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K. Shankarganesh, Bishwajeet Paul & R. D. Gautam

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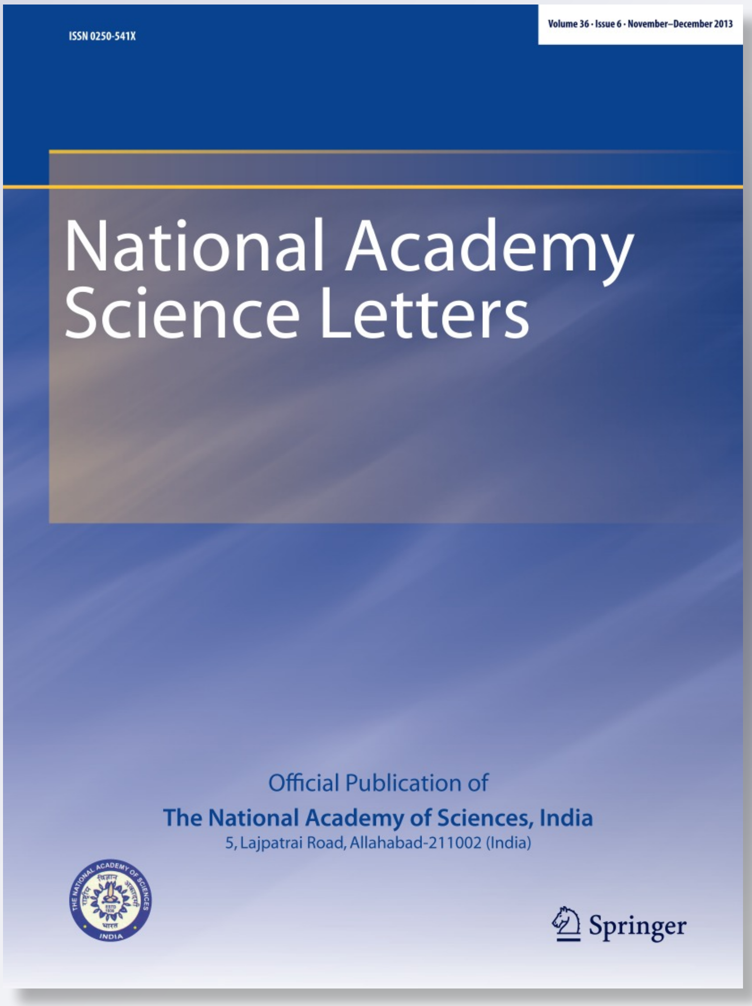

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RESEARCH ARTICLE

Studies on Ecological Safety of Insecticides to Egg Parasitoids, *Trichogramma chilonis* Ishii and *Trichogramma brasiliensis* (Ashmead)

K. Shankarganesh · Bishwajeet Paul · R. D. Gautam

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Abstract The adults of the egg parasitoids, *Trichogramma chilonis* and *T. brasiliensis,* were exposed to nine different insecticides by glass vial residue method. The results indicated that, lambda-cyhalothrin, bifenthrin and indoxacarb were more toxic to *T. chilonis*, and the order of toxicity was lambda-cyhalothrin > bifenthrin > indoxacarb > thiamethoxam > carbosulfan, imidacloprid > acetamiprid > pymetrozine > buprofezin. Whereas, *T. brasiliensis* was more sensitive to carbosulfan and indoxacarb than other insecticides. Carbosulfan and indoxacarb registered 50 % mortality even at 0.001 mg a.i.l^{-1}. Based on the risk quotient value, which is the ratio between field recommended doses and the LC50 of the parasitoid, lambda-cyhalothrin, carbosulfan and indoxacarb were considered dangerous to *T. chilonis*. Whereas all other insecticides produced slightly to moderately toxic. In case of *T. brasiliensis*, thiamethoxam, pymetrozine and buprofezin were found to be slightly to moderately toxic, remaining six insecticides considered dangerous to this parasitoid.

Keywords Egg parasitoid · *Trichogramma brasiliensis* · *T. chilonis* · Synthetic insecticide · LC50 · Film residue

Indiscriminate use of persistent insecticides has disrupted the natural balance of insect pests and their natural enemies leading to pest outbreaks and resurgence in certain cases [1]. However, due to their easy availability, quick and convincing results, chemical insecticides play a vital role in insect pest management. An alternative strategy to manage insect pest populations is to make use of biological control agents such as *Trichogramma* spp. that have been successfully used in management of a variety of insect pests in different agro ecosystems.

Attempts to suppress insect pest populations by biological control measures have often failed because of deleterious effects of chemicals on the beneficial insects [2]. The contact toxicity and impact of chemical residues on *Trichogramma* have been examined in numerous studies. Protocols developed by the International Organization for Biological Control of Noxious Plants and Animals/West Palaearctic Region Section (IOBC/WPRS) working group are available for standardized toxicity testing [3]. For effective insect pest management, temporal synchronization of application of chemical insecticides with parasitoid release at a specified period is imperative. Safe waiting periods for the release of bioagents after insecticidal application need to be determined as the residual toxicity of insecticides has great influence on dispersal and searching activities of parasitoids [4]. In this study we have estimated the potential toxicity of certain commonly used insecticides viz., imidacloprid, acetamiprid, thiamethoxam, bifenthrin, carbosulfan, lambda-cyhalothrin, indoxacarb, pymetrozine and buprofezin against the egg parasitoid *Trichogramma chilonis* Ishii and *Trichogramma brasiliensis* (Ashmead) under laboratory conditions. To compare the environmental concentration i.e. the field recommended dose and the LC50 for the natural enemy, the risk quotient (RQ) parameter was utilized as it was found to be a good indicator for assessing the risk of using these pesticides in the field [5]. RQ is used to assess the risk to non-target arthropods from plant protection products [6] and thus the ecological risk of pesticides [7]. It can be used to assess the safety of predators and parasitoids such as coccinellids [8],

K. Shankarganesh (✉) · B. Paul · R. D. Gautam
Biological Control Laboratory, Division of Entomology, Indian Agricultural Research Institute, New Delhi 110012, India
e-mail: shankar_ento@iari.res.in

Bracon hebetor Say [9] and *Trichogramma cacoeciae* Marchal [3].

The egg parasitoids *T. chilonis* and *T. brasiliensis* were maintained on eggs of *Corcyra cephalonica* Stainton in the Biological Control Laboratory, Division of Entomology, Indian Agricultural Research Institute, New Delhi. The insecticides used in the present investigations were obtained from their respective manufacturers: imidacloprid (Confidor® 62 17.80 SL %, Bayer Crop Science Limited, Mumbai), acetamiprid (Baadshah® 20 % SP, Hindustan Pulverising Mills, Jammu), thiamethoxam, lambda-cyhalothrin, pymetrozine (Actara® WG 25 %, Karate®.

5 EC, Endeavor® WG 50 %, respectively, Syngenta, Mumbai), bifenthrin (Talstar® 10 % EC, FMC India Private Limited, Kanchipuram), carbosulfan (Marshal® 20 % EC, FMC India Private Limited, Kanchipuram), indoxacarb (Avaunt® 15.8 % EC, Dupont India Private Limited, Gurgaon), and buprofezin (Applaud® 25 % SC Rallis India Limited, Mumbai). In most cases these insecticides are being used for the control of insect pests in different crop ecosystems. Commercial formulations of the above mentioned insecticides were diluted with analytical grade acetone to obtain the desired concentrations.

Glass vial residue method was followed to assess the toxicity of insecticides to *Trichogramma* spp. as per the standard procedure by Hassan et al. 1998 with slight modifications. Preliminary range-finding tests were carried out to fix the test concentrations, which caused 10–90 % mortality to the parasitoid. Different concentrations of insecticide solutions were prepared using acetone and water in the ratio 80:20 and used for bioassays. Glass scintillation vials of 15 ml capacity with an internal surface area of 50 cm^2 were used. The vials were soaked in soap water overnight, thereafter these were cleaned thoroughly and rinsed with acetone and air dried for at least 4 h before use. The vials were coated evenly with 0.5 ml of different concentrations of insecticides and dried thoroughly. For the untreated control, 0.5 ml of acetone: water (80:20) was used. Twenty newly emerged adult wasps were released into the vial and secured with a cotton plug. After 4 h of exposure, the wasps were placed in a clean test tube and mortality was recorded 24 and 48 h after treatment (HAT). Each treatment was replicated five times with a total of 100 wasps per treatment. Necessary corrections were made for natural mortality in the control using Abbott's formula [10] then the data was subjected to probit analysis as per Finney [11] and the Log concentration probit mortality curve was obtained. Probit analysis was carried out using SAS version 9.2. Risk quotients for the insecticides were calculated from the LC50 values based on the formula given by Preetha et al. [12].

$$\text{Risk quotient} = \frac{\text{Recommended field rate } \left(\text{g.a.i. ha}^{-1}\right)}{\text{LC}_{50} \text{ of beneficial insect } \left(\text{mg a.i.l}^{-1}\right)}$$

Risk quotient	Category
<50	Harmless
50–2500	Slightly to moderately toxic
>2500	Dangerous

Results and Discussion

In the present study nine insecticides were evaluated against adults of *T. chilonis* and *T. brasiliensi.* The results indicated that lambdacyhalothrin, bifenthrin, indoxacarb were more toxic than other insecticides. Based on LC50 values, the descending order of toxicity to *T. chilonis* were, lambda-cyhalothrin > bifenthrin > indoxacarb > thiamethoxam > carbosulfan > imidacloprid > acetamiprid > pymetrozine > buprofezin (Table 1).

T. brasiliensis was more sensitive to carbosulfan and indoxacarb. The LC50 values of these insecticides were given in Table 2. Carbosulfan @ 0.0003 mg a.i.l^{-1} and indoxacarb @ 0.001 mg a.i.l^{-1} produced 50 % mortality. However buprofezin and pymetrozine found least toxic as compared to other insecticides. The insecticides evaluated were classified based on the RQ values (Table 3). Based on the RQ value, which is the ratio between field recommended doses and the LC50 of the parasitoid, lambda-cyhalothrin, carbosulfan and indoxacarb were considered dangerous to *T. chilonis*. Whereas all other insecticides produced slightly to moderately toxic. In case of *T. brasiliensis*, thiamethoxam, pymetrozine and buprofezin were found to be slightly to moderately toxic, remaining six insecticides considered dangerous to this parasitoid (Table 4).

Low toxic insecticide applied at high dosage will cause serious ecological problem. On the other hand, a high toxic insecticide appliedcat low rate may cause less mortality than a less toxic insecticide applied at a higher rate under field conditions. Therefore, it is imperative to assess the impact of insecticide on natural enemies at field recommended dose.

Our study revealed the toxicities of different groups of insecticides to egg parasitoids *T. chilonis and T. brasiliensis*. The synthetic pyrethroids such as lambda-cyhalothrin and bifenthrin were found to be dangerous. High toxicity of lambda-cyhalothrin to the adults has been demonstrated in *T. exiguum* [13]; *T. cordubensis* [14]; *T. chilonis* [15]; *T. podiisi* [16]; *T.nubilale* [17] similarly,

Table 1 Effect of insecticides on adults of *Trichogramma chilonis*

Name of the insecticide	Heterogenity at 4df x	LC50 mg a.i.l^{-1}	Regression equation	Fiducial limit
Imidacloprid	4.3345	0.016	Y = 7.8866 + 1.03563x	0.0013–0.0021
Acetamiprid	7.5759	0.091	Y = 6.387 + 0.68001x	0.0060–0.0140
Thiamethoxam	3.1419	0.012	Y = 6.9261 + 0.6633x	0.0009–0.0018
Bifenthrin	2.4795	0.003	Y = 7.5764 + 0.7324x	0.0002–0.0005
Carbosulfan	3.0351	0.016	Y = 6.8899 + 0.6748x	0.0011–0.0023
Lambdacyhalothrin	7.9585	0.001	Y = 8.1069 + 0.75129x	0.0001–0.0010
Indoxcarb	10.518	0.008	Y = 7.6824 + 0.86510x	0.0003–0.0016
Pymetrozine	6.6383	0.301	Y = 6.1405 + 0.7498x	0.0215–0.0421
Buprofezine	6.6965	0.363	Y = 5.9992 + 0.6936x	0.0252–0.0521

Table 2 Effect of insecticides on adults of *Trichogramma brasiliensis*

Name of the insecticide	Heterogenity at 4df x	LC50 mg a.i.l^{-1}	Regression equation	Fiducial limit
Imidacloprid	8.4559	0.010	Y = 7.4609 + 0.8213x	0.0007–0.0014
Acetamiprid	8.0227	0.017	Y = 7.0009 + 0.7205x	0.0012–0.0024
Thiamethoxam	3.2764	0.011	Y = 7.1221 + 0.7129x	0.0007–0.0015
Bifenthrin	9.8540	0.012	Y = 8.2571 + 0.8365x	0.0001–0.0003
Carbosulfan	3.8940	0.0003	Y = 8.6996 + 0.82096x	0.00002–0.00004
Lambdacyhalothrin	5.6325	0.002	Y = 5.1032 + 1.3612x	0.0002–0.0020
Indoxacarb	3.3377	0.001	Y = 7.9529 + 0.72011x	0.0001–0.0005
Pymetrozine	6.5355	0.830	Y = 5.9896 + 0.91569x	0.0630–0.1094
Buprofezin	8.9709	0.379	Y = 6.7497 + 1.2312x	0.0303–0.0474

Table 3 Effect of insecticides on adults of *Trichogramma chilonis* based on risk quotient (RQ)

Name of the insecticide	Recommended dose (g a.i ha^{-1})	LC50 mg a.i.l^{-1}	Risk quotient (RQ)[a]	Category[b]
Imidacloprid	25	0.016	1562.5	2
Acetamiprid	80	0.091	879.12	2
Thiamethoxam	25	0.012	2083.3	2
Bifenthrin	50	0.003	1666.6	2
Carbosulfan	250	0.016	15625	3
Lambdacyhalothrin	30	0.001	30000	3
Indoxacarb	75	0.008	9375	3
Pymetrozine	150	0.301	498.3	2
Buprofezin	200	0.363	550.97	2

[a] RQ= Ratio between the field-recommended dose in g a.i ha^{-1} and the LC50 of the beneficial mg a.i.l^{-1}

[b] Category=1: safe; 2: slightly to moderately toxic; 3: dangerously toxic

Hussain et al. [18] reported high mortality of adults of *T. chilonis* when treated with bifenthrin. Indoxacarb and carbosulfan were found to be more toxic and next to synthetic pyretroids against *T. chilonis* and *T. brasiliensis*. Studies on the effect indoxacarb and carbosulfan on *Trichogramma* spp. [19], *Trichogramma pretiosum* [20]; *Trichogramma ostrniae* [21] and *T. chilonis* [12, 18] and [22] showed that these insecticides were detrimental to the adults. Neo nicotinods were introduced into the market to control sucking insect pest and as well as certain leaf chewing insects [23]. However, the use of neonicotinoids should be evaluated carefully in IPM programs [24]. In the present study imidacloprid and thiamethoxam were also equally toxic to *Trichogramma* spp. The toxic effect of neonicotinoids on *Trichogramma* spp. has been demonstrated by several studies, including thiamethoxam toxicity to *T. exiguum* Pinto and Platner[25] and *Trichogramma platneri* [26] and *T. chilonis* [12] *T. nubil*ale [18]. One day-old residues of imidacloprid were reported to be more toxic to *T. platneri* than direct topical application [26] and to *T. chilonis* [12]. The insecticides such as pymetrozine and buprofezin showed slight to moderate toxicity to the *T. chilonis* and *T. brasiliensis*. These results agree with the findings of Preetha et al. [12] on *T. chilonis*. These findings

Table 4 Effect of insecticides on adults of *Trichogramma brasiliensis* based on risk quotient (RQ)

Name of the insecticide	Recommended dose (g a.i ha^{-1})	LC50 (mg a.i.l^{-1})	Risk quotient (RQ)[a]	Category[b]
Imidacloprid	25	0.010	2500	3
Acetamiprid	80	0.017	4705.9	3
Thiamethoxam	25	0.011	2272.7	2
Bifenthrin	50	0.012	4166.7	3
Carbosulfan	250	0.0003	833333	3
Lambdacyhalothrin	30	0.002	15000	3
Indoxacarb	75	0.001	75000	3
Pymetrozine	150	0.830	180.7	2
Buprofezin	200	0.379	527.7	2

[a] RQ= Ratio between the field-recommended dose in g a.i ha^{-1} and the LC50 of the beneficial mg a.i.l^{-1}

[b] Category=1: safe; 2: slightly to moderately toxic; 3: dangerously toxic

not only revealed high susceptibility of wasp to insecticides particularly adults, but also demonstrated that some insecticides may be more compatible or suitable for conserving natural or released populations of *Trichogramma* wasps.

The present study was conducted under laboratory conditions in which insects were subjected to high pressure of insecticide. However, under field condition, the insecticide may have less negative impact on parasitoids. Since, natural enemy can take advantage of natural shelter, avoiding treated areas and other means. Therefore, further studies needs to be carried out to determine insecticides which can be used safely under field conditions without disrupting the ecological balance.

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