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Toxicity of tetraniliprole, chlorantraniliprole, lufenuron and thiocyclam insecticides on *Trichogramma brassicae* Bezdenko and *T. evanescens* Westwood (Hymenoptera: Trichogrammatidae) under laboratory and semi-field conditions

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Abstract

Trichogramma wasp is one of the most successful parasitic species in the world, mainly used to control many pests. The effects of field (RC) and half recommended concentrations (half RC) of four insecticides: 1. Tetraniliprole, 2. Chlorantraniliprole 3. Lufenuron, and 4. Thiocyclam was studied in different preimaginal stages of 1. *Trichogramma brassicae* Bezdenko and 2. *Trichogramma evanescens* Westwood (Hymenoptera: Trichogrammatidae). Parasitized eggs of the angoumois grain moth *Sitotroga cerealella* Olivier (Lepidoptera: Gelechiidae) were treated by 1. The dipping method at the larval, 2. Prepupal, and 3. Pupal stages of the parasitoid. For persistence evaluation, the insecticides were applied at the recommended concentration on tomato plants in a pot by a hand sprayer till the Runoff point. Plants were maintained under a transparent polyethylene rain cover in the field. Leaves of the treated tomato plants were sampled and transferred to the laboratory at time intervals of 3, 5, 16, and 31 days after application. In this experiment were adults (< 24 hours old) of *T. brassicae* and *T. evanescens*. Based on our results, thiocyclam at both RC and half RC was the most harmful insecticide for immature stages of both parasitoids. This insecticide at the prepupal stage (at both RC and half RC) had more adverse effects than in pupal or larval stages. Tetraniliprole, with 23.33% and 21.11% mortality in less than five days, was classified as the short-lived insecticide for *T. brassicae* and *T. evanescens*, respectively. The same result was obtained in the chlorantraniliprole treatment. That caused 25% and 26.11% mortality to the parasitoids, *T. brassicae*, and *T. evanescens*. Lufenuron, with 30.55% and 30.00% mortality in less than five days, was short-lived. However, thiocyclam, with 14.44% and 16.67% mortality in less than 30 days and 65.55% and 69.44% mortality in less than five days, was classified as moderately persistent for those two species. Therefore, according to the results, 1. tetraniliprole, 2. chlorantraniliprole, and 3. lufenuron can control lepidopteran pests by observing the appropriate spraying distance to release *Trichogramma* wasps. Thiocyclam, on the other hand, should be employed with extreme caution.

Keywords: Trichogramma, Persistence, Insecticides, Integrated pest management

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Introduction

Managing the lepidopteran pests in the greenhouse and fields is critical in protecting tomato plants (Biondi et al., 2018). The genus *Trichogramma* spp. (Hymenoptera: Trichogrammatidae) are increasingly recognized as crucial biological control agents of Lepidoptera pests worldwide (Knutson, 2005). The widespread use of pesticides in agricultural ecosystems led to the death of nontarget organisms, directly or indirectly (Beers & Schmidt, 2014). Also, excess use of chemicals in tomato fields led to increased resistant genotypes against different groups of insecticides, contamination of the environment, and pesticide residues on human products (Gill and Grag, 2014).

According to Vianna et al. (2009) family Trichogrammatidae significantly reduced the populations of lepidopteran pests and the number of insecticide applications on tomato crops. Non-selective insecticides do not have acceptable potential as well as biological agents (Desneux et al., 2007). So, it seems that applying biocompatible insecticides alongside biological control agents is the desired method for pest control. Many chemicals can maintain their adverse effects long after application (Nekunam et al., 2020).

Souza et al. (2014) pointed out the side effects of chemical pesticides to reduce their adverse impact on natural enemies presented in crops. Death, disturbance in life parameters such as developmental rate, sex ratios, parasitism, and emergence rate are lethal and sublethal effects of chemical insecticides (Poorjavad et al., 2014). Previous studies showed that integrating biological control agents with pesticides regulated arthropod pest populations without direct or indirect effects on their natural enemies (Ruberson et al., 1998).

In some cases, short-lived insecticides that only slightly interfere with biological control agents should be a solution for effective pest control. Some studies have revealed the effects of many insecticides on different *Trichogramma* species (Hassan, 1998; Hewa-Kapuge et al., 2003; Jiu-Sheng et al., 2009).

Chlorantraniliprole and Tetraniliprole are new systemic insecticides of the anthranilic diamide group with a unique and new mode of action. By binding to the ryanodine receptor, chlorantraniliprole stimulates the release of calcium stores from the sarcoplasmic reticulum of muscle cells, resulting in flare-ups. This insecticide should be used at the critical stage of the insect, usually during the hatching of newly hatched eggs or larvae (Cordova et al., 2006; Graily-Moradi & Hejazi, 2020).

Lufenuron is classified as an insect development inhibitor, belonging to the group of chitin synthesis inhibitors. Consumption of this compound disrupts the regular activity of internal secretory systems and disrupts the growth and development of insects (Talebi Jahromi, 2011). Lufenuron's mechanism of action is interference with chitin synthesis, polymerization, and deposition (Benziony & Arzi, 2000).

Thiocyclam is a group of neristoxins of natural origin that is extracted from worms of the marine annelid category. A nereistoxin analog insecticide selective, stomach acting with some contact action. Nicotinic acetylcholine receptor (nAChR) channel blocker (Rakhshanizabol, 2011).

The present study evaluated the susceptibility of *T. brassicae* and *T. evanescence* to four insecticides: tetraniliprole, chlorantraniliprole, lufenuron, and thiocyclam when applied at the insects' immature stages. To determine the most suitable insecticide, we also investigated the persistence rate of the insecticides under field conditions according to the IOBC procedure.

Materials and Methods

Rearing

The experiments were carried out in the Laboratory of Plant Protection at the Agricultural and Natural Resources Research and Education Center of Markazi Province, Arak, Iran. The egg parasitoids *T. brassicae* and *T. evanescens* (Hymenoptera: Trichogrammatidae) were provided by the Biological Control Department of Plant Protection Research Institute in Tehran, Iran. Parasitoids were reared on the angoumois grain moth, *S. cerealella*, in the laboratory under the controlled conditions of 25 ± 1°C, 60 ± 10% RH, and a photoperiod of 16:8 h (L: D).

Insecticides

The insecticides used were: tetraniliprole (SC 200 Vayego®, Syngenta Co., Swiss), chlorantraniliprole (SC18.4% Coragen®, Dupont Co., USA), lufenuron (EC5% Match®, Syngenta Co., Swiss), and thiocyclam (SP50% Evisect®, Arista Life Science). Field recommended concentrations (RC) and half RC of the insecticides were used (Table 1).

Immature stages bioassay

The effects of insecticides at RC half RC were studied on different preimaginal stages of *T. brassicae* and *T. evanescens*. The egg cards *S. cerealella* were placed in glass tubes (18*180 mm). Parasitized eggs were treated by the dipping method at different intervals suggested by the IOBC (Sterk et al., 1999; Costa et al., 2014). The experiment was repeated six times. The control was distilled water. Randomly selected egg cards, having 140 parasitized eggs, were dipped into the solution of RC or half RC of each insecticide for 10 seconds on the 3rd, 6th, and 9th day after the eggs were parasitized.

These days correspond to the developmental stages of *T. brassicae* and *T. evanescens* larvae (3 day), prepupae (6 day), and pupae (9 day) (Ghorbani et al., 2016). When the dipped eggs were dried (for 3 h), they were placed in glass tubes in the laboratory under the controlled conditions of 25 ± 1°C, 60 ± 10% RH, and a photoperiod of 16:8 h (L: D). A droplet of 10% water and the honey solution was smeared on the internal walls of the containers for adult feeding. The adult emergence rate of parasitoids from each of the three stages was determined and then divided by the control to calculate emergence reduction (Sterk et al., 1999; Costa et al., 2014).

Persistence rate evaluation under semi-field conditions

The insecticides were applied at the RC on tomato plants (Rio grande cultivar) in pots (23*21.5 cm) by a hand sprayer (Royal) till the Runoff point. Plants were maintained under a transparent polyethylene rain cover in the field. Leaves of the treated tomato plants were sampled and transferred to the laboratory at time intervals of 3, 5, 16, and 31 days after application. These intervals were proposed by the IOBC/WPRS Working Group (Sterk et al., 1999; Costa et al., 2014).

The samples were placed in ventilated plastic Petri dishes (10*10*6). Their petioles were placed in a small container containing water. To prevent the leaves from wilting and maintain their moisture. The experiment was repeated with 30 adult individuals (< 24 hours old) of each species assessment of mortality recorded based on 24 h post-exposure time. The persistence rate was evaluated according to each insecticide's IOBC/WPRS Working Group. The categories under laboratory conditions included: A, short-lived (< 5 days); B, slightly persistent (5-15 days); C, moderately endless (16-30 days); D, Persistent (> 30 days) (Sterk et al., 1999; Costa et al., 2014).

Statistical analysis

These experiments were carried out in a completely randomized design (CRD) with six replications. Data on percent efficacy were arcsine-square root transformed to normalize them and subjected to one-way variance analyses. Abbott's formula (Abbott, 1925) was used to correct mortality percentage. The means were separated using the least significant difference (LSD) test at a 5% significance level using SPSS software version 24 (SPSS Inc. 2016).

Table 1. The concentrations and manufacturers of the insecticides that were tested in the study.

Name of insecticides	Trade name	Recommended concentration (ai/hectare)	Manufacturer
Tetraniliprole SC200 (Leaf miner)	Vayego	36	Syngenta, Swiss
Chlorantraniliprole SC 18.4% (Leaf miner)	Coragen	2.76	Dupont, USA
Lufenuron EC5% (Leaf miner, Cotton bollworm)	Match	15	Syngenta, Swiss
Thiocyclam SP50% (Leaf miner, White fly)	Evisect	7.5	Arista life Science

Results

Emergence rate

Trichogramma brassicae

Parasitoid emergence rate after treatment at larval, prepupal, and pupal stages was reduced when treated by the recommended concentration of each insecticide. Maximum and minimum reduction of emergence for thiocyclam was 45.14, 47.36, and 41.31%, and for tetraniliprole was 17.89, 7.77, and 12.66%, respectively (Table 2). The data for half RD of thiocyclam was 39.69, 42.09, and 38.16%; tetraniliprole was 12.44, 3.48, and 8.82%. There were significant differences among insecticides for their effects on emergence rate of the parasitoid at the larval (F = 96.45; df = 8, 53; P = 0.0001), prepupal (F = 149.03; df = 8, 53; P = 0.0001) and pupal stages (F = 103.57; df = 8, 53; P = 0.0001) (Table 2).

Trichogramma evanescens

The reduction of *T. evanescens* emergence rate after treatment at the recommended concentration of thiocyclam was 46.15, 50.45, and 43.31%, and tetraniliprole was 9.26, 4.11, and 5.88% at the larval, prepupal and pupal stages, respectively (Table 3). These values for half RD of thiocyclam were 41.78, 46.15, 40.11%, and for tetraniliprole were 5.59, 1.25, and 2.49%. There were significant differences among insecticides for their effects on emergence rate of the parasitoid at the larval (F = 121.19; df = 8, 53; P = 0.0001), prepupal (F = 128.95; df = 8, 53; P = 0.0001) and pupal stage (F = 101.68; df = 8, 53; P = 0.0001) (Table 3).

Persistency

Trichogramma brassicae

Three days after post-treatment (= DPT), a significant difference was observed among various treatments for the rate of adult parasitoid mortality (F = 216.84; df = 3, 23; P = 0.0001). Thiocyclam caused 65.66 % mortality which was the most among all treatments. However, tetraniliprole showed 23.33% mortality which was the least. At five DPT, thiocyclam caused 55% mortality which differed significantly from other treatments (F = 317.00; df = 3, 3 P = 0.0001).

Tetraniliprole and chlorantraniliprole, with mean mortality of 16.67% and 20%, respectively, showed less effect than thiocyclam but were not significantly different. At 16 DPT thiocyclam caused 44.44% mortality which was the highest and significantly different from the other treatments (F = 204.67; df = 3, 23; P = 0.0001). Tetraniliprole and chlorantraniliprole, with mean mortality of 10% and 12.78%, showed fewer effects. At 31 DPT thiocyclam caused 14.44% mortality which still significantly differed from other treatments (F = 27.18; df = 3, 23; P = 0.0001). Tetraniliprole and chlorantraniliprole, with mean mortality of 7.22% and 7.78%, respectively, showed less effect than thiocyclam, with no statistical difference between the two (Table 4).

Trichogramma evanescens

At three DPT the rate of mortality differed significantly among various treatments (F = 278.95; df = 3, 23; P = 0.0001). Thiocyclam caused 69.44% mortality which was the most among all treatments. However, tetraniliprole showed 21.11% mortality which was the least. The mortality rates of chlorantraniliprole and lufenuron were 26.11 and 30.00%, respectively. At five DPT, thiocyclam caused 57.22% mortality which differed significantly from other treatments (F = 430.57; df = 3, 23; P = 0.0001).

Tetraniliprole and chlorantraniliprole, with mean mortality of 21.11% and 13.33%, respectively, showed fewer effects than thiocyclam without any statistical difference. At 16 DPT, thiocyclam was significantly different from other treatments (F = 308.23; df = 3, 23; P = 0.0001). Tetraniliprole and chlorantraniliprole, with mean mortality of 9.44% and 14.44%, showed fewer effects than thiocyclam. At 31 DPT, thiocyclam significantly differed from other treatments (F = 26.5; df = 3, 23; P = 0.0001). Tetraniliprole and chlorantraniliprole, with mean mortality of 6.11% and 8.89%, respectively, showed fewer effects than thiocyclam without any statistical difference between those two insecticides (Table 5).

Table 2. Effects of insecticide treatments on emergence percentage (mean ± SE) of *Trichogramma brassicae* when treated at larval, prepupal and pupal stages inside its host egg under laboratory conditions.

Treatment	Larvae (%emergence)	%Reduction in the emergence	Pre-pupae (%emergence)	%Reduction in the emergence	Pupae (%emergence)	%Reduction in the emergence
Tetraniliprole						
RC	80.33 ± 1.23bc	17.89	86.00 ± 0.97bc	7.77	83.33 ± 1.14b	12.66
0.5RC	85.67 ± 1.28b	12.44	90.00 ± 1.18ab	3.48	87.00 ± 1.00b	8.82
Chlorantraniliprole						
RC	78.50 ± 1.38cd	19.76	84.17 ± 1.38c	9.74	82.17 ± 1.17b	13.89
0.5RC	83.16 ± 1.51bc	14.99	88.00 ± 0.97b	5.63	86.00 ± 1.46b	9.87
Lufenuron						
RC	69.33 ± 1.31e	29.13	64.5 ± 1.87d	30.83	61.00 ± 1.75cd	36.07
0.5RC	73.16 ± 1.25de	25.21	69.00 ± 1.59d	26.00	64.00 ± 1.66c	32.92
Thiocyclam						
RC	53.67 ± 1.72f	45.14	49.08 ± 1.20e	47.36	56.00 ± 1.67d	41.31
0.5RC	59.00 ± 1.77f	39.69	54.00 ± 1.77e	42.09	59.00 ± 1.77cd	38.16
Control	97.83 ± 0.76a	0	93.25 ± 0.86a	0	95.42 ± 0.99a	0

Means followed by the same letters in each column are not significantly different (LSD test, $p < 0.05$).
RC: Recommended concentration.

Table 3. Effects of insecticide treatment on the adult emergence of *Trichogramma evanescens* when treated at larval, prepupal and pupal stages inside its host egg under laboratory conditions.

Treatment	Larvae (%emergence)	%Reduction in the emergence	Pre-pupa (%emergence)	%Reduction in the emergence	Pupa (%emergence)	%Reduction in the emergence
Tetraniliprole						
RC	86.5 ± 1.12b	9.26	89.33 ± 1.05ab	4.11	88.00 ± 1.15ab	5.88
0.5RC	90.00 ± 1.15ab	5.59	92.00 ± 0.97ab	1.25	91.17 ± 0.98ab	2.49
Chlorantraniliprole						
RC	75.5 ± 1.91cd	20.80	81.17 ± 1.90c	12.88	79.33 ± 1.93c	15.15
0.5RC	80.17 ± 1.17c	15.91	85.00 ± 1.29bc	8.76	84.33 ± 1.45bc	9.80
Lufenuron						
RC	71.5 ± 1.91d	25.00	67.17 ± 1.42d	27.91	65.00 ± 1.59d	30.48
0.5RC	75.17 ± 1.25bc	21.15	70.00 ± 1.65d	24.86	69.00 ± 1.66d	26.02
Thiocyclam RC						
0.5RC	51.33 ± 1.11e	46.15	46.17 ± 2.33e	50.45	53.00 ± 1.73e	43.31
Control	55.5 ± 0.99e	41.78	50.17 ± 1.35e	46.15	56.00 ± 1.77e	40.11
	95.33 ± 1.08a	0	93.17 ± 1.56a	0	93.5 ± 0.99a	0

Means followed by the same letters in each column are not significantly different (LSD test, $p < 0.05$).
RC: Recommended concentration.

Table 4. Mortality of adult stage of *Trichogramma brassicae* wasps after exposure to leaf residues of insecticides at 3, 5, 16, and 31 days post-treatment (DPT) at field conditions.

Insecticide	% Mortality (Mean ± SE)				Classification
	3 DPT	**5 DPT**	**16 DPT**	**31 DPT**	
Tetraniliprole	23.33 ± 1.22c	16.66 ± 0.84c	10.00 ± 0.86c	7.22 ± 0.55b	A Short-lived
Chlorantraniliprole	25.00 ± 0.74bc	20.00 ± 0.81bc	12.78 ± 1.02bc	7.78 ± 0.72b	A Short-lived
Lufenuron	30.55 ± 1.14b	22.22 ± 0.7b	15.55 ± 0.71b	10.55 ± 0.54ab	A Short-lived
Thiocyclam	65.55 ± 1.65a	55.00 ± 1.42a	44.44 ± 1.65a	14.44 ± 0.7a	C, Moderately persistent

Means followed by the same letters in each column are not significantly different (LSD test, $p < 0.05$).

Table 5. Mortality of adult stage of *Trichogramma evanescence* wasps after exposure to leaf residues of insecticides at 3, 5, 16, and 31 days post-treatment (DPT) at field conditions.

Insecticide	% Mortality (Mean ± SE)				Classification
	3 DPT	5 DPT	16 DPT	31 DPT	
Tetraniliprole	21.11 ± 0.73c	13.33 ± 0.86c	9.44 ± 0.55c	6.11 ± 0.54c	A Short-lived
Chlorantraniliprole	26.11 ± 1.02bc	21.11 ± 0.75b	14.44 ± 0.68b	8.89 ± 1.05bc	A Short-lived
Lufenuron	30.00 ± 0.86b	21.67 ± 0.84b	15.00 ± 0.74b	10.00 ± 0.87b	A Short-lived
Thiocyclam	69.44 ± 2.18a	57.22 ± 1.34a	47.22 ± 1.59a	16.67 ± 1.22a	C, Moderately persistent

Means followed by the same letters in each column are not significantly different (LSD test, $p < 0.05$).

IOBC classification

Results regarding the effects of the insecticides on different developmental stages of *T. brassicae* and *T. evanescens* revealed that tetraniliprole and chlorantraniliprole were the most selective compound among the tested insecticides. However, lufenuron and thiocyclam were slightly harmful to both parasitoids (Tables 2 and 3). Persistence tests based on IOBC classification for more than 30% mortality at each period revealed that 1. Tetraniliprole, 2. Chlorantraniliprole and 3. Lufenuron had less than five days of persistence.

This result classified them as short-lived insecticides (class A) for *T. brassicae* wasps. Thiocyclam, which persisted for more than 16 days but less than 30 days, was moderately persistent for the parasitoid (class C) (Table 4).

For *T. evanescence* adult parasitoid, tetraniliprole, chlorantraniliprole and lufenuron had less than five days persistence. This result classified them as short-lived insecticides (class A) for *T. brassicae* wasps. Thiocyclam, which persisted for more than 16 days but less than 30 days, was moderately persistent for the parasitoid (class C) (Table 4).

Discussion

Our study revealed that thiocyclam was the most harmful insecticide for immature stages of both parasitoids (*T. brassicae* and *T. evanescens*). We also found that treatments with thiocyclam at the prepupal stage had more adverse effects than pupal or larval stages. Lufenuron was short-lived and had less impact on the emergence rate of adults. The host egg chorion may protect immatures of Trichogramma against some insecticides (Knutson, 2005), however exiting by wasps at emergence can cause insecticide ingestion by adults before leaving the host egg (Parsaeyan et al., 2020).

Chlorantraniliprole is a novel synthetic chemical belonging to the ryanoid group, and it stimulates the release of calcium stores from the sarcoplasmic reticulum of muscle cells, resulting in flare-ups. The lower toxicity of this insecticide to *Trichogramma* may be due to its mode of action. According to Dinter et al. (2009), chlorantraniliprole has low intrinsic toxicity for beneficial arthropods and nontarget organisms such as earthworms, honey bees, and other pollinators. The harmlessness of chlorantraniliprole was also reported on *Trichogramma japonicum* Ashmead. Chlorantraniliprole caused the lowest mortality (21.25%) in the adults of *T. japonicum* (Uma et al., 2014). The reports were similar to our results. Somebody investigated the effects of chlorantraniliprole on *Palmistichus elaeisis* (Delvare and LaSalle) (Hymenoptera: Eulophidae). The results showed that this insecticide reduced emergence and the progeny metatibia length but did not induce mortality of *P. elaeisis* adults (Pereira et al., 2018). This insecticide has a systemic within the insect body. Also, it has a residual effect on the host egg that allows the impact on parasitoids via ingestion when feeding in the host (Reding and Ranger 2011).

Brugger et al. (2010) reported the effects of recommended field concentration of chlorantraniliprole on the egg parasitoid *T. chilonis* Ishii.

Chlorantraniliprole did not affect the percentage of parasitoid emergence after egg card dipping bioassay. In the experiments of Matioli et al. (2019), although chlorantraniliprole did not act on the exposed specimens of *Cotesia* *flavipes* (Cameron) (Hymenoptera: Braconidae), the insecticide influenced their progeny. The activity of chlorantraniliprole has also been evaluated on immature stages of the omnivorous predator *Macrolophus pygmaeus* Rambur (Hemiptera: Miridae) (Martinou et al., 2014); adults of *Macrolophus basicornis* (Stal) (Passos et al., 2018; Soares et al., 2019), and the flower bug *Orius laevigatus* (Fieber) (Hemiptera: Anthocoridae) (Biondi et al., 2012). In these studies, the insecticide was shown to have little or no lethal and sublethal effects. In similar studies, Gontijo et al. (2014) reported that *Chrysoperla carnea* Stephens (Neuroptera: Chrysopidae) adult couples exposed to stems grown from seeds treated with chlorantraniliprole showed no increase in larval and pupal duration. In contrast, Guo et al. (2013) described that chlorantraniliprole increased significantly mean generation time and doubling time of the diamondback moth, *Plutella xylostella* (L.) (Lepidoptera: Plutellidae).

According to Mahankuda et al. (2019), chlorantraniliprole for adults of *T. chilonis* was slightly harmful. Recommended field concentrations of several pesticides, including chlorantraniliprole, were tested on adults of *T. chilonis* in semi-field conditions. The results showed that chlorantraniliprole had no harmful effects on this species and was included in the group of short-lived persistence pesticides (Kumar et al., 2019), which is the same as our findings.

Recommended field concentration of chlorantraniliprole was slightly harmful to adults of *T. chilonis, T. pretiosum,* and *T. japonicum* (Deshmukh et al., 2018). The laboratory experiments showed that chlorantraniliprole was considered for female adults of *Trichogramma japonicum* (Mohapatra and Shinde, 2021).

Lufenuron is a benzoyl phenyl urea compound that inhibits chitin production (Carmo et al., 2010). When lufenuron was applied to *T. pretiosum* Riley (Hymenoptera: Trichogrammatidae) in the pupal stage, a reduction in the emergence of the F1 generation females was observed (Carvalho et al., 2010). In a similar study, Fontes et al. (2018) investigated the effects of several insecticides, including lufenuron, on immature stages of *T. achaeae* under laboratory conditions. Their results showed that lufenuron had low toxicity in all developmental stages. Takada et al. (2001) reported few side effects of lufenuron on *Trichogramma* spp., which confirmed the results of the present study. However, little differences in the results may be due to dissimilarity in the trial genus, experimental condition, etc. The results showed that lufenuron was also included in the group of dangerous insecticides (Nekunam et al., 2020). Afshari et al. (2014) reported few side effects of lufenuron on adult and prepupae stages of *T. brassicae*, which confirmed the results of the present study. Due to of high total effect of hexaflumuron on adult and immature stages of *T. brassicae*, using of other biocompatible insecticides is recommended in IMP programs of lepidopteran pests (Afshari et al., 2018).

The results of laboratory experiments confirmed that tetraniliprole is compatible with integrated pest management programs (APVMA, 2020). Previous studies indicated no adverse effects of tetraniliprole were observed on two predatory species *Coccinella septempunctata* L. (Coleoptera: Coccinellidae) and *C. carnea* (Gontijo et al., 2014). Also, no harmful effects were observed on predatory mite *Typhlodromus pyri* Scheuten (Acari: Phytoseiidae) and parasitoid wasp *Aphidius rhopalosiphi* De Stefani-Perez (Hymenoptera: Braconidae). Semi-field studies on *Aphidius rhopalosiphi* showed no harmful effects of tetraniliprole on parasitism, and emergence rates were observed in three different crops tomato, cabbage, and eggplant. The results of the present study are similar to the results of this study on the insignificant detrimental effects of tetraniliprole (APVMA, 2020).

The effects of several insecticides, including thiocyclam, on eggs and larvae of first-instar *C. carnea* were investigated *in vitro*. Based on the total effect index of the IOBC classification, thiocyclam was in the slightly harmful category (Asadi Eidvand et al., 2015). Several insecticides' lethal and sub-lethal effects, including thiocyclam, on adult insect *Habrobracon hebetor* Say (Hymenoptera: Braconidae) were investigated *in vitro*. This insecticide reduced the biological parameters, including the intrinsic rate of increase, gross reproduction rate, finite growth rate, net reproduction rate, and increased mean generation time and doubling time of the tested wasp (Fuladi et al., 2015).

The results of the present study are consistent with these studies regarding the detrimental effect of thiocyclam. Like other insects, immature stages of *Trichogramma* have been considered less susceptible to pesticides than adults; the eggshell of the host could provide protection. However, preimaginal mortality of *Trichogramma* parasitoids may be related to partial emergence. When the parasitoid is cutting a small area of the host eggshell with its mandibles, a small quantity of the eggshell surface could be swallowed as well as the product residues on the host surface (Consoli et al., 2001). No information is available on the persistence of tetraniliprole and thiocyclam in references.

IPM programs are globally implemented to control insect pests' infestation, and one part is understanding insecticides' potential effects on natural enemies. Under ideal conditions, the toxicity of pesticides used in the IPM programs should be high to target small or insignificant pests to their natural enemies (Croft 1990). The present study showed that the response sensitivity was at the same level when both parasitoids were exposed to all the tested insecticides.

Pesticides should be used very carefully in IPM programs. Also, further experiments on the behavioral effects of pesticides (e.g., mating behavior (Wang et al., 2018), as well as the transgenerational product (Wang et al., 2017), will help assess the real potential impact of these insecticides on *T. brassicae*, *T. evanescens*, and other non-target organisms. Moreover, further studies under open field conditions are warranted to assess the risks posed by any pesticide entirely.

Conclusion

This research focused on the impact of insecticides on two *Trichogramma* species in Markazi Province. Pesticides that control insect pests without severe side effects on substantial natural enemies are always necessary for integrated control programs. Also, short-lived insecticides could allow a rapid recolonization of the parasitoids. Recent research found non-harmful tetraniliprole and chlorantraniliprole in *T. brassicae* and *T. evanescence* wasps. They are appropriate candidates to be incorporated into IPM programs. By contrast, lufenuron and thiocyclam should be used with care as a part of IPM procedures.

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REFERENCES

Abbott, W. S. (1925). A method for computing the effectiveness of an insecticide. *Journal of Economic Entomology*, *18*, 265-267.

Afshari, A., Hamzepour Chenari, E., Iraji, A., & Asghari Larimi, M. (2018). Lethal and sublethal effects of thiodicarb and hexaflumuron on egg parasitoid, *Trichogramma brassicae* Bezdenko under laboratory conditions. *Plant Protection* (*Scientific Journal of Agriculture*), *41*(1), 75-89.

Afshari, A., Gorzaddin, M., & Mottaki, E. (2014). Side-effects of indoxacarb and lufenuron on *Trichogramma brassicae* Bezdenko (Hymenoptera: Trichogrammatidae) under laboratory conditions. *Plant Protection* (*Scientific Journal of Agriculture*), *37*(3), 61-80.

Asadi eidvand, M. R., Golmohammadi, G. H., & Ghajariyeh, H. (2015). Study of the lethal and sub-lethal effects of four insecticides on first instar eggs and larvae Green *Chrysoperla carnea* (stephens) in vitro. *Iranian Journal of Plant Protection*, *46*(2), 331-339.

Ashtari, S., Sabahi, Q., & Talebi Jahromi, K. (2018). Evaluation of toxicity of some biocompatible insecticides on *Trichogramma brassicae* and *T. evanescens* under laboratory and semi-field conditions. *Journal of Crop Protection*, *7*(4), 459-469.

APVMA, (2020). Public release summary on the evaluation of tetraniliprole in the product Vayego 200 SC Insecticide. 55pp.

Beers, E. H., & Schmidt, R. A. (2014). Impacts of orchard pesticides on *Galendromus occidentalis,* lethal and sub lethal effects, *Crop protection*,16-24.

Benziony, Y., & Arzi, B. (2000). "Use of lufenuron for treating fungal infections of dogs and cats: 297 cases (1997-1999)". *Journal of the American Veterinary Medical Association*, *217*(10): 1510–1513. doi:10.2460/javma.2000.217.1510

Biondi, N., Ferracini, C., & Tavella, L. (2018). Functional response and age-specific foraging behavior of *Necremnus tutae* and *N. cosmopterix,* native natural enemies of the invasive pest *Tuta absoluta* in Mediterranean area. *Journal of Pest Science*. doi:10.1007/s10340-018-1025-6.

Biondi, A., Desneux, N., Siscaro, G., & Zappalà, L. (2012). Using organiccertified rather than synthetic pesticides may not be safer for biological control agents: selectivity and side effects of 14 pesticides on the predator *Orius laevigatus.* Chemosphere, *87*, 803–812.

Brugger, K. E., Cole, P. G., Newman, I. C., Parker, N., Scholz, B., Suvagia, P., Walker, G., & Hammond, T. G. (2010). Selectivity of chlorantraniliprole to parasitoid wasps. *Pest Management Science, 66*, 1075–1081.

Carmo, E. D., Bueno, A., & Bueno, R. C. O. F. (2010). Pesticide selectivity for the insect egg parasitoid *Telenomus remus*. *Biocontrol*, *55*, 455–464.

Carvalho, G. A., Goday, M. S., Parreira, D. S., & Rezende, D. T. (2010). Effect of chemical insecticides used in tomato crops on immature *Trichogramma pretiosum* (Hymenoptera: Trichogrammatidae), *Revista Colombiana de Entomología*, *36*(1), 10-15.

Consoli, F. L., Botelho, P. S. M., & Parra, J. R. P. (2001). Selectivity of insecticides to the egg parasitoid *Trichogramma galloi* Zucchi (Hymenoptera: Trichogrammatidae). *Journal of Applied Entomology*, *125*, 37 - 43.

Cordova, D., Benner, E. A., Sacher, M. D, Raul, J J., Sopa, J. S., & Lahm, G. P. (2006). Anthranilic diamides: A new class of insecticides with a novel mode of action, ryanodine receptor activation. *Pesticide Biochemistry and Physiology*, *84*, 196-214.

Consoli, F. L., Botelho, P. S. M., & Parra, J. R. P. (2001). Selectivity of insecticides to the egg parasitoid *Trichogramma galloi* Zucchi (Hymenoptera: Trichogrammatidae). *Journal of Applied Entomology*, *125*, 37 - 43.

Costa, M. A., Muscardini, V. F., Gontijo, P. D. C., Carvalho, G. A., Oliveira, R. L. D., & Oliveira, H. N. D. (2014). Sub lethal and transgenerational effects of insecticides in developing *Trichogramma galloi*. *Ecotoxicology*, springer.

Croft, B. A. (1990). Arthropod Biological Control Agents and Pesticides. John Wiley & Sons, New York, NY.

Deshmukh, Y. V., Undirwade, D. B., & Dadmal, S. M. (2018). Effect of some newer insecticides on parasitisation by *Trichogramma* species under laboratory condition. *Journal of Entomology and Zoology Studies*, *6*(3), 228-231.

Dinter, A., Brugge, K. E., Frost, N. M., & Woodward, M. D. (2009). Chlorantraniliprole (Rynaxypyr): a novel DuPont™ insecticide with low toxicity and low risk for honey bees (*Apis mellifera*) and bumble bees (*Bombus terrestris*) providing excellent tools for uses in integrated pest management. In: 10th International Symposium of the ICP-Bee Protection Group 423, pp. 84–96.

Desneux, N., Decourtype, A., & Delpuech, J. M. (2007). The sublethal effects of pesticides on beneficial arthropods. *Annual Review of Entomology, 52*, 81-106.

Fontes, J., Roja, I. S., Tavares, J., & Oliveira, L. (2018). Lethal and Sublethal Effects of Various Pesticides on *Trichogramma achaeae* (Hymenoptera: Trichogrammatidae), *Journal of Economic Entomology*, pp.1–8.

Fuladi, M., Golmohammadi, G. H. & Ghajarieh, H. (2015). Lethal and sublethal effects of insecticides azadirachtin, flonicamid, thiacloprid and thiocyclam on parasitoide wasp *Habrobracon hebetor*. *Biocontrol in Plant Protection*, *3*(1), 9-18.

Gill, H. K., Garg, H. (2014). Pesticide: environmental impacts and management strategies. *Pesticides-toxic aspects*, *8*, 187.

Ghorbani, M., Saber, M., Bagheri, M., & Vaez, N. (2016). Effects of diazinon and fipronil on Different Developmental Stages of *Trichogramma brassicae* Bezdenko (Hym.; Trichogrammatidae), *Journal of Agricultural Science and Technology*, *18*, 1267-1278.

Gontijo, P. C., Moscardini, V. F., Michaud, J, P., & Carvalho, G. A. (2014). Nontarget effects of chlorantraniliprole and thiamethoxam on *Chrysoperla carnea* when employed as sunflower seed treatments. *Journal of Pest Science*, *87*, 711–719.

Graily-Moradi, F., & Hejazi, M. J. (2020). Comparitive insecticidal effect of chlorantraniliprole, spirotetramat, dimethoate and diazinon on vegetable leaf miner (*Liriomyza sativae*) under greenhouse condition. *Plant Pest Research*, *10*(1), 41–53.

Guo, L., Desneux, N., Sonoda, S., Liang, P., Han, P., & Gao, X. W. (2013). Sublethal and transgenerational effects of chlorantraniliprole on biological traits of the diamondback moth, *Plutella xylostella* L. *Crop Protection*, *48*, 29–34.

Hassan, S. A. (1998). The initiative of The IOBC/WPRS working group on pesticides and beneficial organisms In: Haskell, P.T. and McEwen, P. (Eds). Ecotoxicology, Pesticisdes and beneficial organisms. Kluwer Academic Publishing, pp. 22-56.

Hewa-Kapuge, S., Dougall, S. M., & Hoffmann, A. (2003). Effects of methoxyfenozide, indoxacarb, and other insecticides on the beneficial egg parasitoid *Trichogramma brassicae* (Hymenoptera: Trichogrammatidae) under laboratory and field conditions. *Journal of Economic Entomology*, *96*(4), 1083-1090.

Jiu-Sheng, Z. H. U., Mei-Li, L., Jing, W., & Shu, Q. I. N. (2009). Toxicity of abamectin on different developmental stages of *Trichogramma evanescens* Westwood and effects on its population dynamics. *Acta Ecologica Sinica*, *29*(9), 4738-4744.

Knutson, A. (2005). The *Trichogramma* manual, The Texas A & M University System. http://insects.tamu.edu/extension/bulletins/b- 6071.html.

Kumar, A., Singh, N. N., & Mishra, V. K. (2019). Toxicity of insecticides to egg parasitoid, *Trichogramma chilonis* Ishii under laboratory and semi-field conditions, *Annals of Plant Protection Sciences*, *27*(1), 24-27.

Mahankuda, B., Sawai, H. R., Gawande, R. W., Neharkar, P. S., & Nagdeote, V. G. (2019). Effect of insecticide residues on the adult survival rate of *Trichogramma chilonis* under laboratory condition, *Journal of Entomology and Zoology Studies*, *7*(2), 1349-1351.

Martinou, A. F., Seraphides, N., & Stavrinides, M. C. (2014). Lethal and behavioral effects of pesticides on the insect predator *Macrolophus pygmaeus*. *Chemosphere, 96*, 167–173.

Matioli, T. F., Zanardi, O. Z., & Yamamoto, P. T. (2019). Impacts of seven insecticides on *Cotesia flavipes* (Cameron) (Hymenoptera: Braconidae). *Ecotoxicology, 28*,1210–1219.

Mohapatra, B., & Shinde, C.U. (2021). Contact toxicity of different insecticides against egg parasitoid, *Trichogramma japonicum* Ashmead under laboratory condition. *Journal of Entomology and Zoology Studies*, *9*(1), 134-139.

Moradigrayeli, F., & Hejazi, M. J. (2020). Comparitive insecticidal effect of chlorantraniliprole, spirotetramat, dimethoate and diazinon on vegetable leaf miner (*Liriomyza sativae*) under greenhouse condition, *Plant Pest Research*, *10*(1), 41-53.

Namvar, P. (2011). Efficiency of thiocyclam SP50% (EvisectR) on leafminer *Liriomyza sativae* Blanchard (Diptera: Agromyzidae). Final report of research of Iranian Research Institute for Plant Protection, 45916, 22 pp.

Nekunam, A., Afshari, A., & Nadimi, A. (2020). Investigation of persistency and toxicity of compound insecticides on cotton bushes in order protection against *Trichogramma brassicae* Bezd. *Iranian Cotton Research Journal*, *8*(2), 107-126.

Parsaeyan, E., Saber, M., Safavi, S. A., Poorjavad, N., & Biondi, A. (2020). Side effects of chlorantraniliprole, phosalone and spinosad on the egg parasitoid, *Trichogramma brassicae. Ecotoxicology*, https://doi.org/10.1007/s10646-020-02235-y.

Passos, L. C., Soares, M. A., Collares, L. J., Malagoli, I., Desneux, N., & Carvalho, G. A. (2018). Lethal, sublethal and transgenerational effects of insecticides on *Macrolophus basicornis*, predator of *Tuta absoluta*. *Entomologia Generalis, 38*,127–143.

Pereira, K. S., Chediak, M., & Zanuncio, J. C. (2018). Chlorantraniliprole impact on survival and progeny quality of the pupa of the parasitoid *Palmistichus elaeisis* (Hymenoptera: Eulophidae). *The Canadian Entomologist*, *151*, 94-100.

Rakhshanizabol, E. (2011). Principles of Agricultural Toxicology, Farhang Jame Publications, 374 pp.

Reding, M. E., & Ranger, C. M. (2011). Systemic insecticides reduce feeding, survival, and fecundity of adult black vine weevils (Coleoptera: Curculionidae) on a variety of ornamental nursery crops. *Journal of Economic Entomology*, *104*, 405–413.

Poorjavad, N., Goldansaz, S. H., Dadpour, H., & Khajeali, J. (2014). Effect of essential oil on some biological and behavioral traits of *Trichogramma embryophagum* and *T. evanescens, Biocontrol*, *59*, 403-413.

Ruberson, J. R., Nemoto, H., & Hirose, Y. (1998). Pesticides and Conservation of Natural Enemies in Pest Management. In: Barbosa P. (Ed.) Conservation Biological Control. Academic Press, San Diego, CA, pp: 207-220.

Shafaghi, F., Ashtari, S., Tohidi, M. T., & Modarres Najafabadi., S. S. (2022). Effectiveness of New Insecticide, Tetraniliprole (Vayego SC200) against tomato Leaf Miner. *Journal of Iranian Plant Protection Research*, *36*(1), 67-78.

Shafaghi, F., Golmohammadi, Gh., Khanizad, A., & Tohidi, M. T. (2016). Evaluation of the Efficacy of Insecticide lufenuron (EC %5) on the Control of Chickpea Field Pod Borer, *Heliothis viriplaca*. *Pesticides in Plan Protection Sciences*, *3*(2), 145-153.

Soares, M. A., Passos, L. C., Campos, M. R., Collares, L. J., Desneux, N., & Carvalho, G. A. (2019). Side effects of insecticides commonly used against *Tuta absoluta* on the predator *Macrolophus basicornis*. *Journal of Pest Science*, *92*, 1447–1456.

Souza, J. R., Carvalho, G. A., Moura, A. P., Couto, M. H. G., & Maia, J. B. (2014). Toxicity of some insecticides used in maize crop on *Trichogramma pretiosum* immature stages, Chilean, *Journal Agricultural Research*, *74*, 234-239.

SPSS Inc. (2016). SPSS for Windows, Version 24. Chicago, SPSS Inc.

Sterk, G., Hassan, S. A., Baillod, M., Bakker, F., Bigler, F., & Blumel, S. (1999). Results of the seventh joint pesticide testing program carried out by the IOBC/WPRS-Working Group ‘Pesticides and Beneficial Organisms. *Biocontrol*, *44*, 99–117.

Takada, Y., Kawamura, S., & Tanaka, T. (2001). Effects of various insecticides on the development of the egg parasitoid *Trichogramma dendrolimi* (Hymenoptera: Trichogrammatidae). *Journal of Economic Entomology*, *94*, 1340–1343.

Talebi Jahromi, K. H. (2013). Pesticides toxicology. Tehran University press. pp: 507.

Uma, S., Jacob, S. & Lyla, K. R. (2014). Acute contact toxicity of selected conventional and novel insecticides to *Trichogramma japonicum* Ashmead (Hymenoptera: Trichogrammatidae). *Journal of Biopesticides*, *7*, 133-136.

Vianna, U. R., Pratisoli, D., Zanuncio, J. C., Lima, E. R., Brunner, J., Pereira, F. F., & Serrao, J. E. (2009). Insecticide toxicity to *Trichogramma pretiosum* (Hymenoptera: Trichogrammatidae) females and effect on descendant generation. *Ecotoxicology*, *18*, 180–186.

Wang, D., Lü, L., & He, Y. (2018). Effects of insecticides on sex pheromone communication and mating behavior in *Trichogramma chilonis*. *Journal of Pest Science, 91*, 65–78.

Wang, S. Y., Qi, Y. F., Desneux, N., & Shy, X. Y. (2017). Sublethal and transgenerational effects of short-term and chronic exposures to the neonicotinoid nitenpyram on the cotton aphid *Aphis gossypii*. *Journal of Pest Science*, *90*, 389–396.

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سمیت حشره‌کش‌های تترانیلی‌پرول، کلرانترانیلی‌پرول، لوفنورون و تیوسیکلام روی دو گونه زنبور *Trichogramma brassicae* Bezdenko و *T. evanescens* Westwood (Hymenoptera: Trichogrammatidae) تحت شرایط آزمایشگاهی و نیمه مزرعه‌ای

صدیقه اشتری[۱*]

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چکیده

زنبورهای تریکوگراما یکی از موفق ترین گونه های پارازیتوئید در دنیا بوده و به طور گسترده در جهان برای کنترل بیشتر آفات استفاده می شوند. به واسطه یافتن حشره‌کش‌هایی با اثرات سوء کمتر روی این زنبورها تاثیر غلظت توصیه شده مزرعه‌ای و نصف غلظت توصیه شده مزرعه‌ای حشره‌کش‌های تترانیلی‌پرول،کلرانترانیلی‌پرول، لوفنورون و تیوسیکلام روی مراحل مختلف رشدی دو گونه زنبور *Trichogramma evanescens* Westwood و *Trichogramma brassicae* Bezdenko مورد بررسی قرار گرفت. تخم های پارازیته شده بید غلات در مراحل لاروی، پیش شفیرگی و شفیرگی به روش غوطه‌وری با محلول‌های حشره‌کش ها تیمار شدند. جهت ارزیابی پایداری حشره کش‌ها، غلظت‌های توصیه شده مزرعه‌ای آن‌ها با یک سم پاش دستی روی گیاهان گوجه فرنگی تا جاری شدن محلول سمی پاشیده شد. گیاهان گوجه فرنگی زیر یک پوشش پلاستیکی به عنوان حفاظ باران نگهداری شدند. نمونه‌برداری از گیاهان گوجه فرنگی در روزهای ۳، ٥، ١٦ و ۳۱ روز پس از تیمار انجام شد. بر اساس نتایج تیوسیکلام در هر دو غلظت (توصیه شده مزرعه‌ای و نصف غلظت توصیه شده مزرعه‌ای) مضرترین حشره کش برای مراحل نابالغ به خصوص مرحله پیش‌شفیرگی هر دو گونه زنبور تریکوگراما بود. تترانیلی‌پرول با درصد مرگ و میر ۲۳/۳۳ و ۲۱/۱۱ در کمتر از پنج روز به ترتیب برای گونه‌های *Trichogramma brassicae* و *T. evanescens* در گروه حشره‌کش‌های بی‌دوام ارزیابی گردید. نتیجه مشابهی برای کلرانترانیلی‌پرول با درصد مرگ و میر ۲٥ و ۲٦/۱۱ به ترتیب برای دو گونه مذکور حاصل شد. همچنین لوفنورون نیز با ۳۰/٥٥ و ۳۰ درصد مرگ و میر به ترتیب برای دو گونه *Trichogramma brassicae* و *T. evanescens* در کمتر از پنج روز بی دوام ارزیابی شد. ولی تیوسیکلام با ١٤/٤٤و ١٦/٦٧ درصد مرگ و میر در ۳۱ روز پس از سم‌پاشی و با ٦٥/٥٥ و ٦٩/٤٤ درصد مرگ و میر در کمتر از ٥ روز برای دو گونه در گروه حشره کش های با دوام متوسط قرار گرفت. بنابراین با توجه به نتایج تترانیلی‌پرول، کلرانترانیلی‌پرول و لوفنورون را می‌توان با رعایت فاصله مناسب سم پاشی جهت رها سازی زنبور تریکوگراما، جهت کنترل آفات بال‌پولکدار استفاده نمود. در مقابل تیوسیکلام بایستی با احتیاط بیشتری مورد استفاده قرار گیرد.

کلیدواژه‌ها: تریکوگراما، پایداری، حشره‌کش‌ها، مدیریت تلفیقی آفت

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