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Fertility and life expectancy of the predator *Supputius cincticeps* (Heteroptera: Pentatomidae) exposed to sublethal doses of permethrin

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ABSTRACT

The stinkbug *Supputius cincticeps* (Stål) (Heteroptera: Pentatomidae) can be found in agricultural and forest ecosystems feeding primarily on larvae of Coleoptera and Lepidoptera, where it can be exposed to insecticide applications. This study therefore aimed to evaluate the reproductive potential of'*S. cincticeps* after exposition to sublethal doses of permethrin (5.74 x 10^{-3}, 5.74 x 10^{-2}, 5.74 x 10^{-1}, 5.74 and 57.44 ppb) through the use of a fertility life table. The development cycle of this predator was determined in order to calculate its net reproductive rate (R_0), the infinitesimal (r_m) and finite (λ) rates of increase in addition to mean generation time (T). The net reproductive (18.31), infinitesimal (r_m) (0.050) and finite (λ) (1.051) rates of increase were higher, while generation time (57.93 days) was shorter for *S. cincticeps* exposed to 5.74x10^{-1} ppb of permethrin than in the control. This indicates a higher rate of population increase of this predator when exposed to this permethrin dose.

Key terms: Asopinae, biological control, pyrethroids, reproduction

INTRODUCTION

Insects can be plant feeders (Lustosa et al., 1999), predators (Zanuncio et al., 2003), or parasitoids (Matos et al. 2004a,b) and they can transmit diseases (Contreras et al., 2002, Uzcanga et al., 2003).

Biological control is important in integrated management of Lepidoptera defoliators of eucalyptus, especially with predatory Pentatomidae of genera *Podisus* and *Supputius* (Pentatomidae: Asopinae) (Zanuncio et al., 1992, 1994). *Supputius cincticeps* (Stål) (Heteroptera: Pentatomidae) and other predators of this family can inhabit many agro-ecosystems, where the use of insecticides can limit its impact in biological control programs (McPherson, 1982). This shows the necessity of using insecticides that are efficient against pests and safe to natural enemies including predators (Guedes et al., 1992; Zanuncio et al., 1993, 1998; Batalha et al., 1995; 1997; Picanço et al., 1996; Suinaga et al., 1996) and parasitoids in integrated pest management programs (Guedes et al., 1992). Pirethroids are efficient against defoliating caterpillars (Elliot et al., 1978) and selective to beneficial insects such as predatory Pentatomidae (Rajakulendran and Plapp, 1982; Pree and Hagley, 1985; Yu, 1988).

Sublethal doses of insecticides that are toxic at high levels may increase the performance of organisms, a process known as hormesis (Calabrese and Baldwin,

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1997a,b; Calabrese, 1999; Forbes, 2000), as reported for insects and mites of economic importance (Calabrese, 1999; Forbes, 2000) and for natural enemies (Zanuncio et al., 2003).

The effect of insecticides can be evaluated with fertility life tables that include estimates of parameters of population growth such as net reproductive rate (R_0), generation time (T) and infinitesimal (r_m) and finite (λ) rates of population increase (Southwood, 1978; Maia et al., 2000).

The aim of the present study was to evaluate parameters of fertility and life expectancy tables for the predator *S. cincticeps* exposed to sublethal doses of permethrin during third instar.

MATERIAL AND METHODS

This research was conducted in the Biological Control Laboratory of the "Centro de Biotecnologia Aplicada à Agropecuária (BIOAGRO)" of the Federal University of Viçosa (UFV)", Municipality of Viçosa, State of Minas Gerais, Brazil at 25 ± 0.5ºC, 75 ± 5% RH and a 12-hour photoperiod.

Zeneca Agro (Holambra, SP, Brazil) supplied the technical grade (96% pure) permethrin used, and the acetone (pa) was purchased from Isolar Ltda (Jacaré, RJ, Brazil). The permethrin was diluted in acetone to obtain the doses of 5.74 x 10^{-3}, 5.74 x 10^{-2}, 5.74 x 10^{-1}, 5.74, and 57.44 ppb based on mg a.i./ mg of wet weight of *S. cincticeps* and acetone in the control treatment.

A total of 450 second instar nymphs of *S. cincticeps* was obtained from eggs of the mass rearing facility of the UFV Biological Control Laboratory where groups of ten individuals were placed in Petri dishes (9.0 x 1.2 cm) with a moist cotton ball and fed *ad lib* with *Tenebrio molitor* L. (Coleoptera: Tenebrionidae) pupae from this laboratory. At the beginning of third instar, 75 *S. cincticeps* nymphs per treatment were placed individual in plastic cups (40 ml). These nymphs were raised until adult stage with *T. molitor* pupae, and water was supplied in 2 ml cylindrical tubes inserted in a circular 0.9 mm hole in the cover of the plastic cups with its lower end closed with a cotton ball to avoid water flowing. Each *S. cincticeps* nymph received 1 µl of the insecticide solution topically applied on its dorsum with a calibrated micro syringe according to the treatment and acetone in the control.

Pairs of *S. cincticeps* adults (one male and one female) were isolated in transparent plastic cups (500 ml) totaling 27, 30, 33, 27, 27, and 24 pairs for the doses of 5.74 x 10^{-3}, 5.74 x 10^{-2}, 5.74 x10^{-1}, 5.74, 57.44 ppb and in the control, respectively with water and *T. molitor* pupae.

Mortality and longevity of females, number of egg masses, eggs, and nymphs, as well as periods of preoviposition, egg laying, and egg incubation were recorded daily. These data were grouped into age classes of seven days and used to elaborate fertility and life expectancy tables during one generation of *S. cincticeps.* Average and standard error of the number of eggs per female were calculated daily for each age class. Egg viability was obtained per egg mass of this predator.

S. cincticeps fertility tables were compiled at each age interval (x) and included specific fertility (m_x) (number of females produced per survival female at age interval x); survival rate (l_x) (survival from age zero to the beginning of age x); gross reproductive rate (GRR) net reproductive rate (R_0); generation time (T); doubling time (DT); infinitesimal (r_m) and finite (λ) rates of population increase; and reproductive value (RVx) (contribution of a female of age *x* for the future population) (Southwood, 1978, Krebs, 1994).

The life *S. cincticeps* expectancy table was compiled with numbers of survivors at the beginning of age x (L_x); number of individuals that died during age x (d_x); survival rate during age x (S_x); survival from age zero to the beginning of age x (l_x); mortality at age interval x (q_x); and life expectancy (e_x). These parameters were used to estimate regression curves for *S. cincticeps* as a function of life expectancy for half of the population (ex50) of this predator by probit analysis (Finney, 1971) with SAS Proc Probit (SAS, 1989). Data on the different treatments were compared with the program developed by Maia et al. (2000).

RESULTS

Females *S. cincticeps* started oviposition at age 35 days with the most sublethal doses of permethrin (Fig. 1) with gross reproductive rate (40.80 females per female) and higher net reproductive rate (R0) (18.31 females per female) with the dose of 5.74 x 10^{-1} ppb of permethrin than in the control (Tables I and II). Maximum reproductive values (RVx) of *S. cincticeps* were registered at age class six with the doses of 5.74 x 10-1 ppb and in the control (Table II).

Generation time (T) of *S. cincticeps* varied from 57.93 days with 5.74 x 10^{-1} ppb to 59.25 days with 5.74 ppb of permethrin, while this value was 59.49 days in the control (Table I), which indicates five generations per year of *S. cincticeps.*

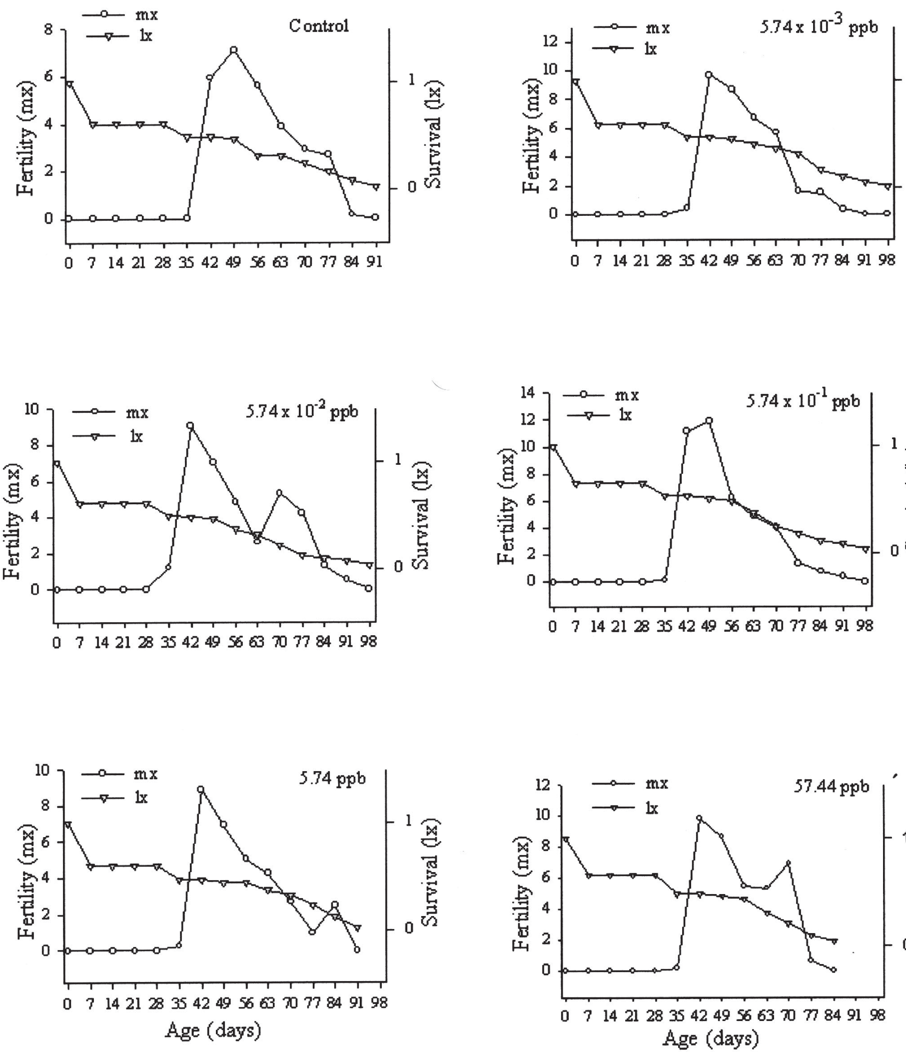

Figure 1. Fertility (m_x) and survival (l_x) of *Supputius cincticeps* (Heteroptera: Pentatomidae) topically exposed to five sublethal doses of permethrin during the third instar and in the control at 25 ± 1 ºC, 75 ± 10% RH, and a 12-hour photoperiod.

TABLE I

Life table parameters of *Supputius cincticeps* (Heteroptera: Pentatomidae) topically exposed to five doses of permethrin during the third instar and in the control at 25 ± 1 ºC, 75 ± 10% RH, and a 12-hour photoperiod

Doses (ppb)	R_o	T	DT	r_m	λ
Control	10.32 b	59.49 a	17.77 b	0.040 b	1.040 b
5.74 x 10^{-3}	14.08 ab	58.21 ab	15.40 ab	0.045 a	1.046 a
5.74 x 10^{-2}	12.66 ab	58.30 ab	15.75 ab	0.045 a	1.045 ab
5.74 x 10^{-1}	18.31 a	57.93 c	13.86 a	0.050 a	1.051 a
5.74	12.54 ab	59.25 a	16.12 ab	0.043 ab	1.044 ab
57.44	14.18 ab	58.44 ab	15.40 ab	0.045 a	1.046 a

R_o= net reproductive rate; T= generation time (days); DT= doubling time (days); rm= infinitesimal rate of increase; λ= finite rate of increase. Means followed by the same letter in the column do not differ significantly by Student *t* test (P= 0.05)

TABLE II

Fertility life table for *Supputius cincticeps* (Heteroptera: Pentatomidae) topically exposed to five doses of permethrin during the third instar and in the control at 25 ± 1 ºC, 75 ± 10% RH, and a 12-hour photoperiod

Doses (ppb)	x	L_x	l_x	m_x	$l_x.m_x$	$x.l_x.m_x$	RV_x	Stage
Control	1	109	1.00	0.00	0.00	0.00	4.64	Nymphs
	2	75	0.69	0.00	0.00	0.00	6.74	
	3	75	0.69	0.00	0.00	0.00	6.74	
	4	75	0.69	0.00	0.00	0.00	6.74	
	5	75	0.69	0.00	0.00	0.00	6.74	
	6	24	0.22	0.00	0.00	0.00	21.06	Adult
	7	24	0.22	5.93	1.30	9.13	21.06	
	8	23	0.21	7.11	1.50	12.01	15.80	
	9	15	0.14	5.61	0.77	6.95	13.31	
	10	15	0.14	3.89	0.54	5.35	7.70	
	11	12	0.11	2.92	0.32	3.54	4.77	
	12	8	0.07	2.68	0.20	2.36	2.77	
	13	4	0.04	0.17	0.01	0.08	0.17	
	14	1	0.01	0.00	0.00	0.00	0.00	
5.74 x 10^{-3}	1	119	1.00	0.00	0.00	0.00	6.86	Nymphs
	2	75	0.63	0.00	0.00	0.00	10.89	
	3	75	0.63	0.00	0.00	0.00	10.89	
	4	75	0.63	0.00	0.00	0.00	10.89	
	5	75	0.63	0.00	0.00	0.00	10.89	
	6	27	0.23	0.43	0.10	0.59	30.25	Adult
	7	27	0.23	9.68	2.20	15.38	29.82	
	8	26	0.22	8.70	1.90	15.21	20.91	
	9	23	0.19	6.68	1.29	11.62	13.80	
	10	21	0.18	5.69	1.00	10.04	7.79	
	11	18	0.15	1.59	0.24	2.64	2.46	
	12	9	0.08	1.49	0.11	1.35	1.74	
	13	6	0.05	0.37	0.02	0.24	0.37	
	14	3	0.03	0.00	0.00	0.00	0.00	
	15	1	0.01	0.00	0.00	0.00	0.00	
5.74 x 10^{-2}	1	111	1.00	0.00	0.00	0.00	6.85	Nymphs
	2	75	0.68	0.00	0.00	0.00	10.13	
	3	75	0.68	0.00	0.00	0.00	10.13	

Table II. Continuación

Doses (ppb)	x	L_x	l_x	m_x	$l_x.m_x$	$x.l_x.m_x$	RV_x	Stage
	4	75	0.68	0.00	0.00	0.00	10.13	
	5	75	0.68	0.00	0.00	0.00	10.13	
	6	30	0.27	1.20	0.32	1.95	25.33	Adult
	7	29	0.26	9.04	2.36	16.53	24.96	
	8	28	0.25	7.03	1.77	14.18	16.49	
	9	22	0.20	4.85	0.96	8.65	12.05	
	10	19	0.17	2.61	0.45	4.47	8.34	
	11	13	0.12	5.33	0.62	6.87	8.37	
	12	7	0.06	4.21	0.27	3.19	5.63	
	13	6	0.05	1.31	0.07	0.92	1.66	
	14	4	0.04	0.53	0.02	0.27	0.53	
	15	2	0.02	0.00	0.00	0.00	0.00	
5.74×10^{-1}	1	105	1.00	0.00	0.00	0.00	10.64	Nymphs
	2	75	0.71	0.00	0.00	0.00	14.89	
	3	75	0.71	0.00	0.00	0.00	14.89	
	4	75	0.71	0.00	0.00	0.00	14.89	
	5	75	0.71	0.00	0.00	0.00	14.89	
	6	33	0.31	0.12	0.04	0.23	33.85	Adult
	7	33	0.31	11.14	3.50	24.51	33.72	
	8	31	0.30	11.92	3.52	28.16	24.04	
	9	29	0.28	6.24	1.72	15.51	12.95	
	10	23	0.22	4.89	1.07	10.71	8.46	
	11	15	0.14	4.02	0.57	6.31	5.48	
	12	11	0.10	1.34	0.14	1.68	1.99	
	13	7	0.07	0.77	0.05	0.67	1.03	
	14	5	0.05	0.37	0.02	0.24	0.37	
	15	2	0.02	0.00	0.00	0.00	0.00	
5.74	1	114	1.00	0.00	0.00	0.00	6.27	Nymphs
	2	75	0.66	0.00	0.00	0.00	9.53	
	3	75	0.66	0.00	0.00	0.00	9.53	
	4	75	0.66	0.00	0.00	0.00	9.53	
	5	75	0.66	0.00	0.00	0.00	9.53	
	6	27	0.24	0.27	0.06	0.38	26.47	Adult
	7	27	0.24	8.91	2.11	14.77	26.21	
	8	25	0.22	6.93	1.52	12.15	18.68	
	9	25	0.22	5.05	1.11	9.96	11.76	
	10	21	0.18	4.26	0.79	7.85	7.99	
	11	18	0.16	2.69	0.42	4.67	4.35	
	12	13	0.11	0.96	0.11	1.31	2.30	
	13	7	0.06	2.49	0.15	1.98	2.49	
	14	1	0.01	0.00	0.00	0.00	0.00	
57.44	1	119	1.00	0.00	0.00	0.00	6.67	Nymphs
	2	75	0.63	0.00	0.00	0.00	10.59	
	3	75	0.63	0.00	0.00	0.00	10.59	
	4	75	0.63	0.00	0.00	0.00	10.59	
	5	75	0.63	0.00	0.00	0.00	10.59	
	6	27	0.23	0.15	0.03	0.20	29.41	Adult
	7	27	0.23	9.87	2.24	15.68	29.27	
	8	26	0.22	8.61	1.88	15.06	20.14	
	9	24	0.20	5.43	1.09	9.85	12.49	
	10	17	0.14	5.30	0.76	7.57	9.97	
	11	11	0.09	6.93	0.64	7.05	7.21	
	12	5	0.04	0.61	0.03	0.31	0.61	
	13	2	0.02	0.00	0.00	0.00	0.00	

x= age (x = seven days); L_x= number of survivors at the beginning of age x; m_x= number of females produced per female of age x; l_x= survival rate from age zero to the beginning of age x; RV_x= reproduction value of age x.

The time necessary for this predator to double its population (DT) was 13.86 days with the doses of 5.74 x 10^{-1} ppb of permethrin, which was shorter than in the control (Table I).

The infinitesimal rate of population increase (rm) for *S. cincticeps* was 0.04 individuals per day in the control group and 0.05 with the dose of 5.74 x 10^{-1} ppb dose of permethrin (Table I), while the finite rate of population increase (λ) was 1.04 and 1.05 females added to the population per day per *S. cincticeps* female in these treatments.

Fertility curves showed maximum reproduction of *S. cincticeps* when this predator was 35 to 56 days old with all permethrin doses (Fig. 1).

Survival curves (l_x) declined until day 7 followed by a period of similar mortality (age classes 7 to 28 days) (Fig. 1). The slope of survival curves was similar with all doses of permethrin, and it decreased with the age of the predator (Fig. 1).

Life expectancy showed that *S. cincticeps* can live up to 105 days with the doses of 5.74 x 10^{-2}, 5.74 x 10^{-1}, and 5.74 ppb, and 91 days in the control. Average life expectancy (ex_{50}) for half of the *S. cincticeps* population with all permethrin doses showed higher mortality and average life expectancy (ex_{50}) at each age interval with 5.74 ppb of permethrin when analyzed by probit (42.6 days) (Table III and Fig. 2).

DISCUSSION

The of 5.74 x 10^{-1} ppb dose of permethrin stimulated population increase in *S. cincticeps* with higher R_0 (18.31 females/ female), RV_x (33.85) and lower T (57.93 days) values, which indicate the occurrence of hormesis with this sublethal dose of permethrin (Calabrese, 1999; Forbes, 2000, Zanuncio, et al., 2003) and GRR of 40.80 females per female. The R0 supplies more precise values than the GRR because it incorporates mortality rate during young and adult stages of organisms (Force and Messenger, 1964). Predators used in pest management should present higher reproduction values, and their oviposition peaks should coincide with the necessity of pest control. Moreover, low T values are important for natural enemies in the laboratory where it is necessary to obtain a higher number of generations per time to compensate for the lower values of R_0 and r_m. The R_0 is less reliable for comparing populations of organisms because the generation time differs between species and it may not express the real capacity of a species to increase in numbers (Price, 1997). Therefore the rm is more commonly used to compare populations of organisms under different conditions because it relates net reproductive rate (R_0) with generation time (T). Furthermore, lower differences

TABLE III

Probit analysis of life expectancy as function of survival of *Supputius cincticeps* (Heteroptera: Pentatomidae) topically exposed to five doses of permethrin during the third instar and in the control at 25 ± 1 ºC, 75 ± 10% RH, and a 12-hour photoperiod

Doses (ppb)	Characteristics				
	Equation	Probability of χ^2	χ^2	ex_{50} (days)	IC (95%) (days)
Control	Y' = 2.6280 - 0.0732 x	1.00	13.81	35.8	(34.74 – 37.05)
5.74 x 10^{-3}	Y' = 2.8128 - 0.0722 x	1.00	16.56	38.9	(37.91 – 40.04)
5.74 x 10^{-2}	Y' = 2.1350 - 0.0602 x	0.99	45.52	35.4	(34.30 – 36.53)
5.74 x 10^{-1}	Y' = 2.4991- 0.0662 x	1.00	22.53	37.7	(36.72 – 38.76)
5.74	Y' = 2.6328 - 0.0617 x	1.00	15.99	42.6	(41.43 – 43.82)
57.44	Y' = 2.2179 - 0.0672 x	1.00	22.10	33.2	(32.31 – 34.14)

IC= Reliability interval (ex_{50}) at 95% probability; X^2= Qui-square; Y'= life expectancy in "probit" and x= survival (%) in decimal logarithm.

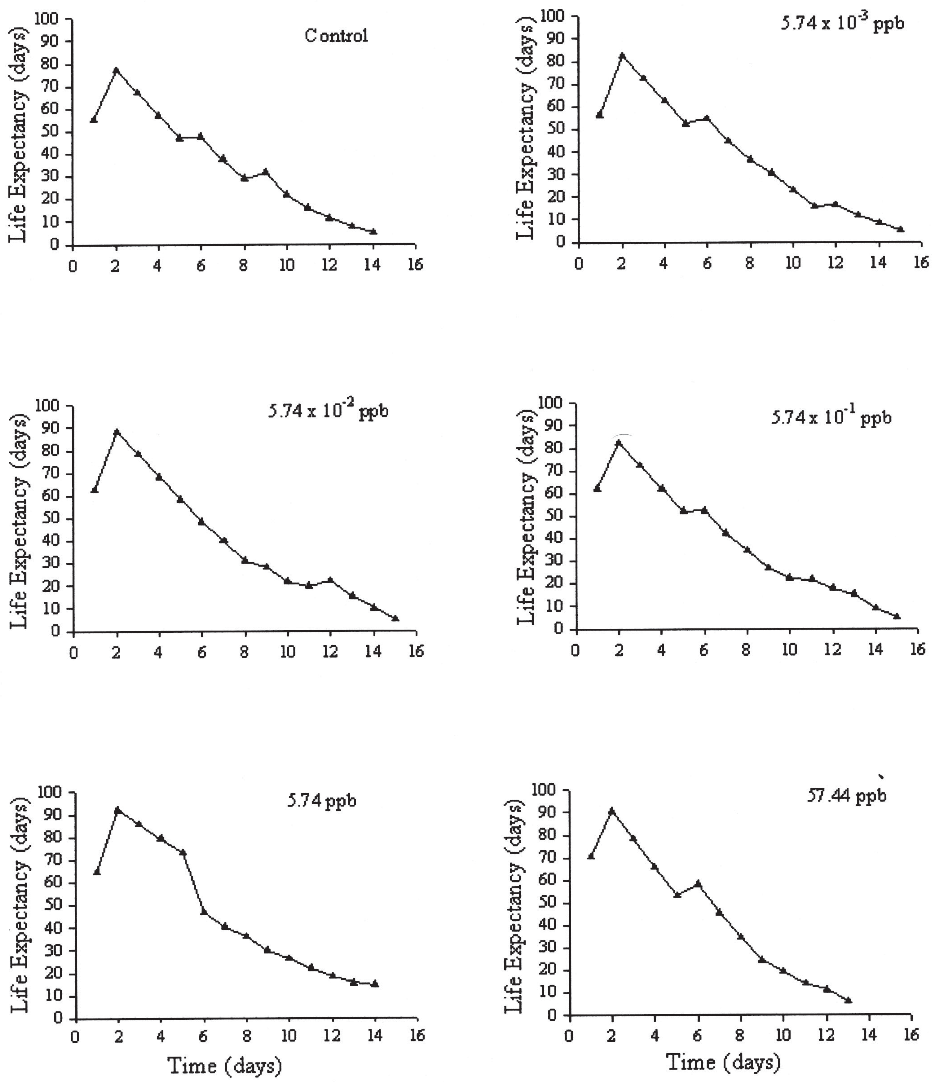

Figure 2. Life expectancy of *Supputius cincticeps* (Heteroptera: Pentatomidae) topically exposed to five sublethal doses of permethrin during the third instar and in the control at 25 ± 1 ºC, 75 ± 10% RH, and a 12-hour photoperiod.

between treatments are not necessarily an indication of similarity because low variations in these numbers can lead to high differences in total values of individuals of a population (Silveira Neto et al., 1976).

Supputius cincticeps showed similar values for T and rm with the doses of 5.74 x 10^{-1} ppb of permethrin to those of Assis et al. (1998) with this predator. These values can differ between Asopinae species because R_0, T and r_m of *Tynacantha marginata* (Dallas) (Heteroptera: Pentatomidae) were 50.68, 69.09 and 1.48, respectively (Moreira et al., 1995).

The best age to release female predators in agro ecosystems for pest control can be defined according to their reproductive values (RV_x). *S. cincticeps* showed a higher reproductive value (33.85) after 42 days with 5.74 x 10^{-1} ppb of permethrin, which was similar to that reported for *Podisus nigrispinus* (Dallas) (Heteroptera: Pentatomidae) (Medeiros et al., 2000).

These results are important for biological control programs where pests are controlled by the progeny of individuals released (De Bach and Hagen, 1964). Specific fertility curves (m_x) showed that *S. cincticeps* females start to reproduce at 28 days, with a higher tendency for population increase when they reach 36 to 42 days.

The *S. cincticeps* survival curve (l_x) for all permethrin doses and the control was type II according to the Rabinovich classification (1978). This curve represents a population with constant number of deaths per unit of time and with a straight line and similar increment on mortality for young and old individuals.

Life expectancy (e_x) for *S. cincticeps* varied with permethrin doses with higher values in the column risk (q_x), which indicates the probability that an individual will die before the time established in the column e_x (Southwood, 1978). Life expectancy decreased with adult age of this predator in all treatments except with the 5.74 ppb dose of permethrin, which showed a longer life expectancy (42.6 days) and better survival rate for *S. cincticeps*.

The insecticide permethrin was selective with all sublethal doses applied, which is desirable for natural enemies and can stimulate population increase of *S. cincticeps*. This predator can present adequate performance in integrated pest management when exposed to sublethal doses of permethrin.

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