54

Management of Diamondback Moth in Central America

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Abstract

In Central America, most information on diamondback moth, *Plutella xylostella* (L.), comes from CATIE in Costa Rica, the National Autonomous University of Nicaragua and the Pan American Agricultural School in Zamorano, Honduras. Assisted by international collaborators, the Zamorano Cabbage IPM Program has developed and implemented improved management practices for key pests and diseases including diamondback moth. Farmers motivated by repeated failures of costly chemical control participate in technology generation and transfer programs. Organophosphorus, carbamate and pyrethroid insecticide resistance levels in Honduras are variable but generally high. The Honduran IPM program makes use of cultural practices (especially irrigation) and microbial control using *Bacillus thuringiensis* Berliner. Farmers using the IPM program reduce applications of synthetic pesticides from nine to two per crop cycle. Pesticide residues in harvested cabbage are dramatically reduced. The program increases farmers' net income. Attempts to complement the action of the native parasitoid *Diadegma insulare* (Cresson) with imported exotics have not yet been successful. Neem provides effective larval control. *Autographa californica* (Speyer) NPV is promising. Glossy cabbage lines are tolerant to DBM.

Introduction

Diamondback moth (DBM), *Plutella xylostella* (L.) (Lepidoptera: Yponomeutidae), is a key pest of crucifers in Central American countries (King and Saunders 1984; Secaira and Andrews 1987); there is considerable concern among scientists, consumers and farmers regarding DBM management. Most published information comes from CATIE in Costa Rica, the National Autonomous University of Nicaragua, and the Pan American Agricultural School in Zamorano, Honduras. Very little literature is available from Guatemala despite the importance of crucifers in that country. The proceedings of three recent regional IPM conferences have yet to be published, but information from dozens of presentations on DBM management is included here. CATIE (1990) published a useful booklet on IPM in Central America on cabbage after this review was completed; readers should consult it for further information.

Resistance to pesticides has been documented in both Costa Rica and Honduras. Ovalle and Cave (1990) found that DBM larvae collected in Zamorano showed 45-, 224-, and 412-fold levels of resistance to methomyl, methamidophos and cypermethrin, respectively (Fig. 1). Resistance levels were somewhat lower in two other Honduran populations. Problems with residues in crucifers are discussed later.

In Honduras and the rest of Central America, cabbage is produced year-round. In some areas, it is produced only during the rainy season and fields are left fallow during the dry season. In other areas, cabbage is continuously cropped using irrigation during the dry season. It is produced primarily above 1000 m. In Honduras, plots range from small backyard gardens to

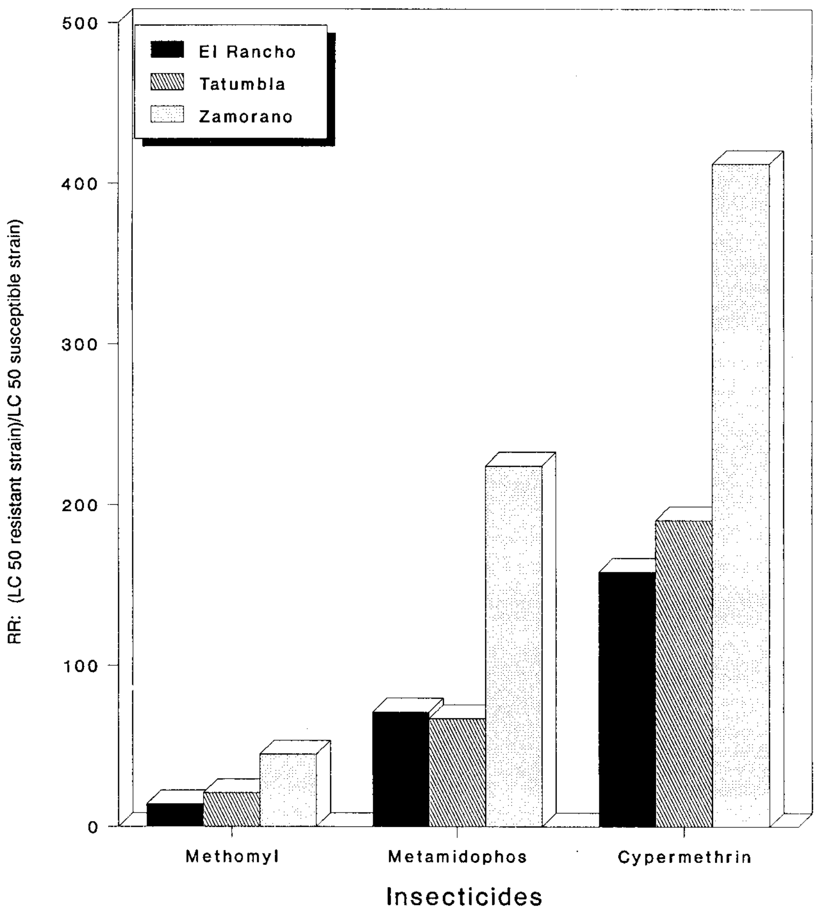

Fig. 1. Resistance levels of three Honduran populations of DBM larvae to commonly used insecticides as compared to a susceptible strain provided by NYSAES (after Ovalle and Cave in press).

about 2 ha. Average plot size is approximately 0.3 ha. Farmers who plant cabbage may be independent producers who finance themselves, or they may depend on credit. In most cases, a share-cropping arrangement (*mediania*) is used (Ardon and Sanchez 1990a). This special form of financing and growing cabbage has several important consequences for IPM technology generation and transfer which are discussed below.

Zamorano's 3-year-old crucifer IPM program focuses on simultaneous technology generation and implementation. Work on DBM is one of several lines of work; other organisms that receive emphasis include *Xanthomonas campestris*, limacid and veronicellid slugs, seedling diseases and pierid pests. The program makes extensive use of participative techniques for technology development and transfer. Ardon and Sanchez (1990b) showed that farmers make more than one-half of the intellectual contributions to studies of cultural control carried out by our research team. They make between one-third and one-half of the intellectual contributions to studies of supervised control, host plant resistance and chemical control. They make less than 15% of the total intellectual contribution to background studies of pest biology and ecology.

Natural Biological Control

Cordero and Cave (in press) reared three primary parasitoids from DBM larvae and pupae. Neither *Opius* sp. nor *Coccygomimus punicipes* (Cresson) appear to be important. *Diadegma insulare* (Cresson) accounted for 99% of the primary and facultative parasitoids reared. It was taken throughout the year and in all crucifer-producing areas of Honduras sampled. Cordero and Cave (1990) reported parasitization levels of 9-36% (mean = 23%) in insecticide-treated fields and 18-47% (mean = 29%) in untreated fields.

Two species of *Spilochaleis* are facultative hyperparasitoids, and 11 species of obligate hyperparasitoids attack *D. insulare* (Table 1). Three vespids, *Polybia diguetana* du Buysson, *Polybia occidentalis nigratella* du Buysson and *Brachygastra mellifica* (Say) are DBM predators (Cordero and Cave, in press). Natural enemies of eggs have not been studied. No naturally occurring epizootics affecting DBM have been observed in Honduras.

Table 1. Predators, parasitoids and hyperparasitoids associated with DBM in Honduras (Cordero and Cave 1990).

Primary Parasitoids	
1. *Diadegma insulare* (Cresson)	
2. *Opius* sp.	
3. *Coccygomimus punicipes* (Cresson)	
Facultative Hyperparasitoids	
1. *Spilochalcis pseudofulvovariegata* Becker	
2. *Spilochakis petioliventris* (Cameron)	
Obligate Hyperparasitoids	Predators
Isdromas lycaenae (Howard)	*Polybia diguetana* du Buysson
Mesochorus sp. 1	*Polybia occidentalis nigratella* du Buysson
Mesochorus sp. 2	*Brachygastra mellifica* (Say)
Trichomalus sp. 2	
Pteromalinae Genus species 1	
Pteromalinae Genus species 2	
Haltichella ornaticornis (Cameron)	
Spilochakis hirtifemora (Ashmead)	
Ceraphron sp.	
Epyris sp.	
Apenesia sp.	

Manipulation and Conservation of Natural Enemies

In addition to the use of *Bacillus thuringiensis* Berliner var. *kurstaki* and application of insecticides only as needed, we know of no work to preserve and enhance naturally occurring DBM parasitoids and predators. Farmers are encouraged not to destroy *Polybia* nests, and a few farmers even move *Polybia* nests to the edge of cabbage fields in an attempt to increase the effectiveness of these predators (Bentley 1990).

Classical Biological Control

Attempts to introduce the larval parasitoid *Cotesia plutellae* (Kurdjumov) into Honduras (see Waage and Cherry in this Volume), Belize and Costa Rica have not resulted in pest suppression. We have made occasional recoveries in the highlands surrounding Zamorano. We also released the pupal parasitoid *Diadromus collaris* (Gravenhorst) during 1990 in three sites; it was established at least temporarily in Zamorano and has been recovered in the highlands 20 km from a release site. Cordero and Cave (in press) expected that the hyperparasitoids recorded in their survey would not inhibit the establishment and potential effectiveness of the introduced species. Zamorano intends to continue its efforts in classical biological control in cooperation with the International Institute of Biological Control, the Caribbean Agricultural Research and Development Institute and other collaborators.

Microbial Control

Bacillus thuringiensis has rapidly become an essential component of programs to manage DBM in Honduras and other Central American countries (Fig. 2). In 1980, an unpublished government survey revealed that no Honduran farmers used it. In 1988, 12% relied exclusively on *B. thuringiensis* for DBM control and 34% either tank-mixed or rotated it with synthetic insecticides. By 1989, 24 and 28% relied exclusively or partially on *B. thuringiensis*. The efficacy and cost effectiveness of *B. thuringiensis* have been shown by Centeno (1990) in Nicaragua, Varela and Guharay (in press) in Nicaragua, Mora and Secaira (1989) in Honduras, Moncada and Sánchez (1990) in Honduras, and Cerna (1990) in Honduras. The Nicaraguan government is attempting to produce *B. thuringiensis* locally. A liquid formulation of *B. thuringiensis* is produced in Guatemala. In Honduras, Moncada and Sanchez (1990) showed that a Guatemalan commercial formulation of *Autographa californica* (Speyer) NPV controlled DBM larvae as well as Dipel and better than other synthetic insecticides (Fig. 3).

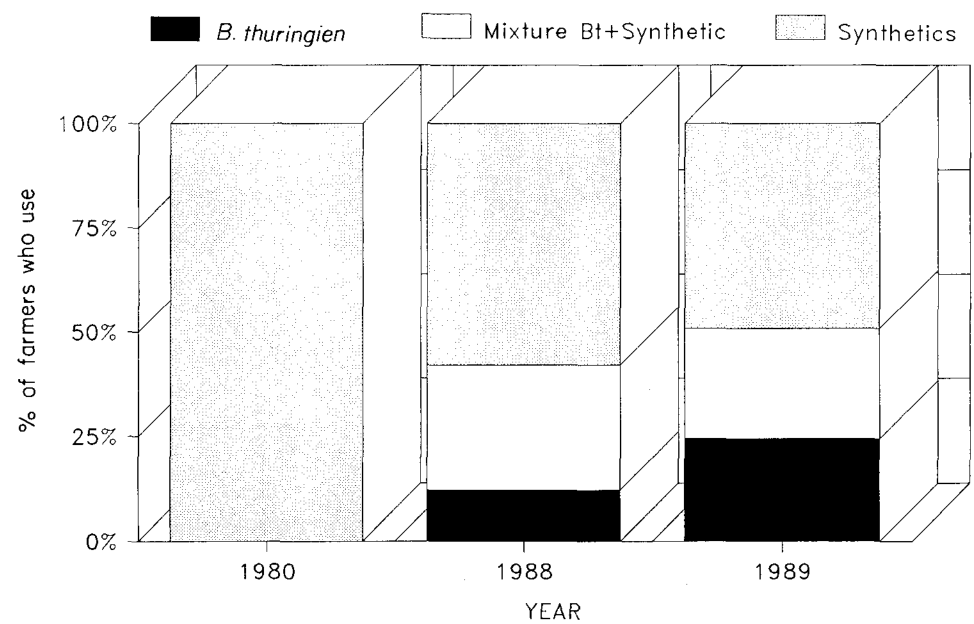

Fig. 2. *Bacillus thuringiensis*-based insecticides are replacing synthetic insecticides in Honduran cabbage. Unpublished data from interviews of 93, 57 and 60 producers in the Siguatepeque region.

Botanical Extracts

Extracts of plants with insecticidal properties are widely researched in Central America. In Nicaragua, 240,000 neem trees (*Azadirachta indica* A. Juss) are producing fruits. The previous Nicaraguan government sponsored a major research and development program to use aqueous extracts for control of key agricultural pests, including DBM (Barahona and Miranda 1990; Barahona 1990). In Honduras, Sánchez et al. (1990 a) and Moncada and Sánchez (1990) reported that aqueous extracts of neem provide effective control of DBM larvae (Fig. 3). These same researchers also found that the application of water extracts of onion, garlic and pepper, or old cabbage leaves reduced DBM larval populations somewhat compared to water only check.

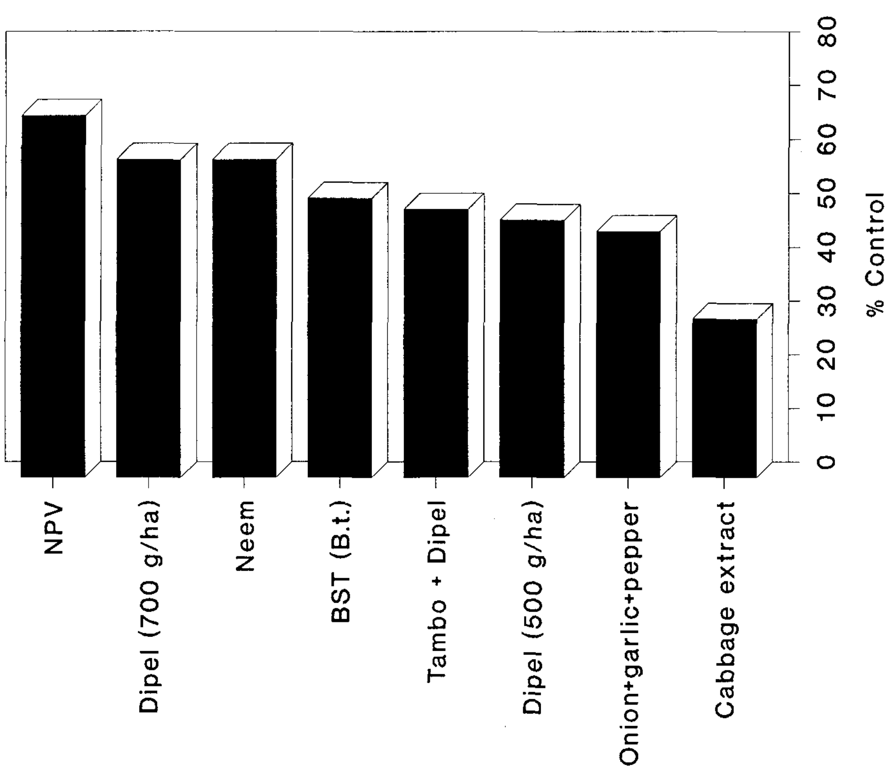

Fig. 3. Efficacy of microbial insecticides and botanical extracts for control of DBM in Honduran cabbage as compared to water only check (after Moncada and Sánchez 1990).

Chemical Control

Until recently, Honduran producers relied almost exclusively on synthetic insecticides for DBM control. Farmers applied on average six and ten times in the wet and dry seasons, respectively. Preferred products of the last 5 years such as fenvalerate, deltamethrin, cypermethrin, methomyl, carbaryl, methamidophos and mevinphos were shown by Portillo and Jimenez (1990), Navarro (1990), Mora and Secaira (1989), Moncada and Sánchez (1990), and Herrera and Secaira (1990) to be mostly ineffective in Honduras (Fig. 4). Tambo 440EC, a commercial mixture of cypermethrin (0.4 kg ai/ha) and profenofos (0.04 kg ai/ha), provided reasonable control and was sold until this year; it has now fallen out of favor with farmers. Costa Rican farmers make 16 calendarized applications (Carballo et al. 1989a). Most farmers

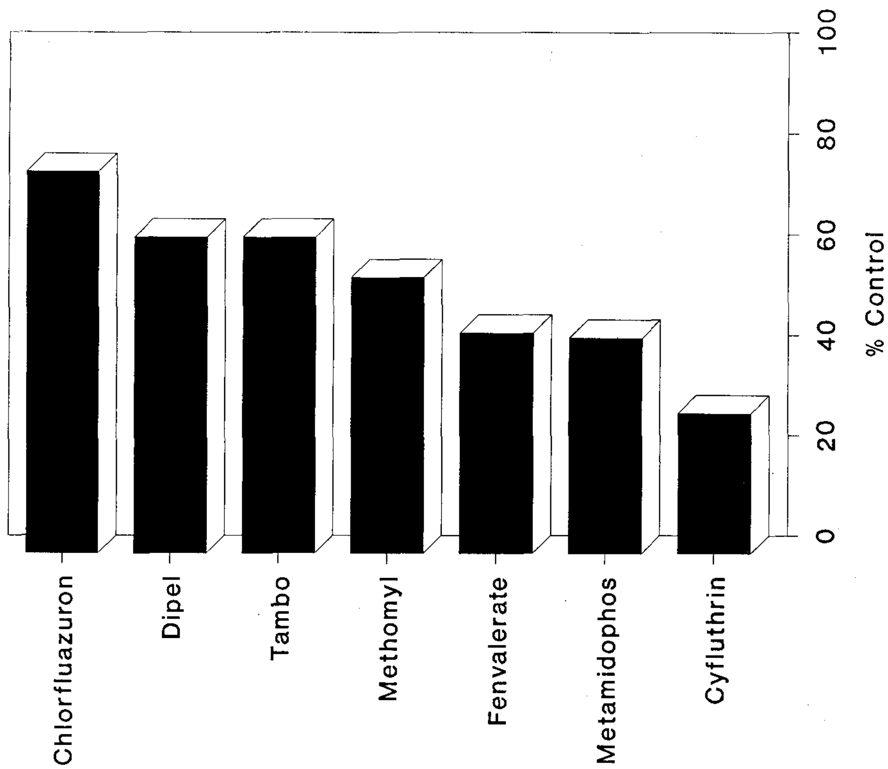

Fig. 4. Efficacy of synthetic insecticides for control of DBM in Honduran cabbage as compared to untreated check (after Moncada and Sanchez 1990).

apply using backpack sprayers and 300-400 l water/ha. Spraying during the afternoon gave the same control as at others times of the day (Chávez 1989). Mixtures of synthetic insecticides with microbials are increasingly common, as are rotations and tank mixes of *B. thuringiensis* and synthetic insecticides.

The current Zamorano extension program suggests that farmers should apply appropriate organophosphorus products until 20 days after transplant for DBM and cutworm control. Thereafter, we suggest preventive calendar applications of *B. thuringiensis* once weekly during the dry season and once every 2 weeks during the rainy season.

During the 1989 dry season and 1990 rainy season, Sánchez et al. (1990b) determined insecticide residues in 57 randomly selected lots of cabbage in Honduras. They detected 24 different insecticides mostly in trace quantities (Fig. 5); these residues appear to be low-level contaminants resulting from applications made in previous years. However, cypermethrin and chlordane residues averaged 5.5 and 4.3 ppm in the dry season, respectively. In the wet season these values dropped to 0.8 and 0.6 ppm, respectively. These unacceptably high residues are especially distressing considering that chlordane has not been registered for use on food crops for a decade. During the dry season 1990, residues of cypermethrin and chlordane on cabbage produced by farmers using the Zamorano IPM program were 0 and 0.3 ppm, respectively, while conventional farmers' cabbage contained 1.9 and 8.3 ppm. The high levels found cannot be explained as background contamination. Nor do the data support the idea that chlordane is being used consciously by a few misguided farmers since levels varied little from farmer to farmer. We are currently investigating the possiblity that a common commercial product has been adulterated during the formulation/distribution process. The Guatemalan broccoli export industry suffered a major setback in 1990 when the U.S. rejected large quantities of frozen broccoli found to be tainted by illegal residues of phenthoate.

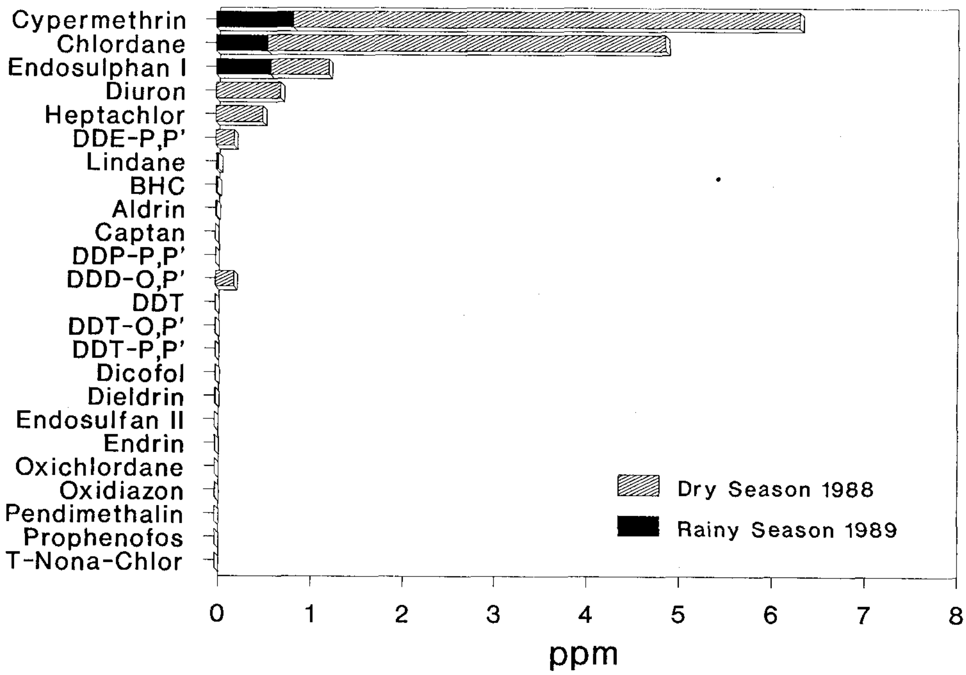

Fig. 5. Mean pesticide residues in cabbage taken from three principal Honduran markets in two seasons (Sánchez et al. 1990).

Bentley (1990), Bentley and Andrews (1990a, b) and Andrews and Bentley (1990) have discussed the pressures that lead to Honduran farmer's heavy reliance on agrochemicals for pest control. Primary factors include a crisis management mindset ("we fetch the pill when we have a headache"), a desire to be modern, and continuous pressure from technical people who either only believe in chemical control or who receive personal benefit when farmers use agrochemicals. Farmers are aware of the health risks they take when they use pesticides and perceive that pesticides induce new and exacerbate existing pest problems. They often explain pesticide treadmill problems as due to the result of adulterated products or the ability of salespersons to seed purchased inputs with pest inoculum.

Scouting and Supervised Control

King and Saunders (1984) stated that preventive insecticide applications are almost always necessary after head formation or when one larva is found in 10 plants. Andrews (1984) provided quidelines for sampling programs and action thresholds for cabbage, broccoli and cauliflower. In cabbage, weekly insecticide applications should be made to seedbeds. After transplant six larvae in 60 plants justifies an insecticide application. Vásquez and Secaira (1990) concluded that visual inspection of cabbage heads is an effective means of making management decisions. They concluded that 50 and 100 samples per homogeneous field provided unequivocal results in 64 and 78% of the cases, respectively; when the population was near the action threshold, sample size to make unequivocal decisions increased to unreasonable levels.

Farmers use various decision criteria to time applications (Ardon and Sánchez 1990c; Carballo and Hruska 1989). Risk-averse farmers and those wishing to minimize managerial time use calendarized sprays. Some farmers apply on the basis of a subjective appraisal of adult DBM population levels, and others evaluate total adult Lepidoptera populations (DBM, pierids and others).

Carballo et al. (1989b) tested in Costa Rica the usefulness of incremental damage levels (i.e. increases in foliar damage from one sampling period to the next) as decision criteria. The 10% new damage threshold provided the highest net income and reduced insecticide applications from 16 to 9 as compared to the calendar treatment.

Bentley and Andrews (1990b) and Andrews and Bentley (1990) questioned the utility of quantitative action thresholds for resource-scarce farmers with diverse economic portfolios. It seems that cabbage in Honduras is a situation in which precise sampling procedures are best considered irrelevant sacred cows of IPM ideologues. They will not be adopted for two reasons. First, they require quantitative sampling and record-keeping skills that farmers do not have, and time that can be better invested elsewhere. Second, the sharecropping arrangement means that all sampling chores fall to the junior partner, while savings accrue to the senior partner. With a strong move toward dependence on microbial insecticides well underway, the Zamorano group has rethought the action threshold concept, turning it on its head; simple scouting procedures should be used by farmers to determine if it is safe to cancel or delay a calendar application.

Cultural Control

Andrews (1984) listed eight cultural practices for DBM. Crop residue destruction has been widely promulgated; major benefits are obtained in management of plant pathogens but the effect on DBM and its parasitoids is not known.

The complex rotational schemes involving six or more crops and cycles of up to 7 years used by Honduran farmers (Ardon and Sánchez 1990a) are probably effective for minimizing soil pest and disease damage, but their role in reduction of DBM damage is not known. There is no basis for evaluating their effect on either DBM or parasitoid numbers.

Honduran farmers often use overhead irrigation systems. Mora (1990) compared DBM infestations in insecticide only plots with irrigated, unsprayed plots and irrigated plots receiving insecticide applications. Lowest DBM incidence and highest yield quality and quantity were obtained when irrigation and insecticides were combined.

Many Central American farmers and some researchers have studied intercrops (Guadamuz et al. 1990). Even in the best cases, intercropping does not appear to provide substantial reduction of DBM populations. The common recommendation to interplant tomato and cabbage is not promising as the former is generally grown at lower altitudes than the latter. Current interest in Honduras focuses on interplanting cabbage and garlic.

Marenco (unpublished data) found so few DBM in the wild plants *Brassica campestris* and *Lepidium* spp. that he concluded they are probably not important alternate hosts. The role of uncultivated host plants in maintenance of natural enemy populations is not known.

Host Plant Resistance

During 1988 and 1989, glossy lines developed by Mike Dickson and collaborators at New York Agricultural Experiment Station were compared in Honduras under farmers' conditions to nonglossy lines from the same source and to commercial hybrids (Mora et al. 1988). Glossy lines suffered much less DBM damage than the others, but at least some seemed to be highly susceptible to *Xanthomonas campestris* (Dowson). When outer leaves were removed, farmers and consumers felt that the glossy lines could meet market standards.

Present and Future IPM Programs for Central American Crucifers

The Zamorano IPM program places emphasis on simultaneous generation and implementation of technologies using methods that stimulate farmer participation and responsive science. While this approach is not a panacea any more than tech packs or farming systems were (Bentley and Andrews, 1990b), it has led to rapid popularization of implementable technologies. DBM management is being transformeed in Honduras and neighboring countries. However, reliance on microbial control is fragile and needs to be complemented with other procedures mentioned in this paper. Aphids, thrips and pierids become more important when synthetic insecticides are replaced by *B. thuringiensis*. Judicious use of existing tools is needed if more resistance problems are to be avoided. Socioeconomic reality should continue to be the focal point for all IPM work in poor tropical countries. Increasing international trade in the Caribbean Basin, social polarization, economic restructuring, and technological intensification are key processes that are rapidly transforming horticultural production and protection. IPM programs will make use of many technologies for DBM and other pests. Production of pesticide-free produce may be a feasible, lucrative undertaking. The Zamorano program wants to collaborate with other organizations that seek to rationalize pest management practices in crucifers and other crops grown in the tropics.

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