Potential Impact of Pyrethroid Resistance in *Helicoverpa zea* to the Midwest Processing Industry: Sweet Corn and Snap Beans

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Abstract

Midwest food processors are well positioned to avoid major crop losses, and product contamination resulting from pyrethroid resistance in corn earworm (CEW), *Helicoverpa zea* (Boddie). However, we do recognize risks associated with late-season plantings, particularly for sweet corn and snap beans. CEW usually migrate into the production areas by late July to mid-August. Crops at risk for most Midwest locations primarily include sweet corn planted after 10 June and snap beans planted after 10 July (about 25% of the Midwest acreage). Pyrethroid insecticides continue to be the commercial standard, with alternative chemistries either ineffective or more expensive. The CEW "treatment window" for sweet corn is from row tassel to dark brown silk and, for snap beans, from bloom to 10 days before harvest. In sweet corn, CEW is only vulnerable as an adult, egg, or early instar feeding on the silk. If left untreated, or with insecticide failure, we anticipate a loss of about one square inch of kernels per larva (2 cases/ton of final cut-corn product). The loss of kernels and the creation of black kernels from contamination associated with feeding injury are estimated to have a market cost in excess of $100/acre, or $6 million for Midwest sweet corn and snap beans. We currently have no effective alternative insecticides for CEW for either crop. In the short term, processors will likely use higher rates of pyrethroids, shorter intervals, and/or additional treatments. Long term, we will increasingly rely on a "process-out" approach to husk out, wash out, and vision-sort larval contaminants and damaged kernels.

Introduction

Pyrethroids are the commercial standard for control of corn earworm (CEW), *Helicoverpa zea* (Boddie), in sweet corn and snap beans in the Midwestern US (12). The broad spectrum of control, reduced active ingredient per acre, economical price, and high efficacy against CEW and other pests resulted in their rapid adoption and use since the late 1980s (5,6,8). However, since 2001, reports of CEW pyrethroid resistance in small-plot research trials have become common (8). To date, commercial growers of sweet corn and snap beans in the Midwest have not experienced crop failure as a result of resistance issues, but have had to make adjustments in rates and timing to match fluctuating pest populations. Unfortunately, alternative insecticides currently available have not demonstrated better control and are significantly more expensive (12).

Most CEW that migrate to the sweet corn and snap bean processing areas of the Midwestern US (north of 42°N latitude) either do not have time to complete pupation to facilitate adult emergence or are not known to survive the winter at these latitudes (9). Thus, pest management activities in the northern Midwestern states will likely have little impact on the CEW levels of resistance. Light-trap data for some southern locations in the Midwest do indicate the possibility of reverse migrations in the fall (Flood, unpublished), but the extent and significance has not been determined.
In this paper, we develop a plan to manage CEW in the Midwestern US by reviewing CEW migration patterns and the use of the "treatment window" within an integrated pest management (IPM) context (2,5). We also discuss options currently available to manage CEW and pest damage on processing crops.

**Corn Earworm Migration and Management**

State departments of agriculture, university personnel, and the Midwest Food Processors Association have a long-term cooperative monitoring network for CEW and other moth pests. Network data are summarized graphically on the VegEdge website [www.vegedge.umn.edu (7)], and are also distributed via the Minnesota Fruit and Vegetable Newsletter (7). The system aids in disseminating CEW flight activity at several locations in the Midwestern US, but currently lacks a national scope. Several vegetable insect pests in the Midwest region annually migrate to vegetable crops, including CEW (5).

The first edition of the book *Vegetable Insect Management* (4), published before the introduction of genetically modified (GM) field crops, recapped decades of pheromone and black light trap data as indicators of migration patterns and re-infestation potentials for CEW and other pests. Treatment frequency and insecticide rates were adjusted to the nightly trap catch results. The IPM programs discussed in the book are still valid. However, the second edition of this book (5) highlighted the impact of GM field crops on ECB populations — specifically, an apparent region-wide suppression effect in several Midwest states (2). GM crop impacts on CEW were not highlighted in the book (5). Some recent trends are reviewed here. Corn earworm trap catch results from 1958 to 2006 have been annually consistent with respect to timing of occurrence (2). However, when the top 12 CEW Midwest migration events (highest moth catch densities) in the 58-year data base were examined, none of these events occurred after 1985 (10). Pyrethroid insecticides were introduced to southern field crops during this period and, since the southern US is considered the primary source area for Midwest CEW immigrants, the improved control of CEW in the South could be partially responsible for the reduced flights into the Midwest. Moreover, since 1996, the introduction and high adoption rates for GM cotton transformed to express various *Bacillus thuringiensis* (Bt) proteins toxic to CEW has significantly reduced CEW flights in some southern states, including Mississippi (1). Although most Bt cotton to date (e.g., Bollgard I) is not known to provide complete control of CEW, the use of Bt cotton on about 45 to 70% of the southern cotton acreage as of 2005 (depending upon the state) may have also contributed to reduced regional source populations (1). That said, CEW infestations in other southern crops (e.g., field corn, sorghum, and soybean) result in continued pyrethroid use and selection pressure (11). The potential loss of pyrethroids as a large-area population suppression tool in the South, given a current lack of alternatives, could create larger, more damaging populations in the Midwest.

**Defining the Treatment Window**

Insect pest management throughout much of the US can be managed around winter weather (5). As noted in recent reviews, CEW is one of several insect pests in North America that is only known to overwinter as pupae south of 40°N latitude (2,9,10). Above this latitude, the CEW can only colonize crops by migrating north each year, from the southern US and/or Mexico, from source regions south of the freeze lines (9,10). Despite the overwintering barrier, CEW successfully migrates north each year to the Midwest region from several southern states (6,9,10), although its arrival in the upper Midwest does not occur until late July to early August (8).

Once CEW arrives, as indicated by moth catches in pheromone or light traps (2,8), specific treatment windows for sweet corn and snap beans can be used to further optimize control programs. The sweet corn treatment window was developed by reviewing the results of multiple insecticide application timing scenarios for commercial treatment programs at several Midwest production plants over a 10-year period (Fig. 1). The harvest results of the commercial programs determined the growth stage (instar) for both CEW and European
corn borer (ECB); percentage control was calculated based on the mid- and late-
instars surviving in the treated and untreated plots. Larval instar and heat unit
accumulations were used to determine when the insects infested the field. The
dates were cross-referenced to trap catches and insecticide treatment scenarios.
In addition, small-plot ground trials designed to assess the value of each
treatment were conducted over multiple years. Although the analysis includes
both CEW and ECB, we have found the relationship works well for both pest
species. Following this analysis, we can see that the most efficacious control
occurs at approximately 28 days before harvest during "row-tassel" and early
silk stages (5). Using similar field trial results during 1978-2005, a treatment
window has also been developed for CEW in snap beans by placing CEW eggs on
snap beans from 50 to 7 days before harvest (3,6). Percentage survival and pod
contamination were determined for each infestation date to develop the
treatment window. Field monitoring and pest management programs validated
the approach. The treatment window for snap beans is from bud stage (about 26
days before harvest) to 10 days before harvest. Corn earworm control is best
achieved by cleaning existing infestations as pyrethroid programs lack adequate
residual control of the adults or larvae (3,6).

**At-risk Acres**

In the Midwest, processing vegetables that are susceptible to CEW are
planted from April to August. Given the usual arrival of CEW migrants from the
South in late July to August, the primary risk of infestations include sweet corn
planted after 10 June and green beans planted after 10 July. As CEW arrive
when the majority of crops are beyond the treatment window, only 25% of the
250,000 Midwest acres of sweet corn and 20% of the 108,000 acres of green
beans are at risk. Snap beans and sweet corn are at a higher risk south of 42°N
latitude. Processors reduce the risk by planting only the early and late season
crops in this area. The first crop will be at a 50% risk and the second crop will be
at 100% risk. The attractiveness of the upper Midwest to extend the production
season will be in jeopardy. The loss in production will be significant.

CEW damage to sweet corn and loss estimates are summarized in Fig. 2. The
processing companies cannot tolerate these losses, but will make adjustments in
the insect control program (Table 1). These pest management adjustments will
add costs to production, but until total resistance occurs, will reduce the loss in
production and marketable product. Increased use of pyrethroid insecticides in
the Midwest will not impact national CEW populations, as the insect does not
overwinter throughout most of the production area (2). Analysis of several years’
trap data indicates a proportion of the Midwest CEW population can disperse
southward in September (Flood, unpublished data). However, the degree to
which these moths find suitable hosts to overwinter is unknown. As noted in Table 1, new resistance management programs will require major alterations and require us to refocus more effort to this problem. The failure of control materials will require a shift in production areas to avoid the risk. Moving more sweet corn production to the Pacific Northwest would be one option to consider, as populations tend to be more local and not subjected to extensive pyrethroid pressure (unpublished data). A second option would be to plant more crops early and process more crops in shorter harvest intervals to avoid the late-season losses. However, capital costs for either option would be extensive and result in increased inefficiencies and fixed overhead costs.

Table 1. Short-term and long-term options for the Midwestern processing industry, in response to pyrethroid resistance in *H. zea*.

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<tr>
<th><strong>Current short-term CEW management options: Modify pyrethroid use</strong></th>
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<tr>
<td>• Increase rate of pyrethroid (+ $2.50/acre per application for 2 to 4 applications)</td>
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<tr>
<td>• Shorten interval and add a treatment (+ $10/acre during Treatment Window)</td>
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<tr>
<td>• Different chemistry or tank mixtures (e.g., Lannate + $20 to $40/acre per program)</td>
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<tr>
<td>• New application technology (+ $40,000 per aircraft)</td>
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<tr>
<td>Impact: Added average cost to the Midwest at-risk acres = ~ $10 to $20/acre (short-term cost increase = $900,000 for sweet corn and $300,000 for snap beans)</td>
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<th><strong>Long-term CEW management options</strong></th>
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<td>• Reallocation of current production acres to manage risk to less at-risk areas</td>
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<td>• Utilize resistant varieties or varieties adapted to low risk areas</td>
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<tr>
<td>• Modify pest management control tactics</td>
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<td>• Assist in registration of new pesticides and resistance management programs</td>
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<tr>
<td>• &quot;Process out&quot; the contamination</td>
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**Note:** *Bt sweet corn is not an option for processing crop industry* (12).

Subsequently, assuming the current trends for pyrethroid resistance continue (8), new IPM and resistance management strategies will be needed for the industry to remain viable in the Midwest region. The failure of control materials will require a shift in production areas to avoid the risk. If suitable alternatives cannot be located, the production season would be shortened. Another management option would be to utilize sweet corn varieties with more tip cover (conventional breeding) to provide more protection of the kernels. Although Bt sweet corn is effective (12), it is not an option for the processing industry. The Midwest Food Processors Association have a long-term working relationship with IR-4 Minor Crops Registration Group, EPA, and the agrichemical industry and will assist in the evaluation, development, and
registration of new insecticide materials that meet EPA standards for environmental, safety, and efficacy standards. GM crops have reduced agrichemical industry research into development of new products and this could continue to be an issue.

The primary advantage of sweet corn processing is the ability to process out larval contaminants (Figs. 3 to 6). Prior to the introduction of pyrethroid materials we lacked suitable CEW insecticide control options. Equipment was subsequently developed to clean up raw product after harvest. We will still suffer the loss of kernel damage, but we are still able to process the sweet corn. Primary tools include sweet corn huskers that spin out CEW larvae during husking, and two long rubber rollers rotating at high speeds; the rollers grasp the husk leaves and pull them off the ear. In the process, the ear is also spinning and CEW larvae are readily spun off. A third essential tool is the Olney Floatation Washer (Fig. 3) that utilizes starch bubbles in a tank. Corn kernels will sink while small bubbles become attached to the CEW larval spines and float the larvae out in the waste stream.

In snap beans, CEW can reduce yields and pod quality (Fig. 6). However, unlike ECB, where larvae spend considerably more time boring into pods, the CEW larva is a surface feeder in snap beans and is a production risk primarily by reducing pod weights and subsequent marketable yield (3). In untreated small plots trials, the numbers of beans per untreated plot infested by CEW have been reduced by 50% due to larval feeding on the pin beans and small beans (unpublished data). Thus, the primary post-harvest tool will continue to be processed out using state-of-the-art vision sorters (Figs. 4 and 5).
In summary, the Midwest processors will manage the CEW threat and make the necessary business decisions to manage the pest. Corn earworm resistance will likely be a reality for several years, and we will plan for it. The development and registration of new control tools will be a primary focus, and these tools will be part of an IPM approach. We will have both added losses and added costs associated with resistance. We may face significant losses in damaged kernels and beans but will not subject our customers to the damage by using "process-out" methods. Corn earworm management will demand a more global approach to a local problem and a local approach to a global problem. For additional information, refer to *Vegetable Insect Management* (5).

**Literature Cited**


