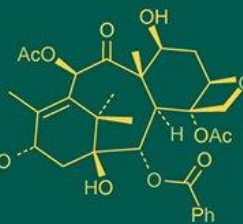
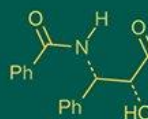


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Contact toxicity of selected insecticides against adult females of *Trichogramma chilonis* (ISHII) (Hymenoptera: Trichogrammatidae) reared on *Corcyra cephalonica* (stainton) under laboratory conditions

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Abstract

Trichogramma chilonis Ishii is a key gregarious egg parasitoid extensively deployed in inundative biological control programs against lepidopteran pests in India. However, the indiscriminate use of synthetic insecticides in modern agriculture poses a severe threat to the survival and efficacy of this natural enemy. The present study was conducted during 2020–21 under laboratory conditions ($27 \pm 2^\circ\text{C}$ and $65 \pm 5\%$ RH) to evaluate the contact toxicity of six commonly used insecticides against newly emerged adult females of *T. chilonis* mass-reared on UV-irradiated eggs of the rice moth, *Corcyra cephalonica* (Stainton). Transparent plastic bioassay chambers were treated with field-recommended concentrations of bifenthrin 10% EC, chlorantraniliprole 18.5% SC, thiamethoxam 25 WG, imidacloprid 17.8% SL, cartap hydrochloride 50 SP, and fipronil 5% SC. Mortality was recorded at 12, 24, 36, and 48 hours after treatment (HAT). The results revealed significant differences among the treatments. Thiamethoxam recorded the lowest mean adult mortality (44.40%), followed by imidacloprid (52.78%) and chlorantraniliprole (53.78%), suggesting a relatively higher degree of compatibility. In contrast, fipronil 5% SC was the most toxic, causing the highest mean mortality (77.31%), closely followed by bifenthrin 10% EC (74.05%) and cartap hydrochloride 50 SP (69.50%). All insecticides exhibited a time-dependent increase in toxicity, with mortality escalating substantially between 36 and 48 HAT. These findings underscore the necessity of rigorous pesticide selectivity screening before integrating chemical and biological control tactics in IPM programs.

Keywords: *Trichogramma chilonis*, *Corcyra cephalonica*, contact toxicity, insecticide safety, egg parasitoid, integrated pest management, adult mortality.

Introduction

The egg parasitoid *Trichogramma chilonis* Ishii (Hymenoptera: Trichogrammatidae) occupies a pivotal position in the biological control of economically important lepidopteran pests, including sugarcane borers, cotton bollworms, and vegetable caterpillars. Its amenability to mass production on factitious hosts, particularly the rice moth *Corcyra cephalonica* (Stainton), has made it the cornerstone of augmentative biological control programs across several countries, including India (Manjunath, 1993; Smith, 1996) [5, 13]. The parasitoid's short life cycle, high fecundity, and host-searching efficiency make it an ideal candidate for large-scale inundative releases (Scholler *et al.*, 2005) [11].

Integrated Pest Management (IPM) aims to unify safe and sustainable chemical and biological control methodologies. However, the non-judicious and prophylactic application of broad-spectrum insecticides has precipitated numerous ecological backlashes, including the development of insecticide resistance in target pests, pest resurgence, toxic residues in food commodities, and the destruction of non-target beneficial arthropods such as parasitoids and predators (Armes *et al.*, 1992; Shukla and Jadhav, 2014) [1, 12]. Given that approximately 30 per cent of agricultural produce in India is lost to pests, farmers often resort to excessive pesticide applications, inadvertently compromising the very biological control agents that form the backbone of IPM.

For the successful integration of *T. chilonis* into pest management strategies, it is imperative to ascertain the safety profile of routinely applied insecticides to this parasitoid. The side effects of pesticides on biocontrol agents must be quantified under controlled laboratory conditions before their recommendation in IPM schedules (Finney and Fisher, 1964) [4]. While several new-generation insecticides are marketed as “target-specific,” their compatibility with minute hymenopteran parasitoids remains equivocal and demands empirical validation. Against this backdrop, the present investigation was undertaken with the specific objective of evaluating the contact toxicity of selected conventional and new-generation insecticides against adult females of *T. chilonis* reared on *C. cephalonica* eggs under laboratory conditions.

Materials and Methods

Experimental site and climatic conditions

The experiments were carried out during 2020–21 in the Bio-control Laboratory, Department of Agricultural Entomology, College of Agriculture, Sardar Vallabhbhai

Patel University of Agriculture and Technology, Meerut, Uttar Pradesh, India. The laboratory was maintained at 27 ± 2 °C and $65 \pm 5\%$ relative humidity (RH).

Source and rearing of insect cultures

The culture of *Trichogramma chilonis* was procured from the Bio-control Laboratory, Uttar Pradesh, and reared on UV-irradiated (15 W for 1 hour) eggs of *Corcyra cephalonica* in glass vials (15 × 7.5 cm) placed in a BOD incubator at 27 ± 2 °C and $65 \pm 5\%$ RH. The parasitized eggs turned black 3–4 days after parasitization. Newly emerged adults were provided with a 50 per cent honey solution as food and were subsequently used for the toxicity assays.

Insecticides tested

Six commercially available insecticides and an untreated control were evaluated for their contact toxicity to *T. chilonis*. The details of the insecticides, their formulations, trade names, and recommended doses are presented in Table-1.

Table 1: Details of insecticides tested against *Trichogramma chilonis*

Sl. No.	Insecticide	Trade Name	Formulation	Dose Tested	Manufacturer
1	Bifenthrin	Talstar	10% EC	2.0 ml/L of water	FMC India Private Limited, Bangalore
2	Chlorantraniliprole	Coragen	18.5% SC	0.3 ml/L of water	E.I. DuPont India Pvt. Ltd.
3	Thiamethoxam	Actara	25 WG	0.25 g/L of water	Syngenta India Limited
4	Imidacloprid	Confidor	17.8% SL	0.3 ml/L of water	Bayer CropScience Limited
5	Cartap hydrochloride	Cartap	50 SP	0.75 g/L of water	Cheminova India Limited
6	Fipronil	Regent	5% SC	1.5 ml/L of water	Bayer CropScience Limited
7	Control (Untreated)	—	—	—	—

Contact toxicity bioassay on adult females

The contact toxicity was evaluated using a residual exposure method. Transparent plastic containers (7.5 cm diameter × 7 cm height) with tight-fitting lids were converted into pesticide-testing units. Small windows were cut on two sides of each container and sealed with fine muslin cloth using waterproof adhesive to prevent fumigant action and to ensure adequate aeration.

The inner surfaces of the containers and lids were uniformly sprayed with 2.5 ml of the respective insecticide solution using a manual atomizer. In the control treatment, containers were sprayed with distilled water. All treated containers were air-dried thoroughly for 10 minutes to evaporate the carrier solvent.

Twenty newly emerged, mated female wasps were released gently into each treated container. A fine streak of 5 per cent honey solution was provided inside the container as adult food. The containers were then sealed and kept under laboratory conditions. Mortality observations were recorded at 12, 24, 36, and 48 hours after treatment (HAT). The experiment was laid out in a Completely Randomized Design (CRD) with three replications for each treatment. Wasps that remained motionless and did not respond to a gentle probing with a camel hair brush were considered dead.

Per cent adult mortality = (Number of dead adults / Total number of adults exposed) × 100

Statistical analysis

The percentage mortality data were subjected to angular transformation ($\arcsine \sqrt{\text{percentage}}$) prior to statistical analysis to homogenize the variance. The transformed data

were analyzed using Analysis of Variance (ANOVA) appropriate for a Completely Randomized Design. Critical differences (CD) at the 5 per cent level of significance and standard errors of means ($\text{SEm} \pm$) were computed to compare the treatment means.

Results

The contact toxicity data revealed significant differences in adult mortality among the six insecticides and the untreated control at all observation intervals (Table 2). The progression of mortality over time indicated that all synthetic insecticides were toxic to *T. chilonis* females, although the degree of toxicity varied markedly between molecules.

Mortality at 12 HAT

At 12 hours after exposure, thiamethoxam 25 WG caused the lowest mortality (14.68%), which was significantly lower than all other insecticides. Imidacloprid 17.8% SL and chlorantraniliprole 18.5% SC recorded comparatively moderate mortalities of 21.28% and 28.18%, respectively. Cartap hydrochloride 50 SP (36.35%), bifenthrin 10% EC (51.48%), and fipronil 5% SC (56.19%) were markedly more toxic at this early interval. The untreated control recorded only 2.21% natural mortality.

Mortality at 24 HAT

The trend persisted at 24 HAT, with thiamethoxam again exhibiting the lowest mortality (35.35%). Chlorantraniliprole (48.48%) and imidacloprid (49.38%) remained statistically comparable and intermediate in toxicity.

Table 2: Contact toxicity of selected insecticides to adult females of *Trichogramma chilonis* (figures in parentheses are angular transformed values)

Treatment	12 hr	24 hr	36 hr	48 hr	Mean
T ₁ : Bifenthrin 10% EC	51.48 (53.26)	58.48 (57.36)	89.87 (90.38)	96.36 (93.21)	74.05 (75.98)
T ₂ : Chlorantraniliprole 18.5% SC	28.18 (32.21)	48.48 (47.28)	59.18 (60.28)	79.27 (81.38)	53.78 (55.87)
T ₃ : Thiamethoxam 25 WG	14.68 (13.29)	35.35 (36.28)	48.29 (51.39)	79.28 (81.39)	44.40 (45.39)
T ₄ : Imidacloprid 17.8% SL	21.28 (23.25)	49.38 (51.39)	53.25 (55.29)	87.21 (89.39)	52.78 (53.69)
T ₅ : Cartap hydrochloride 50 SP	36.35 (37.21)	56.96 (55.98)	86.98 (88.21)	97.69 (93.38)	69.50 (70.39)
T ₆ : Fipronil 5% SC	56.19 (61.29)	64.38 (65.39)	91.38 (90.25)	97.28 (94.32)	77.31 (76.29)
T ₇ : Control (Untreated)	2.21 (3.69)	3.14 (4.12)	5.58 (7.21)	7.29 (9.28)	4.56 (7.36)
SEm±	0.57	0.49	0.47	6.01	—

Cartap hydrochloride (56.96%), bifenthrin (58.48%), and fipronil (64.38%) continued to inflict significantly higher mortality. The increase in mortality from 12 to 24 HAT was most pronounced in thiamethoxam and chlorantraniliprole, indicating a cumulative but relatively slower toxic action.

Mortality at 36 HAT

By 36 HAT, a steep escalation in mortality was observed across all treatments. Fipronil (91.38%) and bifenthrin (89.87%) approached near-total mortality, followed closely by cartap hydrochloride (86.98%). Chlorantraniliprole (59.18%) and imidacloprid (53.25%) maintained their intermediate status, while thiamethoxam (48.29%) still recorded the lowest kill among the insecticides. The control mortality remained negligible (5.58%).

Mortality at 48 HAT and Mean Toxicity

At 48 HAT, cartap hydrochloride (97.69%), fipronil (97.28%), and bifenthrin (96.36%) caused near-complete mortality, leaving virtually no survivors. Imidacloprid (87.21%), chlorantraniliprole (79.27%), and thiamethoxam (79.28%) were relatively less lethal at this terminal observation, though their absolute toxicity had also risen sharply.

Considering the mean mortality across all observation intervals, the overall toxicity ranking from least to most toxic was: thiamethoxam (44.40%) < imidacloprid (52.78%) < chlorantraniliprole (53.78%) < cartap hydrochloride (69.50%) < bifenthrin (74.05%) < fipronil (77.31%). The mean mortality in the untreated control was only 4.56%.

Discussion

The present investigation unequivocally establishes that all six tested insecticides exert significant contact toxicity to adult females of *Trichogramma chilonis*, albeit with differential intensity. Among the tested molecules, the neonicotinoid thiamethoxam 25 WG emerged as the least toxic, registering the lowest mean mortality of 44.40%. This finding aligns with Renuka and Sawai (2020) [9], who reported thiamethoxam to be selective towards different life stages of *T. japonicum*, and with Singh *et al.* (2018) [7], who observed comparatively moderate effects of certain neonicotinoids on trichogrammatid emergence. The comparatively lower contact toxicity of thiamethoxam may be attributed to its differential binding affinity to nicotinic acetylcholine receptors in *Hymenoptera* vis-à-vis its systemic mode of action, which reduces direct contact exposure on treated surfaces.

Imidacloprid 17.8% SL, another neonicotinoid, recorded a mean mortality of 52.78%, placing it in the moderately toxic category in the present study. These results corroborate the findings of Saha *et al.* (2017) [10] and Nirvesh Singh *et al.*

(2018) [7], who reported imidacloprid as having low to moderate toxicity to immature stages and adult emergence of *T. chilonis*. However, its escalating toxicity by 48 HAT (87.21%) suggests that prolonged residual exposure can severely compromise parasitoid survival, necessitating careful timing of its application in the field.

Chlorantraniliprole 18.5% SC, an anthranilic diamide, caused a mean mortality of 53.78%. Deshmukh *et al.* (2018) [3] reported chlorantraniliprole as harmless to *Trichogramma* spp. when irradiated host eggs were exposed, but slightly harmful on unirradiated eggs under the IOBC classification. Our direct contact bioassay on adults indicates a moderate level of toxicity, suggesting that while the molecule is relatively safe to immature parasitoids developing inside host eggs, free-living adult wasps are more vulnerable to direct topical or residual contact. This distinction is critical for field integration, as adult wasps foraging on treated foliage are at higher risk.

Cartap hydrochloride 50 SP exhibited high mean mortality (69.50%), with mortality exceeding 97 per cent by 48 HAT. This indicates that thiocarbamate insecticides, though often considered less persistent than organophosphates or pyrethroids, possess substantial acute contact toxicity to minute parasitoids. Such high acute toxicity necessitates avoidance of cartap in habitats where *T. chilonis* releases are planned.

Bifenthrin 10% EC, a synthetic pyrethroid, inflicted a mean mortality of 74.05%. Pyrethroids are well-documented broad-spectrum neurotoxins with high toxicity to parasitoids and predators (Bhargavi, 2015; Patra and Samanta, 2017) [2, 18]. The rapid knockdown effect and strong residual activity of bifenthrin evidently render it highly detrimental to *T. chilonis*. Similarly, fipronil 5% SC was the most toxic treatment overall, causing 77.31% mean mortality and exceeding 97 per cent mortality by 48 HAT. These results are in close agreement with Mohapatra and Shinde (2021) [6], who categorized fipronil as “harmful” to *T. japonicum* females, causing cent per cent mortality under contact toxicity trials, and with Wang *et al.* (2012) [15], who identified fipronil as one of the most toxic insecticides to *T. chilonis* based on sublethal concentration values. The phenylpyrazole mode of action of fipronil, which disrupts GABA-gated chloride channels, appears to be particularly lethal to parasitic *Hymenoptera*.

The time-course mortality data revealed that toxicity was generally cumulative, with the sharpest increase observed between 36 and 48 HAT for most treatments. This suggests that even brief residual exposures can lead to delayed mortality, a factor often underestimated in rapid screening assays. The significant disparity between the safest (thiamethoxam) and the most toxic (fipronil) molecules underscores the importance of molecule selection in IPM

scheduling. For broad-spectrum insecticides like fipronil and bifenthrin, strict restraint around parasitoid release windows is warranted, whereas molecules such as thiamethoxam and chlorantraniliprole may offer a wider compatibility margin, provided applications are timed to minimize adult wasp exposure.

In the context of the Indian agricultural landscape, where *T. chilonis* trichocards are widely distributed for management of cotton bollworms and sugarcane borers, the indiscriminate co-application of highly toxic insecticides can nullify the economic investment in biological control. Therefore, the present findings advocate for the incorporation of parasitoid safety data into pesticide recommendation protocols. Future studies should expand this evaluation to include sublethal effects on parasitization efficiency, host-searching behavior, progeny sex ratio, and the safety of these insecticides to immature stages developing within parasitized host eggs to fully characterize their compatibility.

Conclusion

The laboratory screening of six commercially important insecticides against adult females of *Trichogramma chilonis* revealed significant variation in contact toxicity. Thiamethoxam 25 WG was identified as the comparatively safest molecule among the tested insecticides, with the lowest mean adult mortality (44.40%). Imidacloprid 17.8% SL and chlorantraniliprole 18.5% SC were moderately toxic. Conversely, fipronil 5% SC and bifenthrin 10% EC were highly toxic, causing 77.31% and 74.05% mean mortality, respectively, and should be regarded as incompatible with *T. chilonis* in integrated management programs. Cartap hydrochloride 50 SP also exhibited high toxicity (69.50%). These findings emphasize that the selection of insecticides in IPM regimes must be predicated not only on efficacy against target pests but also on rigorous safety assessments for key biological control agents. The adoption of comparatively safer molecules, coupled with temporal separation of chemical and biological control interventions, will be pivotal in realizing the synergistic potential of IPM.

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