

# Management Approaches for Cruciferous Insect Pests in Central North America

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## Abstract

The primary insect pests of cruciferous crops in the midwest United States include root maggots, aphids, thrips and a complex of three lepidopterous larvae. Management of the pest complex has been based primarily on multiple insecticide applications and has resulted in the development of resistance in several pest species, pesticide residues on food, environmental contamination and worker safety problems. In 1987, the diamondback moth, *Plutella xylostella* (L.) caused widespread damage and could not be controlled effectively with conventional broad-spectrum insecticides. Resistance was confirmed in 1988 and 1989 and the most probable source of resistance was identified as resistant larvae imported on transplants grown in southern states. To combat annual importation of varying levels of diamondback moth resistance, a management program was implemented on eight commercial farms in Wisconsin. The program was based on reducing selection pressure on the whole pest complex by treating only at predetermined thresholds, which varied with plant growth stage, and promoting natural control by increasing use of specific bacterial insecticides. In the commercial fields treatment thresholds of 35% infestation with any species of lepidopterous larvae prior to cupping, 25% infestation during cupping and 15% during heading were implemented. An average of 2-4 applications of *Bacillus thuringiensis* Berliner var *kurstaki* for diamondback moth control followed by 1-2 late-season applications of a pyrethroid insecticide for cabbage looper were required and all fields were rated as 95-100% marketable, using fresh market standards, at harvest.

## Introduction

Cruciferous crops in the midwestern states of the U.S. are susceptible to damage by a wide range of insect pests. A relatively small complex of key pests occurs annually, however, and management of these pests is essential to meet the stringent marketing standards for damage- and pest-free produce. The key pests are the cabbage maggot *Delia radicum* (L.) (Diptera: Anthomyiidae), the cabbage aphid *Brevicoryne brassicae* (L.) (Homoptera: Aphididae), thrips *Thrips tabaci* (Lindeman) (Thysanoptera: Thripidae), and a complex of three lepidopterous larvae, the diamondback moth (DBM), *Plutella xylostella* (L.) (Lepidoptera: Yponomeutidae) (L.), the imported cabbage worm (ICW) *Artogea rapae* (L.) (Lepidoptera: Pieridae) and the cabbage looper, *Trichoplusia ni* (Hubner) (Lepidoptera: Noctuidae). All key pests are normally present annually and management of the complex has been based primarily on multiple applications of broad-spectrum insecticides. Such unilateral approaches to control have resulted in the repeated development of resistance (McEwen and Chapman 1952; Chapman 1960) in several pest species and subsequent control failures. In response to control failures, growers have habitually switched to newly registered insecticides which have generally provided effective control. In the past decade, however, the availability of new insecticides has become increasingly difficult to predict and, coupled with product withdrawals, cancellations and regulation based on toxicological or environmental standards, it has become important to retain the efficacy of existing materials.

In 1987, widespread control failures occurred with DBM in North America and this insect, which had hitherto been of relatively minor importance in northern growing regions, became the most destructive pest in the lepidopteran complex. Resistance of DBM to registered insecticides which had been widely reported from tropical and subtropical areas of the world (Sun et al. 1986) was found to be widespread in North America in 1988 (Shelton and Wyman 1990). In North America, resistance was most severe in southern states but isolated instances of high resistance were also detected in northern growing regions. The source of resistance in the northern states was shown by Shelton and Wyman (1990) to be primarily through importation of DBM larvae on transplants grown in the south. Shelton and Wyman (1990) also demonstrated close correlation of resistance levels in New York State with resistance in transplant (seedling) production areas in the south.

Since early season production of transplants is not practical in the midwestern states and resistance in the south is endemic, a situation exists whereby midwestern growers must manage highly variable levels of imported resistance annually on a field-by-field basis.

A resistance management program was thus established for Wisconsin growers and implemented in a series of large-scale experimental plots which were established with commercial growers in 1990. The program was designed to reduce selection pressure by crop monitoring and strict adherence to treatment thresholds, and to enhance naturally occurring biological controls by increasing use of specific bacterial insecticides.

## Materials and Methods

Eight experimental fields of commercial cabbage varying in size from 0.8 – 4 ha were established in southeastern and central Wisconsin. A resistance management program was implemented in each field (Table 1) to provide cooperating growers with control options that would reduce the potential for DBM resistance and provide effective control of all foliar pests. Fields were scouted weekly by random selection of 25-100 heads which were examined for lepidopterous larval infestation and the presence of other pests. For treatment of lepidopterous larvae, thresholds of 35% infestation prior to the cupping stage, 25% infestation during cupping and 15% infestation during heading, were used. These thresholds were lower than previously published thresholds (Shelton et al. 1983) to permit initiation of DBM control measures at lower population densities and to ensure high levels of marketability based on fresh market standards. A plant was classed as infested when a larva of any of the lepidopterous pests was detected. All species were considered equivalent in this program. Larvae were recorded by size, and pupae were counted but not included in determination of infestation.

Table 1. Field resistance management on cabbage in Wisconsin, 1990.

Pest situation	Recommendation
Early Season (April-June)	
(1) DBM or imported cabbage worm	Use <i>B. thuringiensis</i>
Mid Season (July-August)	
(1) DBM or ICW only	Continue <i>B. thuringiensis</i>
(2) Cabbage looper present	
a) cupping	Use organophosphorus insecticide
b) heading	Use pyrethroid insecticide
(3) Aphid or thrips present	Use organophosphorus insecticide
Late Season (Sept.-Oct.)	
(1) Any Lepidoptera on heads	Use pyrethroid
(2) Thrips or aphids present	Use organophosphorus insecticide

In the resistance management program (Table 1), the growing season was divided into three time periods, early, mid and late. Since transplanting dates varied between fields from early May to late June, the time of occurrence of pest species relative to the stage of plant growth also varied. In general, however, for a field transplanted in mid May, the early season pests were exclusively DBM in these studies with very few ICW detected. In order to reduce selection pressure from broad-spectrum insecticides, only *B. thuringiensis* (*B. thuringiensis*, MVP or Javelin at 5.2 l/ha) was recommended during early season. Previous studies (Quick 1984) have demonstrated that DBM is heavily parasitized in Wisconsin in untreated plots (83% over 3 years, 1981-84) and that *B. thuringiensis* did not markedly disrupt parasitization levels (57% over 3 years). Early season adherence to *B. thuringiensis* treatments for DBM was thus utilized to promote development of naturally occurring biological control agents. ICW, which can also infest cabbage during early season in Wisconsin and are also susceptible to *B. thuringiensis* treatment, were only detected in these trials at low levels.

In mid season the management program recognized three options depending on the pest situation. If only DBM or ICW were detected the *B. thuringiensis* regime was continued to further promote biological control. If cabbage looper, which is not as effectively controlled by *B. thuringiensis*, was present, a broad-spectrum control was recommended, with an organophosphorus insecticide used during cupping (methamidophos) and a pyrethroid (esfenvalerate or permethrin) used during heading. Other pest species commonly occur during mid season (July-August) and a short persistence organophosphorus insecticide was recommended for thrips or aphid control at this stage to reduce selection pressure on DBM.

During late season, all fields were in the heading stage and could be harvested at any time as dictated by marketing strategies. Pyrethroids were recommended at this stage for all Lepidoptera to provide damage-free produce at harvest. Organophosphorus insecticides were retained for late season thrips or aphid infestations.

At harvest 100 heads/field were rated for damage on a 1-6 scale of increasing damage with 1 representing no feeding on the head or four wrapper leaves, 2 and 3 representing increasing but slight wrapper leaf damage, and 4,5 and 6 representing increasing head damage. All heads with a rating of 3 or below were considered marketable according to fresh market standards.

At the conclusion of the trials adjacent fields, which were treated using the grower's standard program, were compared for insecticidal inputs and marketability.

## Results

Although the level of pest infestation varied between the eight trial fields, the pattern of infestation through the season was similar. All fields were infested early with DBM, with infestations increasing to above threshold levels during the precupping period. Two to three applications of *B. thuringiensis* were generally extremely effective in reducing DBM populations to subeconomic levels with MVP and Javelin both providing good control. ICW infestation occurred sporadically and did not reach damaging levels in any fields. *Bacillus thuringiensis* applications were effective in controlling ICW where infestation did occur.

Cabbage looper populations were high in all fields in mid to late season with infestations occurring in late July and August. One to two applications of esfenvalerate provided excellent control.

Aphids were not present in any of the test fields. Thrips did occur in several fields at damaging levels, however, and although parathion was applied, effective control was difficult to achieve.

Damage ratings at harvest were generally excellent with 95-100% marketable produce in all fields. The only loss in marketability resulted from thrip infestation on susceptible varieties.

Survey information is provided for two fields in Tables 2 and 3 to illustrate lepidopteran infestation patterns and efficiency of management actions.

In the Pfeffer field (Table 2) in Racine, Wisconsin, DBM infestation was detected early and by 21 June, the precupping threshold was surpassed and MVP was applied on 23 June.

Table 2. Management of lepidopterous larvae on cabbage, Pfeffer Farm, Racine, Wisconsin, 1990.

Survey date	Heads sampled	% infested	Total lepidopterous larvae/100 head <sup>a</sup>											
			DBM			Cabbage looper			Imported Cabbage worm					
			Small larvae	Large larvae	Pupae	Small larvae	Large larvae	Pupae	Small larvae	Large larvae	Pupae			
14 June	100	33	27	10	1	0	6	1	0	0	0	0	0	0
21 June	100	42	31	33	1	0	35	1	0	0	0	0	0	0
27 June	100	6	3	3	3	1	34	1	1	0	0	0	0	0
6 July	100	14	13	2	2	1	9	1	1	0	0	0	0	0
11 July	50	58	60	20	0	4	18	0	4	0	0	10	4	0
18 July	25	4	0	4	0	0	24	0	0	0	0	0	0	0
25 July	100	1	1	0	0	0	12	0	0	0	0	0	0	0
31 July	100	9	0	0	0	13	5	1	1	0	0	0	0	0
7 Aug	50	18	0	0	0	10	2	12	12	0	0	0	2	0
17 Aug	50	0	0	0	0	0	0	0	0	0	0	0	0	0
24 Aug	50	0	0	0	0	0	0	0	0	0	0	0	0	0
31 Aug	50	0	0	0	0	0	0	0	0	0	0	0	0	0

<sup>a</sup>B. thuringiensis (MVP 5.2 l/ha) applied 23 June, 15 July; Pyrethroid (esfenvalerate 0.07 kg AI/ha) applied 8 August.

Table 3. Management of lepidopterous larvae on cabbage, Hartung Farm, Arlington, Wisconsin, 1990.

Survey date	Heads sampled	% infested	Total lepidopterous larvae / 100 head <sup>a</sup>											
			DBM			Cabbage looper			Imported Cabbage worm					
			Small larvae	Large larvae	Pupae	Small larvae	Large larvae	Pupae	Small larvae	Large larvae	Pupae			
2 July	100	19	12	10	8	1	0	0	0	0	0	0	0	0
9 July	100	63	35	53	76	0	2	0	0	12	0	12	0	0
16 July	50	40	18	24	138	1	0	0	0	0	0	0	2	9
23 July	30	17	3	17	53	3	0	0	0	0	0	0	0	0
30 July	33	58	3	9	22	64	9	0	0	3	0	0	0	0
6 Aug	25	60	4	0	4	92	40	0	0	0	0	0	4	0
13 Aug	25	24	0	0	8	12	8	0	0	8	0	0	0	0
23 Aug	25	0	0	0	0	0	0	0	0	0	0	0	0	0
30 Aug	25	12	0	0	0	4	8	0	0	0	0	0	0	0

<sup>a</sup>*B. thuringiensis* 5.2.1/ha applied 12 July, 20 July; Pyrethroid (esfenvalerate 0.07 kg AI/ha) sprayed 30 July, 6 August.

The treatment was highly effective in reducing larval levels but pupae were not affected and a high population of small larvae was produced by the emerging adults necessitating a second MVP spray on 15 July. When plants were in the heading stage, cabbage looper infestation increased to threshold levels and esfenvalerate was applied on 8 August. Control was effective and no further treatments were necessary in this field and 100% marketable heads were produced at harvest. The three-spray regime was as effective as the standard grower practice of 4-5 regular sprays of broad-spectrum materials.

At the Hartung farm in Arlington, extremely high populations of DBM occurred early in the season (Table 3), with 63% infestation on 9 July. MVP was applied on 12 July and although infestation was reduced to 40%, cabbage was in the cupping stage and a second application was made on 20 July which reduced infestation to 17%. Cabbage looper infestation increased suddenly in early August and two applications of esfenvalerate (30 July, 6 August) were required to reduce populations below the heading threshold of 15%. The Arlington field was planted to a kraut cabbage variety with extremely large frame leaves, and insecticidal coverage was poor, accounting for the slow response of looper populations to the pyrethroid applications.

Although relatively large populations of cabbage looper were present during heading, damage was confined largely to frame leaves and 100% marketability was achieved. This level of control was superior to the grower standard practice which utilized two methamidophos applications and two pyrethroids and achieved only 92% marketability.

## Discussion

The resistance management program was successful in providing excellent levels of marketability. Early season reliance on *B. thuringiensis* was effective in DBM management in all cases. As plants increase in size and begin cupping, however, pesticide coverage becomes increasingly important. This is particularly evident under dry conditions. The use of only *B. thuringiensis* for DBM control in early to mid season will also promote establishment of DBM parasites which are extremely effective natural mortality factors.

Recent reports of resistance to *B. thuringiensis* in DBM (Tabashnik et al. 1990; Shelton and Wyman 1990) raise concerns regarding the continued effective use of *B. thuringiensis* as a tool to promote natural control and reduce selection pressure from broad-spectrum insecticides. In Shelton and Wyman's survey of *B. thuringiensis* resistance in southern states, however, such resistance was not uniformly distributed among transplant production areas. The importation of *B. thuringiensis* resistance to the north could thus be expected to be sporadic and vary with time and location. Careful field scouting and strict adherence to thresholds to reduce exposure to a minimum would be effective in delaying resistance development to *B. thuringiensis*. The utilization of rapid in-field resistance screening techniques would also help in selecting management options.

The continued use of specific materials such as *B. thuringiensis* is critical in the management of resistance to conventional insecticides, which is present at higher levels and is more widely distributed. The integration of biological control, cultural control, host plant resistance and other management techniques will play an increasingly important role in resistance management for all cruciferous pests in the future.

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