Sweet corn insect management by insecticides in Ohio, 2013

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Objective: In response to the apparent development of resistance to pyrethroid insecticides across the midwestern USA, a trial was conducted for the seventh 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.

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 seven 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 24 June. Adults of three pest species were monitored by pheromone traps: corn earworm (CEW) in one Hartstack trap, European corn borer (ECB) in one Scentry Heliothis 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 ECB and FAW.

Insecticide products were applied seven times on a 3- to 4-day schedule. The sequence of products and spray dates are detailed in Table 1. The spray program was initiated on 19 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 27.8 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; Coragen 1.67SC (chlorantraniliprole), 3.5 fl oz/A in the DuPont treatment and 5 fl oz/A in the FMC treatment, both plus MSO 0.5%; Asana XL 0.66EC (esfenvalerate), 9.6 fl oz/A; Lannate LV 2.4WSL (methomyl), 24 fl oz/A; Hero 1.24EC (bifenthrin + zeta-cypermethrin), 6.4 fl oz/A, plus NIS 0.25%; Mustang Max 0.8EC (zeta-cypermethrin), 4 oz/A, plus NIS 0.25%; Radiant 1SC (spinetoram), 4.5 fl oz/A; Blackhawk 36WG (spinosad), 3.2 oz/A.

Table 1. Schedule of insecticide treatments in sweet corn trial, South Charleston, Ohio, 2013.

Treatment number & short name	spray #1 on 8/19	spray #2 on 8/22	spray #3 on 8/25	spray #4 on 8/28	spray #5 on 9/1	spray #6 on 9/4	spray #7 on 9/7
1: pyrethroid	Warrior	Warrior	Warrior	Warrior	Warrior	Warrior	Warrior
2: Dupont	Coragen + Asana	Coragen	Coragen	Lannate	Lannate	Lannate	Lannate
3: FMC	Hero	Hero	Hero	Coragen	MustangMax	Hero	MustangMax
4: Dow-1	Hero	Hero	Radiant	Radiant	Lannate	Lannate	Lannate
5: Dow-2	Hero	Hero	Blackhawk	Blackhawk	Lannate	Lannate	Lannate
6: untreated control	none	none	none	none	none	none	none

Silk-clipping by beetles was evaluated on 23 August, 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 were also evaluated. Samples of 20 ears from the center two rows per plot were harvested and evaluated on 11 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: Plants began silking at the same time that the corn earworm moth population had a rise in activity, thus there was moderately high pest pressure during the critical first week of early silking (Table 2), but the corn earworm population was less abundant than usual for this time of year. Corn earworm pressure fell to low levels for most of the second and third week of silking. Fall armyworm was also present throughout the silking period at moderate levels, and European corn borer was present during the second half of the silking period (Table 2).

Silk clipping was significantly less in all insecticide-treated plots than in untreated plots ($P < 0.0001$; Table 3). The most common silk clipping insect was the western corn rootworm beetle, but a few northern corn rootworm 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 ($P = 0.0060$; Table 3). The number of predatory *Orius* bugs was significantly higher in plots that had been treated with Coragen plus Asana than in those treated with Warrior or Hero ($P < 0.0001$; Table 3). No corn leaf aphids were detected during early silking.

In the untreated control, only 51% of husked ears had no worm-damaged kernels, and only 32% of ears had no damage to kernels, husks, silks, or shanks (Table 4). The percentage of husked ears with no worm-damaged kernels was significantly higher in four treatments (Hero/Coragen/Mustang, Hero/Blackhawk/Lannate, Hero/Radiant/Lannate, and Warrior) than in the Coragen/Lannate treatment, and the percentage of husked ears with no worm-damaged kernels was significantly higher in the Coragen/Lannate treatment than in the untreated control ($P < 0.0001$, Table 4). By the more strict definition of damage, the percentage of husked ears with no worm damage to kernels, husks, silks, and shanks ranged from 96.2 to 98.8% and was significantly higher in all five insecticide programs than in the untreated control ($P < 0.0001$, Table 4).

The number of damaged kernels at the tip of each ear was significantly fewer in all insecticide treatments than in untreated plots ($P = 0.0001$; Table 5), as was the number of damaged kernels at the butt end ($P = 0.0008$; Table 5). The length of damage followed similar trends, both at the ear tip ($P < 0.0001$, Table 6) and at the butt end ($P = 0.0003$, Table 6).

The most abundant species of caterpillar found in harvested ears was European corn borer, followed by corn earworm then fall armyworm. Most of the corn earworm larvae were in the large size category (Table 7). There were significantly fewer larvae of each species in all five insecticide treatments than in the untreated control (ECB: $P < 0.0001$; CEW: $P < 0.0001$; FAW: $P = 0.0030$; Table 7); there were no significant differences among the five insecticide treatment programs. Two other insects found at harvest were corn leaf aphid in the husks, which did not differ among treatments ($P = 0.0858$, Table 8), and predatory *Orius* bugs which were significantly more abundant in untreated ears than in all insecticide-treated ears ($P < 0.0001$, Table 8).

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

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Table 2. Pheromone trap catches of three key species in sweet corn trial, S. Charleston, Ohio, 2013.

Date	Corn earworm		Mean number of moths per day		Activities
	Mean number of moths per day	Relative pressure[a]	European corn borer	Fall armyworm	
14-Jun	1.0	Moderate			
17-Jun	0.7	Moderate			
19-Jun	1.0	Moderate			
20-Jun	0.0	None			
24-Jun	0.3	Low			
1-Jul	1.4	High			
3-Jul	2.0	High			
8-Jul	0.6	Moderate			
11-Jul	0.0	None			
16-Jul	2.6	High			
19-Jul	0.3	Low			
22-Jul	0.0	None	0.3		
24-Jul	0.0	None	0.0		
26-Jul	0.0	None	0.0		
29-Jul	1.3	High	0.0		
31-Jul	0.5	Low	0.0		
2-Aug	1.0	Moderate	0.0		
5-Aug	0.3	Low	0.0		
7-Aug	0.5	Low	0.5		
9-Aug	0.0	None	1.0		
12-Aug	0.7	Moderate	0.0	0.0	
15-Aug	1.3	High	1.0		
16-Aug	2.0	High		0.5	
18-Aug	0.5	Low	0.0		
19-Aug	3.0	High	0.0	4.7	Spray #1 on 8/19
21-Aug	3.5	High	0.0	1.5	
22-Aug	2.0	High			Spray #2 on 8/22
23-Aug	0.0	None	0.0	1.5	
25-Aug	2.5	High			Spray #3 on 8/25
26-Aug	0.0	None		1.0	
28-Aug	0.5	Low	0.2		Spray #4 on 8/28
30-Aug	0.5	Low	2.0	0.5	
1-Sep	0.5	Low	2.0	0.0	Spray #5 on 9/1
4-Sep	5.3	High	2.7	0.0	Spray #6 on 9/4
6-Sep	0.5	Low	0.0	2.0	
7-Sep	0.0	None	0.0	0.0	Spray #7 on 9/7
9-Sep	0.0	None	0.7	0.0	
11-Sep	1.5	High	0.0	2.0	Harvest on 9/11
13-Sep	18.0	Very high	0.0	6.5	
16-Sep	1.3	High	0.0	0.0	
18-Sep	4.5	High	0.0		
20-Sep	2.0	High	0.5		
23-Sep	0.3	Low	0.0		
25-Sep	0.5	Low	0.0		
4-Oct	0.9	Moderate	0.1		

[a] Pest pressure categories: <0.2 moth per night = very low; 0.2 to 0.5 moth per night = low; 0.5 to 1.0 moth per night = moderate; 1 to 13 moths per night = high; >13 moths per night = very high.

Table 3. Silk clipping damage in sweet corn trial on 8/23/2013, S. Charleston, Ohio.

Treatment	Insecticide applied by time of evaluation	% of silk clipped[a,b]	Rating[a] of silk clipping (scale 0 to 4)[c]	Number[a] of beetles per ear			Number[a] of *Orius* predators per ear
				Western corn rootworm	Northern corn rootworm	total	
Hero/Coragen/ Mustang	Hero, twice	0.6 B	0.00 B	0.02 B	0.00 B	0.02 B	0.00 C
Hero/Blackhawk/ Lannate	Hero, twice	0.0 B	0.00 B	0.00 B	0.00 B	0.00 B	0.02 C
Hero/Radiant/ Lannate	Hero, twice	0.0 B	0.00 B	0.00 B	0.00 B	0.00 B	0.08 C
Warrior	Warrior, twice	0.6 B	0.02 B	0.02 B	0.00 B	0.02 B	0.02 C
Coragen+Asana/ Lannate	Coragen+Asana once, then Coragen alone	0.6 B	0.02 B	0.05 B	0.05 A	0.10 B	0.65 A
Untreated control	(none)	13.1 A	0.52 A	0.68 A	0.00 B	0.68 A	0.35 B
Probability (treatment effect in ANOVA)		*P < 0.0001*	*P = 0.0001*	*P = 0.0049*	*P = 0.0450*	*P = 0.0060*	*P < 0.0001*

[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. Insect damage to sweet corn ears at harvest on 9/11/2013, S. Charleston, Ohio.

Treatment	% of husked ears with no worm-damaged kernels[a,b]	% of ears with no worm damage to kernels or to husks, silks, shanks[a,b]
Hero / Coragen / Mustang	100 A	98.8 A
Hero / Blackhawk / Lannate	100 A	98.8 A
Hero / Radiant / Lannate	100 A	98.8 A
Warrior	98.8 A	97.5 A
Coragen+Asana / Lannate	96.2 B	96.2 A
Untreated control	51.2 C	32.5 B
Probability (treatment effect in ANOVA)	*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.

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

Table 5. Number of sweet corn kernels damaged by insects at harvest on 9/11/2013, S. Charleston, Ohio.

Treatment	Number of damaged kernels per ear[a]			
	Tip third of ear	Middle third of ear	Butt third of ear	Total
Hero / Coragen / Mustang	0.0 B	0	0.0 B	0.0 B
Hero / Blackhawk / Lannate	0.0 B	0	0.0 B	0.0 B
Hero / Radiant / Lannate	0.0 B	0	0.0 B	0.0 B
Warrior	0.01 B	0.01	0.0 B	0.02 B
Coragen / Lannate	0.15 B	0	0.0 B	0.15 B
Untreated control	3.15 A	1.29	0.4 A	4.85 A
Probability (treatment effect in ANOVA)	*P=0.0001*	*P = 0.1287*	*P = 0.0008*	*P<0.0001*

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

Table 6. Length of insect damage on sweet corn ears at harvest on 9/11/2013, S. Charleston, Ohio.

Treatment	Length of damage (cm)[a]		
	From tip end	From butt end	Total
Hero / Coragen / Mustang	0.0 B	0.0 B	0.0 B
Hero / Blackhawk / Lannate	0.0 B	0.0 B	0.0 B
Hero / Radiant / Lannate	0.0 B	0.0 B	0.0 B
Warrior	0.1 B	0.0 B	0.09 B
Coragen / Lannate	0.1 B	0.0 B	0.06 B
Untreated control	1.8 A	0.8 A	2.5 A
Probability (treatment effect in ANOVA)	*P < 0.0001*	*P = 0.0003*	*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. Species of insect larvae in sweet corn ears at harvest on 9/11/2013, S. Charleston, Ohio.

Treatment	Number[a] of larvae per ear						
	Corn earworm				European corn borer	Fall armyworm	Total
	Small	Medium	Large	Total			
Hero/ Coragen/ Mustang	0	0	0.00 B	0.00 B	0.00 B	0.00 B	0.00 B
Hero/ Blackhawk/ Lannate	0	0	0.00 B	0.00 B	0.01 B	0.00 B	0.01 B
Hero/ Radiant/ Lannate	0	0	0.00 B	0.00 B	0.01 B	0.00 B	0.01 B
Warrior	0	0	0.00 B	0.00 B	0.01 B	0.00 B	0.01 B
Coragen/ Lannate	0	0.01	0.00 B	0.01 B	0.02 B	0.00 B	0.04 B
Untreated control	0	0.01	0.10 A	0.11 A	1.06 A	0.05 A	1.22 A
Probability (treatmeneffect in ANOVA)	-	*P = 0.5988*	*P < 0.0001*	*P < 0.0001*	*P < 0.0001*	*P = 0.0030*	*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. Insects other than caterpillars in sweet corn ears at harvest on 9/11/2013, S. Charleston, Ohio.

Treatment	Number of ears with corn leaf aphid (out of 20 ears per sample)	Number [a] of ears with *Orius* predators (out of 20 ears per sample)
Hero / Coragen / Mustang	0.8	0.0 B
Hero / Blackhawk / Lannate	0.5	0.0 B
Hero / Radiant / Lannate	0.4	0.0 B
Warrior	0.5	0.0 B
Coragen / Lannate	0.4	0.0 B
Untreated control	0.1	0.2 A
Probability (treatment effect in ANOVA)	*P = 0.0858*	*P < 0.0001*

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