Monitoring and Control of European Corn Borer, *Ostrinia nubilalis* (Lepidoptera: Pyralidae), on Bell Peppers in Ohio¹

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**ABSTRACT** Field studies were undertaken to document pod infestation by European corn borer (*Ostrinia nubilalis*) during the harvest season, to evaluate timings of insecticide applications, and to evaluate whether monitoring populations in traps is an appropriate basis for timing insecticide applications. Over a three year period at several locations, acephate was sprayed on 5-d to 14-d schedules, and pepper pods were evaluated during periodic harvests. Damage by *O. nubilalis* was usually highest in the first two harvests, when as few as 36% of the pods were undamaged in untreated plots. Later harvests were less affected by *O. nubilalis* but were sometimes infested by fall armyworm (*Spodoptera frugiperda*) or corn earworm (*Helicoverpa zea*). In 1990, when *O. nubilalis* populations were moderate in size, fewer infested pods and higher yields were found in plots treated on a 7-d schedule than on a 14-d schedule. In 1991, when populations were exceptionally high, damage was high even in plots sprayed every 7 d. In 1992, when populations were low to moderate, damage was light and no yield advantage resulted from a variable 5- to 10-d schedule versus a 7-d schedule. A 7-d schedule was suitable in years with average *O. nubilalis* activity, starting when blacklight traps consistently caught one or more moths per night. Pheromone traps appear to be an acceptable alternative to blacklight traps, but a pheromone-based threshold has not yet been tested. Management of European corn borer on peppers in Ohio must be supplemented in the later part of the season by management of fall armyworm and corn earworm.

**KEY WORDS** Peppers, Lepidoptera, Pyralidae, *Ostrinia nubilalis*, acephate, blacklight traps, pheromone traps

Production of peppers (*Capsicum annuum* L.) in Ohio expanded in the early 1990s, reaching 440 ha (1,100 acres) valued at $4.9 million in 1991. Much of the new acreage is planted with red bell peppers for the processing market and the remainder with green or red bell peppers for the fresh market. Red bell peppers are grown to full maturity when their red color and sweet flavor increase their value.

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Because processors have near-zero tolerance for insect-contaminated peppers, growers are acutely aware of the need to effectively manage European corn borer, *Ostrinia nubilalis* (Hübner) (Lepidoptera: Pyralidae), which is the key pest of peppers in the midwestern USA.

Eggs of *O. nubilalis* are laid on the underside of pepper leaves and hatch in three to seven days. Within two to twelve hours after egg hatch, larvae enter pods by boring near the calyx. Larvae can also bore into stems and branches causing limb breakage. In Ohio, the first generation is active in June and usually does not attack peppers because at that time, pepper plants are small, do not yet have pods, and are less attractive than corn as a mating and egg-laying site for *O. nubilalis*. The second generation is active in August; in hot years, there may be a third generation in September. The second and third generations attack peppers because maturing corn is less attractive to *O. nubilalis* than peppers in late summer. Infestation of *O. nubilalis* larvae in peppers becomes apparent three to five weeks after peak captures of male and female moths in blacklight traps (Elliott et al. 1978).

*O. nubilalis* larvae in peppers are difficult to control with insecticides because they are exposed to sprays or residues for a short time before they bore into and are protected by the pod. Pepper growers use a protective management strategy for control of larvae by applying insecticides, with particular attention to covering the calyx end of pods. In the 1960s and early 1970s, the standard insecticide treatment for control of this pest on peppers was carbaryl or DDT applied every 3 days (Sleesman 1973). Since the mid-1970s, acephate has been commonly used; studies in Ohio showed excellent control of *O. nubilalis* with acephate used on a 5 to 8-d schedule (Sleesman 1974), a 10-d schedule (Sleesman 1975), and even on a 14-d schedule (Ladd et al. 1982). The standard practice currently in use is to apply foliar sprays of acephate, permethrin, or methomyl with a hydraulic boom sprayer weekly until harvest. Granular carbofuran was commonly used on peppers as a soil treatment until 1991, when a registration change restricted its use.

Ohio pepper growers interested in maximizing control of *O. nubilalis* but minimizing use of insecticides are seeking information about the appropriate time to start and stop spraying for *O. nubilalis* control and the best interval between sprays. A practice currently recommended for peppers in some areas is to begin insecticide treatment on a 7-d schedule once blacklight trap captures of *O. nubilalis* average five or more moths per night (Ghidiu 1992) or four or more female moths per night for three consecutive nights (Showers et al. 1989). Improvements in pheromone trapping techniques for *O. nubilalis* indicate that pheromone traps may be a suitable alternative to blacklight traps for use in pest management programs (Fletcher-Howell et al. 1983).

This study was undertaken to document pepper pod infestation by *O. nubilalis* during the harvest season, to evaluate various options for timing insecticide applications on peppers, and to evaluate blacklight and pheromone traps for monitoring Ohio populations of *O. nubilalis*. 
Materials and Methods

**Study locations.** All experiments were conducted on Ohio State University research farms. Pepper plots were established at Columbus, in central Ohio, in 1990 and 1991; at Fremont, 160 km north of Columbus, in 1990 and 1992; and at Piketon, 120 km south of Columbus, in 1992. Moths were monitored at all sites where pepper plots were established, as well as at Fremont in 1991 and in Columbus in 1992.

**Trapping.** Adult populations of *O. nubilalis* were monitored with electric blacklight traps and pheromone traps from May until October. One blacklight trap (O. B. Enterprises Inc., Oregon, WI) per site was placed adjacent to farm buildings about 100 m from pepper plantings. Blacklight traps were emptied four to seven days per week.

Pheromone lures were placed in large cone-shaped traps made of plastic mesh ('Heliotis trap', Scentry Inc., Buckeye, AZ); cone traps have been shown to be superior to sticky cardboard traps for monitoring *O. nubilalis* (Webster et al. 1986). The 'Iowa' blend of pheromone components for *O. nubilalis* was supplied by Scentry Inc. (Buckeye, AZ) in 1990 and by Trécé Inc. (Salinas, CA) in 1991 and 1992. Previous studies showed that lures with the 'Iowa' blend (Klun et al. 1973) were more effective than the 'New York' blend (Kochansky et al. 1975) in five Ohio locations tested (C. W., unpublished data). The number of pheromone traps used per site was one in 1990 and 1991, and three in 1992. Traps were placed along the edge of pepper plantings. Traps were emptied weekly and lures replaced every four weeks.

**Experimental design.** In all plantings, four replicates of each treatment were arranged in a randomized complete block design. Pepper cultivars used were 'Resistant Giant 4' in 1990, 'Merced' in 1991, and 'North Star' in 1992; each of these was common in commercial fields that year. Peppers were transplanted on 24-25 May 1990, 17 May 1991, 26 May 1992 at Fremont, and 17 June 1992 at Piketon. Foliar spray treatments were applied in 380 to 475 liters water per ha (40 to 50 gal/acre) with hollow cone nozzles at a pressure of 4.2 to 5.5 kg/cm² (60 to 80 lb/in²) delivered by a tractor-drawn hydraulic boom sprayer. Plot dimensions are specified below for individual sites.

Fully ripe red pods were harvested at 2 to 3-week intervals from the center two rows per plot. At the final harvest, scheduled just before the first predicted frost, green pods over 5 cm wide also were harvested. Pods that were too rotten to pick were not harvested. Harvested pods were counted, weighed, cut open, and rated for damage and presence of *O. nubilalis*. Presence of fall armyworm, *Spodoptera frugiperda* (Smith), and corn earworm, *Helicoverpa zea* (Boddie) (Lepidoptera: Noctuidae), in pods also was recorded.

Harvest data were subjected to analysis of variance (ANOVA) and means were compared by orthogonal contrasts using the JMP microcomputer program (SAS Institute 1989). Individual harvests were analyzed separately, and red pod harvests were also summed over each season and analyzed as a cumulative harvest. Percentage data were transformed by arcsine \((x^{0.5})\) before analysis to prevent variances from being a function of means (Sokal & Rohlf 1981).
Insecticides and rates. Acephate (Orthene 75S [soluble powder], Valent U.S.A. Corp., Walnut Creek, CA) was used at two rates: 1.12 kg product per ha (1.0 lb/acre) is referred to here as the low rate, and 1.46 kg/ha (1.3 lb/acre) as the high rate. Carbofuran (Furadan 15G [granular], FMC Corp., Philadelphia, PA) was used at two rates: 149 g product per 100 linear m of row (1.0 lb per 1,000 linear ft) is referred to here as the low rate, and 209 g per 100 m (1.4 lb per 1,000 ft) as the high rate.

Treatments, 1990. Different schedules of insecticide application were compared in four treatments: high intensity, low intensity, intermediate intensity, and an untreated control. In high intensity plots, carbofuran was sidedressed at the low rate 2 wk after planting and at the high rate 6 wk after planting. In high intensity plots, acephate was sprayed 4 wk after the second carbofuran application then every 7 d until mid-September, for a total of seven sprays. In low intensity plots, carbofuran was sidedressed at the low rate 4 wk after planting and at the high rate 10 wk after planting. In low intensity plots, acephate was sprayed 4 wk after the second carbofuran application then every 14 d until mid-September, for a total of two sprays. In the intermediate intensity treatment, plots were not treated with carbofuran but were sprayed with acephate every 14 d starting in late July, which was when catch of O. nubilalis in blacklight traps increased to consistently ≥1 moth per night. Intermediate intensity plots were sprayed four times at Fremont and five times at Columbus. In low intensity plots, acephate was used only at the low rate. In high and intermediate intensity treatments, the first acephate applications were at the low rate; the high rate of acephate was then used, starting in early August in Columbus and in late August at Fremont. Control plots were not treated with insecticides. At Fremont, plot size was 3.6 m by 4.8 m with four single rows per plot. At Columbus, plots were 3.0 m by 7.5 m with two twin-row beds per plot.

Treatments, 1991. Acephate sprayed every 7 d versus 14 d was evaluated again at Columbus but without the added factor of carbofuran applications. Carbofuran was deleted due to a registration change in early 1991 that restricted it to one application at planting at a rate of 75 g 15G product per 100 m of row (8 oz per 1,000 ft) for aphid control; this low rate was unlikely to control O. nubilalis. Pepper plots were treated with acephate at the high rate on three schedules, starting once O. nubilalis catch in the blacklight trap was consistently ≥1 moth per night. The high intensity plots were sprayed every 7 d for a total of 15 sprays, and the low intensity plots were sprayed every 14 d for a total of 8 sprays. The variable intensity plots were sprayed every 14 d when the blacklight trap was catching 1 to 5 moths per night, or every 7 d when the trap was catching > 5 moths per night. Variable intensity plots were sprayed 11 times. An untreated control treatment also was evaluated. Plot size was 3.0 m by 6.0 m with two twin-row beds per plot.

Treatments, 1992. Three treatments were evaluated at Fremont and Piketon in plots that were larger than in the previous two years. Plot size was 7.5 m by 15.0 m at Fremont with five twin-row beds per plot; plot size was 7.2 m by 12.0 m at Piketon with eight single rows per plot. In the untreated control treatment, no insecticides were used. In both the high
intensity treatment and the variable treatment, acephate was applied starting once pods were present and *O. nubilalis* catch in the blacklight trap was consistently ≥ 1 moth per night. The first treatments were in early July at Fremont, at the end of the first flight, and in late July at Piketon, at the start of the second flight. In the high intensity treatment, acephate was applied on a 7-d schedule. In the variable treatment, peppers were treated with acephate on a 10-d schedule when there were 1 to 5 moths per night in blacklight traps, or on a 5-d schedule when there were > 5 moths per night. Acephate in Fremont was applied at the low rate until mid-August and at the high rate thereafter; only the high rate was used at Piketon. Due to low moth catches in traps at Piketon, the threshold for the 5-d spray schedule was modified to 4 moths per night in the blacklight trap. At Fremont, both treatments were sprayed 10 times. At Piketon, there were 9 sprays in high intensity and 10 sprays in variable intensity treatments.

**Results**

**Pest species.** The predominant pest infesting harvested pepper pods was *O. nubilalis*, but *S. frugiperda* and *H. zea* were also important at times. An unidentified species (Lepidoptera: Tortricidae) was occasionally found in pods. In Columbus in 1990, *O. nubilalis* predominated in the first harvest, but equal numbers of *O. nubilalis* and *S. frugiperda* were found in the second harvest; *S. frugiperda* predominated in the remaining harvests, although mixed with substantial numbers of *H. zea* in the final harvest (Fig. 1). In 1991, *O. nubilalis* predominated in all harvests at Columbus (Fig. 1); *S. frugiperda* was present throughout the season and accounted for 6% of larvae found, while *H. zea* was present in the last three harvests and accounted for 5% of larvae found. In 1992, *O. nubilalis* and an unidentified Tortricid accounted for damage in the few peppers that were infested at both sites (Fig. 1). Damage caused by these species can be assumed to be proportional to the percentages of larvae found, but these proportions are approximate because many damaged pods did not contain a larva at harvest.

**Blacklight trapping.** Blacklight trap monitoring of *O. nubilalis* indicated that populations at Fremont were larger, in all years, than at Columbus or Piketon (Fig. 2), probably because corn production was more intensive in Fremont than in Columbus or Piketon. Peak catches ranged from 34 moths per week at Piketon in 1992 to nearly 3,000 per week in Fremont in 1991 (Fig. 2). Emergence in northern and southern Ohio in 1992 was surprisingly similar in timing despite a separation of 280 km; only one moth was trapped at Piketon one week before the first moth was trapped at Fremont. There were the normal two generations of *O. nubilalis* in 1990 and 1992 but three generations in 1991. In years with two generations, moths from the overwintering generation began emerging in mid-May and peaked in mid-June. There was a 3- to 4-week period from late June to late July when very few moths were active. Moths of the first summer generation began to emerge in late July, flight activity peaked in mid-August, and ended in early October.
Fig. 1. Relative occurrence of species found in pepper pods at harvest. Sum of larvae found in all plots per harvest is plotted, and for each species, the percentage of total larvae found on each date is given above each bar.
In 1991, development of *O. nubilalis* was accelerated due to higher than normal temperatures; blacklight traps showed peak flights in late May, late July, and late August (Fig. 2). Although there was not as sharp a drop in trap catches between the second and third flights as between the first and second flights, observations of degree-day accumulations were evidence that there was a third generation in 1991. If degree-days are accumulated once flight activity of the overwintering generation begins, an average of 1150 degree-days (base = 50° F) accumulate from the start of one generation’s flight to the start of the next generation’s flight (Showers et al. 1989). In Columbus in 1991, 1150 degree-days accumulated by the last week of June and 2300 degree-days accumulated by the third week of August; these two times coincided with when there was a sharp increase in the number of moths trapped. Observations of larval size provided further evidence that there was a third generation. In pods harvested on 12 August, late instars (20 to 25 mm long) predominated, which were assumed to be second generation. Pods harvested in a nearby field on 30 August (unpublished data) were infested by some late instars, but primarily by early instars (6 mm long), which were assumed to be third generation.
Pheromone trapping. Pheromone traps detected increasing *O. nubilalis* activity at about the same time as blacklight traps, and the number of male moths caught in pheromone traps was approximately the same as in blacklight traps in most weeks (Fig. 3), particularly in 1992 when more attention was paid to trap placement. The peak catch in pheromone traps tended to occur one to two weeks later than in blacklight traps, and catch in pheromone traps was more prolonged than in blacklight traps. Peak catch per week in pheromone traps was as low as 20 male moths at Piketon in 1992 and as high as 220 moths in Fremont in 1992. During the first half of a flight period, higher numbers of males were caught in blacklight traps than in pheromone traps, whereas the opposite trend was seen during the second half of a flight period (Fig. 3). In blacklight traps, there were slightly more females than males before the peak of a flight period, and slightly more males than females after the peak (Fig. 2). During the 3- to 4-week lull between major flight periods, pheromone traps caught 0 to 7 moths per week, just as the blacklight traps did. During the first week after this lull, pheromone traps caught between 3 and 12 male moths while blacklight traps caught between 9 and 24 total moths. During the second week after the lull, pheromone traps caught between 6 and 24 male moths while blacklight traps caught between 18 and 193 total moths.

Observations of *O. nubilalis* catch in pheromone traps indicated that trap placement was important, particularly the proximity of traps to vegetation. Traps placed within 30 cm of the plant canopy caught more than traps placed higher. If pheromone traps were placed over bare ground, as sometimes happened when fields were cultivated or lanes were mowed, then they usually had fewer moths than traps placed over vegetation. When traps were consistently placed close to vegetation in 1992, trap catch was more similar to that in blacklight traps (Fig. 3).

Infestation and treatment effects, 1990. At Fremont, *O. nubilalis* infestation in pepper pods was highest in the first two harvests, when only 36% and 41% of pods in untreated plots were undamaged, respectively (Fig. 4). Infestation in untreated plots was lower (59% undamaged) in the small third harvest, and lowest in the final harvest (100% undamaged red pods; 79% undamaged green pods). Damage was surprisingly high in the third harvest plots; the most likely explanation is that spray penetration was insufficient in the tall and dense canopy. The percentage of undamaged pods was significantly higher in high intensity plots than in untreated plots in all harvests ($P < 0.05$; individual $P$ values shown in Fig. 4), except for the final harvest of red pods. Analysis of the cumulative harvest showed that damage in low and intermediate intensity treatments was similar to untreated control plots, although damage trends in these treatments were inconsistent among individual harvests.

Similar differences were found in yield at Fremont. Yields were significantly higher in high intensity plots than in untreated plots in the second and fourth red pod harvests and in the final green pod harvest (Fig. 5). No treatment differences were found in the first, third, or cumulative harvests. Yields in low and intermediate intensity treatments were similar to untreated controls (Fig. 5).
Fig. 3. Weekly catches of European corn borer, males only, in blacklight and pheromone traps at three sites, mid-May to mid-October.
Fig. 4. Mean percentage of pepper pods undamaged by insects on periodic harvest dates and in cumulative harvests; pods harvested were red except for dates marked 'G' for green pod harvest. Within each group of columns, $P$ value for treatment effect from ANOVA is shown at top of graph; where $P \leq 0.05$, treatments marked by different letters are significantly different from each other.
Fig. 5. Mean yield (kg) of pepper pods per plot on periodic harvest dates and in cumulative harvests; pods harvested were red except for dates marked 'G' for green pod harvest. Within each group of columns, $P$ value for treatment effect from ANOVA is shown at top of graph; where $P \leq 0.05$, treatments marked by different letters are significantly different from each other.
At Columbus in 1990, damage was apparent throughout the harvest period, with only 38 to 75% of pods undamaged in untreated plots. There were more treatment differences in yield than in percentage undamaged pods, due to the number of insect-infested pods that were too rotten to harvest. The percentage of undamaged pods was significantly higher in high intensity plots than untreated plots in the second harvest and the cumulative harvest (Fig. 4). Yield in high intensity plots was significantly higher than in untreated plots in the first, fourth, fifth, cumulative red, and green pod harvests (Fig. 5). Damage and yields in low and intermediate intensity treatments were intermediate between high intensity plots and untreated plots.

**Infestation and treatment effects, 1991.** Damage in the first harvest was due to late instars of second generation *O. nubilalis*. Damage was light in the second harvest (Fig. 4); these pods were developing during the period between the second and third generations. Damage in the last three harvests was due to third-generation *O. nubilalis*. Damage was most severe in the fourth harvest when only 40 to 59% of pods were undamaged. There were no significant treatment effects on percentage undamaged pods (Fig. 4) or yield (Fig. 5) on any harvest date or for cumulative red pod harvests.

Pods and plants were small throughout the 1991 planting, most likely due to drought conditions soon after transplanting. At all harvests, damage was surprisingly high in high intensity plots, probably due to unusually high levels of *O. nubilalis* activity in July and August (Fig. 2); higher than normal temperatures and low rainfall apparently contributed to good survival of pests. Damage was surprisingly low in untreated plots, especially in the first harvest; this may have been due to pepper harvest starting early, at a time when corn was still attractive to *O. nubilalis*. Small plot size and drift of acephate from treated plots were other possible confounding factors.

To follow up on observations in 1990 that some of the late-season damage was restricted to the cap and stem portions of pepper pods, which are discarded during processing, damage in 1991 was recorded separately for the cap and stem versus the remainder of the pod. The percentage of total damage that was to caps only was 2% in the first harvest, 9% in the second and third harvests, 10% in the fourth harvest, 26% in the final harvest of red pods, and 25% in the final harvest of green pods.

**Infestation and treatment effects, 1992.** Field trials were strongly influenced by weather in 1992, especially from mid-July to mid-August when heavy rains prevented timely insecticide applications. At Fremont, peppers in high intensity plots were sprayed an average of every 10 d during the 14-wk period when a 7-d schedule was called for, while peppers in the variable plots were sprayed every 14 d during the 4-wk period when a 10-d schedule was called for, and every 10 d during the 8-wk period when a 5-d schedule was called for. The 1992 summer was unusually cool, which caused emergence of *O. nubilalis* to be about one week later than normal. Cool wet weather promoted rapid disease development at Fremont, where pepper plants collapsed from *Phytophthora* blight after the second harvest, thus leaving few harvestable pods in the final harvest.
Pepper harvests at both locations in 1992 showed little insect damage even in untreated control plots. At Fremont, peppers in both high intensity and variable intensity plots were significantly less damaged (Fig. 4) and higher yielding (Fig. 5) than in untreated plots in the second harvest, but there were no treatment differences in the first, third, or cumulative harvests. The lack of differences between high intensity and variable treatments at Fremont is not surprising because they were treated the same number of times although not on the same dates. At Piketon, a treatment effect was apparent in the percentage of undamaged pods in the first, third, and cumulative red pod harvests, when peppers in high intensity and variable plots were significantly less damaged than untreated peppers (Fig. 4); there was no effect of treatment on yield (Fig. 5). Although no advantage of variable over high intensity sprays was observed, it must be considered that treatments were not as timely as planned due to wet field conditions.

Discussion

Monitoring. Blacklight trap monitoring of *O. nubilalis* populations was useful for describing seasonal trends as well as differences among years and among locations. Several trends were apparent in data from blacklight traps over the three year period. A catch of zero to seven moths per week, or an average of zero to one moth per night, represented low density populations; this was typical in the 3- to 4-week period between the first and second flights, usually from late June to late July. A catch of more than 35 moths per week, or an average of five moths per night, represented high populations typical during the 3- to 5-week period of peak flight. A catch of intermediate numbers, 8 to 34 moths per week, was typical of the 1- to 2-week periods before and after peak flights. A key question for pepper management is how important are these intermediate population levels. Although guidelines for management of *O. nubilalis* on pepper in some areas call for insecticide treatment once blacklight trap captures reach an average of five or more moths per night (Ghidiu 1992) or four or more female moths per night for three consecutive nights (Showers et al. 1989), a more conservative approach was taken in my study by starting treatments when the moth catch reached the intermediate category, i.e., when moth catch consistently exceeded one moth per night. With my results showing that only 82 to 90% of pods were undamaged in high intensity treatments in the first harvests in some trials, even when sprays were based on this more conservative threshold, it is unlikely that Ohio pepper growers would be willing to use the higher thresholds unless further research can demonstrate their effective use under Ohio conditions.

Although blacklight traps are appealing for research purposes because they can document activity of female as well as male moths, pheromone traps appear to be an acceptable alternative for growers who wish to monitor *O. nubilalis* populations. Monitoring with target-specific pheromone traps is far less time-consuming than blacklight traps, which require sorting of target species from nontarget species. Pheromone traps also are less expensive. Care must be taken in placing pheromone traps close to
vegetation rather than over bare ground. The importance of pheromone trap placement relative to vegetation when monitoring *O. nubilalis* was also observed by Fletcher-Howell et al. (1983). Traps should be set up as soon as plants begin to flower, to target any lingering moths of the overwintering generation and moths of the one or two summer generations. Pheromone traps appear to be more reliable for detecting the beginning and peak of activity periods than for monitoring the end of activity periods. The slight lack of synchrony in catch of *O. nubilalis* males in blacklight and pheromone traps observed in this study was similar to that documented by Oloumi-Sadeghi et al. (1975), who found that peak capture of males in a sticky cardboard type of pheromone trap occurred after peak capture of males and females in blacklight traps and after peak egg-laying on corn.

An alternative to traps as an *O. nubilalis* monitoring tool is field scouting. Twenty pepper plants per plot were scouted weekly in 1992 with *O. nubilalis* egg masses as the primary target, but presence of other pests and natural enemies was also recorded (C. W., unpublished data). Disadvantages of scouting were that pepper plants were brittle and difficult to examine without breaking stems, and egg masses were difficult to locate. Scouting peppers was beneficial for aphid detection during early summer, but was of questionable value for management of *O. nubilalis*.

**Control by Insecticides.** Although the high intensity treatments provided better control of *O. nubilalis* and higher yields than other treatments in 1990, it was impossible to separate the relative contributions of carbofuran versus acephate with the experimental design used. It is likely that improved control was due to the 7-d schedule of acephate, and higher yields were due to carbofuran, which is known to have a general growth enhancing effect on various crops (e.g., Pless et al. 1971). A surprising result at both sites in 1990 was the ineffectiveness of a 14-d spray schedule, in contrast to the excellent control by acephate on a 14-d schedule reported by Ladd et al. (1982) for peppers grown in northeastern Ohio in 1980 and 1981. The *O. nubilalis* population pressure was much lower in the 1980-81 study, based on damage in untreated control plots, than in Fremont or Columbus in 1990. The poor control in plots treated every 7 d in 1991 led to the hypothesis tested in 1992 that a 5-d schedule may be needed during periods of peak moth activity. However, with the low levels of insect damage in 1992, even in untreated control plots, no advantage of a 5-d schedule was seen. A late planting of sweet corn near the pepper plantings at both sites in 1992 possibly acted as a trap crop and contributed to lower than expected damage to peppers, as has been suggested by Showers et al. (1989).

The difficulty in controlling this pest even with an intensified spray schedule suggests that components of the management system other than the spray schedule should be explored for improved control. A controlled droplet applicator may be a more effective delivery system than a conventional hydraulic boom sprayer for controlling this pest (Grafius et al. 1990). True systemic insecticides may be more effective than the limited systemic activity that characterizes acephate applied as a foliar spray.

One difference between the two study sites in 1990 was that there was little insect damage in the final harvest at Fremont, but there was
substantial damage in the final harvest at Columbus. Both sites were treated for the last time in mid-September. Presence of fall armyworm and corn earworm at Columbus but not at Fremont (Fig. 1) explains this difference in damage. These data indicate that potential damage by fall armyworm and corn earworm is great enough that maintaining insecticide applications until a week before the final harvest may be warranted at some sites. Pheromone traps have been an effective monitoring tool for corn earworm in Ohio sweet corn fields and can be suggested for pepper fields in September and October. Fall armyworm can be monitored in the adult stage by pheromone or blacklight traps, or in larval stages by scouting nearby plantings of sweet corn, a crop on which their feeding is easily detected. Further studies are needed to evaluate management tactics for these two pests in pepper fields.

Conclusions. Information on *O. nubilalis* activity obtained from traps was useful for the first management decision of the pepper-growing season, which is determining when to initiate a spray schedule. A level of < 1 moth per night in blacklight traps corresponded to a low density *O. nubilalis* population, and a threshold of ≥ 1 moth per night in blacklight traps was appropriate for initiating a spray schedule. Pheromone traps appear to offer an acceptable and less time-consuming alternative to blacklight traps; a threshold of > 1 male moth per night in pheromone traps could be tested in comparison with the blacklight threshold.

The second pest management decision is determining how often to spray. This study showed that a 7-d insecticide spray schedule was suitable for control in peppers in Ohio in years with average *O. nubilalis* activity. Increasing the intensity of treatments during periods of peak moth activity and decreasing the intensity of treatments during periods of low moth activity seems logical, but the levels of moth activity that correspond to high and low activity need to be defined and tested in large scale field experiments before any recommendation on variable schedules can be made.

The third pest management decision is determining when to stop spraying. Traps were useful for determining when activity of *O. nubilalis* moths tapered off to low levels, usually in late September. Sprays for *O. nubilalis* control could be discontinued at this point, but the potential exists for late-season damage by fall armyworm and corn earworm. Additional data is needed to develop guidelines for monitoring and control of these two pests of peppers.

Despite the status of European corn borer as the key pest of bell peppers, surprisingly few studies have been published on its damage and management. The data on pepper management options that were obtained in this three-year study will be valuable in helping pepper growers evaluate their insect management programs, but there is a need for additional information. The fluctuations in *O. nubilalis* populations and damage to peppers from year to year and from site to site suggest that a longer term study would be needed to refine the monitoring and control options explored here.
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