Ohio Sweet Corn Insecticide Trial, 2018

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Introduction: In continued response to the apparent development of resistance to pyrethroid insecticides across the midwestern USA, a trial was conducted in Ohio to monitor the performance of pyrethroid insecticides for control of corn earworm, and to evaluate non-pyrethroid alternative insecticides and transgenic hybrids as replacements for the standard pyrethroid spray schedule. A secondary objective was to evaluate the effects of alternative programs on other pests: European corn borer, fall armyworm, and corn rootworm beetles, 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 a high rate in one treatment and three times at a lower rate in another treatment. The trial also included Hero as a pre-mix in comparison with its two components as a tank mix.

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 six treatments were set up in a randomized complete block design. Five treatments used a standard bicolor hybrid, 'Providence' and one treatment used the transgenic 'Remedy' which is part of the Attribute-II series that contains Cry1Ab and Vip3A genetic traits. Each plot was four rows wide and 40 feet long, with 30-inch row spacing. Plots were seeded on 6/19/2018. Adults of four pest species were monitored by pheromone traps: corn earworm (CEW) in one Hartstack trap, European corn borer (ECB) in one Scentry Heliothis trap, fall armyworm (FAW) in one all-green unitrap, and western bean cutworm (WBCW) in one standard unitrap; lures for WBCW were by Trécé while all other lures were Hercon brand. Lures were replaced every 2 weeks for CEW and every 4 weeks for ECB, FAW, and WBCW.

Insecticide products were applied six times on a 2-day to 5-day schedule; a 3-day schedule had been intended but needed to be modified due to rain events. The spray program was initiated on 8/10/2018, 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 26.5 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.

The sequence of products and spray dates are detailed in Table 1. Rates of insecticide and adjuvant products used were: Warrior II 2.08CS (lambda-cyhalothrin), 1.92 fl oz/A; Hero 1.24EC (bifenthrin + zeta-cypermethrin), 5.15 fl oz/A plus NIS 0.25% in treatment 1, and 10.3 fl oz/A plus NIS 0.25% in treatment 4; Brigade 2EC, 1.7 fl oz/A plus NIS 0.25%; Mustang Maxx 0.8EC, 4 fl oz/A plus NIS 0.25% in treatments 1 and 2, and 3.4 fl oz/A plus NIS 0.25% in treatment 2; Coragen 1.67SC (chlorantraniliprole), 4 fl oz/A in treatments 1 and 2, and 3.5 fl oz/A in treatment 4; Asana XL 0.66EC (esfenvalerate), 5.8 fl oz/A; and Lannate LV 2.4WSL (methomyl), 24 fl oz/A.

Silk-clipping damage by beetles was evaluated on 8/13/2018, just before the second spray, 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 8/29/2018. 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 extremely high pest pressure during the critical first week of early silking, and pressure remained high for the following 2.5 weeks until harvest. Pheromone trapping showed that European corn borer was present for its first generation in June at low levels but not detectable for second generation in August, while fall armyworm and western bean cutworm were present at only trace levels (Table 2).

During early silking, silk clipping damage was significantly less in all insecticide-treated plots than in untreated plots and in the transgenic ‘Remedy’ plots ($P = 0.0110$; Table 3). Presence of at least one pyrethroid in the first spray in each program is the likely reason for prevention of silk-clipping. The most common silk clipping insects were the western corn rootworm beetle and the northern 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 the all-Warrior and the FMC-1 treatment than in untreated and transgenic ‘Remedy’ plots ($P = 0.0195$; Table 3). The number of predatory *Orius* bugs did not differ significantly among treatments ($P = 0.38$; Table 3). Corn leaf aphid was a target of scouting but was not found in this field. The silk-clipping damage on the transgenic plants is not surprising due to the known lack of toxic activity of these hybrids to pests other than caterpillars, and shows the potential benefit of a spray during early silking to target beetles before they clip the fresh silks.

At harvest, ears in all treatments showed kernels with injury by caterpillars. 75 to 87.5% of ears in the four insecticide treatments had no caterpillar-injured kernels, which was significantly better than 0% of ears with no caterpillar-injured kernels in the untreated check plots ($P < 0.0001$); there were no significant differences among the four insecticide programs, including the all-Warrior treatment (Table 4). The least damaged treatment was the transgenic ‘Remedy’ hybrid which without any insecticide sprays resulted in only 2.5% of ears with injured kernels, which was significantly less injury than in the four insecticide programs (Table 4).

The number of damaged kernels (Table 5) showed the same trends as the percentage of ears with any kernels injured (Table 4). All four insecticide programs and the transgenic ‘Remedy’ treatment had significantly fewer damaged kernels than the untreated check, in the tip third of the ear ($P < 0.0001$), the middle third of the ear ($P = 0.0006$), and the whole ear ($P < 0.0001$), but not in the butt third of the ear ($P = 0.09$) (Table 5). The length of the damaged area from the ends of the ear also showed the same trends, with significantly shorter damage in the four insecticide programs and the transgenic ‘Remedy’ compared to the untreated check, at the tip end ($P < 0.0001$) and the butt end ($P = 0.0013$) (Table 6).

The species of caterpillars found in ears at harvest was primarily corn earworm, but European corn borer was also found (Table 7). Most of the corn earworm were in the large size category. There were significantly fewer caterpillars in the four insecticide programs and the transgenic ‘Remedy’ treatment than in the untreated check, for medium corn earworm ($P < 0.0001$), large corn earworm ($P < 0.0001$), total corn earworm ($P < 0.0001$), European corn borer ($P < 0.0001$), and total caterpillars ($P < 0.0001$), and no significant differences among the five control programs for the same categories (Table 7).

Conclusions: Under the conditions of very high populations of corn earworm during silking, the pyrethroids Hero, Mustang plus Brigade, and Warrior at the maximum rate were still effective for control of corn earworm but were less effective than the transgenic ‘Remedy’ hybrid. Coragen is an excellent alternative to pyrethroids to use in a program for control of corn earworm as well as other caterpillar species. Lannate is another product that is effective when used in a spray program. The transgenic 'Remedy' without an insecticide application in early silking was susceptible to silk-clipping by beetles.

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Table 1. Schedule and rates of insecticide treatments in sweet corn trial, South Charleston, Ohio, 2018.

Treatment	hybrid	spray 1 8/10	spray 2 8/13	spray 3 8/15	spray 4 8/19	spray 5 8/22	spray 6 8/24
1: FMC-1	Providence	Hero 1.24EC: 5.12 fl oz/A + NIS 0.25%	Hero 1.24EC: 5.12 fl oz/A + NIS 0.25%	Hero 1.24EC: 5.12 fl oz/A + NIS 0.25%	Coragen 1.67SC: 4 fl oz/A	Coragen 1.67SC: 4 fl oz/A	Mustang Maxx 0.8EC: 4 fl oz/A + NIS 0.25%
2: FMC-2	Providence	Brigade 2EC: 1.7 fl oz/A + Mustang Maxx 0.8EC: 3.4 fl oz/A + NIS 0.25%	Brigade 2EC: 1.7 fl oz/A + Mustang Maxx 0.8EC: 3.4 fl oz/A + NIS 0.25%	Brigade 2EC: 1.7 fl oz/A + Mustang Maxx 0.8EC: 3.4 fl oz/A + NIS 0.25%	Coragen 1.67SC: 4 fl oz/A	Coragen 1.67SC: 4 fl oz/A	Warrior II 2.08CS: 1.92 fl oz/A + NIS 0.25%
3: All Warrior	Providence	Warrior II 2.08CS: 1.92 fl oz/A	Warrior II 2.08CS: 1.92 fl oz/A	Warrior II 2.08CS: 1.92 fl oz/A	Warrior II 2.08CS: 1.92 fl oz/A	Warrior II 2.08CS: 1.92 fl oz/A	Warrior II 2.08CS: 1.92 fl oz/A
4: standard	Providence	Asana XL 0.66EC: 5.8 fl oz/A + Coragen 1.67SC: 3.5 fl oz/A	Coragen 1.67SC: 3.5 fl oz/A	Coragen 1.67SC: 3.5 fl oz/A	Hero 1.24EC: 10.3 fl oz/A + NIS 0.25%	Hero 1.24EC: 10.3 fl oz/A + NIS 0.25%	Lannate LV 2.4WSL: 24 fl oz/A
5: untreated	Providence	none	none	none	none	none	none
6: transgenic, no spray	Remedy	none	none	none	none	none	none

Table 2. Weekly catch of moths in pheromone traps in sweet corn field used for insecticide trial, S. Charleston, Ohio, 2018.

Week	Number of moths				Notes
	Corn earworm	European corn borer	Fall armyworm	Western bean cutworm	
May 20-26		set		0	
May 27 - June 2	set	0	set	set	
June 3-9	3	1	0	0	
June 10-16	4	2	0	0	
June 17-23	11	8	0	0	
June 24-30	1	2	0	0	
July 1-7	3	0	0	0	
July 8-14	18	1	0	3	
July 15-21	1	0	0	0	
July 22-28	1	0	0	0	
July 29 - Aug 4	1	0	0	0	
August 5-11	800	-	-	-	Spray 1 on 8/10
August 12-18	367	0	1	0	Spray 2 on 8/13 Spray 3 on 8/15
August 19-25	240	0	0	0	Spray 4 on 8/19 Spray 5 on 8/22 Spray 6 on 8/24
Aug. 26 - Sept 1	143	0	0	0	Harvest on 8/29
Sept 2-8	102	0	0	0	
Sept 9-15	24	0	0	0	
Sept 16-22	31	0	0	0	
Sept 23-29	85	0	0	0	
Sept 30 - Oct 6	22	0	0	0	

Table 3. Silk clipping damage in sweet corn trial on 8/13/2018, before the second 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 *Orius*[a] predators per ear
				Western corn rootworm[a]	Southern corn rootworm	Northern corn rootworm	Japanese beetle	Total[a]	
Remedy	(none)	3.1 A	0.1	0.45 A	0.00	0.20	0.00	0.65 A	0.42
Standard	Asana + Coragen once	0.0 B	0.0	0.02 B	0.02	0.10	0.00	0.15 BC	0.38
FMC-1	Hero once	0.0 B	0.0	0.00 B	0.02	0.00	0.00	0.02 C	0.48
FMC-2	Brigade + Mustang once	0.0 B	0.0	0.00 B	0.02	0.05	0.00	0.08 BC	0.52
Warrior	Warrior once	0.0 B	0.0	0.00 B	0.00	0.00	0.00	0.00 C	0.20
Untreated	(none)	5.6 A	0.2	0.22 AB	0.02	0.18	0.02	0.45 AB	0.32
P (ANOVA treatment effect)		*P =0.0110*	*P=0.0841*	*P=0.0165*	*P=0.86*	*P=0.15*	*P=0.45*	*P=0.0195*	*P = 0.38*

[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 on sweet corn ears at harvest on 8/29/2018, S. Charleston, Ohio.

Treatment	% of husked ears with no worm damage[a,b]	% of husked ears with worm-damaged kernels[a,b]
Remedy	97.5 A	2.5 C
Standard (Asana+Coragen, Coragen, Hero, Lannate)	87.5 B	10.0 B
FMC-1 (Hero, Coragen, Mustang)	82.5 B	17.5 B
FMC-2 (Brigade+Mustang, Coragen, Warrior)	80.0 B	20.0 B
Warrior only	75.0 B	25.0 B
Untreated	0.0 C	100.0 A
ANOVA treatment effect	*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.

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

Table 5. Number of sweet corn kernels damaged by insects by harvest on 8/29/2018, S. Charleston, Ohio.

Treatment	Mean number of damaged kernels per ear			
	Tip third of ear[a]	Middle third of ear[a]	Butt third of ear	Total[a]
Remedy	0.3 B	0.0 B	0.00	0.3 B
Standard	1.6 B	0.0 B	0.00	1.6 B
FMC-1	1.4 B	0.0 B	0.05	1.4 B
FMC-2	2.0 B	0.0 B	0.00	2.0 B
Warrior	2.3 B	0.0 B	0.08	2.4 B
Untreated	21.8 A	0.8 A	0.55	23.1 A
ANOVA treatment effect	*P < 0.0001*	*P = 0.0006*	*P = 0.09*	*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 8/29/2018, S. Charleston, Ohio.

Treatment	Mean length of damage (cm)	
	From tip end[a]	From butt end[a]
Remedy	0.08 B	0.00 B
Standard	0.22 B	0.00 B
FMC-1	0.70 B	0.00 B
FMC-2	0.35 B	0.00 B
Warrior	0.85 B	0.00 B
Untreated	3.18 A	2.60 A
ANOVA treatment effect	*P < 0.0001*	*P = 0.0013*

[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 8/29/2018, S. Charleston, Ohio.

Treatment	Mean number of larvae per ear					
	Corn earworm[a]				European corn borer[a]	Total[a]
	Small	Medium	Large	Total		
Remedy	0.02	0.08 B	0.00 B	0.10 B	0.00 B	0.10 B
Standard	0.02	0.00 B	0.02 B	0.05 B	0.00 B	0.05 B
FMC-1	0	0.02 B	0.05 B	0.08 B	0.00 B	0.08 B
FMC-2	0.02	0.00 B	0.05 B	0.08 B	0.00 B	0.08 B
Warrior	0	0.05 B	0.02 B	0.08 B	0.02 B	0.10 B
Untreated	0.02	0.48 A	1.05 A	1.55 A	0.45 A	2.0 A
ANOVA treatment effect	*P =0.82*	*P <0.0001*	*P <0.0001*	*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.