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Field-persistent toxicity of various insecticides against potent predator, *Cheilomenes sexmaculata* (F.)

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Abstract
The result of the investigation on field persistent toxicity of various insecticides on grub and adult stages of *C. sexmaculata* revealed that due to weather effect, the toxicity of all the insecticide reduced with time. The treatment of control (water spray) had no detrimental effect on predator. Among the different insecticides tested, profenophos and indoxacarb were found to be extremely harmful to the grub stage while novaluron and profenophos were grouped as extremely harmful to the adult stage. Further, imidacloprid and thiamethoxam were comparatively harmless to slightly harmful against the both stages. Rest of the all insecticides showed moderately harmful to the both stages

Keywords: Field-persistent toxicity, *C. sexmaculata*, grub and adult, etc

Introduction
India has made remarkable achievements in agricultural research and food production with the adoption of modern agricultural technologies, thereby compound growth rate of various crops increased during last few decades and ultimately agricultural yield increased several times and also expected to double the farmer's income in upcoming years by incorporation of suitable and effective pest management strategies, despite that the expected yield have not been achieved so far because of most of the crops are being attacked by many insect pest especially sucking insect by causing quality deterioration and yield loss, thus reduces farmer's income drastically. Bio-control agents, such as predators and parasitoids, are considered as key tools in integrated insect pest management (Patil and Sathe, 2003) [7]. The potent predator, lady beetle *Cheilomenes sexmaculata* (F.) is one of the beautiful insects found in all parts of the world. Lady beetles with its immature and adult stages play important role in biological ecosystems and have been used in different regions of the world to manage pests such as aphids, mealy bugs, thrips and mites (Tank *et al*., 2007) [12]. Many efforts have been made to protect this potent predator from exposure of hazardous insecticides as this insect has become integral part of modern agriculture. The most severe constraint to realizing the potential use of natural enemies in field crops is disruption through the widespread application of insecticides with broad toxicity to both pest and their natural enemies. Coccinellids can tolerate many insecticides which is an advantage over other predators. The widespread use of insecticides has harmful influence on biological control agents in many crop systems, for example these insecticides have a direct or indirect effect on the population of parasitoids and predators. Sometime, the indiscriminate use of the insecticides seriously affects the population of these biological control agents. As a result of this, the natural pressure of predatory beetle on sucking pests is decreased and outbreaks of the insect pests occur in many agricultural lands and sometime secondary insect pests become serious major pests that cause economic losses to agricultural crops. The use of insecticides accompanied with indigenous bio-control agents are considered as a rapid and effective management strategies for different sucking insect pests. However, not much attention is being paid on field-persistent toxicity of insecticides to the lady beetle in many cropping ecosystem, which forms an integral component of modern IPM technologies for pest management (Shanmugapriya and Muralidharan, 2017) [8]. There is an urgent need to develop suitable and safer insecticides against *Cheilomenes sexmaculata* (F.). Hence, an attempt was therefore made to find out the field-persistent toxicity of various insecticides against *Cheilomenes sexmaculata* (F.) under extended-laboratory conditions.

Materials and Methods

To determine the field-persistence toxicity of various insecticides against *C. sexmaculata*, second instar grub and freshly emerged adults were obtained from laboratory culture and they were used in susceptibility test to various insecticides during 2010-11 and 2011-12 in Bio-control Laboratory, Department of Agricultural Entomology, N.M. College of Agriculture, Navsari Agricultural University, Navsari (Gujarat) at 24.93 ± 0.81 ^{0}C and 23.01 ± 0.78 ^{0}C temperature; and 61.16 ± 1.21 and 60.61 ± 2.29 per cent relative humidity during 2010-11 and 2011-12, respectively.

Method of insecticidal application

The experiment was conducted as per the methodology suggested by Patel (2010) [6]. To study the field persistent toxicity of various insecticides against *C. sexmaculata*, Indian bean *var*. *Katargam* was raised at College farm, N.M.C.A., Navsari Agricultural University, Navsari. All the recommended agronomical practices were followed. In the entire plot, 30 rows of Indian bean were maintained to study the present investigation. From the each maintained rows, three consecutive rows were selected for spraying purpose with the help of Knapsack lever operated spray pump as per the treatment. From each selected row, 30 plants were randomly selected and tagged. These tagged plants were sprayed with predetermined insecticides as per the treatments (Table-1). The spraying for first and second trial was done on 18/12/2010 (*Rabi* 2010-11) and 27/12/2011 (*Rabi* 2011-12), respectively. The special care was also taken during the spraying to obtain uniform coverage of insecticides on each such selected plant. Leaves from the sprayed plants of respective treatment and control treatment were plucked at 0 (2 hours), 1, 3, 7 and 15 days after spray without disturbing the deposits during the handling and leaf disks were cut out, so as to fit in a Petri plate (110 mm).

Table 1: Details of insecticides tested on grub and adult of coccinellid, *C. sexmaculatus*

Treatment No.	Treatment details	Concentration (%)	Dose (g or ml/1 lit.)
T_1	Imidacloprid 17.8% SL	0.005	0.28 ml
T_2	Thiamethoxam 25% WG	0.005	0.20 g
T_3	Acetamiprid 20 % SP	0.004	0.20 g
T_4	Clothianidin 50 % WDG	0.003	0.06 g
T_5	Profenophos 50 % EC	0.075	1.5 ml
T_6	Spinosad 2.5 % SL	0.002	0.8 ml
T_7	Novaluron 10 % EC	0.0075	0.75 ml
T_8	Indoxacarb 14.5 % SC	0.01	0.69 ml
T_9	Endosulfan 35 % EC**	0.075	2.14 ml
T_{10}	Control (Water spray)	-	-

****** Endosulfan is banned on 13.05.2011 for production, use and sale in all over India as per directives of Hon'ble Supreme Court of India

Method of observations

Grub: The field persistent toxicity to grub of predatory coccinellids was tested by using the methodology suggested by Upadhyay and Agrawal (1995) [13] with Completely Randomized Design (CRD) with ten treatments repeated thrice. For the purpose, ten second instar grub of *C. sexmaculata* were released per treatment per repetition in each Petri plate (110 mm) individually along with bean aphid, *Aphis craccivora* Koch on plucked leaves of respective treatment. The Petri plates were placed on rake as per treatment. The mortality data was recorded at 24 hours after exposure. The moribund grub was also considered as dead. The data obtained on per cent mortality of grub of *C. sexmaculata* were converted into angular transformed values and then subjected to statistical analysis.

Adult: A similar methodology was employed as per grub of *C. sexmaculata* to study the field persistent toxicity of adults. The mortality data was recorded at 24 hours after exposure. The data obtained on per cent adult mortality of *C. sexmaculata* were converted into angular transformed values and then subjected to statistical analysis.

The magnitude of the response of toxicant exposure on the predatory coccinellids was subjected to classify as per International Organization of Biological Control (IOBC) toxicity ratings (Sterk *et al*., 1999) [10]. For semi-field or extended laboratory trials, IOBC employs a following scale to categories the tested insecticides. Thus, the same scale was also employed in present investigation to differentiate the evaluated insecticides in to various groups of toxicity.

Score	IOBC Toxicity Rating for natural enemies	
	Mortality (%)	Category
1	< 25	Harmless
2	25-50	Slightly harmful
3	51-75	Moderately harmful
4	> 75	Harmful

Results and Discussion

The data in terms of percentage of mortality recorded at 0 (2 hours), 1, 3, 7 and 15 days after spray application are presented in Table-02 and 03, and discussed as hereunder.

Grub

The data on the per cent grub mortality over two years (Overall pooled) are presented in Table-2. The results revealed that control (water spray) had zero per cent grub mortality and remained safe to second instar grub of *C. sexmaculata*. Among the various tested insecticides, imidacloprid 0.005 per cent and thiamethoxam 0.005 per cent showed less grub mortality i.e. 15.33 and 21.67 per cent, respectively while acetamiprid 0.004, spinosad 0.002 and endosulfan 0.075 per cent were slightly harmful i.e. 33.00, 42.67 and 45.67 per cent grub mortality, respectively. However, clothianidin 0.003 and novaluron 0.0075 per cent were moderately harmful i.e. 60.33 and 70.33 per cent grub mortality, respectively. Finally, two insecticides *viz*., indoxacarb 0.01 per cent and profenophos 0.075 per cent registered 85.33 and 93.67 per cent grub mortality, thus grouped as harmful insecticides. The ANOVA of pooled data recorded on per cent grub mortality over period revealed that the interaction effect between treatment and period showed non-significant difference indicating consistent performance of various treatments with regards to their impact on grub stage of *C. sexmaculata*. Based on the overall pooled data, the ranking to the various insecticides were made and presented hereunder.

Score		Category		Perceived insecticides against grub
1	=	Harmless (<25% mortality)	:	imidacloprid and thiamethoxam
2	=	Slightly harmful (25-50% mortality)	:	acetamiprid, spinosad and endosulfan
3	=	Moderately harmful (51-75% mortality)	:	clothianidin and novaluron
4	=	Harmful (<75% mortality)	:	profenophos and indoxacarb

Adult

The pooled data recorded on the per cent adult mortality over two years (Overall pooled) are presented in Table-3. The results further indicated that control (water spray) treatment had zero per cent adult mortality and remained totally safe to adult of *C. sexmaculata*. None of the insecticide found to be absolutely harmless to the adults of *C. sexmaculata* under the present investigation. Thereafter, imidacloprid 0.005, thiamethoxam 0.005 and acetamiprid 0.004 per cent recorded as slightly harmful (29.33, 42.67 and 48.33 per cent adult mortality, respectively). However, spinosad 0.002, endosulfan 0.075, clothianidin 0.003 and indoxacarb 0.01 per cent were moderately harmful (53.00, 55.00, 73.67 and 75.00 per cent adult mortality, respectively). Finally insecticides like novaluron 0.0075 and profenophos 0.075 per cent were recorded as completely harmful insecticides to the adults of *C. sexmaculata* by registering 75.00 and 90.33 per cent adult mortality. The ANOVA of pooled data recorded on per cent adult mortality over period revealed that the interaction effect between treatment and period showed non-significant difference indicating consistent performance of various treatments with regards to their impact on adult stage of *C. sexmaculata*. Based on the overall pooled data, the ranking to the various insecticides were made and presented hereunder.

Score		Category		Perceived insecticides against adult
1	=	Harmless (<25% mortality)	:	No insecticide
2	=	Slightly harmful (25-50% mortality)	:	imidacloprid, thiamethoxam and acetamiprid
3	=	Moderately harmful (51-75% mortality)	:	spinosad, endosulfan and clothianidin and indoxacarb
4	=	Harmful (<75% mortality)	:	novaluron and profenophos

In past, Balikai and Liganppa (2004) [2] who reported that the treatment of malathion (5 dust @ 20 kg/ha) was highly toxic to larvae and adult of *M. sexmaculatus* followed by *Datura metel* Linn., Neem soap, endosulfan, *Azadirachta indica* (A. Juss), *Pongamia pinnata* (L.) kernels, *Vinca rosea* Linn and *Adhatoda vasica* Nees had moderately to less of toxic to larvae. Furthermore, Bhatt (2005) [4] indicated that dimethoate 0.03 per cent proved to be highly toxic to the third instar larvae and adults of *M. sexmaculatus* followed by fenubucarb 0.1 per cent, methyl-o-demeton 0.025 per cent and acetamiprid 0.004 per cent while, imidacloprid 0.005 per cent found to be least toxic to the larvae and adults. Gour and Pareek (2005) [5] revealed that cypermethrin was found to be most toxic to the larvae and adult of *C. septempunctata* followed by dimethoate than endosulfan and rated as highly toxic insecticide. Moreover, imidacloprid, ethofenprox and malathion were found to be moderately toxic. However, acephate and cartap hydrochloride were more toxic than Endosulfan. Previously, Bandral (2006) [3] revealed that the highest mortality of adult of *C. septempunctata* was exhibited by cypermethrin 0.01 per cent and malathion 0.05 per cent than dimethoate 0.03 per cent and methyl-O-demeton 0.025 per cent. Looking to the toxicity of different insecticides against *C. sexmaculata*, it appears that the beetles were more sensitive to the tested insecticides than the larval stage which is in agreement with the Tank (2006) [11]. Similarly, Tank *et al*. (2007) [12] reported that dichlorvos, cypermethrin and fenvalerate found to be highly toxic in nature to the larvae and only dichlorvos registered as more toxic to the adults of *C. sexmaculata* whereas quinalphos and phosphamidon were found moderately toxic to both larvae and adults. Acetamiprid and endosulfan proved to be safer insecticides while dimethoate, methyl-o-demeton and monocrotophos appeared to be relatively safer to the larvae. Solangi *et al*., (2007) [9] observed that spinosad showed less toxicity while present investigation is disagree with results showed that spinosad caused slightly to moderately toxic to the *C. sexmaculatus*. The discrepancies in present findings are might be due to differences in the stage of test insect/adopted methodology for the investigation. Awasthi *et al*. (2013) [1] indicated that acephate was relatively safer and indoxacarb was toxic to *Cheilomenes sp*. The findings of above workers are more or less in line with the present findings.

Conclusion

It is ascertained that there was no insecticide under testing found totally safe except control (water spray) to the grub and adult of *C. sexmaculata.* However, imidacloprid and thiamethoxam were comparatively harmless to the grub. Moreover, acetamiprid, spinosad and endosulfan were slightly harmful to grub. Moreover, clothianidin and novaluron were moderately harmful and remaining insecticides i.e. profenophos and indoxacarb were found extremely harmful to the grub stage of *C. sexmaculata*. Moreover, it is evident that the insecticides *viz*., imidacloprid, thiamethoxam and acetamiprid were slightly harmful to adult. Further, spinosad, endosulfan and clothianidin and indoxacarb were moderately harmful to adult. In case of insecticides *viz*., novaluron and profenophos were grouped as extremely harmful to the adults of *C. sexmaculata*. The findings pertaining to the endosulfan cannot be considered as key result as it is banned on 13/05/2011 for production, use and sale in all over India. However, in view to minimize of the possible detrimental effects of these pesticides on *C. sexmaculata*, the use of these products should be considered with greatest care for incorporation in IPM programme.

Table 2: Field persistence toxicity of various insecticides against grub of *C. sexmaculata* under laboratory condition (Based on Pooled)

Treat. No.	Treatment detail	Conc. (%)	Per cent mortality of grub of *C. sexmaculata* at					
			Pooled* 2010-11	Toxicity Rating	Pooled* 2011-12	Toxicity Rating	Overall Pooled (2010-12)	Toxicity Rating
T_1	Imidacloprid 17.8 % SL	0.005	18.69 (14.00)	1	21.28 (16.67)	1	19.99 (15.33)	1
T_2	Thiamethoxam 25 % WG	0.005	24.36 (20.00)	1	27.46 (23.33)	1	25.91 (21.67)	1
T_3	Acetamiprid 20 % SP	0.004	33.37 (31.33)	2	35.39 (34.67)	2	34.38 (33.00)	2
T_4	Clothianidin 50 % WDG	0.003	49.96 (58.67)	3	52.09 (62.00)	3	51.02 (60.33)	3
T_5	Profenophos 50 % EC	0.075	77.46 (92.66)	4	80.33 (94.67)	4	78.90 (93.67)	4
T_6	Spinosad 2.5 % SL	0.002	39.74 (41.33)	2	41.27 (44.00)	2	40.51 (42.67)	2
T_7	Novaluron 10 % EC	0.0075	56.81 (68.67)	3	59.33 (72.00)	3	58.07 (70.33)	3
T_8	Indoxacarb 14.5 % SC	0.01	67.58 (84.00)	4	71.00 (86.67)	4	69.29 (85.33)	4
T_9	Endosulfan 35 % EC**	0.075	41.29 (44.00)	2	43.23 (47.33)	2	42.26 (45.67)	2
T_{10}	Control (Water spray)	-	0.91 (0.00)	1	0.91 (0.00)	1	0.91 (0.00)	1
	S. Em ± (T)	-	2.17		2.14		1.43	
	(YxT)	-	2.09		2.11		1.39	
	C.D. at 5% (T)	-	6.51		6.14		4.04	
	(YxT)	-	NS		NS		NS	
	C.V. (%)	-	10.60		9.33		9.95	

*Pooled of 2 Hours after spraying (HAS), and 1, 3, 7 and 15 Days after spraying (DAS)
Figures in parentheses are original values whereas those outside parentheses are arcsine transformed values.
** Endosulfan is banned on 13.05.2011 for production, use and sale in all over India as per directives of Hon'ble Supreme Court of India

Table 3: Field persistence toxicity of various insecticides against adults of *C. sexmaculata* under laboratory condition (Based on Pooled)

Treat. No.	Treatment detail	Conc. (%)	Per cent mortality of adults of *C. sexmaculata* at					
			Pooled* 2010-11	Toxicity Rating	Pooled* 2011-12	Toxicity Rating	Overall Pooled (2010-12)	Toxicity Rating
T_1	Imidacloprid 17.8 % SL	0.005	30.38 (28.00)	2	32.13 (30.67)	2	31.25 (29.33)	2
T_2	Thiamethoxam 25 % WG	0.005	39.00 (40.67)	2	41.54 (44.67)	2	40.27 (42.67)	2
T_3	Acetamiprid 20 % SP	0.004	42.56 (46.00)	2	45.30 (50.67)	2	43.93 (48.33)	2
T_4	Clothianidin 50 % WDG	0.003	58.39 (71.33)	3	61.62 (76.00)	4	60.01 (73.67)	3
T_5	Profenophos 50 % EC	0.075	75.67 (89.33)	4	77.82 (91.33)	4	76.75 (90.33)	4
T_6	Spinosad 2.5 % SL	0.002	45.30(50.67)	2	48.13 (55.33)	3	46.72 (53.00)	3
T_7	Novaluron 10 % EC	0.0075	71.65 (85.33)	4	75.37 (88.67)	4	73.51 (83.00)	4
T_8	Indoxacarb 14.5 % SC	0.01	60.72 (73.33)	3	63.50 (76.67)	4	62.11 (75.00)	3
T_9	Endosulfan 35 % EC**	0.075	47.26 (54.00)	3	48.53 (56.00)	3	47.89 (55.00)	3
T_{10}	Control (Water spray)	-	0.91 (0.00)	1	0.91 (0.00)	1	0.91 (0.00)	1
	S. Em ± (T)	-	2.15		2.18		1.45	
	(YxT)	-	2.03		2.14		1.37	
	C.D. at 5% (T)	-	6.19		6.25		4.10	
	(YxT)	-	NS		NS		NS	
	C.V. (%)	-	9.73		9.39		9.55	

*Pooled of 2 Hours after Spraying (HAS), and 1, 3, 7 and 15 Days after Spraying (DAS)
Figures in parentheses are original values whereas those outside parentheses are arcsine transformed values.
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