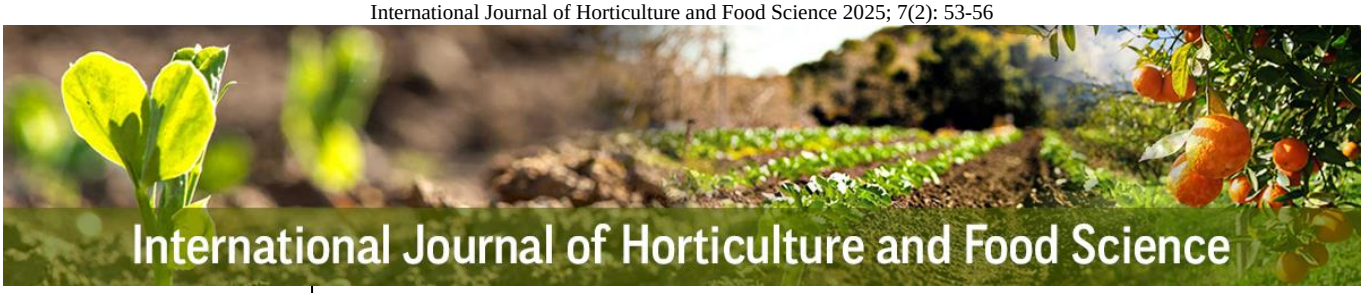

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Effect of three insecticides on the life table parameters of a Harpactorinae reduviid *Rhynocoris longifrons* (Stal˚) (Hemiptera: Reduviidae)

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Abstract
Three commonly used organophosphorus insecticides in the agro ecosystems namely, monocrotophos, quinalphos and dimethoate were studied for their efficacy on the life table parameters in the laboratory in a Harpactorinae reduviid predator *Rhynocoris longifrons* (Stal). The LC_{50} was calculated for all the three insecticides for 24, 48, 72 and 96 hour durations. All the insecticides increased their incubation period, stadial period, pre oviposition period and nymphal mortality and decreased their fecundity, hatchability and adult longevity. Maximum reduction was noticed in the monocrotophos treated category followed by quinalphos and dimethoate. The Gross reproductive rate and Net reproductive rate of *R. longifrons* is 78.00 and 94.38 respectively which is reduced to 57.00 and 29.36, 69.00 and 34.54 and 64.00 and 31.58 respectively for monocrophos, quinalphos and dimethoate treated category in *R. longifrons*.

Keywords: Insecticides, relative toxicity, biological parameters, table studies, *R. longifrons*

1. Introduction
There is less awareness among the people in the usage of synthetic pesticides on beneficial insects. In order to achieve sustainability, integrated pest management (IPM) represents a remarkable improvement over previous conventional approaches, so optimizing the effectiveness of the entomophagy activity of natural enemies of pests is a determining factor. IPM does not necessarily require the suppression of insecticides, but rather affects the need to reduce their dependence, by eliminating unnecessary applications. Although these toxins are targeted at plant pests, many of them are broad spectrum biocides that have profound effects on non-target species in agro ecosystems. However, the correct integration of chemical and biological control is essential part of sustainable pest management, for which a correct interpretation of the impact of insecticide treatments, is required. Much less is known about the effects of chemical pesticides on predators and parasites than on herbivorous pests (Croft, 1990; Croft and Brown, 1975) [8, 9]. Exposure to insecticides to predators can occur from direct contact with spray residues, even by feeding on plant material and also consuming prey contaminated with pesticides (Cloyd and Bethke, 2011; He *et al*., 2012, 2018) [7, 19, 18]. Conventional pest management practices mostly rely on intervention technologies without regard to measurable pest management needs and disrupt natural enemies and the ecosystem services that an integrated pest management strategy provides (Douglas *et al*., 2015) [10].
In IPM agro ecosystems a great proportion of non-target insects are mainly affected by sub lethal dose/concentration values. A sub lethal dose/concentration defined as inducing no apparent mortality in the experimental population. The effects induced have been described affecting biology, physiology, or behavior of individuals or populations that survive to the exposure to a toxicant at lethal or sub lethal dose/concentration. For the correct integration of insecticide applications and biological control, the influence of the insecticide side effects on beneficial insects should be evaluated. There seems to be a close relationship between the application of insecticides and the development of behavioral resistant populations.
This finding has suggested establishing a practical procedure based on the realization of small scale field applications, to subsequently monitor beneficial insect reactions, useful for identifying ecological agro ecosystems.

Life table analysis is one of the most effective means of studying population density, which is also altered by the sub lethal doses of insecticides by affecting the physiology of insects. It is from this standpoint that the present investigation has been undertaken and the information incorporated in this paper examine these issues with respect to *R. longifrons* exposed to the sub lethal dose of monocrotophos, dimethoate and quinalphos.

In continuation of this, the present study is aimed at understanding the impact of three commonly used organophosphate insecticides on a Harpactorinae reduviid *Rhynocoris longifrons* (Stal). Reduviids (commonly called assassin bugs) are very promising biological control agents included in the family Reduviidae and *R. longifrons* is predominantly found in the agroecosystems particularly in the fruit and vegetable crops and voraciously predates on various economically important insect pests such as *Achaea janata* Linnaeus, *Helicoverpa armig*era Hubner, *Spodoptera litura* (Fabricius) and *Corcyra cephalonica* Stainton (Ambrose, 2003) [2]. They possess essential characteristics for acting as an active biocontrol which include limited prey range, host searching efficiency, high fecundity, short life cycle, female-biased population, high predatory efficacy, favourable for mass culture, adaptability to new environmental conditions and free from parasites, parasitoids as well as predators (Ambrose and Kumar, 2016) [3]. It is crucial to consider the potential impacts of insecticides on beneficial insects like assassin bugs and adopt strategies to minimize harm. Hence, this study will be very useful in the selection of insecticides in the agro ecosystems where *R. longifrons* is commonly used for biocontrol programme.

Materials and Methods

Adults and nymphs of *R. longifrons* were collected from the foothills of Chunkankadai (longitude-77°23′5.03″E; latitude-8°12′2.74″N), Kanyakumari district, Tamilnadu. They were maintained in the laboratory at 30±2 °C, relative humidity ranging from 75-80% and photoperiod between 11-13 hrs on the larvae of *Corcyra cephalonica* Stainton. LC_{50} concentration of each insecticide was calculated for the III instar nymphs of *R. longifrons* by conducting preliminary studies. LC_{50} concentration of 48 hr duration was taken as one toxic unit and 1/10 values of the 48 hr LC_{50} of each insecticide was considered as sub lethal concentration. They were 0.0016, 0.0058 and 0.0030% for monocrotophos, quinalphos and dimethoate, respectively. Twenty µl of the insecticide were applied topically on the thoracic region. For each insecticide fifteen III instar nymphs were treated, separately.

A control set up was maintained with 15 III instar nymphs and they were treated with 20 µl of water. Both the experimental as well as control individuals were maintained at room temperature (30±2 °C). Insecticidal concentration was maintained continuously for 20 days with fresh fresh application of insecticide every day and were fed daily. The insects which are applied with the insecticides were reared up to adults. All the data on the stadial period, nymphal mortality, adult longevity, pre oviposition period, post oviposition period, age specific survival/mortality were recorded daily. Fecundity was also recorded daily until all the females died.

Life tables were constructed by the determination of each age interval, the survival rate (l_x) and the mean number of female progeny per female (m_x) still alive at such age intervals. The intrinsic rates of increase of population (r_c), finite rate of increase in numbers, true generation time, time required to double the population, rate of multiplication per week and annual rate of increase were calculated by using Birch's formula (1948) which was elaborated by Watson (1964) [25], Laughlin (1965) [21], Southwood (1978) [24] and Bellows *et al* (1996) [4] where the finite rate of increase in population (λ) represents the number of individuals added to the population per female per day.

Results and Discussion

The present work investigated the sub lethal effects of three commonly used insecticides in the agroecosystems against *R. longifrons*. Among the three insecticides tested monocrotophos exhibited highest toxicity followed by quinalphos and dimethoate against the reduviid *R. longifrons.* The LC_{50} value recorded was 0.021, 0. 039 and 0.069 mg/litre^{-1} for monocrotophos, quinalphos and dimethoate, respectively for 24 hrs duration (Table 1). In 48 hrs duration also monocrotophos recorded maximum toxicity followed by quinalphos and dimethoate with the LC_{50} value of 0.016, 0.030 and 0.058 respectively. Similar trend was noticed for the 72 and 96 hrs duration also. Highest mortality was observed in the monocrotophos treated insects followed by quinalphos and dimethoate treated insects which is similar to the observation of George and Ambrose (2006) [16] in *R. marginatus* and George (2004) [12] in *R. longifrons*. These results resulted due to either the insecticides affect the nervous system or disrupt the hormonal balance and it is in corroboration with results of another Harpactorinae reduviid *Sycanus collaris* Kammatterikunnu and Thattanteparambil (2025) [20].

Table 1: Relative toxicity of three insecticides on *R. longifrons*

Insecticide	Duration (hrs)	LC_{50}	'r'	Fiducial Limit	P
Monocrotophos	24	0.021	0.931	0.014-0.032	< 0.01
	48	0.016	0.948	0.011-0.026	< 0.01
	72	0.012	0.961	0.009-0.020	< 0.01
	96	0.009	0.889	0.005-0.016	< 0.01
Quinalphos	24	0.039	0.981	0.030-0.048	< 0.001
	48	0.030	0.963	0.022-0.039	< 0.001
	72	0.023	0.944	0.015-0.030	< 0.01
	96	0.019	0.968	0.010-0.026	< 0.001
Dimethoate	24	0.069	0.986	0.052-0.084	< 0.001
	48	0.058	0.936	0.041-0.072	< 0.01
	72	0.049	0.944	0.034-0.062	< 0.01
	96	0.040	0.961	0.029-0.057	< 0.01

In the normal insects the incubation period is 7.31±0.34 days and it is significantly extended to 9.51±0.46, 8.42±0.22 and 7.84±0.31 days by the insecticides monocrotophos, quinalphos and dimethoate, respectively (Table 2). Extended incubatory period may be due the lack of energy created by the insecticides by making stress in the female insects to lay the eggs. Similarly the stadial period is also increased from 7.11±0.45 days for the control I instar insects to 9.84±0.94, 8.96±0.44 and 8.11±0.54 days in the insects treated with monocrotophos, dimethoate and quinalphos, respectively. Similar increased trend in the insecticides treated category was noticed in the II instar, III instar, IV instar and V instar insects treated with insecticides. In all these categories monocrotophos extended

the stadial period to a maximum which is followed by quinalphos and dimethoate. Extended nymphal duration has interpreted as a result of either larval starvation or increasing consumed energy. Reduction in larval nutrition efficiency and increase larval consumption of energy in detoxification process by the insecticides were already noticed by many scientists and is in corroboration with Bhat *et al*., (2013) [5]. Similar increase in the stadial period was also noticed by George and Ambrose (2004) [15] in *R. marginatus* and George and Ambrose (2006) [16] in *R.kumarii* by treatment with different insecticides.

Table 2: Insecticidal impact on the biology of *R. longifrons*

Parameters	Control	Monocrotophos	Quinalphos	Dimethoate
Incubation Period (days)	7.31±0.34	9.51±0.46	8.42±0.22	7.84±0.31
Stadial period				
I instar	7.11±0.45	9.84±0.94	8.96±0.44	8.11±0.54
II instar	6.94±0.38	9.38±0.81	8.36±0.59	7.82±0.41
III instar	7.81±0.53	9.89±0.38	9.11±0.66	8.39±0.38
IV instar	7.98±0.61	10.62±0.56	9.49±0.44	8.81±0.56
V instar	15.36±1.14	19.11±1.33	18.59±1.26	17.48±1.44
Adult Longevity				
Male	81.38±10.43	70.46±6.31	77.11±7.43	80.13±6.91
Female	89.62±12.48	72.23±0.55	79.32±6.88	82. 55±7.18

The adult longevity of the males and females are highly reduced by the treatment with the sub lethal concentration of the insecticides. The normal adult longevity of males and females is 81.38±10.43 and 89.62±12.48 days, respectively is considerably reduced to 70.46±6.31 and 72.23±0.55, 77.11±7.43 and 79.32±6.88 and 80.13±6.91 and 82.55±7.18 days respectively for the insects treated with monocrotophos, quinalphos and dimethoate. Similarly, the egg laying capacity of the normal insects (120.38±9.11) is drastically reduced in the insects which are treated with monocrotophos (70.31±6.31) quinalphos (81.16±7,88) and dimethoate (92.54±7.99) (Table 2).

Life table studies have been used to assess the effects of different variables on insect population dynamics (George, 2004) [15]. Life table parameters such as the intrinsic rate of increase, net reproductive rate and total pre oviposition period can be used to determine population growth chatacteristics (George *et al.*, 2002) [17]. The gross reproductive rate and the net reproductive rate (R_o) are drastically reduced by the insecticides. Normal gross reproductive rate of 78.00 is reduced to 57.00, 69.00 and 64.00 by the insecticides monocrotophos, dimethoate and quinalphos, respectively. (Table 3). The maximum reduction was noticed in the monocrotophos treated insects. Similar trend was noticed in the net reproductive rate also which indicates the highest negative impact of monocrotophos. on the capacity to multiply in a generation. This might be due to the hydroxylation processes of some steroids which reduce the availability of ecdysone by which insecticides increased the moulting period (George and Ambrose, 2004) [15].

Table 3: Insecticidal impact on the life table parameters of *R. longifrons*

Parameters	Control	Monocrotophos	Quinalphos	Dimethoate
Gross Reproductive rate ($\sum m_x$)	78.00	57.00	69.00	64.00
Net Reproductive rate ($R_o = \sum l_x m_x$)	94.38	29.36	34.54	31.58
Mean length of Generation ($Tc = \sum l_x m_x X / R_o$)	94.84	120.14	116.33	103.56
Estimated value of intrinsic rate of increase in numbers(r_c)	0.039	0.026	0.029	0.034
Corrected r_m	0.041	0.028	0.031	0.035
True Generation Time ($T = \log eR_o/r_m$)	88.46	103.56	98.46	92.59
Finite rate of increase in numbers (λ)	1.038	1.028	1.032	1.035
Doubling Time	14.59	22.38	19.58	17.85
Weekly Multiplication rate	1.286	1.184	1.220	1.256
Annual rate of increase	6.1×10^6	4.1×10^4	4.9×10^5	5.8×10^6

The mean length of generation in the normal insects (94.84 days) is increased by the insecticides. Maximum increase was observed in the monocrotophos treated category (120.14 days) followed by quinalphos (116.33 days) and dimethoate (103.56 days). Similar observation was noticed in another three Harpactorinae reduviids *R. marginatus*, *R.kumarii* and *R. fuscipes* by George 1996; George and Ambrose, 1998 and 1999 which indicates the highest toxicity of monocrotophos. The intrinsic rate of natural increase (R_c) and Finite rate of increase (λ) are also reduced by the insecticides than the normal insects which shows the effect of insecticides on the development of insects by reducing the egg output. The reduced fecundity by insecticides was caused by the disruption of parental reproductive physiology or it might be due to the lower food intake (Ambrose, 1999) [21]. This means that the insects develop well only in the absence of heavily toxic insecticides in the field and also by the sufficient supply of food.

The weekly multiplication rate of normal *R. longifrons* is 1.286 times which is reduced by the insecticides to 1.184, 1.220 and 1.256 times respectively by the insecticides monocrotophos, quinalphos and dimethoate (Table 3). The same trend in reduction was noticed in the annual rate of increase also which is in line with the findings of Muthupandi (2001) [22] and Nambirajan (2003) [23] in another Harpactorinae reduviids.

Conclusion

By this study it was clearly understood that the insecticides reduced the reproductive capacity, longevity and increased the developmental time. This observation suggest that the application of these three commonly used insecticides monocrotophos, quinalphos and dimethoate in the agroecosystem could affect the biology and physiology of non-target reduviid biocontrol agent *R. longifrons*. Moreover, the studies revealed that all the three tested insecticides considered to induce a more negative impact for all the biology and life table parameters of *R. longifrons* both in the larval and adult stage and was they are not recommended for use as an inevitable part of integrated pest management. Among the three insecticides tested monocrotophos was highly toxic followed by quinalphos. Dimethoate is somewhat a safer insecticidewhich can be applied in the IPM programme. Hence, screening of insecticides is very much important to safe guard the non-target beneficials such as *R. longifrons* which is proved as an excellent ecofriendly biocontrol agent on various vulnerable insect pests in the fruit and vegetable crops.

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