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Relative toxicity of insecticides to the crucifer pests *Plutella xylostella* and *Myzus persicae* and their natural enemies

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ABSTRACT

The widespread and intensive use of conventional pesticides, particularly insecticides, presents a major risk to natural enemies of target pests, as well as to the environment in general. The aim of this study was to investigate the differential intrinsic toxicity of insecticides to two key pests of crucifers, *Plutella xylostella* and *Myzus persicae* and their respective hymenopteran parasitoids, *Cotesia vestalis* and *Aphidius colemani*. Such knowledge can help inform effective integration of insecticides and biological control in IPM systems. Three insecticides generally regarded as being compatible with natural enemies (abamectin, spinosad and indoxacarb) and one compound regarded as harmful to natural enemies (lambda-cyhalothrin) were examined. A comparative measure of the intrinsic toxicity of fresh deposits of insecticides on Chinese cabbage leaf discs was determined for both pest and parasitoids species after exposure to insecticide for 24 h and 120 h, and after 24 h exposure to insecticide plus 96 h on untreated leaf discs. Differences in the susceptibility of pests and parasitoids to different insecticides were marked for *P. xylostella* and *C. vestalis*, LC_{50} values being significantly lower for the pest species. Such differences were not observed for *M. persicae* and *A. colemani*. There was a direct relationship between dose, exposure time and toxicity for all insecticides tested. All insecticides tested showed lower toxicity to both parasitoids compared with *P. xylostella*, which suggests that for this pest species side-effects on parasitoids can be minimised through IPM practices that reduce exposure time to such non-target organisms.

1. Introduction

The diamondback moth *Plutella xylostella* L. (Lepidoptera: Plutellidae) is an oligophagous species, which is the most important cosmopolitan pest of crucifer crops and has become particularly difficult to control because of its ability to develop resistance to pesticides (Furlong et al., 2013; Johnson et al., 2009). The overuse of insecticides against *P. xylostella* has also resulted in damaging effects on its natural enemies, particularly key species such as the larval endoparasitoid, *Cotesia vestalis* Kurdjumov (syn. *Cotesia plutellae*) (Hymenoptera: Braconidae) (Li et al., 2007; Haseeb and Amano, 2002). *Cotesia vestalis* parasitizes all four larval instars of *P. xylostella*, preferring the second and third instars (Shi et al., 2002).

The peach-potato aphid *Myzus persicae* (Sulzer) (Hemiptera: Aphididae) is a highly polyphagous species, which feeds on 40 different families of plants (Blackman and Eastop, 2000). Overuse of pesticides has also resulted in widespread resistance in *M. persicae* (Foster et al., 2007; Barber et al., 1999) and negative impacts on non-target organisms (Foster et al., 2012). *Aphidius colemani* (Hymenoptera: Braconidae) is one of the important parasitoid species for *M. persicae* and is available commercially for biological control of aphids on horticultural crops (Jones et al., 2003; Fernández and Nentwig, 1997).

Today, many insecticides with a relatively narrow range of activity are marketed against specific groups of insect pests; these compounds can be far less harmful to the beneficial insects, including natural enemies such as *C. vestalis* (Cardwell et al., 2005). Abamectin, indoxacarb and spinosad are insecticides generally regarded as reduced risk or compatible with natural enemies (Liu and Zhang, 2012; Zhao et al., 2006) and lambda-cyhalothrin is regarded as harmful to natural enemies (Tillman and Mulrooney, 2000).

Knowledge of the potential impact of pesticides on parasitoids and other natural enemies is important for the successful integration of chemical and biological control measures (Blumel, 2004). Adult parasitoids can be directly affected during spray application

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of pesticides and subsequently through residual exposure during foraging, oviposition and feeding (Wali et al., 2007) In addition to lethal effects, neurotoxic insecticides can alter parasitoid behaviour (Furlong and Zalucki, 2010: Longley, 1999; Elzen, 1989).

Finding a balance between the effective use of chemicals against target species and their effects on natural enemies is crucial in IPM (Stara et al., 2011; Longley and Jepson, 1996). In the present study, two crucifer pest-parasitoid systems were used to obtain comparable baseline data on the intrinsic toxicity of four insecticides, reported in separate previous studies to show differential toxicity against various pests and natural enemies. Insecticides were chosen on the bases of their compatibility against beneficial insects such as abamectin, spinosad and indoxacarb and their incompatibility to natural enemies for example lambda-cyhalothrin.

2. Materials and methods

2.1. Plants

Chinese cabbage *Brassica chinensis* pekinensis cv Wonk Bok (E. W. King and Co., Ltd, Colchester, UK) were maintained in a greenhouse at 25 ± 1 °C with supplementary lighting (16 h Photoperiod). Seeds were sown weekly in individual pots (13 cm dia.) using John Innes No 2 compost (Fargro Ltd, Littlehampton, UK) to produce a continuous supply of plants of the same age throughout experiments. Plants were watered every 2 days. No chemical sprays or other chemical treatments were used during plant production. To maintain the culture of insects, and to carry out experiments, 6 to 8 week-old potted plants were used.

2.2. Insects

2.2.1. P. xylostella

Plutella xylostella was obtained from a laboratory strain (Lab-UK) maintained at Silwood Park, Imperial College London. Insects were reared in screen cages (42 cm × 43 cm × 55 cm) in a controlled temperature (CT) room at 25 ± 1 °C, with a relative humidity (RH) of 70 ± 5% and a 16 h photoperiod. Adults were provided with 20% (w/v) honey solution as a source of food. Chinese cabbage plants were provided for oviposition and larvae reared on plants, which were replaced as required.

2.2.2. C. vestalis

Cotesia vestalis were obtained from a culture at Silwood Park (Staley et al., 2011) and reared on *P. xylostella* by exposing a mixed population of larval stages to newly emerged male and female parasitoids in a screen cage. Parasitoid cultures were maintained under the same environmental condition as for *P. xylostella*. Adult parasitoids were provided with a 20% honey solution as a source of food.

2.2.3. M. persicae

Myzus persicae was obtained from Koppert Ltd (Haverhill, Suffolk, UK) and maintained on Chinese cabbage under CT room conditions same as provided for *P. xylostella*.

2.2.4. A. colemani

Aphidius colemani mummies were obtained from Koppert Ltd as required. On arrival, the mummies were kept in a collecting cage (42 cm × 43 cm × 55 cm) under CT room conditions (Section *P. xylostella*) until adult *A. colemani* emerged. The adults were fed with 20% honey solution.

2.3. Insecticides

Four formulated products were tested: lambda-cyhalothrin (Karate®, 5% EC, Syngenta, UK), indoxacarb (Steward®, 30% G, Dupont de Nemours, France), spinosad (Tracer®, 48% SC, Dow AgroSciences, UK) and abamectin (Vertimec® 1.8% EC, Syngenta, UK). Compounds were stored at 5 °C and test solutions were freshly prepared in 50 ppm Triton X-100 (Sigma Aldridge, U.K.) in distilled water for each set of experiments.

2.4. Leaf-dip bioassays

2.4.1. P. xylostella larvae

Leaf disc bioassays for *P. xylostella* 3rd instar (L3) larvae were conducted on Chinese cabbage leaves (Sayyed et al., 2000). Leaf discs (4.8 cm) were immersed for 10 s in test solutions and then placed on a corrugated aluminium foil rack and left at ambient temperature (25 °C) for 1 h to dry. The dose ranges used for each compound were: lambda-cyhalothrin (0.001–1 ppm); abamectin (0.001–0.10 ppm); indoxacarb (0.003–1 ppm) and spinosad (0.005–1 ppm). Control leaf discs were dipped in a 50 ppm Triton X-100 solution.

Treated leaf discs were transferred to 5 cm deep plastic Petri dishes containing a single 4.8 cm dia. filter paper (Whatman No. 1) moistened with distilled water. Three L3 *P. xylostella* were introduced per Petri dish with 10 replicates per treatment, including the control (n = 30 larvae per treatment). Mortality for each pesticide was assessed after 24 h and 120 h. In a second experiment, *P. xylostella* larvae were transferred to untreated leaves after 24 h, and mortality recorded after a further 96 h.

2.4.2. C. vestalis adults

Cotesia vestalis adults (male and female 1–7 day-old) were exposed to treated leaf discs (Section *P. xylostella*). The lids of the Petri dishes were modified with a small hole in the centre to introduce three adult parasitoids per dish, which was then covered with tape. Doses used were: lambda-cyhalothrin (2–10 ppm); abamectin (8–18 ppm); indoxacarb (8–14 ppm) and spinosad (8–18 ppm). Control leaf discs were dipped in 50 ppm Triton X-100 solution. Mortality was recorded after 24 h and 120 h. In a second experiment, insects were exposed to pesticide residues for 24 h, and then transferred to untreated leaf discs in Petri dishes with 20% honey as a food source and mortality recorded after a further 96 h. Each treatment was replicated 10 times (n = 30) per treatment.

2.4.3. M. persicae adults

Myzus persicae were bioassayed on leaf discs treated with insecticides as described above (Section *P. xylostella*) with three adult apterous *M. persicae* per Petri dish. Each treatment was replicated 10 times (n = 30 insects per treatment). Mortality was recorded after 24 h and 120 h. In a second experiment, insects were transferred to untreated leaves after 24 h of exposure and mortality recorded after a further 96 h. Doses used were: lambda-cyhalothrin (1.5–3.5 ppm); abamectin (2.5–4.5 ppm); indoxacarb (12–20 ppm) and spinosad (20–40 ppm).

2.4.4. A. colemani adults

The same method was used as for *C. vestalis*. Doses used were: lambda-cyhalothrin (1.5–6.5 ppm); abamectin (2–6 ppm); indoxacarb (14–22 ppm) and spinosad (20–35 ppm).

2.5. Statistical analysis

All analysis was conducted using R version 3.0.2 (R Development Core Team R, 2013). Estimated LC_{50} values with 95%