DETOXIFICATION OF ISOTHIOCYANATE 
ALLELOCHEMICALS BY GLUTATHIONE 
TRANSFERASE IN THREE LEPIDOPTEROUS SPECIES

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Abstract—Glutathione transferase activity towards various plant isothiocyanates was studied in larvae of the two generalists, fall armyworm [Spodoptera frugiperda (J.E. Smith)], and cabbage looper [Trichoplusia ni (Hübner)], and the specialist, velvetbean caterpillar (Anticarsia gemmatalis Hübner) using the midgut soluble fraction as enzyme source. The generalists, but not the specialist, are adapted to feeding on isothiocyanate-containing crucifers. Allyl and benzyl isothiocyanate were found to be metabolized by glutathione transferase from the two generalist species, but no activity was detected with the specialist. The transferase activity towards these allelochemicals in the cabbage looper was two- to sixfold higher than that in the fall armyworm. In all instances, activity was induced by various allelochemicals including indole 3-acetonitrile, indole 3-carbinol, flavone, xanthotoxin, and its own substrates. The induction ranged from 1.3- to 10.1-fold depending on the allelochemical, with the fall armyworm being more inducible. The transferase system of fall armyworm also metabolized another analog, 2-phenylethyl isothiocyanate, but activity can only be observed after induction. Bioassay results showed that these isothiocyanates were all toxic to the lepidopterans, causing acute toxicity in neonates and final-instar larvae. The results suggest that glutathione transferase plays an important role in the detoxification of isothiocyanates and hence food-plant adaptation in phytophagous insects.

Key Words—Glutathione transferase, isothiocyanate metabolism, fall armyworm, Spodoptera frugiperda, cabbage looper, Trichoplusia ni, velvetbean caterpillar, Anticarsia gemmatalis, Lepidoptera, Noctuidae.
INTRODUCTION

The glutathione transferases are a group of enzymes that catalyze the conjugation of reduced glutathione to electrophilic compounds. The reaction is considered an important pathway for xenobiotic detoxification since the resulting conjugates are further transformed to more excretable metabolites such as mercapturic acids (Boyland and Chasseaud, 1969).

In insects, glutathione transferases catalyze the metabolism of organophosphorus and organochlorine insecticides and are involved in the development of resistance to these compounds (Motayama and Dauterman, 1980; Tanaka et al., 1981; Clark and Shamaan, 1984). It is also believed that glutathione transferase plays an important role in insect herbivory through the detoxification of toxic plant allelochemicals. However, unlike insecticides, knowledge about the detoxification of plant allelochemicals by this enzyme is limited. Recently, we demonstrated that toxic α,β-unsaturated carbonyl allelochemicals such as trans-cinnamaldehyde, trans,trans-2,4-decadienal, trans-2-hexenal, and benzaldehyde were detoxified by glutathione transferase prepared from the midguts of fall armyworm larvae (Wadleigh and Yu, 1987). Transferase activity towards these compounds was induced by various dietary allelochemicals including, in some cases, the substrate itself.

In cruciferous plants, isothiocyanates (RNCS) are an important component of the chemical defenses against nonadapted insect herbivores, but they provide no protection against adapted herbivores that include crucifers in their normal host range (Feeny, 1977). The mechanism of isothiocyanate detoxification in the adapted herbivores is not completely understood. Previous research has shown that 2-phenylethyl isothiocyanate was a substrate for microsomal oxidases in the fall armyworm (Yu, 1987a). Detoxification by glutathione transferase is also likely since allyl and benzyl isothiocyanate were metabolized in vivo via glutathione-dependent conjugation in mammals (Brüsewitz et al., 1977; Mennicke et al., 1983). The reaction occurs as follows: RNCS + GSH → RNHC(S)SG.

The purpose of this research was to examine the detoxification of isothiocyanates by glutathione transferase in the fall armyworm, cabbage looper, and velvetbean caterpillar. The role of enzyme induction in detoxification was also investigated. The fall armyworm and cabbage looper are generalists adapted to feeding on isothiocyanate-containing crucifers. The velvetbean caterpillar is a specialist insect feeding primarily on certain species of plants in the Leguminosae.

METHODS AND MATERIALS

Insects. Larvae of the fall armyworm, Spodoptera frugiperda (J.E. Smith) (FAW), cabbage looper, Trichoplusia ni (Hübner) (CL), and velvetbean cat-