age-stage specific survival rate (s_{xj}) (where x = age in days and j = stage); the age-specific survival rate (l_x); the age-specific fecundity (m_x); and the population growth parameters [the net reproductive rate (R_0); the intrinsic rate of increase (r); the finite rate of increase (λ); mean generation time (T) and the gross reproductive rate (GRR)] were also calculated (Chi and Liu 1985; Chi and Su 2006).

The means and standard errors of the population parameters were estimated using the Bootstrap

procedure with 100,000 re-sampling; the life table parameters of *P. citri* untreated (control) and treated with pesticides (cyflumetofen and spiroticlofen) were compared by using a paired bootstrap test (Wei *et al.* 2020).

RESULTS

The lethal and sublethal concentrations of cyflumetofen and spiroticlofen on *P. citri* adult females are mentioned in Table 1. Based on LC₅₀ and LC₉₀ values and their fiducial limits, spiroticlofen was more toxic than cyflumetofen.

Table 1. Mean lethal and sublethal concentrations (ppm) of cyflumetofen and spiroticlofen against *Panonychus citri* adult females.

Acaricides	LC ₂₀ (ppm)	LC ₅₀ (ppm)	LC ₉₀ (ppm)	Slope	Chi-square value
Cyflumetofen	2.79	10.23	73.93	1.49 ± 0.184	2.131
Spiroticlofen	2.30	7.28	42.15	1.68 ± 0.194	2.315

*Fiducial limits (ppm).

Developmental time, longevity and total life span

The effects of LC₂₀ sublethal concentrations of cyflumetofen and spiroticlofen on developmental time, longevity, and total life span of offspring from the treated and untreated females are presented in Table 2.

Table 2. Developmental durations, longevity and total life span (days) of offspring from *Panonychus citri* females treated with LC₂₀ sublethal concentration of cyflumetofen and spiroticlofen.

Female	Mean ± S.E.		
	Control (29)	Cyflumetofen (24)	Spiroticlofen (22)
Egg	5.86 ± 0.23 ^a	6.13 ± 0.22 ^a	5.64 ± 0.18 ^a
Larva	1.93 ± 0.11 ^a	2.17 ± 0.11 ^a	2.14 ± 0.12 ^a
Protonymph	1.76 ± 0.09 ^a	1.79 ± 0.10 ^a	1.73 ± 0.09 ^a
Deutonymph	2.31 ± 0.09 ^a	2.42 ± 0.10 ^a	2.45 ± 0.11 ^a
Pre-adult	11.86 ± 0.19 ^b	12.50 ± 0.25 ^a	11.95 ± 0.18 ^{ab}
Adult longevity	14.14 ± 0.43 ^a	11.42 ± 0.42 ^b	11.55 ± 0.47 ^b
life span	26.00 ± 0.49 ^a	23.92 ± 0.48 ^b	23.50 ± 0.52 ^b
Male	Control (8)	Cyflumetofen (7)	Spiroticlofen (6)
Egg	5.25 ± 0.25 ^a	5.29 ± 0.18 ^a	5.17 ± 0.31 ^a
Larva	1.75 ± 0.16 ^a	1.86 ± 0.26 ^a	1.83 ± 0.17 ^a
Protonymph	1.63 ± 0.18 ^a	1.71 ± 0.29 ^a	1.67 ± 0.21 ^a
Deutonymph	2.25 ± 0.16 ^a	2.29 ± 0.29 ^a	2.33 ± 0.21 ^a
Pre-adult	10.88 ± 0.29 ^a	11.14 ± 0.46 ^a	11.00 ± 0.26 ^a
Adult longevity	11.50 ± 0.68 ^a	8.43 ± 0.57 ^b	7.50 ± 0.62 ^b
life span	22.37 ± 0.68 ^a	19.57 ± 0.78 ^b	18.50 ± 0.56 ^b

Numbers in parentheses represent the number of replicates.

Means in each row with the same letters are not significantly different (Paired bootstrap test, $P < 0.05$).

The egg incubation period was not affected by LC₂₀ sublethal concentration of both pesticides; it was 6.13 and 5.64 days for cyflumetofen and spiroticlofen, respectively compared to 5.86 days for

untreated females.

No significant differences were observed in the developmental durations of larval, protonymphal and deutonymphal stages of *P. citri* offspring from treated or untreated females (Table 2).

Adult longevity of female and male mites exposed to LC₂₀ concentration of cyflumetofen and spirodiclofen were short in comparison with control. The life span of female or male offspring from treated females significantly reduced compared with control; while no significant differences between cyflumetofen and spirodiclofen on developmental time, longevity and total life span of both sexes were observed.

Longevity and reproduction

The adult pre-oviposition period (APOP) and the total pre-oviposition period (TPOP) of *P. citri* females were not affected by the LC₂₀ of cyflumetofen and spirodiclofen. While significant differences were scored in oviposition period between offspring from treated females compared with untreated ones. It was reduced from 10.03 days in control to 8.04 and 7.86 days, respectively. So, the LC₂₀ sublethal concentration of cyflumetofen and spirodiclofen showed harmful effects on daily rate of eggs/female during oviposition period.

Applying LC₂₀ concentrations caused significant reduction in total fecundity of *P. citri* (Table 3). The total fecundity per female of *P. citri* was decreased from 37.17 eggs/female (in control) to 25.79 and 24.91 eggs/female by LC₂₀ sublethal concentration of cyflumetofen and spirodiclofen, respectively.

Table 3. Longevity and fecundity of offspring *Panonychus citri* from females treated with LC₂₀ sublethal concentration of cyflumetofen and spirodiclofen.

Parameters	Mean ± S.E.		
	Control (29)	Cyflumetofen (24)	Spirodiclofen (22)
APOP (day)	1.55 ± 0.09 ^a	1.29 ± 0.09 ^a	1.59 ± 0.12 ^a
TPOP (day)	13.41 ± 0.21 ^a	13.79 ± 0.26 ^a	13.55 ± 0.22 ^a
Oviposition (day)	10.03 ± 0.32 ^a	8.04 ± 0.42 ^b	7.86 ± 0.44 ^b
Total fecundity (eggs/female)	37.17 ± 1.95 ^a	25.79 ± 1.93 ^b	24.91 ± 2.31 ^b

APOP, Adult pre-oviposition period and TPOP total pre-ovipositional period.

Numbers in parentheses represent the number of replicates.

Means in each row with the same letters are not significantly different (Paired bootstrap test, $P < 0.05$).

Life table parameters

Life table parameters described and compared the effects of LC₂₀ concentrations of cyflumetofen and spirodiclofen by using the age-stage, two-sex life table demographic characteristics of *P. citri*. The life table parameters of offspring from the treated females by LC₂₀ concentration of cyflumetofen and spirodiclofen are demonstrated in Table 4.

The obtained results showed that exposure of females to cyflumetofen and spirodiclofen reduced the net reproductive rate (R_0) and intrinsic rate of increase (r) compared to the control. Similarly, the finite rate of increase (λ) for the control was significantly higher than those of both acaricides (Table 4).

The intrinsic rate of increase (r) value was decreased by the LC₂₀ sublethal concentration; it was 0.156 and 0.153 day⁻¹ for cyflumetofen and spirodiclofen respectively, compared with control (0.183 day⁻¹).

However, the generation time (T) and gross reproduction rate (GRR) were affected only by the

LC₂₀ concentration of spirodiclofen. Also, no significant differences were noted in value of r , R_0 and λ between offspring from females treated by cyflumetofen and spirodiclofen.

Table 4. Mean (\pm SE) life table parameters of offspring from *Panonychus citri* females treated with LC₂₀ sublethal of cyflumetofen and spirodiclofen.

Parameters	Treatments		
	Control	Cyflumetofen	Spirodiclofen
Intrinsic rate of natural increase (r) (day ⁻¹)	0.183 \pm 0.01 ^a	0.156 \pm 0.01 ^b	0.153 \pm 0.01 ^b
Finite rate of increase (λ) (day ⁻¹)	1.200 \pm 0.01 ^a	1.169 \pm 0.01 ^b	1.165 \pm 0.01 ^b
Net reproductive rate (R_0) (eggs/individual)	26.95 \pm 2.98 ^a	15.48 \pm 2.29 ^b	13.70 \pm 2.31 ^b
Generation time (T) (day)	18.04 \pm 0.26 ^a	17.51 \pm 0.33 ^a	17.16 \pm 0.28 ^b
Gross reproduction rate (GRR) (eggs/individual)	31.66 \pm 2.94 ^a	24.04 \pm 2.85 ^a	22.21 \pm 2.77 ^b

Means in each row with the same letters are not significantly different (Paired bootstrap test, $P < 0.05$).

Age-specific survivorship, age and age-stage-specific fecundity

Figure 1 shows significant change in the l_x of female developed from treated and untreated females by LC₂₀ concentration of cyflumetofen and spirodiclofen. It remained stable till the 11th day with untreated females, while it decreased after the 10th and 6th day in cyflumetofen and spirodiclofen treatments, respectively.

The maximum values of m_x were 3.59 eggs/individual/day which occurred on the 17th day of the life span of untreated mites, while it decreased to 3.03 and 2.97 eggs/individual/day on the 17th and 16th day of the life span for cyflumetofen and spirodiclofen treatments, respectively. Likewise, the f_x and $l_x m_x$ of the female offspring showed the same trend in treated and untreated individuals of *P. citri*.

The age-specific survival rate of *P. citri* individuals untreated and treated with LC₂₀ concentrations of cyflumetofen and spirodiclofen is illustrated (Fig. 2). The total lifetime for the untreated mites was 31 days, while it decreased to 29 and 28 days for LC₂₀ treatments of cyflumetofen and spirodiclofen, respectively.

The age-stage survival rate (S_{xj}) illustrates the probability that a newborn would survive to age x and stage j (Fig. 2). The curves indicate differences between the stages of development and the survival of each specific age-stage of the mite. The probability of a newly hatched larva to survive until the adult stage was higher in the control (0.73 for females and 0.20 for males) than in cyflumetofen and spirodiclofen treatments (0.60 and 0.55 for females and 0.18 and 0.15 for males), respectively. The survival rates of protonymph and deutonymph were decreased by the LC₂₀ concentration of cyflumetofen and spirodiclofen compared with the control.

Age-stage specific life expectancy

The estimated age-stage specific life expectancies indicated that the expected lifetime for a newly hatched mite (e_{xj}) from untreated females was the highest as it recorded 24.35 days. It decreased in females treated with LC₂₀ concentration of cyflumetofen and spirodiclofen to 20.95 and 18.80 days, respectively. In general, life expectancy decreased gradually with the individual's age (Fig. 3). Overall, the life expectancy of all stages decreased with usage of cyflumetofen and spirodiclofen.

DISCUSSION

The life-table analysis is one of the best methods for evaluating lethal and sublethal effects of pesticides (Daniels and Allan 1981). This study is the first research on the sublethal effects of cyflumetofen on life-table parameters of *P. citri*. Spirodiclofen was introduced as a compound that

inhibits lipid biosynthesis (Marcic 2007; Saber *et al.* 2018). It is commonly used as a highly effective acaricide against economically important mite species on many fruits crops since it delivers well to excellent long-term efficacy (Bretschneider *et al.* 2007).

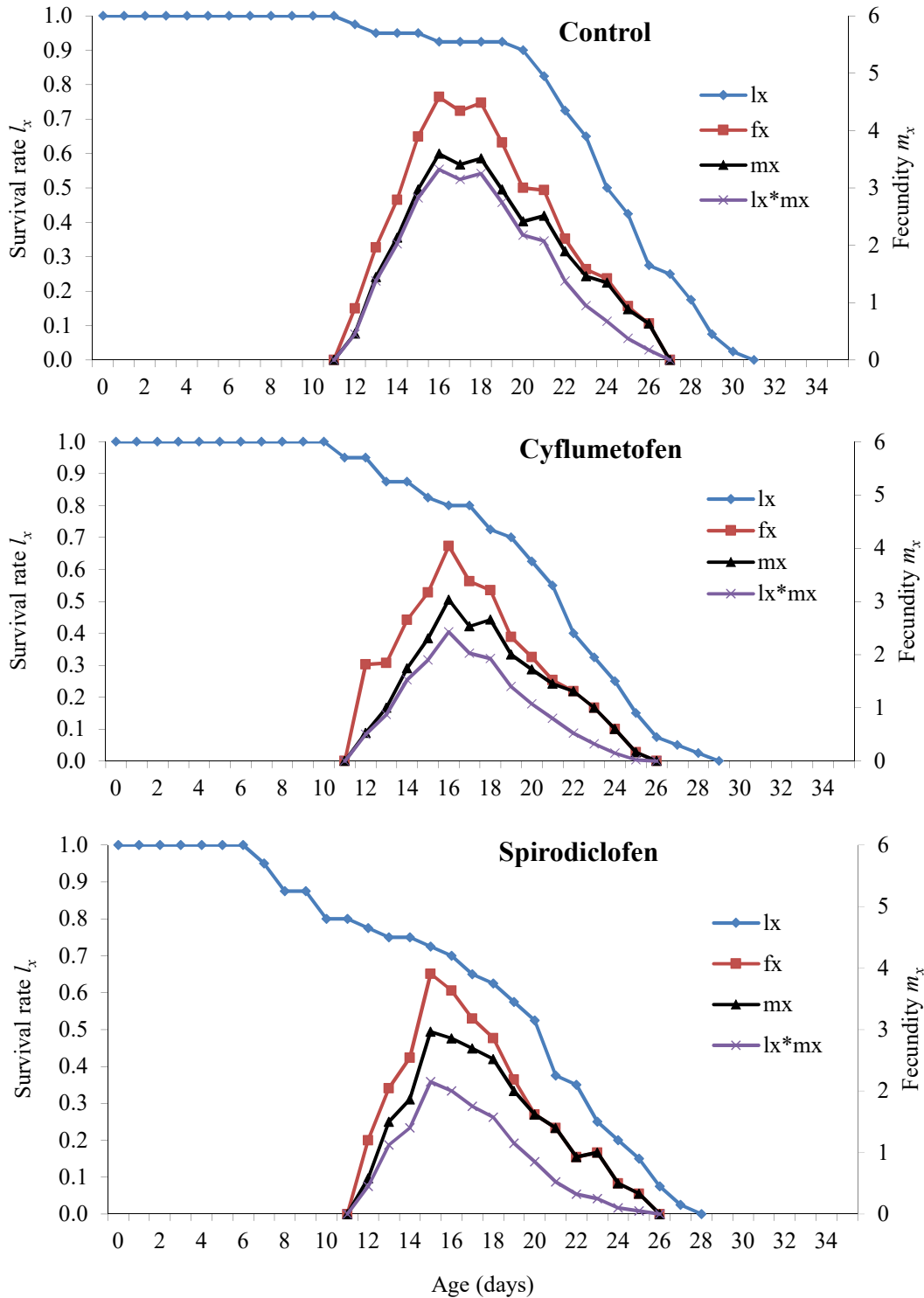


Figure 1. Age specific survival rate (l_x), fecundity (m_x), maternity ($l_x m_x$) and age-stage specific fecundity (f_x) of offspring from *P. citri* females treated with LC_{20} sublethal concentration of cyflumetofen and spiroadiclofen compared with untreated females.

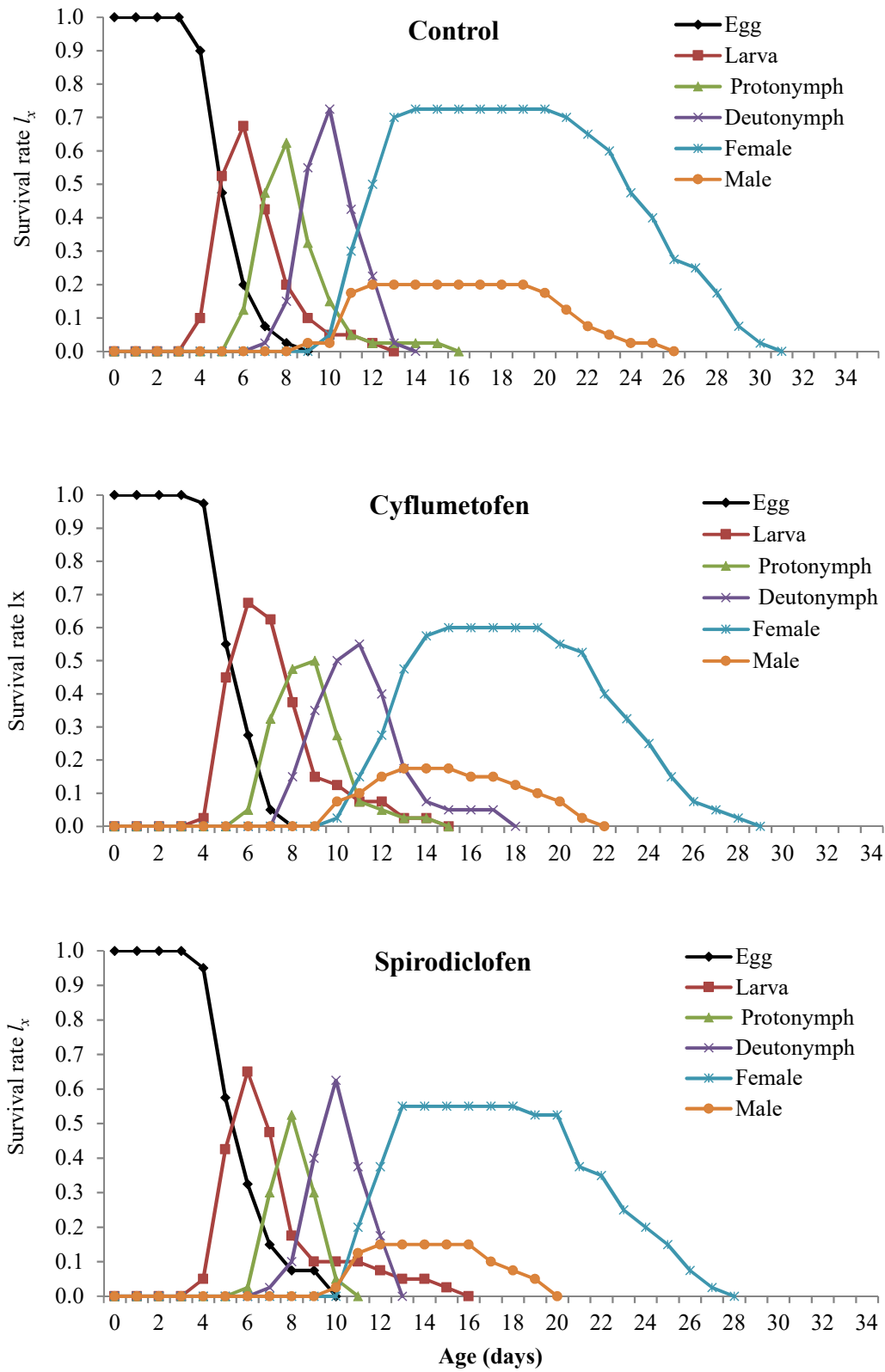


Figure 2. Age-stage specific survival rate (S_{xy}) of offspring from *P. citri* females treated with LC_{20} sublethal concentration of cyflumetofen and spiroadiclofen compared with untreated females.

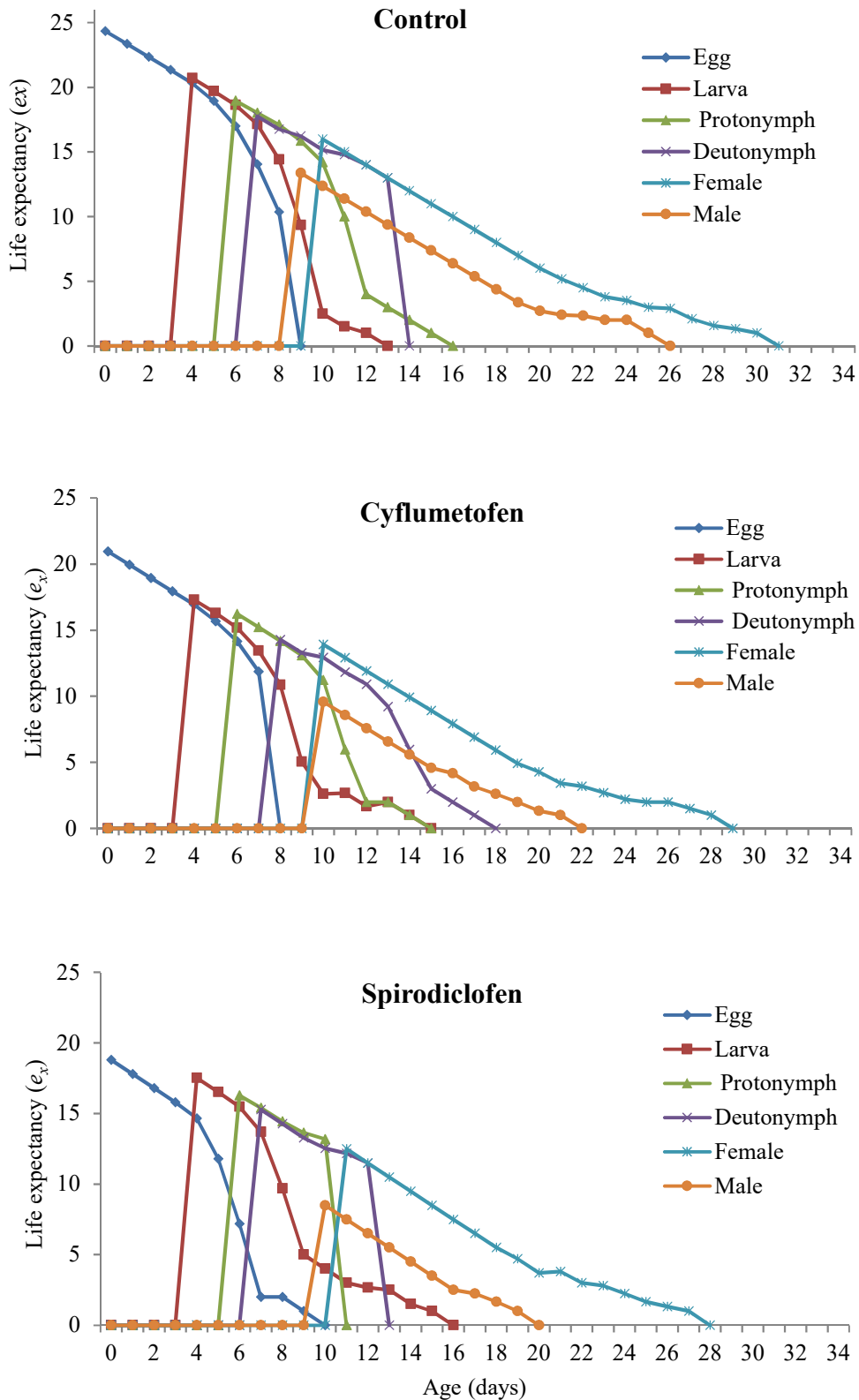


Figure 3. Age-stage life expectancy (e_{xj}) of offspring from *P. citri* females treated with LC₂₀ sublethal concentration of cyflumetofen and spirodiclofen compared with untreated females.

Our results confirmed that the LC₂₀ concentration of cyflumetofen and spiroadiclofen was highly effective in inducing significant changes in developmental durations and reproduction of *P. citri*. The sublethal concentration (LC₂₀) of the two pesticides decreased the fecundity of citrus red mite female; this may be due to reduced oviposition period and female longevity after treatments.

Numerous studies have shown that the tetranychid mite life history and life table parameters get affected by the sublethal concentrations of spiroadiclofen (Marcic 2007; Van Pottelberge *et al.* 2009; Ouyang *et al.* 2012; Saber *et al.* 2018). Spiroadiclofen effects were most obvious on the first day after treatment, when not only female fecundity, but also eggs' fertility were decreased, i.e., more non-viable eggs were laid (Van Pottelberge *et al.* 2009). Ouyang *et al.* (2012) reported that spiroadiclofen was effective in reducing both total egg production and the number of normally shaped eggs. Also, the sublethal effects of spiroadiclofen reduced fecundity and viability of eggs in *Tetranychus* adult females (Marcic 2007; Sun *et al.* 2010; Saber *et al.* 2018).

On the contrary, there have been fewer studies indicating the sublethal effect of cyflumetofen on tetranychid mite life history traits. Cyflumetofen showed considerable negative effects on *T. urticae* life-tables but it had moderate effects on *P. persimilis* (Abdel-Rahman and Ahmed 2018). The sublethal concentrations of pesticides may increase pest developmental time and reduce adult longevity and total fecundity (Wang *et al.* 2009; He *et al.* 2013; Song *et al.* 2013).

Our results revealed that the population growth rate of *P. citri* was affected by LC₂₀ sublethal concentrations of cyflumetofen and spiroadiclofen as a result of negative effects on reproduction period, fecundity and, finally in the population parameters (i.e., r , λ , R_0 , and T). Similar effects on life-table parameters were recorded by Saber *et al.* (2018), who treated *T. urticae* adult females with LC₂₅ sublethal concentrations of spiroadiclofen, abamectin and pyridaben, and showed the tested pesticides causing greater reduction in life-table parameters (r , λ , R_0).

In our experimental conditions, mites treated with spiroadiclofen had reduced age-specific survival rate (l_x) values (Fig. 1). Furthermore, $l_x m_x$ (age-specific maternity) values were reduced by cyflumetofen and spiroadiclofen which corresponds with the results of (Marcic 2007; Saber *et al.* 2018) indicating that the tested acaricides would significantly reduce mite growth.

In this study, comparable results were observed, since the e_{xj} of female offspring from the untreated females was 16 days but, it decreased to 13.92 and 12.50 days of female offspring from the females treated with cyflumetofen and spiroadiclofen, respectively. In general, life expectancy was decreased by cyflumetofen and spiroadiclofen treatments compared with the control in both sexes. Lower age-specific life expectancy was observed in treated mites by cyflumetofen and spiroadiclofen acaricides. Mohammadi *et al.* (2016) and Saber *et al.* (2018) reported that life expectancy (e_{xj}) of the tetranychid mite treated with pesticides was affected differently in individuals of the same age, stage and sex.

CONCLUSION

The sublethal concentration (LC₂₀) of tested pesticides had notable effects on all biological parameters of *P. citri*. It reduced the intrinsic natural increase (r), net reproductive rate (R_0), finite rate of increase (λ) and fecundity. Finally, studies of sublethal effects on biological parameters of citrus red mite allow us to have the most complete explanation of the population-level responses to acaricides. The cyflumetofen and spiroadiclofen have an acaricidal activity against *P. citri*. So, these results provide a baseline for the response of *P. citri* to them which will aid mite management programs in citrus.

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اثرات جانبی سیفلومتوفن و اسپیرودیکلوفن بر پارامترهای زیستی کنه قرمز مرکبات، *Panonychus citri* McGregor (Acari: Tetranychidae)

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چکیده

کنه قرمز مرکبات، *Panonychus citri* McGregor (Acari: Tetranychidae) که کنترل آن بیشتر بر اساس استفاده از کنه‌کش‌ها است، یکی از آفات اصلی مرکبات در سراسر جهان است. مقادیر کشنده و زیرکشنده سیفلومتوفن و اسپیرودیکلوفن روی کنه قرمز مرکبات برآورد شد. مقادیر LC₂₀ و LC₅₀ سیفلومتوفن و اسپیرودیکلوفن به ترتیب ۲/۷۹ و ۱۰/۲۳ پی‌پی‌ام، و ۲/۳۰ و ۷/۲۸ پی‌پی‌ام بود. اثرهای غلظت LC₂₀ سیفلومتوفن و اسپیرودیکلوفن بر آماره‌های جدول زیستی ماده‌های *P. citri* مورد مطالعه قرار گرفت. این دو کنه‌کش اثرهای معنی‌داری بر آماره‌های زیستی *P. citri* از جمله زمان رشد، میزان زنده‌مانی و بارآوری داشت. همچنین، قرار گرفتن ماده‌ها در معرض LC₂₀ میزان باروری خالص (R_0)، میزان افزایش متناهی (λ) و میزان افزایش ذاتی (r) را بسیار کاهش داد. میزان افزایش ذاتی در ماده‌های تیمار شده با سیفلومتوفن و اسپیرودیکلوفن به ترتیب ۰/۱۵۶ و ۰/۱۵۳ و برای ماده‌های تیمار نشده ۰/۱۸۳ در روز بود. غلظت‌های زیرکشنده، آماره‌های جدول زیستی کنه قرمز مرکبات را تحت تأثیر قرار داده و در نتیجه ممکن است بر رشد جمعیت نسل‌های آینده آن تأثیر بگذارد. این نتایج پایه‌ای برای پاسخ *P. citri* به آفتکش‌های سیفلومتوفن و اسپیرودیکلوفن است که به مدیریت کنترل کنه در مرکبات کمک می‌کند.

واژگان کلیدی: کنه‌کش‌ها؛ سیفلومتوفن؛ آماره‌های جدول زیستی؛ *Panonychus citri*؛ اسپیرودیکلوفن.

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