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Comparative susceptibility of thirteen selected pesticides to three different insect egg parasitoid *Trichogramma* species

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ABSTRACT

The parasitoid *Trichogramma* species are indispensable natural enemies of many lepidopterans and it plays an important role in integrated pest management (IPM) programs throughout the world. Laboratory studies were conducted to compare the susceptibility of three *Trichogramma* egg parasitoid species to ten common insecticides and three herbicides. The adults of *Trichogramma dendrolimi, T. chilonis*, and *T. ostriniae* were exposed to the above-mentioned pesticides by a glass-vial residue method. Among the four neonicotinoids, dinotefuran and thiamethoxam exhibited extremely toxic effects on the *Trichogramma dendrolimi* and *T. chilonis*, with Risk Quotient (RQ) values ranging from 1471.2 to 5492.5. However, these two neonicotinoids have a relatively low toxicity to *T. ostriniae,* with RQ values 433.6 and 915.4, respectively. In addition, Imidacloprid and acetamiprid were slightly to moderately toxic to all the tested parasitic wasps and their RQ values are less than 500. For pyrethroids, all the selected compounds were slightly to moderately toxic to three *Trichogramma* species except that cyhalothrin was dangerously toxic to *T. dendrolimi* and *T. chilonis,* with RQ values 2567.6 and 3950.4. Among the three herbicides tested, pendimethalin, butralin and napropamid were slightly to moderately toxic to egg parasitoids, with all RQ values below 1000. For two avermectins, abamectin were slightly to moderately toxic to all three wasps with RQ values 635.6, 148.3 and 254.2, respectively. However, emamectin benzoate was found to be safe for the parasitoids. Furthermore, *T. dendrolimi* showed higher sensitivity than *T. chilonis* and *T. ostriniae* to the pesticides based on the comparison of LR_{50} (application rate causing 50% mortality) values. The present results provide informative data for implementing biological and chemical control strategies in integrated pest management.

1. Introduction

The abundance and diversity of the *Trichogramma* species are known to have a significant effect on the biological pest control in many crop ecosystems (Gardner et al., 2011; Smith, 1996; Hussain et al., 2010). The ease of laboratory rearing and extensive geographical distribution of these egg parasitoids have led to an increase in their utilization in plant protection (Pinto, 2006; Preetha et al., 2009).

The *Trichogramma* spp. wasps have been extensively used in many crop ecosystems against the target arthropod pests, such as the borers of the genus *Diatraea* (Lepidoptera: Crambidae) in sugarcane (Dias-Pini et al., 2012), the white-backed planthopper *Sogatella furcifera* (J. E. Smith) (Horváth) (Homoptera: Delphacidae) in corn field (Souza et al., 2013; Lou et al., 2014), and the leafminer *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae) in greenhouse tomatoes (Zappalà et al., 2013). In recent years, certain countries have developed strategies to bring the use of plant-protection products closer to a more sustainable ecology in accordance with the basic preconditions of the integrated pest management (IPM) programs (European Commission, 2009) aimed at integrating the chemical and biological control of target pests. However, the control of these pests still depends largely on the pesticides that are not universally compatible with beneficial arthropod (Campiche et al., 2006; Dawar et al., 2016). Therefore, more selective chemicals are required to improve the ecological system service by conserving those beneficial organisms (Jacas and Urbaneja, 2009). Moreover, *Trichogramma* spp. wasps are considered to be appropriate indicator species for checking the potential side effects of various compounds (Consoli et al., 2001).

Trichogramma dendrolimi, T. chilonis, and *T. ostriniae* are the three dominant beneficial arthropods among egg parasitoids (Ko et al., 2015;

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Table 1
Detailed information of pesticide used in this study.

Pesticide	Technical grade (a.i.)	Manufacturer	Maximum Field-recommended rate (g a.i. ha^{-1})
Avermectins			
Emamectin benzoate	72%	Zhejiang Qianjiang Biochemical Co., Ltd	3.75
Abamectin	92%	Zhejiang Qianjiang Biochemical Co., Ltd	32.4
Neonicotinoids			
Imidacloprid	97%	Qingdao Hailir Pesticides and Chemicals Grop Co., Ltd	30
Acetamiprid	97%	Qingdao Hailir Pesticides and Chemicals Grop Co., Ltd	22
Dinotefuran	95.2%	Zhejiang Qianjiang Biochemical Co., Ltd	150
Thiamethoxam	98.2%	Jiangsu Changlong Chemical Co., Ltd	60
Pyrethroids			
Bifenthrin	96%	Qingdao Hailir Pesticides and Chemicals Grop Co., Ltd	30
Cyhalothrin	97%	Shandong Sino-agri United Biotechnology Co., Ltd	18.7
Alpha-cypermethrin	95%	Zhejiang Qianjiang Biochemical Co., Ltd	125.5
Deltamethrin	98%	Jiangsu Changlong Chemical Co., Ltd	14.1
Herbicides			
Pendimethalin	98%	Shandong Sino-agri United Biotechnology Co., Ltd	1000
Butralin	96%	Zhejiang Qianjiang Biochemical Co., Ltd	1800
Napropamid	91%	Shandong Sino-agri United Biotechnology Co., Ltd	1800

Parsaeyan et al., 2018). It is essential to evaluate the toxicity of some common pesticides to these parasitic wasps after contact exposure. The determination of the acute toxicity of a chemical towards non-target arthropods relies primarily on the determination of an acute median lethal concentration (LC_{50}). According to the acute toxicity test result, the most sensitive species among these three egg parasitoid wasps is then considered as an indicator species.

To minimize the negative effects of pesticides on *Trichogramma* species, it is indispensable to evaluate the potential toxicity risk of some chemicals currently being used in pest management (Preetha et al., 2010). Researchers have been looking for newer and safer chemicals to decrease the use of broad-spectrum insecticides (Elbert et al., 2008). Several of these novel insecticides, including avermectins and neonicotinoids, have been registered for use on various crops to control pests in a more efficient way (Ishaaya and Degheele, 2013). A variety of compounds are deemed relatively safe to beneficial non-target arthropods. However, some researches have questioned the safety of these compounds and have shown that they are not always selective for natural enemies (Cloyd and Bethke, 2011; Prabhaker et al., 2011). In addition, there are few toxic data about these pesticides on these selected *Trichogramma* spp., although the toxicity of some chemicals on other Trichogramma wasps has been studied (Parsaeyan et al., 2018; Wang et al., 2014). Most studies conducted to determine the toxicity of chemicals to beneficial arthropods mainly concentrated on certain insecticides. However, most of the herbicides used in agricultural practices also have certain negative effects on arthropods (Mandal et al., 2006; Sebai et al., 2012). Therefore, in the present study, the toxicity of some commonly used insecticides and herbicides to adults of the three egg parasitoids was evaluated. A "glass-tube membrane method" was established for the acute lethal exposure processes. The *Trichogramma* spp. adults were tested in the laboratory to classify the risk category of chemicals in accordance with the guidelines of the International Organization for Biological and Integrated Control of Noxious Animals and Plants (IOBC).

Considering the crucial role of the above-mentioned compounds and parasitoids, the objective of this study was to investigate the toxic risk of pesticides to *T. dendrolimi*, *T. chilonis*, and *T. ostriniae* and select the most sensitive species as the potential indicator species to protect egg parasitoids. The results of this study will make a significant contribution in optimizing the use of these pesticides within the framework of IPM.

2. Materials and methods

2.1. Insects

The egg parasitoids *Trichogramma dendrolimi, T. chilonis*, and *T. ostriniae* used in the tests originated from parasitized eggs of the rice moth, *Corcyra cephalonica* Stainton (Lepidoptera: Pyralidae), purchased weekly from Beijing Academy of Agricultural and Forestry Science (BAAFS). The host eggs were glued on cardstock (7.5 × 6 cm) with rubber cement and killed by UV radiation before they were exposed to wasps. The card papers need to be cut into approximately 1 × 7 cm strips when they were exposed to parasitoids in glass tubes (9.5 cm height × 2.2 cm diameter, covered with a black cloth) containing about 60 mixed-gender adults of *Trichogramma*. After 24 h of exposure, the exposed card strips were transferred to other new appropriate containers of the same size, and a small piece of thick paper that had been dipped into a 10–15% honey solution was maintained in glass tube as food for emerging parasitoids. All organisms were maintained in incubators at 25 ± 1 °C and 70 ± 10% relative humidity with a 14:10 h (L: D) photoperiod. Adult parasitoids with a uniform age of 24–48 h after emergence were used in the tests.

2.2. Pesticides

Thirteen compounds from four chemical classes were selected for this study (Table 1). These compounds were chosen because of their extensive use in agricultural practice and they play an essential role in managing pests (Wang et al., 2014). Moreover, they represented different chemical classes. The active ingredients of these pesticides rather than their commercial formulations were used, because the objective of this study was to evaluate the acute effects of the active ingredients on *Trichogramma* spp. survival while excluding the effects of adjuvants in commercial products. Therefore, the stock solutions were dissolved into the analytical reagent of acetone prior each experiment due to their lower solubility in water. The pesticides concentration measured in the stock solution approximated the intended concentration. Different test solutions were obtained by diluting the stock solution.

2.3. Acute contact toxicity

Experiments were conducted by exposing the *Trichogramma* adults to the residues of the pesticides applied on glass tubes. The preliminary tests were carried out to confirm the concentration gradient that caused 15–85% mortality in wasps. To determine the dose-response relationship, the adult wasps were exposed to five or six different doses of each pesticide with twofold geometrical differential. The acetone solutions of pesticides were applied to the inner surface of the tested glass tubes (height: 8.0 cm; diameter: 2.5 cm; internal surface area: 66.5 cm^2). One milliliter of each solution was applied to achieve the full coverage of the internal surface of the glass tube, with 1 mL of pure acetone as a solvent control and the same volume of deionized water as a blank control. The tubes were regularly rotated with a pipe roller to obtain a homogeneous