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Susceptibilities to methamidophos and enzymatic characteristics in 18 species of pest insects and their natural enemies in crucifer vegetable crops

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Abstract

The susceptibilities to methamidophos as well as the kinetic and inhibitory parameter of acetylcholinesterases (AChE) and the activities of carboxyestsrases (CarE) and glutathione-*S*-transferases (GST) were studied in 18 species field populations of insects collected in Fuzhou, China during April and May 2000 and 2001. The insect species included five hymenopteran endoparasitoids, one hymenopteran exoparasitoid, one hymenopteran hyperparasitoid, one dipteran predator, four coleopteran predator ladybirds, six herbivorous pest insects of lepidoptera, diptera, homoptera, and coleoptera, respectively. There existed significant correlations between the susceptibility to methamidophos and the k_i values of AChE to methamidophos, dichlorvos, and carbofuran and between the k_i and V_{max} values of AChE among 18 species of insects. The six herbivorous pests and four ladybirds showed significantly low k_i and V_{max} values of AChE compared to the seven parasitoids and predator *Epistrophe balteate*. It was difficult to correlate the susceptibility to methamidophos or the k_i values with the K_m values of AChE, or with the activity of CarE and GST. The activities of CarE and GST varied depending on the different insect species. Significant synergisms of piperonyl butoxide (PB), triphenyl phosphate (TPP), and diethyl maleate (DEM) with methamidophos were observed in 14 pest insects and their natural enemies. Synergisms of PB were found to be the greatest. Reduced k_i values suggested that insensitive AChE might play a critical role in the tolerance to methamidophos in the 18 insect species. The detoxification enzymes, mixed-function oxidase (MFO), CarE, and GST, were believed to be involved in the tolerance to methamidophos. MFO might play the most important role, and CarE or GST might be important in the tolerance in some insect species. Different models of tolerance to methamidophos and enzymatic potential were existed in parasitoids, predators, and herbivores based on the different selection of insecticide pressure (either directly by exposing to the spray in the field, or indirectly by the insecticides penetrated into the body of host insects) as well as different ecological and biological habitats.
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1. Introduction

Some studies on the comparative toxicity and the biochemical mechanisms in pest insects and their natural enemies were reported in the previous works. Aldrin epoxidase (a cytochrome P-450 monooxygenase or MFO), epoxide hydrolase, glutathione-*S*-transferases (GST), and general esterase levels in inseticide-resistant and -susceptible strains of the spider mite, *Tetranychus urticae* (Koch), and the phytoseiid predator, *Amblyseius fallacies* (Garman) were studied [1]. The *cis*/*trans* epoxide hydrolase levels were measured among arthropod herbivores, omnivores, saprophages, and entomophages varying in feeding specialization from monophagy to polyphagy. Common trends in detoxification enzyme levels of herbivores and entomophages were found [1,2]. Herbivores and entomophagous natural enemies had different detoxifying enzyme profits and the activities of microsomal mixed-function oxidase (MFO) in parasitoids were much lower than those in herbivorous hosts by comparing the detoxifying enzymes, MFO, *trans*-epoxide hydrolase (*trans*-EH), *cis*-epoxide hydrolase (*cis*-EH), and 1-naphthyl acetate esterase, in 36 arthropod species of differing feeding strategies. Major selectivity was found for MFO and EH [3]. The comparison of detoxification enzyme system in lepidopteran pest *Argyrotaenia citrana* (Fernald) and its hymenopteran ectoparasite *Oncophanes americanus* (Weed) was conducted. The epoxide hydrolase enzyme system might be an appropriate target for exploiting selectivity differences between pests and natural enemies [4]. Rumpf et al. [5] reported that the activities of acetylcholinesterase (AChE) and GST were assayed as biomarkers of sublethal exposure to insecticides in larvae of two lacewing species, the Chrysopid *Chrysoperla carnea stephens* and the Hemerobiid *Micromus tasmaniae* Walker. The activity of AChE was less inhibited in *C. carnea* larvae, which reflected its higher tolerance to organophosphates in mortality tests. The activity of GST increased significantly in *M. tasmaniae* larvae treated with sublethal doses of cypermethrin and decreased significantly in larvae treated with fenoxycarb. In contrast, no changes in GST activity were observed in *C. carnea* larvae for any of the tested compounds. Inhibition of AChE in lacewings proved a useful tool to study the impact of different organophosphates used in the integrated pest management. The induction of detoxification enzymes in insects is a widespread phenomenon, probably representing one of most basic mechanisms of adaptation. MFO, GST, and carboxyestsrase (CarE) could be inducible by drugs, pesticides, secondary plant substances, and other synthetic compounds [6]. The activities of gut epoxidase of last instar larvae of 35 species of Lepidoptera showed that higher activity of midgut microsomal oxidase enzymes in polyphagous than in monophagous species, which indicated that the natural function of these enzymes is to detoxify natural insecticides present in the larval food plants [7]. The metabolic mechanisms of insecticide resistance observed in some selected pest insect species with chewing and sucking habits might reflect the fundamental difference in the makeup of their detoxifying enzymes (MFO, GST, and CarE), originally equipped to cope with various metabolites or allelochemicals in their host plants [8]. The activities of microsomal monooxygenase and GST in pest *Plutella xylostella* (L.) were far higher than those in its two parasitoids, *Cotesia plutellae* Kurdjumov and *Diadegma semiclausum* Hellen (Hymenoptera: Ichneumonidae), while CarE activities were similar between *C. plutellae* and *P. xylostella* [9]. The biochemical mechanisms of methamidophos resistance in *Diaeretiella rapae* (M'Intosh) were related to the insensitive AChE and oxidative metabolism by MFO [10]. Oxidative degradation was believed to play a critical role in resistance to methamidophos, fipronil, avermectin, fenvalerate, and cypermethrin in F_0 parents and its F_{21} progenies of *D. rapae*. To a lesser extent, hydrolytic reactions were also partially involved in the resistance to these five insecticides by using the synergists PB, TPP, and DEM. On the other hand, the mediated detoxification of oxidative degradation and hydrolytic reactions was thought to be