Sweet corn insect management by insecticides in Ohio, 2015
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Introduction: In response to the apparent development of resistance to pyrethroid insecticides across the midwestern USA, a trial was conducted for the ninth year in Ohio to monitor the performance of pyrethroid insecticides for control of corn earworm, and to evaluate non-pyrethroid alternatives as replacements for the standard pyrethroid spray schedule. A secondary objective was to evaluate the effects of insecticide programs on other pests: European corn borer, fall armyworm, corn rootworm beetles, and corn leaf aphid, as well as effects on natural enemies of these pests. This trial differed from previous trials in the rate and positioning of Hero, which in this trial was used twice at 5.15 fl oz/A, within the allowed limit of 10.3 fl oz/A per season; Hero had previously been used at the rate of 6.4 fl oz/A.

Methods: A trial was conducted at the Ohio Agricultural Research and Development Center's Western Agricultural Research Station near South Charleston in Clark County. Four replicates of five treatments were set up in a randomized complete block design. All treatments used a standard bicolor hybrid, 'Providence'. Each plot was four rows wide and 40 feet long, with 30-inch row spacing. Plots were seeded on 5 July, which was 2 weeks later than planned, due to wet soil conditions that prevented earlier seeding. Adults of two pest species were monitored by pheromone traps: corn earworm (CEW) in one Hartstack trap, and fall armyworm (FAW) in one all-green unitrap; lures were Hercon brand and were replaced every 2 weeks for CEW and every 4 weeks for FAW.

Insecticide products were applied six times on a 3-day schedule. The sequence of products and spray dates are detailed in Table 1. The spray program was initiated on 28 August, once silks appeared on approximately 25% of plants. Sprays were applied by a "HiBoy"-style Spider sprayer (West Texas Lee Company, Inc., Idalou TX) that applied 27.0 gallons per acre at 50 PSI, with ConeJet-18 nozzles on drop pipes directed at the ear zone in the center two rows per plot. Rates of insecticide and adjuvant products used were: Warrior II 2.08CS (lambda-cyhalothrin), 1.92 fl oz/A; Blackhawk 36WG (spinosad), 3.3 oz/A plus NIS 0.25%; Asana XL 0.66EC (esfenvalerate), 5.8 fl oz/A; Radiant 1SC (spinetoram), 6 fl oz/A plus NIS 0.25%; Coragen 1.67SC (chlorantraniliprole), 3.5 fl oz/A; Hero 1.24EC (bifenthrin + zeta-cypermethrin), 5.15 fl oz/A plus NIS 0.25%; Lannate LV 2.4WSL (methomyl), 24 fl oz/A.

Table 1. Schedule of insecticide treatments in sweet corn trial, South Charleston, Ohio, 2015.

Treatment	spray #1 on 8/28	spray #2 on 8/31	spray #3 on 9/3	spray #4 on 9/6	spray #5 on 9/9	spray #6 on 9/12
1: pyrethroid	Warrior	Warrior	Warrior	Warrior	Warrior	Warrior
2: Blackhawk	Asana + Blackhawk	Blackhawk	Blackhawk	Hero	Hero	Lannate
3: Radiant	Asana + Radiant	Radiant	Radiant	Hero	Hero	Lannate
4: standard	Hero	Coragen	Hero	Coragen	Lannate	Lannate
5: untreated	none	none	none	none	none	none

Silk-clipping damage by beetles was evaluated on 3 September, between the second and third sprays, on 10 ears per plot; damage was rated on a scale of 0 to 4 with a rating of 1 for light (25% of silk clipped), a rating of 2 for moderate (50% of silk clipped), a rating of 3 for heavy (75% of silk clipped), and a rating of 4 for extreme (100% of silk clipped); density of silk-clipping beetles, generalist predators, and corn leaf aphid present on silks were also evaluated. Samples of 10 ears from the center two rows per plot were harvested and evaluated on 18 September. Each ear was rated for the number of kernels damaged, the location of damage, the length of damage from ear tip, and species, size, and location of caterpillars found. Data were subjected to analysis of variance (ANOVA) and mean comparisons by least significant difference (LSD) tests in the SAS 9.3 microcomputer statistics program.

Results: Corn plants began silking at the same time that the corn earworm moth population had a sharp rise in activity (Table 2), thus there was high pest pressure during the critical first week of early silking. Corn earworm pressure fell to moderate levels during the third week of silking. Fall armyworm was also present throughout the silking period at low levels (Table 2).

Silk clipping was significantly less in all insecticide-treated plots than in untreated plots (P = 0.03; Table 3). The most common silk clipping insect was the western corn rootworm beetle, but a few southern corn rootworm beetles and Japanese beetles were also present (Table 3). The total number of beetles per ear was significantly lower in all insecticide-treated plots than in untreated plots (P = 0.02; Table 3). The number of predatory *Orius* bugs was significantly higher in the standard treatment that had been sprayed with once with Hero and once with Coragen than in plots sprayed twice with Warrior (P = 0.03; Table 3). Corn leaf aphids were detected at low density during early silking and did not differ among treatments (P = 0.70; Table 4).

At harvest, untreated control plots had 97.5% of husked ears with worm-damaged kernels, and 2.5% of ears had no damage to kernels but had damage in husks, silks, or shanks (Table 5). In the four insecticide treatments, the percentage of husked ears with worm damaged kernels ranged from 7.5 to 20.0%; all were was significantly lower than the untreated control, and none of the four insecticide treatments differed significantly from each other (P <0.0001; Table 5). The number of damaged kernels at the tip of each ear, in the middle third of each ear, and total, was significantly fewer in all insecticide treatments than in untreated plots (P < 0.0001; Table 6). The length of damage followed similar trends, both at the ear tip end, at the butt end, and total (P < 0.0001, Table 7).

The dominant species of caterpillars found in harvested ears were European corn borer (ECB) and corn earworm (CEW), with only a trace of fall armyworm (Table 8). Most of the corn earworm larvae were in the large size category, but small and medium larvae were also present (Table 8). There were significantly fewer larvae of ECB and CEW in all four insecticide treatments than in the untreated control (ECB: P < 0.0001; CEW: $P \leq 0.003$; Table 8); the density of larvae did not differ significantly among the four insecticide treatment programs. One other pest found in husks at harvest was corn leaf aphid, which did not differ among treatments (P = 0.09, Table 4).

Conclusions: Under the conditions of high populations of corn earworm during early silking followed by moderate populations of corn earworm during late silking, the pyrethroids Hero at 5.15 fl oz/A and Warrior at the maximum rate were still effective for control of corn earworm. Radiant, Blackhawk, and Coragen are excellent alternatives to pyrethroids for control of corn earworm as well as other species. Warrior also controlled silk clipping beetles during early silking but did not allow survival of *Orius* predatory bugs, while Hero provided control of silk clipping beetles yet allowed survival of *Orius* predatory bugs.

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Table 2. Pheromone trap catches in sweet corn trial, S. Charleston, Ohio, 2015.

Week	Number of moths		Notes
	Corn earworm	Fall armyworm	
June 21-27	4	0	
Jun 28 - Jul 4	2	0	
July 5-11	12	3	
July 12-18	1	1	
July 19-25	6	0	
Jul 26 - Aug 1	2	1	
August 2-8	0	0	
August 9-15	1	1	
August 16-22	80	2	
August 23-29	314	0	Spray 1 on 8/28
Aug 30 - Sep 5	368	0	Spray 2 on 8/31 Spray 3 on 9/3
September 6-12	75	2	Spray 4 on 9/6 Spray 5 on 9/9 Spray 6 on 9/12
September 13-19	4	6	Harvest on 9/18
September 20-26	-	-	
Sep 27 - Oct 3	4	14	

Table 3. Silk clipping damage in sweet corn trial on 9/3/2015, after the first two insecticide sprays; S. Charleston, Ohio.

Treatment	Insecticide applied by time of evaluation	% of silk clipped[a,b]	Rating of silk clipping (scale 0 to 4)[a,c]	Number of beetles per ear				Number of predators per ear	
				Western corn rootworm[a]	Southern corn rootworm	Japanese beetle	Total[a]	*Orius*[a]	Lady beetles
Warrior	Warrior, twice	0.0 B	0.00 B	0.00 B	0.00	0.00	0.00 B	0.02 B	0.00
Hero/ Coragen	Hero once, Coragen once	0.0 B	0.00 B	0.00 B	0.00	0.02	0.02 B	0.38 A	0.00
Radiant	Radiant twice, Asana once	0.6 B	0.02 B	0.05 B	0.02	0.00	0.08 B	0.18 AB	0.00
Blackhawk	Blackhawk twice, Asana once	1.2 B	0.05 B	0.08 AB	0.00	0.00	0.08 B	0.22 AB	0.00
Untreated control	(none)	6.2 A	0.25 A	0.18 A	0.08	0.00	0.25 A	0.32 A	0.05
P (ANOVA treatment effect)		*0.0304*	*0.0452*	*0.0374*	*0.13*	*0.44*	*0.0220*	*0.0301*	*0.0625*

[a] Within each column, means followed by same letter are not significantly different (P>0.05); mean separations by LSD.

[b] Values shown are actual percentages but ANOVA based on transformed values.

[c] Silk clipping rating: 0 = none, 1 = light (25%), 2 = moderate (50%), 3 = heavy (75%), 4 = extreme (100%).

Table 4. Corn leaf aphid presence in sweet corn ears in insecticide trial, 2015, S. Charleston, Ohio.

Treatment	Number of ears with corn leaf aphid, during early silk (9/3/2015)	Number of ears with corn leaf aphid, at harvest (9/18/2015)
Radiant	0.08	0.2
Hero/Coragen	0.05	0.1
Blackhawk	0.08	0.2
Warrior	0.02	0.2
Untreated control	0.02	0.0
ANOVA treatment effect	*P = 0.70*	*P = 0.09*

Table 5. Insect damage on sweet corn ears at harvest on 9/18/2015, S. Charleston, Ohio.

Treatment	% of husked ears with no worm damage[a,b]	% of husked ears with worm-damaged kernels[a,b]	% of ears with no worm damage to kernels but worm damage on husks, silks, or shanks[b]
Radiant	87.5 A	7.5 B	5.0
Hero/Coragen	75.0 A	12.5 B	12.5
Blackhawk	72.5 A	12.5 B	15.0
Warrior	72.5 A	20.0 B	7.5
Untreated	0.0 B	97.5 A	2.5
ANOVA treatment effect	*P < 0.0001*	*P < 0.0001*	*P = 0.43*

[a] Within each column, means followed by same letter are not significantly different (*P*>0.05); mean separations by LSD.

[d] Values shown are actual percentages but ANOVA based on transformed values.

Table 6. Number of sweet corn kernels damaged by insects at harvest on 9/18/2015, S. Charleston, Ohio.

Treatment	Number of damaged kernels per ear			
	Tip third of ear[a]	Middle third of ear[a]	Butt third of ear	Total[a]
Radiant	0.6 B	0.0 B	0.0	0.6 B
Hero/Coragen	1.4 B	0.0 B	0.0	1.4 B
Blackhawk	1.4 B	0.0 B	0.0	1.4 B
Warrior	1.9 B	0.1 B	0.0	2.0 B
Untreated control	20.2 A	2.0 A	1.6	23.8 A
ANOVA treatment effect	*P < 0.0001*	*P = 0.0001*	*P = 0.08*	*P < 0.0001*

[a] Within each column, means followed by same letter are not significantly different (*P*>0.05); mean separations by LSD.

Table 7. Length of insect damage on sweet corn ears at harvest on 9/18/2015, S. Charleston, Ohio.

Treatment	Length of damage (cm)		
	From tip end[a]	From butt end[a]	Total[a]
Radiant	0.2 B	0.0 B	0.2 B
Hero/Coragen	0.2 B	0.0 B	0.2 B
Blackhawk	0.2 B	0.0 B	0.2 B
Warrior	0.6 B	0.0 B	0.6 B
Untreated control	3.0 A	1.9 A	4.8 A
ANOVA treatment effect	*P < 0.0001*	*P < 0.0001*	*P < 0.0001*

[a] Within each column, means followed by same letter are not significantly different (*P*>0.05); mean separations by LSD.

Table 8. Species of insect larvae in sweet corn ears at harvest on 9/18/2015, S. Charleston, Ohio.

Treatment	Number of larvae per ear						
	Corn earworm[a]				European corn borer[a]	Fall army-worm	Total[a]
	Small	Medium	Large	Total			
Radiant	0.02 B	0.00 B	0.00 B	0.02 B	0.05 B	0.00	0.1 B
Hero/Coragen	0.00 B	0.05 B	0.08 B	0.12 B	0.10 B	0.00	0.2 B
Blackhawk	0.02 B	0.00 B	0.10 B	0.12 B	0.00 B	0.02	0.2 B
Warrior	0.00 B	0.00 B	0.08 B	0.08 B	0.05 B	0.00	0.1 B
Untreated control	0.10 A	0.25 A	0.68 A	1.02 A	1.10 A	0.02	2.2 A
ANOVA treatment effect	*P =0.0013*	*P = 0.0030*	*P <0.0001*	*P <0.0001*	*P <0.0001*	*P = 0.61*	*P <0.0001*

[a] Within each column, means followed by same letter are not significantly different (*P*>0.05); mean separations by LSD.