EVOLUTION OF PESTICIDE RESISTANCE IN APPLE PESTS AND THEIR NATURAL ENEMIES (1)

B.E. TABASHNIK (2) & B.A. CROFT (3)

(2) Department of Entomology, University of Hawaii, Honolulu, HI 96822, U.S.A.
(3) Department of Entomology, Oregon State University, Corvallis, OR 97331, U.S.A.

Evolution of pesticide resistance in 24 apple pest and natural enemy species was simulated with a computer model. Population ecology parameters were varied among species while physiological, biochemical and genetic assumptions were held constant. There was good agreement between the model's predictions and observed historical patterns of azinphosmethyl resistance among pests and natural enemies. Correspondence between predicted and observed was improved by assuming that natural enemies evolved resistance only after their prey/hosts became resistant, but not by assuming greater initial susceptibility in natural enemies. Results suggest that ecological factors may be important in determining rates of resistance evolution.

KEY-WORDS : Pesticide resistance, apple pests, natural enemies, simulation model.

Evolution of resistance to chemical pesticides in insects and mites is a serious threat to agricultural production. Unfortunately, pests evolve resistance faster than beneficial predators and parasites, which limits integration of biological and chemical pest controls (Croft & Brown, 1975; F.A.O., 1981). Better understanding of resistance evolution is needed to devise management strategies to retard resistance in pests and to promote it in natural enemies. Although hypotheses have been proposed to explain why pests develop resistance faster than natural enemies (Huffaker, 1971; Croft & Morse, 1979), there is much unexplained variation in rates of resistance evolution among pests and among natural enemies.

Most resistance research has focused on biochemical and physiological aspects of arthropods' responses (Plapp, 1976; Georghiou, 1972; Geissbuhler et al., 1982). Modeling studies have examined how ecological factors might influence resistance evolution in insects (Comins, 1977; Taylor & Georghiou, 1979; Tabashnik & Croft, 1982) but heretofore there have been only single-species models. Natural enemy species have not been modeled and model predictions have not been tested against field observations.

In 1980, we initiated a long-range project to model resistance development in agricultural arthropods and to explore resistance management strategies (fig. 1). We first developed a general model (Step 1, fig. 1) of resistance evolution (Tabashnik & Croft, 1982). In the study reported here, we simulated resistance evolution in 24 species of apple pests and natural enemies, then compared predicted rates of evolution with those observed in the field (Steps 2 and 3, fig. 1). This validation represents a step towards our goal of developing more realistic models for resistance management (Steps 4-5, fig. 1).

(1) This is paper no. 2843 of the Hawaii Institute of Tropical Agriculture & Human Resources journal series, and no. 7245 of the Oreg. Agric. Exp. Sta. journal series.
Fig. 1. Overall approach for using modeling to devise resistance management strategies.

Apple arthropods were selected because apple has a low economic threshold for direct damage from pests and it is sprayed intensively (Croft & Hoyt, 1983). In most intensively sprayed crops, a particular pesticide or class of pesticides is used for a few years, then abandoned due to pest resistance (Adkisson et al., 1982). Several pests and natural enemies associated with apple have developed resistance to azinphosmethyl (an organophosphorus pesticide), yet this compound has remained a major pest control tool for almost three decades because key apple pests have not become resistant to it (Croft, 1982). The long-term patterns of evolution of resistance to azinphosmethyl among the diverse insects and mites inhabiting apple orchards in North America constitute a unique data set which can be used to test hypotheses about resistance. In this study we sought to test the hypothesis that variation in rates of resistance evolution among apple species can be explained by differences in population ecology. We also used our model to test hypotheses proposed to explain why natural enemies develop resistance more slowly than pests.

METHODS

THE MODEL

We used the model of Tabashnik & Croft (1982), with some modifications. The arthropod life cycle was divided into 20 substages, with transition probabilities between substages determined by natural and pesticide mortalities. Resistance was controlled primarily by one gene with 2 alleles, with a concentration-mortality line for each of 3 genotypes: susceptible (SS), heterozygous (RS) and resistant (RR). Resistance was co-dominant; concentrations killing 50 % (LC50) of SS, RS and RR were 0.001, 0.01 and 0.1 (arbitrary units), respectively.