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RESIDUAL TOXICITY OF INSECTICIDES TO EGG PARASITOIDS OF *SPODOPTERA FRUGIPERDA* (J E SMITH)

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ABSTRACT

A laboratory study was carried out to assess the residual toxicity of certain insecticides to egg parasitoids of *Spodoptera frugiperda (*J E Smith), *Trichogramma chilonis* Ishii, *T. pretiosum* Riley (Hymenoptera: Trichogrammatidae), and *Telenomus remus* Nixon (Hymenoptera: Scelioniadae). The median lethal concentrations were recorded at 24 and 48 hr after exposure period to adults of egg parasitoids to nine insecticides. Among the tested spinetoram was found to be "dangerous", however, chlorantraniliprole, chlorantraniliprole + lambdacyhalothrin, chlorpyriphos + cypermethrin, indoxacarb, cyantraniliprole, emamectin benzoate, thiamethoxam + lambdacyhalothrin and azadirachtin were found to be "slightly to moderately toxic" to *T. chilonis* and *T. pretiosum*. Chlorantraniliprole, emamectin benzoate, indoxacarb and spinetoram were found to be "dangerous", however, chlorpyriphos + cypermethrin, thiamethoxam + lambdacyhalothrin, chlorantraniliprole + lambdacyhalothrin, cyantraniliprole and azadirachtin were "slightly to moderately toxic" to *T. remus.*

Key words: *Trichogramma chilonis*, *T. pretiosum*, *T. remus*, LC_{50}, insecticides, residual toxicity, moderately toxic, slightly toxic, dangerous, egg parasitoids, invasive pest, *Spodoptera frugiperda*, *Corcyra cephalonica*, risk quotients

The fall army worm, *Spodoptera frugiperda* (J E Smith) (Lepidoptera: Noctuidae), is an important invasive pest originating from America. In India, the pest was first observed on maize crop Shivamogga and neighboring districts of Karnataka (Sharanabasappa et al., 2018). Since then, several synthetic chemical insecticides have been recommended and used as emergency responses to check the pest's distribution and minimize its damage (Bharadwaj et al., 2020). Globally, a large amount of money is annually spent in attempts to control this pest (Bueno et al., 2010; Cruz, 1996). In many cases, the application of insecticides does not solve the problem but cause a negative impact, such as contamination of the environment, risk to human health and other non-target organisms and cause resistance (Beserra and Parra, 2004; Agboyi et al., 2020). For the effective and sustainable management of this invasive pest, an excellent alternative is the development and dissemination of ecologically and environmentally friendly crop protection methods, such as biological control (Bueno et al., 2010; Agboyi et al., 2020). The natural enemies are greatly reduced due to the injudicious application of nonselective insecticides and their repeated spraying. Thus, assessment of safety of insecticides to natural enemies is thus, essential. Parasitic Hymenoptera are often more susceptible to insecticides than their hosts. The objective of this study was to determine the residual toxicity of nine insecticides, commonly used for suppression of *S. frugiperda* assessing the adult mortality of egg parasitoids.

MATERIALS AND METHODS

The egg parasitoids such as *Trichogramma chilonis*, *T. pretiosum*, and *T. remus* maintained at the Bio-Control Laboratory, Department of Agril. Entomology, College of Agriculture Latur, during 2019-2020 were used. The insecticides recommended for the control of *S. frugiperda* on maize viz., are azadirachtin 0.15%EC (Coromandal International Ltd.), chlorantraniliprole 18.5%SC (DuPont India Pvt. Ltd.), chlorantraniliprole 9.3% + lambdacyhalothrin 4.6%ZC (Syngenta Group of Companies Pvt. Ltd.), chlorpyriphos 50% + cypermethrin 5%EC (TATA chemicals Ltd.), cyantraniliprole 10.26%OD (DuPont India Pvt. Ltd.), emamectin benzoate 5%SG (Syngenta Group of Companies Pvt. Ltd.), indoxacarb 15.8%EC (Gharda Chemicals Ltd.), spinetoram 11.7%SC (T Stanes and Co. Pvt. Ltd.) and thiamethoxam 12.6 + lambda-cyhalothrin 9.5%ZC (Syngenta Group of Companies Pvt. Ltd.) were assessed.

Insecticides were prepared in distilled water with three concentration of each insecticide (one lower than recommended (half dose of recommended), one recommended (full dose of recommended) and one higher than recommended (double dose of recommended). Cleaned glass test tubes (50 ml capacity with an internal surface area of 50 cm^2) were rinsed with distilled water and air dried for 4 hr, coated evenly with 0.5 ml of each concentration dried thoroughly and used to assess the residual toxicity of insecticides to parasitoids as per the standard procedure proposed by Hassan et al. (1998) with slight modification. Preliminary range-finding tests were carried out to fix the test concentrations that caused 10-90% mortality of the parasitoid. As a control, distilled water was used. Ten newly emerged adults of respective egg parasitoids were released in the treated test tube, and mortality was recorded at 24 and 48 hr after treatment. These experiments were carried out in a completely randomized design (CRD) with five replications.

Corrections for natural mortality in the control were made as per Abbott (1925) for the *T. chilonis*, *T. pretiosum*, and *T. remus* bioassays. The data were subjected to probit analysis by Finney (1971) using Polo Plus 1.0 (LeOra software) to determine the median lethal concentration (LC50). The risk quotient was calculated by a simple, screening-level methodology identifying high- or low-risk situations. In this method, the estimated environmental concentration (EEC) is compared to an effect level, such as an LC_{50} (EPA, 2016). The insecticides were classified into various categories based on risk quotient values such as < 50, which means harmless, a value between 50 and 2500, which means slightly to moderately toxic, and > 2501 which means dangerous and classified as 'class 1', 'class 2' and 'class 3' numbers respectively (Preetha et al., 2009; Cheng et al., 2018).

RESULTS AND DISCUSSION

Mortality were recorded at 24 and 48 hr after the exposure period to adults of *T. chilonis*, *T. pretiosum* and *T. remus* to different insecticides and presented in Tables 1 and 2, respectively.

Trichogramma chilonis: The data revealed that among the insecticides tested in dry film test tube residue bioassay, chlorantraniliprole exhibited higher toxicity to *T. chilonis* adults followed by chlorantraniliprole + lambda cyhalothrin, spinetoram, indoxacarb, thiamethoxam + lambda-cyhalothrin, emamectin benzoate, chlorpyriphos + cypermethrin, cyantraniliprole and azadirachtin was found to be less toxic to the adults of *T. chilonis* after 24 and 48 hr, respectively (Table 1). According to Khan (2020) spinetoram induced mortality was >95% in four residual-age treatments of *T. chilonis* and was found to be the most harmful for both emergence and parasitism. The combination product of lambdacyhalothrin + thiamethoxam recorded least emergence, indicating its detrimental effects on *T. chilonis* (Sant et al., 2019). Chlorantraniliprole and indoxacarb had a lesser effect on adult emergence and were categorized as harmless (< 30% mortality), by Duraimurugan and Lakshminarayana (2018), while emamectin benzoate was rated as slightly harmful (30-79% mortality) to *T. Chilonis* (Wang et al., 2012). The data on the risk quotient to *T. chilonis* adults at 24 and 48 hr interval of exposure are presented in Table 2. The results of present study are similar to those of Khan (2020) who found that spinetoram was most harmful to *T. chilonis*. Sharanabasappa et al. (2018) shows that azadirachtin was slightly harmful, and chlorantraniliprole was moderately harmful to *T. chilonis*. Based on risk quotient values Chunke (2017) illustrated that, chlorantraniliprole and indoxacarb were moderately toxic, and cyantraniliprole and emamectin benzoate were slightly toxic to *T. chilonis*.

Trichogramma pretiosum: The data revealed that among the insecticides tested in dry film test tube residue bioassay, chlorantraniliprole + lambdacyhalothrin exhibited maximum toxicity to *T. pretiosum* adults followed by chlorantraniliprole, indoxacarb, spinetoram, thiamethoxam + lambda cyhalothrin, chlorpyriphos + cypermethrin, emamectin benzoate, and cyantraniliprole and azadirachtin was found to be least toxic to the adults of *T. pretiosum* after 24 and 48 hr intervals of exposure (Table 1). The findings of the current study are consistent with those of Grande et al. (2018) that spinetoram adversely affected immature and pre-emergent adult *T. pretiosum*. Singh et al. (2016) found indoxacarb harmless (>30% mortality) against adults of *T. pretiosum* while spinetoram induced nearly 100% adult mortality, however <10% mortality was in chlorantraniliprole (Khan et al., 2015).

The data on risk quotient to *T. pretiosum* adults at 24 and 48 hr intervals of exposure are presented in Table 2. These results are similar with those of Grande et al. (2018) on chlorantraniliprole and classified as harmless/ slightly harmful to *T. pretiosum*. Chlorantraniliprole + lambdacyhalothrin at highest rate at 25 gm a.i./ ha was classified as moderately harmful to *T. pretiosum*. Chlorantraniliprole and azadirachtin

Table 1. Toxicity of insecticides to *T. chilonis*, *T. pretiosum* and *T. remus*

Egg parasitoids		*T. chilonis*				*T. pretiosum*				*T. remus*			
Insecticides	Period (hr)	LC_{50} (mg a.i./ ℓ)	90% fiducial limits of LC_{50} Lower limit	Upper limit	χ^2 Value	LC_{50} (mg a.i./ *l*)	90% fiducial limits of LC_{50} Lower limit	Upper limit	χ^2 Value	LC_{50} (mg a.i./ ℓ)	90% fiducial limits of LC_{50} Lower limit	Upper limit	χ^2 Value
Azadirachtin 0.15%EC	24	12.7625	0.7034	231.54	0.0109	8.9369	0.5786	138.05	0.0023	6.5610	1.7168	25.0735	0.2168
	48	13.0672	0.7271	234.82	0.0122	9.0629	0.5902	139.14	0.0015	6.5032	1.7775	23.7929	0.2072
Chlorantraniliprole 18.5%SC	24	0.0818	0.0267	0.2500	0.1068	0.1095	0.0435	0.2752	0.0538	0.0576	0.0157	0.2109	0.2072
	48	0.0823	0.0275	0.2463	0.1073	0.1099	0.0439	0.2749	0.0630	0.0571	0.0149	0.2184	0.2168
Chlorantraniliprole 9.3% + Lambdacyhalothrin 9.5%ZC	24	0.1399	0.0705	0.2778	0.0058	0.1006	0.0156	0.6464	0.0003	0.4217	0.1234	1.4409	0.0449
	48	0.1406	0.0712	0.2775	0.0060	0.1017	0.0159	0.6486	0.0001	0.4245	0.1231	1.4634	0.0403
Chlorpyriphos 50% + cypermethrin 5%EC	24	0.5182	0.2388	1.1247	0.0482	0.4711	0.1366	1.6240	0.0403	0.7301	0.2905	1.8350	0.0538
	48	0.5212	0.2409	1.1278	0.0522	0.4741	0.1387	1.6199	0.0449	0.7329	0.2931	1.8329	0.0630
Cyantraniliprole 10.26%OD	24	1.1509	0.5319	2.4902	0.0522	1.0932	0.3653	3.2714	0.1073	2.1450	0.1388	33.1340	0.0023
	48	1.2653	0.3703	4.3229	0.0449	1.0996	0.3599	3.3593	0.1068	2.1751	0.1416	33.3947	0.0015
Emamectin benzoate 5%SG	24	0.3929	0.0616	2.5035	0.0001	0.7150	0.0462	11.0446	0.0015	0.0697	0.0184	0.2635	0.0115
	48	0.3972	0.0618	2.5506	0.0003	0.7250	0.0472	11.1315	0.0023	0.0696	0.0179	0.2704	0.0189
Indoxacarb 15.8%EC	24	0.1754	0.0556	0.5529	0.1188	0.1800	0.0589	0.5500	0.1068	0.1268	0.0346	0.4641	0.2072
	48	0.1765	0.0572	0.5446	0.1193	0.1811	0.0605	0.5419	0.1073	0.1257	0.0329	0.4805	0.2168
Spinetoram 11.7%SC	24	0.1729	0.0472	0.6328	0.2072	0.1529	0.0395	0.5913	0.0085	0.1681	0.0446	0.6334	0.2127
	48	0.1714	0.0448	0.6552	0.2168	0.1527	0.0384	0.6068	0.0151	0.1677	00437	0.6436	0.2345
Thiamethoxam 12.6 + Lambdacyhalothrin 9.5%ZC	24	0.2624	0.0686	1.0029	0.2168	0.3575	0.0231	5.5223	0.0023	0.0545	0.0178	0.1666	0.1068
	48	0.2601	0.0711	0.9517	0.2072	0.3625	0.0236	5.5657	0.0015	0.0548	0.0183	0.1642	0.1073

Table 2. Toxicity and risk quotient of insecticides to *T. chilonis*, *T. pretiosum* and *T. remus*

Insecticides	Recommended Dose (mg a.i./ ha)	Period (hr)	*T. chilonis* Risk quotient	*T. chilonis* Category	*T. pretiosum* Risk quotient	*T. pretiosum* Category	*T. remus* Risk quotient	*T. remus* Category
Azadirachtin 1500 ppm	2500	24	195.88	2	279.71	2	381.03	2
		48	191.31	2	275.84	2	384.42	2
Chlorantraniliprole 18.5%SC	150	24	1833.74	2	1369.86	2	2604.16	3
		48	1822.60	2	1364.87	2	2626.97	3
Chlorantraniliprole 9.3%+ Lambdacyhalothrin 9.5%ZC	200	24	1429.59	2	1988.07	2	474.27	2
		48	1591.08	2	1966.56	2	471.14	2
Chlorpyrifos 50% + cypermethrin 5%EC	1000	24	1929.75	2	2122.69	2	1369.67	2
		48	1918.64	2	2109.25	2	1364.44	2
Cyantraniliprole 10.26%OD	600	24	381.99	2	474.19	2	279.72	2
		48	384.44	2	471.14	2	275.84	2
Emamectin benzoate 5%SG	200	24	509.03	2	279.72	2	509.03	3
		48	503.52	2	275.86	2	503.52	3
Indoxacarb 15.8%EC	330	24	1881.41	2	1833.33	2	1881.41	3
		48	1869.68	2	1822.19	2	1869.68	3
Spinetoram 11.7%SC	450	24	2602.66	3	2943.10	3	2602.66	3
		48	2625.43	3	2946.95	3	2625.43	3
Thiamethoxam 12.6 + lambdacyhalothrin 9.5%ZC	125	24	379.82	2	276.06	2	379.82	2
		48	380.98	2	272.27	2	380.98	2

were slightly and moderately harmful when irradiated *Corcyra* eggs were exposed to *T. pretiosum*, while chlorantraniliprole and azadirachtin found slightly harmful when unirradiated *Corcyra* eggs were exposed to *T. pretiosum* (Sharanabasappa et al., 2018).

Telenomus remus: The data revealed that among the insecticides tested in dry film test tube residue bioassay, chlorantraniliprole exhibited greater toxicity to *T. remus* adults followed by thiamethoxam + lambda-cyhalothrin, emamectin benzoate, indoxacarb, spinetoram, chlorantraniliprole + lambda-cyhalothrin, chlorpyrifos + cypermethrin, and cyantraniliprole. Azadirachtin was found to be lower toxic to the adults of *T. remus* (Table 2). Present results are the accordance to Pazini et al. (2016) who states that chlorantraniliprole, lambdacyhalothrin, lambdacyhalothrin + thiamethoxam reduced parasitism by 10, 97 and 100% when adults of *Telenomus sp.* were exposed to dry residues of pesticides. Liu et al., (2016) showed that emamectin benzoate, indoxacarb and chlorantraniliprole were dangerously toxic to *T. remus* adults.

The data on risk quotient of insecticides to *T. remus* adults at 24 and 48 hr interval of exposure are presented in Table 2. Based on risk quotient values Pazini et al. (2019) classified the thiamethoxam + lambdacyhalothrin as slightly to moderately toxic to *Telenomus sp.* with RQ values ranging from 79.55 and 1646.67. Feltrin-Campos et al. (2018) shows that chlorantraniliprole + lambdacyhalothrin mixture at its highest dose was classified as noxious. Liu et al. (2016) shows that emamectin benzoate and indoxacarb were dangerously toxic to *T. remus* adults at 24 hr post-treatment. According to Silva et al. (2022) thiamethoxam + lambdacyhalothrin sprayed on pupae significant reduction of adult emergence of *Telenomus* sp. compared with the control and it was classified as slightly harmful (class 2) for *Telenomus* sp.

Based on risk quotient values, among the insecticides, spinetoram was found to be highly dangerous to the adults of *T. chilonis* and *T. pretiosum.* Chlorantraniliprole, emamectin benzoate, indoxacarb, and spinetoram were found to be highly dangerous to the adults of *T. remus*. Azadirachtin was found to be least toxic to the adults of all egg parasitoids. However, under field condition, the insecticide may be performing differently with all three parasitoids. Since, all three natural enemies can take advantage of natural shelter, avoiding treated areas and other means.

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R S Mahajan and V K Bhamare conceptualized and designed the study, R S Mahajan conducted the study, analyzed the data, and authored the report under the supervision of V K Bhamare.

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CONFLICT OF INTEREST

No conflict of interest.

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