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Effects of Conventional Insecticides and Insect Growth Regulators on Fecundity and Other Life-Table Parameters of *Micromus tasmaniae* (Neuroptera: Hemerobiidae)

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ABSTRACT Effects of 3 conventional insecticides (methyl parathion, azinphos-methyl, cypermethrin) and 3 insect growth regulators (fenoxycarb, diflubenzuron, and tebufenozide) on life-table parameters of *Micromus tasmaniae* Walker were determined in adults derived from insecticide-treated larvae. The following parameters were compared with the control: sex ratio, longevity, sterility, and fecundity. Power analysis was used to increase the efficiency and the predictability of the life-table test. Diflubenzuron resulted in a higher proportion female lacewings. Longevity was reduced for females emerging from fenoxycarb- and diflubenzuron-treated larvae. Total number of eggs was reduced for diflubenzuron- and fenoxycarb-treated lacewings, as well as the following generation of tebufenozide-exposed lacewings. Daily number of eggs was reduced for the diflubenzuron treatment. Peak egg production was increased for lacewings exposed to azinphos-methyl and was decreased for the following generation of tebufenozide-exposed lacewings. Diflubenzuron treatment resulted in an extended preoviposition period. Oviposition periods were reduced for lacewings treated with fenoxycarb, diflubenzuron or azinphos-methyl as well as for the following generation of the tebufenozide treatment. The time to peak egg production was similar for all treatments. Methyl parathion, cypermethrin, and tebufenozide treatments showed no differences in any of the tested life-table parameters in the 1st generation. In summary, the insect growth regulators fenoxycarb and diflubenzuron had a more severe impact on life-table parameters than the 2 organophosphates and the pyrethroid. In future research, increased attention should be paid to long-term (e.g., the following generation) effects on life-table parameters.

KEY WORDS *Micromus tasmaniae*, lacewings, life-table parameters, fecundity, power analyses, insecticides

THE USE OF beneficial arthropods for integrated pest management has become widespread, and the benefits of this tactic have been widely recognized. In view of the recent development of new insecticide classes (i.e., juvenoids and ecdysone agonists), that are slower acting and produce a greater degree of sublethal effects than conventional insecticides (i.e., organophosphates and pyrethroids), it is important to gain a better understanding of sublethal effects on beneficial arthropods (Croft 1990, Stark and Wennergren 1995). The significance of sublethal effects on so-called life-table parameters has been summarized by Croft (1990).

Although neuropteran chrysopids (especially *Chrysoperla carnea* Stephens) have been used as biological control agents for some time, and are being produced commercially in the northern hemisphere (Hassan 1974, Karelin et al. 1989), hemerobiids are relatively new candidates for biological and integrated pest control (Leathwick 1989, Stelzl and Hassan 1992). A wide range of literature is available on the effects of insecticide on chrysopids, however, little is known about the sublethal effects of insecticides on hemerobiids *Micromus tasmaniae* Walker is one of the most abundant beneficial predators in Australasia and has high potential for use in integrated pest management.

In this study, the effects of 5 different classes of insecticides on the fecundity and on other life-table parameters of *M. tasmaniae* are examined and compared: 2 organophosphates (methyl parathion and azinphos-methyl), 1 pyrethroid (cypermethrin), and 3 insect growth regulators including 1 juvenile hormone analogue (fenoxycarb), 1 chitin syntheses inhibitor (diflubenzuron), and 1 ecdysone-based moulting inducer (tebufenozide). The organophosphates and the pyrethroid were chosen as representatives of conventional insecticides. However, the 3 classes of insect growth regulators reflect the more recent and more slowly acting generation of insecticides with a more selective mode of action.

Because of high natural variation in fecundity and longevity of lacewings, a large number of replicates (individual pairs of lacewings) is necessary for meaningful statistical analyses of insecticide effects

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on life-table parameters. The oviposition period of *M. tasmaniae* can last up to 12 wk with a length of ≈5–6 wk (i.e., if conditions are optimal). Because each test pair must be supplied with aphids at least twice a week and its containers must be cleaned twice weekly to avoid fungal or viral contamination, it is time consuming to carry out fecundity testing with *M. tasmaniae*. Therefore, a further objective of this study was to increase the time efficiency of the life-table test by determining the effects of a shortened monitoring period and of a reduced number of replicates on the level of significance of the results.

Materials and Methods

Chemicals. Insecticides were methyl parathion (Folidol M50, emulsifiable concentrate (EC), 60% [AI]), azinphos-methyl (Gusathion M35, wettable powder (WP), 35% [AI]), cypermethrin (Ripcord, EC, 20% [AI]), fenoxycarb (Insegar WP, 25% [AI]), tebufenozide (Mimic 20 F, flowable liquid (FL), 20% [AI]), and diflubenzuron (Dimilin 25 WP, 25% [AI]).

Insects. A laboratory colony of *M. tasmaniae* was derived from adult insects collected in Canterbury, New Zealand. Larvae and adults of *M. tasmaniae* were reared on pea aphids, *Acrythosiphon pisum* (Harris), and kept at 19°C, 60% RH, and a photoperiod of 16:8 (L:D) h. The generation following the field-collected lacewings was used for all experiments.

Application of Insecticides. Glass petri dishes (9 cm diameter) were sprayed with 2 ml of an aqueous suspension of each insecticide at 8 mbar using Potter tower equipment, which was housed in a self-constructed spray chamber. Controls were sprayed with water. This resulted in a homogeneous spray coverage of 0.93 ± 0.08 μl (mean ± SE) fluid per square centimeter. The quantities (μg) of methyl parathion, azinphos-methyl, cypermethrin, fenoxycarb, diflubenzuron, and tebufenozide deposited per square centimeter were 0.05, 0.007, 0.002, 0.005, 0.07, and 7.44, respectively. These quantities allowed 50% of the exposed lacewings to reach the fertile adult stage and were based on the results of dose–response experiments (Rumpf 1994, Rumpf et al. 1997). An exception was tebufenozide, which did not cause any mortality even at concentrations much higher than the recommended field rate. It was applied at a rate of 10 times that of the recommended field coverage and, additionally, was used as an example to test possible effects in the following generation of lacewings. At least 20 petri dishes were sprayed per treatment. After the spray deposit had dried, 20 *M. tasmaniae* larvae (3rd instars, 30.5 ± 11.5 h since 2nd larval molt) were transferred to each petri dish. A daily supply of pea aphids served as food for the surviving larvae, which were kept on the contaminated petri dishes until adult emergence. After emergence, the sex of the lacewings was determined and 1 female and 1 male lacewing were paired and transferred to a clean petri dish. Only lacewings that hatched within 10 h of each other were paired. Variable survival rates from the insecticides and differing times of emergence resulted in different sample sizes (n = 27–65). The adult lacewings were fed on pea aphids, and the eggs were laid on small pieces of black linen attached to the petri dishes. The lacewings were fed 3 times a week and the petri dishes were cleaned at the same time.

Life-Table Parameters. Effects of the insecticides on the sex ratio of emerging adults, longevity of adult females, proportion of sterile pairs, total number of eggs, mean number of eggs per day of oviposition, number of eggs at time to peak production, preoviposition period, oviposition period, and time to peak egg production were determined.

Statistical Analysis. The Pearson chi-square test was used to determine the significance of differences in the sex ratio and the proportion of sterile pairs of lacewings. This analysis was conducted using paired comparisons of each insecticide with the water-treated control.

Analysis of the number of eggs at the day of peak production and the average number of eggs per female per day was conducted using analysis of variance (ANOVA) (Wilkinson 1990).

Differences in longevity of female lacewings, total number of eggs per female, preoviposition period, oviposition period, and day of peak egg production were determined by ANOVA using $\log_e$-transformed data (parameters showed a right-skewed distribution). Data reported are geometric means. When the ANOVA showed significant differences ($P < 0.05$) among the means, paired comparisons of each mean with the control were made using least significant difference (LSD) tests. To determine the life span of adult females, only individuals for which the time to death had been monitored were used. When females did not oviposit for >5 d in succession but were still alive, they were released and their time to death could not be recorded. Sterile pairs of lacewings were excluded from ANOVA.

Power analysis (Dallal 1988) based on the results of the ANOVA was used to determine the minimum percentage differences detectable between insecticide and control treatments for the different life-table parameters at $P < 0.05$. This detection level was determined for full and time-reduced monitoring periods and for varying numbers of replicates. To assess the comparative sensitivity of the 6 oviposition parameters as well as the longevity of female lacewings, the minimum percentage difference, detectable with power 80% and alpha 0.05, was calculated. This was calculated with n = 50 and 25 and under 4 stopping scenarios (when 100 and 50% of all pairs had ceased laying, when daily egg production was <30% of peak production, and when the mean number of eggs per couple was <5/d). These stopping scenarios had to be calculated independently for each insecticide and the control treatment if data analysis were to have equal prerequisites for each treatment. Graphs showing the

Table 1. Sex ratio, longevity, and fertility of *M. tasmaniae* exposed to insecticides during their larval development compared with water-treated controls

Treatment	Female ratio		Longevity of female lacewings[a]			Sterile pairs	
	%	n	Days	n	95% CI	%	n
Water	53.0	202	46.1	52	38.7-54.8	1.6	65
Methyl parathion	60.8	102	38.6	32	31.1-47.9	5.1	39
Azinphos-methyl	62.4	101	36.4	20	29.3-45.2	3.7	27
Cypermethrin	50.0	100	41.6	44	34.9-49.7	6.0	50
Fenoxycarb	56.1	57	29.1***	32	24.0-35.5	0.0	34
Diflubenzuron	64.9*	148	34.1**	42	28.2-41.1	13.5	52
Tebufenozide (1st)	55.8	77	39.1	40	30.4-49.2	4.6	44
Tebufenozide (2nd)	56.3	103	38.8	38	33.5-45.2	4.0	50

***, Differs significantly ($P < 0.001$) from value for water in same column; **, differes significantly ($P < 0.01$) from value for water in same column; *, differs significantly ($P < 0.05$) from value for water in same column.
[a] $F = 2.471$; df = 7, 292.

proportion of lacewings for the different stopping scenarios against time for the 7 treatments were constructed using Kaplan-Meier (Kaplan and Meier 1958) estimates.

Results

Emerging adults of the control and the cypermethrin treatment showed almost equal numbers for both sexes (Table 1). However, in all other treatments, greater numbers of female were produced (Table 1). The greatest proportion of females was produced in the diflubenzuron treatment, which was significantly different from the water-only control treament ($\chi^2 = 4.961$, df = 1, $P = 0.026$). The female adult lacewings emerging from fenoxycarb- and diflubenzuron-treated larvae died ≈ 2 wk earlier than the water-only control insects (Table 1).

There was no significant difference ($\chi^2 = 11.624$, df = 7, $P = 0.114$) between the proportions of sterile lacewing pairs throughout the treatments (Table 1). However, a strong trend toward an increase in infertility was observed for diflubenzuron-treated lacewings, where 13% of all pairs did not lay any eggs. Although increased infertility could be observed for almost all insecticide treatments, generally the number of sterile pairs was low (0-13%) in all treatments.

Total numbers of eggs produced per female were reduced by ≈50% for diflubenzuron-exposed lacewings, 40% for fenoxycarb-exposed lacewings, and 30% for the 2nd generation of tebufenozide-exposed lacewings compared with the control value (Table 2). Diflubenzuron-treated females deposited significantly fewer eggs per day than the control females ($P < 0.01$). When the number of eggs deposited by each lacewing pair at their day of peak production was compared, azinphos-methyl-exposed lacewings produced significantly ($P < 0.01$) higher numbers of eggs, whereas the following generation of tebufenozide-treated lacewings produced significantly ($P < 0.01$) lower numbers of eggs, than the water-treated control insects (Table 2).

The time profile for oviposition demonstrates significant differences between lacewings treated with the 3 insect growth regulators (diflubenzuron, fenoxycarb, and tebufenozide) and azinphos-methyl compared with the control insects (Table 3). The preoviposition period (time between adult emergence and 1st oviposition) was increased for diflubenzuron-exposed lacewings, whereas the length of the oviposition period was reduced for all

Table 2. Mean numbers of eggs laid by *M. tasmaniae* exposed to insecticides during their larval development compared with water-treated control groups

Treatment	n	Eggs/female[a]	95% CI	Eggs/female/d	95% CI	Eggs on day of peak production[c]	95% CI
Water	64	546	434-687	14.6	13.5-15.7	31.0	28.9-30.1
Methyl parathion	37	462	371-575	13.1	11.8-14.3	27.2	24.6-29.9
Azinphos-methyl	26	411	281-602	16.5	13.7-19.3	36.9**	32.1-41.7
Cypermethrin	47	512	441-595	13.7	12.4-14.9	30.5	28.4-32.6
Fenoxycarb	34	326**	223-477	15.9	14.2-17.6	30.9	27.5-34.3
Diflubenzuron	45	271***	176-417	11.9**	10.4-13.4	30.4	26.6-34.2
Tebufenozide (1st)	42	420	321-551	14.8	13.2-16.3	32.5	29.4-35.5
Tebufenozide (2nd)	48	374*	261-536	13.0	11.7-14.4	25.9**	23.4-28.3

***, Differs significantly ($P < 0.001$) from value for water in same column; **, differs significantly ($P < 0.01$) from the value for water in same column; *, differs significantly ($P < 0.05$) from value for water in same column.
[a] F = 2.998; df = 7,335.
[b] F = 3.777; df = 7,314.
[c] F = 4.097; df = 7,335.

Table 3. Preoviposition period, oviposition period, and time to peak egg production by *M. tasmaniae* exposed to insecticides during their larval development compared with water-treated control groups

Treatment	Preoviposition period[a]			Oviposition period[b]		Time to peak egg production[c]	
	n	Day	95% CI	Day	95% CI	Days after emergence	95% CI
Water	64	4.6	4.3-4.9	39.8	33.9-46.8	10.4	8.9-12.2
Methyl parathion	37	4.7	4.4-5.1	36.4	30.4-43.5	10.9	9.1-13.1
Azinphos-methyl	26	4.8	4.4-5.2	27.8*	20.7-37.3	9.6	8.7-10.7
Cypermethrin	47	4.6	4.4-4.9	39.0	34.4-44.2	10.9	9.6-12.4
Fenoxycarb	34	4.2	4.0-4.5	22.0***	15.8-30.6	10.1	10.9-11.8
Diflubenzuron	45	5.2**	4.7-5.7	29.0*	22.5-37.4	10.8	9.5-12.4
Tebufenozide (1st)	42	4.8	4.5-5.1	33.3	27.8-39.9	12.2	10.9-13.6
Tebufenozide (2nd)	48	4.8	4.3-5.4	30.8*	24.2-39.3	11.1	9.3-13.3

***, Differs significantly ($P < 0.001$) from value for water in same column; **, differs significantly ($P < 0.01$) from value for water in same column; *, differs significantly ($P < 0.05$) from value for water in same column.

[a] $F = 2.603$; df = 7,335.

[b] $F = 3.636$; df = 7,314.

[c] $F = 0.773$; df = 7,335.

treatments. This reduction was significant only for lacewings treated with fenoxycarb ($P < 0.001$), diflubenzuron ($P < 0.05$), azinphos-methyl ($P < 0.05$) and for the following generation of the tebufenozide treatment ($P < 0.05$) (Table 3). Time to peak egg production was similar for all treatments, and no significant ($P > 0.05$) difference was observed when compared with the control data (Table 3).

These differences in oviposition led to a shift from the normal oviposition curve for control females. For all treatments, the laying pattern showed a rapid linear increase to reach the peak egg production in ≈5 d. The decline in oviposition started, for all treatments, with a rapid reduction, followed by a period of constant egg production, which was followed by a final rapid fall to no production (Figs. 1-3). The oviposition curves were created using calculated means for the preoviposition period, number of eggs at peak oviposition, time to peak oviposition, and length of the oviposition period. The curves between these points were best fitted using a linear function from the start of the oviposition period to its peak and a cubic function from the peak to the end of oviposition. Changes in the oviposition curve are demonstrated in Fig. 1 for azinphos-methyl-, in Fig. 2 for fenoxycarb and diflubenzuron-treated lacewings, and in Fig. 3 for the lacewing generation following that exposed to tebufenozide. The curves for methyl parathion-, cypermethrin- and 1st-generation tebufenozide-treated lacewings followed that for the control, (Figs. 1 and 2).

The most sensitive oviposition parameters (percentage difference detectable ≤30) to show effects of treatments were the mean number of eggs per day of oviposition, the number of eggs at the day of peak production, the length of the preoviposition period, and the time to peak oviposition (Table 4). If alternative stopping rules were applied (reducing the length of the monitoring period) (Table 4), the minimum percentage difference detectable for the mean number of eggs per day of oviposition and for the number of eggs at peak production was elevated and, therefore, the sensitivity of these test parameters was reduced. The sensitivity of following test parameters was increased if the monitoring period was stopped before 100% of the pairs ceased oviposition—total number of eggs per female, day of peak production, and length of the oviposition period (Table 4). Variables with endpoints before the end of the monitoring periods, such as the duration of the preoviposition period, and with extended endpoints, such as longevity of females, were not effected by the different stopping scenarios (Table 4). The proportion of lacewings for the different stopping scenarios against time were compared for the 7 treatments shown in Figs. 4-6. An increase in the number of replicates from 25 to 50 pairs of lacewings generally decreased the minimum detectable difference by ≈10% (Table 4).

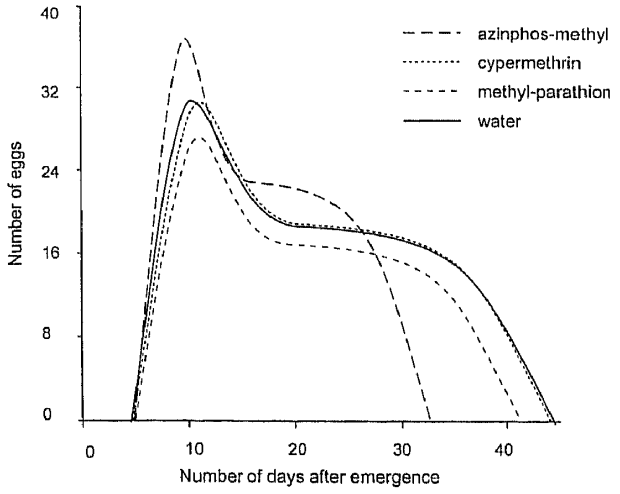

Fig. 1. Oviposition curves (using calculated means for preoviposition period, time to peak oviposition and length of oviposition period) for control lacewings, and lacewings treated with methyl parathion, azinphos-methyl, and cypermethrin.

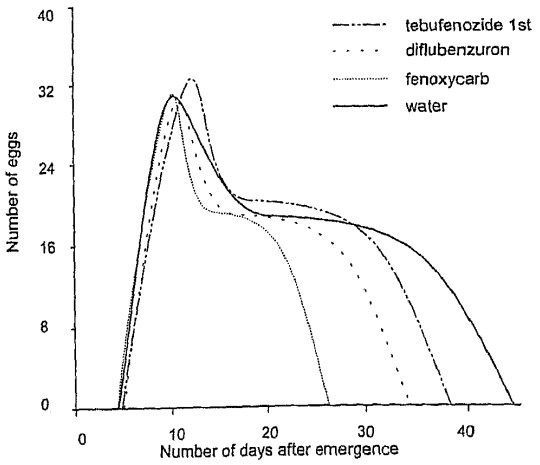

Fig. 2. Oviposition curves (using calculated means for preoviposition period, time to peak oviposition and length of oviposition period) for control lacewings, and lacewings treated with fenoxycarb, diflubenzuron, and tebufenozide. Curve for tebufenozide treatment shows oviposition patterns of lacewing adults emerging from insecticide-exposed larvae (tebufenozide 1st).

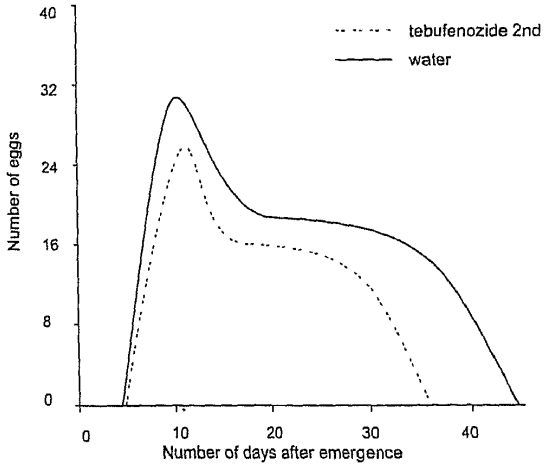

Fig. 3. Oviposition curves (using calculated means for preoviposition period, time to peak oviposition, and length of the oviposition period) for control lacewings and the lacewing generation following that exposed to the insecticides (tebufenozide 2nd).

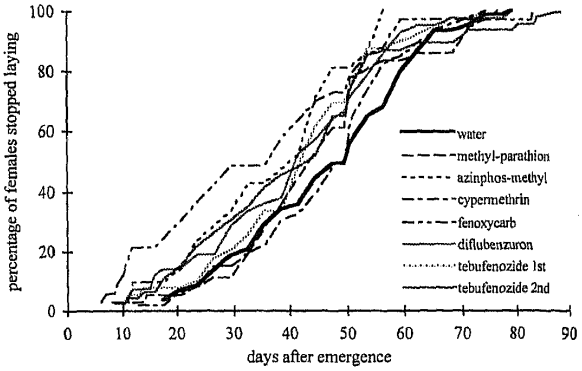

Fig. 4. Proportion of lacewings that have ceased laying against time for the 7 treatments in relation to the sensitivity of the fecundity test. The proportions shown are Kaplan–Meier estimates.

Discussion

These results demonstrate the importance of life-table examinations because it could be shown that, although the insect growth regulators fenoxycarb and diflubenzuron caused no short-term mortality (24-h test) in *M. tasmaniae* (Rumpf 1994, Rumpf et al. 1997), they still have an impact on the health of exposed individuals. Despite that only 3rd instars were exposed to the insecticides, and the emerging adults were kept in an insecticide-free environment, the sex ratio of the adults was altered in the diflubenzuron treatments. Longevity of females as well as fecundity of lacewing pairs and the length of the oviposition period were reduced in the fenoxycarb and diflubenzuron treatments. Tebufenozide caused no mortality during the remaining life cycle of *M. tasmaniae*, after exposure of larvae, even at a concentration 10 times that of the highest recommended field rate (Rumpf 1994, Rumpf et al. 1997). There was no impact on the measured life-table parameters for the parent generation, which emerged from the exposed larvae. However, when the life-table parameters were evaluated for the following generation, fecundity and the length of the oviposition period was reduced. These results

Table 4. Comparative sensitivity of test parameters: Calculation of minimum percentage difference statistically detectable with power 80% and alpha 0.05 at $n = 25$ and $n = 50$

	% difference statistically detectable when							
	100% stopped laying	n	50% stopped laying	n	No. eggs/day <30% of eggs at day of peak production	n	No. eggs/female is <5/d	n
No. eggs/female ($\log_e$)[a]	49, 38	25, 50	45, 34	25, 50	45, 34	25, 50	45, 35	25, 50
No. eggs/female/d[b,c]	27, 19	25, 50	37, 26	25, 50	40, 29	25, 50	35, 25	25, 50
No. eggs/female/d of peak production[b,c]	26, 19	25, 50	32, 23	25, 50	32, 23	25, 50	32, 23	25, 50
Preoviposition period[a,b]	27, 19	25, 50	27, 19	25, 50	27, 19	25, 50	27, 19	25, 50
No. days/to peak egg production ($\log_e$)[a,b]	30, 22	25, 50	25, 19	25, 50	25, 18	25, 50	26, 19	25, 50
Oviposition period, d ($\log_e$)[a]	38, 29	25, 50	35, 26	25, 50	35, 26	25, 50	37, 28	25, 50
Longevity females ($\log_e$)[a]	33, 25	25, 50	33, 25	25, 50	33, 25	25, 50	33, 24	25, 50

[a] Sensitivity of test parameter increases or remains unchanged as test duration is shortened.
[b] Most sensitive test parameters (percentage difference detectable ≤30 for $n = 25$).
[c] Sensitivity of test parameter decreases as test duration is shortened.

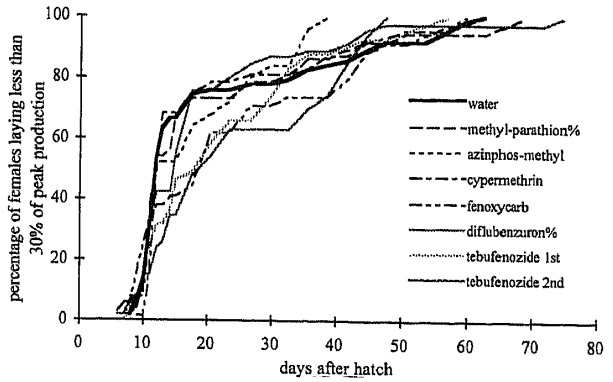

Fig. 5. Proportion of lacewings laying < 30% of their mean peak production against time for the 7 treatments in relation to the sensitivity of the fecundity test. The proportions shown are Kaplan-Meier estimates.

demonstrate that sublethal effects may surface after several generations and stresses the importance of long-term evaluations, in particular in view of the use of some pesticides in integrated pest management. Sublethal effects, as described in this study, can interfere with the synchrony between pest species and their natural enemies. Additionally they can, in the long term, lead to the eradication of entire populations of beneficial arthropods. Whether the magnitude of the effects described in our study would lead to the eradication of lacewing populations, or to a severe disruption of the synchrony between this predator and its prey species, remains to be investigated. Thorough and long-term assessments of the population dynamics of this species in agroecosystems (e.g., in relation to weather conditions, harvesting patterns, and the existing invertebrate fauna) would be the necessary next step to achieve this goal.

When comparing the results achieved for the 3 insect growth regulators (diflubenzuron, fenoxycarb, tebufenozide) with those for the other insecticides tested, it is concluded that, at the rates applied (LC_{50}), the insect growth regulators fenoxycarb and diflubenzuron had a more severe impact on the life-table

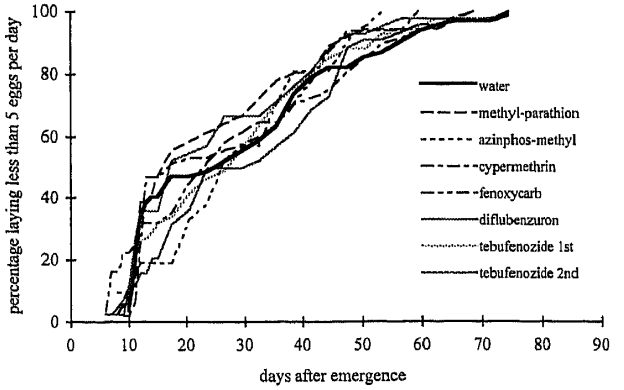

Fig. 6. Proportion of lacewings laying < 5 eggs per day against time for the 7 treatments in relation to the sensitivity of the fecundity test. The proportions shown are Kaplan-Meier estimates.

parameters than the 2 organophosphates and the pyrethroid. Methyl parathion and cypermethrin had no effect on any of the parameters measured while azinphos-methyl caused a shift in the oviposition curve through a shortened oviposition period, which was compensated for by an increased number of eggs at peak production. Thus, fecundity was not affected. The severe effects of diflubenzuron on the tested life-table parameters observed with brown lacewings in this study corroborate earlier findings on the effects of diflubenzuron in other insect species (Rup and Chobra 1985, Equbal Ahmad 1992, Kim et al. 1992). Tebufenozide and fenoxycarb also have been shown to influence fecundity (e.g., the reduction of fecundity in adults of the tufted apple bud moth, *Platynota idaeusalis* Walker, that survived sublethal concentrations of fenoxycarb or tebufenozide) (Biddinger 1993).

Because the parameters affected for *M. tasmaniae* not always are the same as those affected for *C. carnea* in insecticide exposure tests, separate tests for each of the 2 lacewing species must be conducted. This is important because, in the past, researchers often generalized the toxic effects of insecticides for taxonomic orders or families of beneficial arthropods, as summarized by Theiling and Croft (1988). For example, exposure of *C. carnea* to diflubenzuron resulted in a high reduction of fecundity (total number of eggs) if adult lacewings were fed on diflubenzuron-treated aphids and longevity was not affected (Zaki and Gesraha 1987). However diflubenzuron affected both fecundity and longevity in *M. tasmaniae*. Shour and Crowder (1980) determined life-table parameters with *C. carnea* after contamination of 3rd instars with permethrin, and reported that fecundity, peak egg production, and the duration of the oviposition period remained unaffected after treatment. This corresponds with the results obtained for *M. tasmaniae* in our study. However, decreased longevity of surviving adult lacewings as reported in C. carnea could not be confirmed for *M. tasmaniae* in this study, because longevity remained unaffected.

The results of our study also show that the sensitivity of the test (percentage difference between the treatments statistically ($P < 0.05$) detectable), if it was stopped early, decreased for the total number of eggs produced per pair of lacewings, whereas it increased for the mean number of eggs per female per day. The increase and decrease in sensitivity were caused by the omission of eggs from pairs of brown lacewings that were still ovipositing when the majority had already ceased. This exclusion reduced the variability for the total number of eggs, because the lacewing pairs that kept ovipositing ultimately laid more eggs than those that finished at an earlier time. However, the average number of eggs produced per day is similar for lacewings with extended or shorter oviposition periods, because those with longer oviposition periods lay more eggs during early oviposition than those with shorter oviposition periods, and lay less as oviposition declines. If stopped early, the mean number of eggs per

day is likely to be higher than that of the other pairs, thus increasing variability. It is recommended to shorten the evaluation time of the test by applying 1 of the suggested early stopping scenarios because the results do not lose much sensitivity, and some parameters become more sensitive. However, the test system becomes more time efficient because the evaluation time is reduced to almost half that of the duration of the original test. The data collected for the insecticide and water treatments provided estimates on average control values as well as information on the inherent variability of the different life-table parameters. This formed the basis for an estimate of the sensitivity of the various life-table parameters at different sample sizes and at shortened testing times through power analysis. One of the major difficulties when carrying out fecundity testing (specifically), and life-table testing (in general) and for setting up standardized test systems has been to estimate the number of replicates to be used and the time frame of the experiments to achieve statistically valid ($P < 0.05$) and scientifically meaningful data. These difficulties could be overcome as indicated by the data presented here, and it would be possible to forecast the sensitivity of a planned test if statistical power were determined before experimentation.

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