Sweet Corn Insecticide Trial in Ohio, 2010

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Celeste Welty, Jim Jasinski, and Bob Precheur
Ohio State University

Background: The development of resistance to pyrethroid insecticides in corn earworm populations has been a concern to Ohio growers during the past few years. This is the fourth year that we have evaluated alternatives for corn earworm management. The main objective of this project was to continue to monitor the development of resistance to pyrethroid insecticides in Ohio populations of corn earworm, and to evaluate non-pyrethroid alternatives as replacements for the standard pyrethroid spray schedule. Other objectives were to evaluate different spray timings, and to evaluate the effects of several insecticide programs on other pests, particularly European corn borer, fall armyworm, corn rootworm beetles, and corn leaf aphid, as well as effects on natural enemies.

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 twelve treatments were set up in a randomized complete block design. Eleven treatments used a standard hybrid ('Providence'), and one treatment used its transgenic B.t. isoline ('Attribute BC 0805'). Each plot was four rows wide and 40 feet long, with 30-inch row spacing. Plots were seeded on 23 June. Corn earworm moths were monitored by pheromone in one Hartstack trap, and fall armyworm moths were monitored by pheromone in one all-green unitrap; lures for both were Hercon brand and were changed every 2 weeks.

Eight treatments were involved an insecticide screening trial for a comparison of different insecticide products that were all applied six times on a uniform 3- to 4-day schedule, as detailed in Table 1. Six treatments were involved an insecticide timing trial in which a single insecticide (Warrior) was applied on five different timing schedules. The spray program was initiated on 10 August, once silks appeared on approximately 20% of plants. The application dates are detailed in Table 2. Sprays were applied by a "Hi-Boy"-style Spider sprayer (West Texas Lee Company, Inc., Idalou TX) that applied 28.1 gallons per acre at 54 PSI, with ConeJet-18 nozzles on drop pipes directed at the ear zone in the center two rows per plot. Products and rates of insecticides used were: Coragen 1.67SC (chlorantraniliprole), 3.5 fl oz/A + MSO 0.5%; Asana XL 0.66EC (esfenvalerate), 9.6 fl oz/A; Lannate LV 2.4WSL (methomyl), 24 fl oz/A; Voliam Xpress 0.417+0.835 ZC (lambda-cyhalothrin + chlorantraniliprole), 7 fl oz/A; Hero 1.24EC (bifenthrin + zeta-cypermethrin), 8 fl oz/A; Mustang Max 0.8EC (zeta-cypermethrin), 4 oz/A; and Warrior II 2.08CS (lambda-cyhalothrin), 1.92 fl oz/A.

Silk-clipping damage was rated as 0, 25, 50, 75, or 100% clipped, and density of silk-clipping beetles, generalist predators, and corn leaf aphid were evaluated on 10 ears per plot during early silking on 13 August. Samples of 20 ears from the center two rows per plot were harvested and evaluated on 31 August. 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. Each ear was rated as infested or not infested by corn leaf aphid. The percentage of ear fill with normal kernels was estimated for each ear. Data were subjected to analysis of variance (ANOVA) and mean comparisons by least significant difference (LSD) tests in the SAS 9.1 microcomputer statistics program.

Results: The crop developed more quickly than usual due to frequent rains and above average temperatures. Plants began silking during the same week that the corn earworm moth population had a sharp rise in activity (Figure 1), thus there was heavy pest pressure during the critical silking period. During the silking period, the moth catch in the pheromone trap ranged from 11 to 270 moths per night (Table 3). The corn earworm population in 2010 was larger than in 2009 and similar to 2007.

Comparison of harvested ears after treatment with different insecticide programs showed that all insecticides resulted in significantly less damage than in the untreated control, by all four damage variables: the percentage of ears with no kernel damage (a liberal measure); the percentage of ears with no damage to kernels, silks, husks, or shank (a conservative measure); the number of damaged kernels per ear; and the length of kernel damage from ear tip (Table 4). The percentage of ears with no kernel damage was 1% in the untreated control, and ranged from a high of 94% in the Voliam Xpress treatment to a low of 21% in the transgenic Attribute treatment; there was significantly less damage in Voliam Xpresss, Hero, and Coragen early treatments than in the Coragen mix, Coragen late, and Warrior treatments (Table 4). The percentage of ears with no damage to kernels, silks, husks, or shank was zero percent in the untreated control, and ranged from a high of 91% in the Voliam Xpress treatment to a low of 6% in the Attribute treatment (Table 4). The number of kernels damaged was 26.9 per ear in the untreated control, and ranged from 0.8 kernel per ear in the Voliam Xpress treatment to 6.4 kernels per ear in the Attribute treatment; most damaged kernels were in the tip third of the ear (Table 4). The length of kernel damage from ear tip was 7.5 cm in the untreated control, and ranged from 0.2 cm in the Voliam Xpress treatment to 2.3 cm in the Attribute treatment (Table 4). Among the three treatments with different sequences of Coragen, Asana, and Lannate, the best treatment was when Coragen was in the first two sprays, and the least effective treatment was when Coragen was in the last two sprays. Corn leaf aphid incidence in harvested ears was light and did not differ significantly among treatments (Table 4). The percentage of ear fill with normal kernels ranged from 92 to 97% and did show significant treatment effects (Table 4). No phytotoxicity was observed.

The species complex that caused damage to ears was equally corn earworm (0.8 larva per ear in untreated plots) and European corn borer (0.9 larva per ear in untreated plots); fall armyworm was also present (0.08 larva per ear in untreated plots) but at much lower density (Table 5). The total number of caterpillars per ear was significantly lower in the Voliam Xpress, Hero, Coragen, and Warrior treatments than in the untreated control, and the number in the transgenic Attribute treatment was intermediate (Table 5). Similar trends were seen for small and large corn earworm as well as for European corn borer (Table 5). For the total of corn earworm of all sizes, the number in the Attribute treatment was not significantly different than the untreated control, and both were significantly higher than in the other treatments (Table 5).

Comparison of harvested ears after one insecticide, Warrior, was applied on five timing schedules showed that all schedules resulted in significantly less damage than in the untreated control, by all four damage variables (Table 6). Among the different schedules, there was generally less damage on the shorter schedules than the longer ones. The percentage of ears with no kernel damage was significantly higher in the 2-day and 3-day schedules than in the 3- to 4-day, or 5-day schedules, while the 4-day schedule was intermediate (Table 6). There were fewer treatment differences in insect density than in damage; there were significantly fewer larvae after all treatment schedules than in the untreated control, for the number of total caterpillars, total corn earworm, and European corn borer per ear (Table 7).

The most common species of silk-clipping beetle found by scouting on 13 August was western corn rootworm beetle, but a few northern and southern corn rootworm beetles and Japanese beetles were found. Significant differences among treatments were found in the percentage of silk clipped and in the number of beetles per ear (Table 8). Clipping and total beetle density were significantly higher in the transgenic Attribute treatment and in non-transgenic after no spray or after Coragen than after Asana, Voliam Xpress, Hero, or Warrior treatments (Table 8).

Corn leaf aphid populations evaluated at the same time as silk clipping on 13 August showed some significant treatment differences. Aphid ratings ranged from 0 in unsprayed plots to 0.17 in the Warrior plots that had been sprayed once (Table 8). It was not determined whether treatment differences were due to direct toxicity to the aphids or to indirect effects via toxicity to natural enemies of the aphids. The most common generalist predator found during early silking was *Orius insidiosus*; a few lady beetle larvae were also found (Table 8). *Orius* density differed significantly among treatments, and ranged from a low of 0.02 per plant in plots that had been sprayed twice with Warrior, to a high of 2.2 per plant in plots that had been sprayed once with Coragen (Table 8). The only treatment that had good beetle control but with good survival of *Orius* was the Asana treatment.

Conclusions: Pyrethroids were less effective for caterpillar control in 2010 than they had been in 2009; Warrior at the maximum rate resulted in 60% of ears undamaged in 2010 while it had resulted in 94% of ears undamaged in 2009. The lower efficacy of pyrethroids could be due to the heavier populations of corn earworm in 2010 or to increased frequency of insecticide resistance. For earworm and borer control, Coragen is best used early in silking rather than later in silking. When applied at early silking, Coragen will not control silk-clipping beetles; inclusion of a pyrethroid in early silking will provide good control of silk-clipping beetles. Under conditions of heavy pest pressure, the transgenic Attribute corn does provide better control than untreated but significantly lower control than the insecticide sprays; the addition of two sprays to the Attribute plots would have resulted in improved control if it had been done as in previous years' trials. Under conditions of heavy pressure from corn earworm, insecticide sprays every 2- or 3-days during silking provided significantly better control than sprays every 4- or 5-days.

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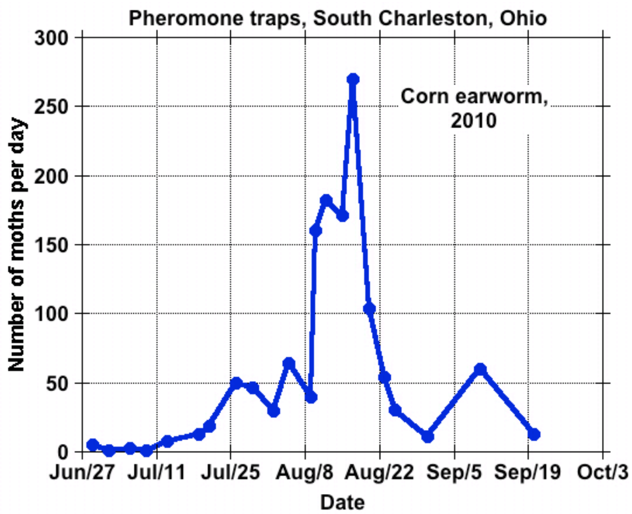
Table 1. Sequence of insecticides used in sweet corn insecticide screening trial, Clark County, Ohio, 2010.

Treatment number (and short name)	*Hybrid*	*Spray 1*	*Spray 2*	*Spray 3*	*Spray 4*	*Spray 5*	*Spray 6*
1 (Coragen mix)	Providence	Asana	Lannate	Coragen	Asana	Lannate	Coragen
2 (Coragen late)	Providence	Asana	Lannate	Asana	Lannate	Coragen	Coragen
3 (Coragen early)	Providence	Coragen	Coragen	Asana	Lannate	Asana	Lannate
4 (Hero)	Providence	Hero	Hero	Hero	Lannate	Mustang Max	Mustang Max
5 (Voliam Xpress)	Providence	Voliam Xpress	Voliam Xpress	Voliam Xpress	Voliam Xpress	Warrior	Warrior
6 (Warrior)	Providence	Warrior	Warrior	Warrior	Warrior	Warrior	Warrior
7 (Attribute [B.t.], no spray)	Attribute BC 0805	-	-	-	-	-	-
8 (untreated)	Providence	-	-	-	-	-	-

Table 2. Spray schedules and application dates in sweet corn insecticide trial, Clark County, Ohio, 2010.

Treatment number	*Spray schedule*	*Spray application dates*	*Total number of sprays*
9	2-day	8/10, 8/12, 8/14, 8/16, 8/18, 8/20, 8/22, 8/24, 8/26, 8/28, 8/30	11
10	3-day	8/10, 8/13, 8/16, 8/19, 8/22, 8/25, 8/28	7
1 - 6	3- to 4-day	8/10, 8/13, 8/16, 8/19, 8/23, 8/27	6
11	4-day	8/10, 8/14, 8/18, 8/22, 8/26, 8/30	6
12	5-day	8/10, 8/15, 8/20, 8/25, 8/30	5

Figure 1. Seasonal trends in catch of corn earworm and fall armyworm in pheromone traps, South Charleston, Clark County, Ohio, 2010.



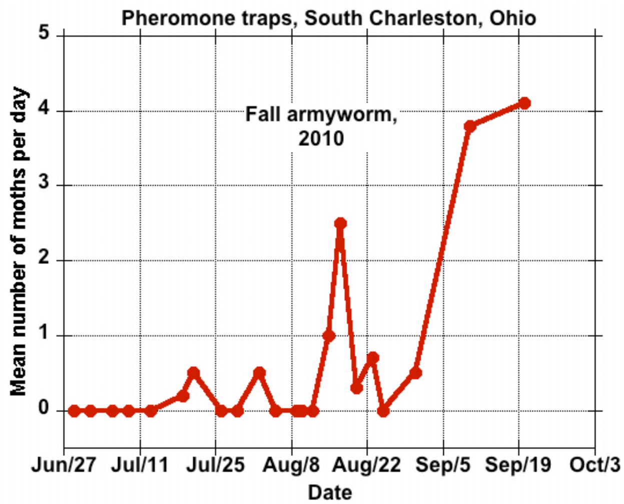


Table 3. Pheromone trap catches, South Charleston, Clark County, Ohio, 2010.

Date	*Corn earworm moths per day*	*Fall armyworm moths per day*
6/29/10	4.7	0.0
7/2/10	0.7	0.0
7/6/10	2.8	0.0
7/9/10	1.3	0.0
7/13/10	7.3	0.0
7/19/10	12.8	0.2
7/21/10	18.5	0.5
7/26/10	49.6	0.0
7/29/10	46.3	0.0
8/2/10	29.5	0.5
8/5/10	64.0	0.0
8/9/10	40.0	0.0
8/10/10	160.0	0.0
8/12/10	182.0	0.0
8/15/10	171.0	1.0
8/17/10	270.0	2.5
8/20/10	103.7	0.3
8/23/10	54.3	0.7
8/25/10	30.5	0.0
8/31/10	11.2	0.5
9/10/10	60.0	3.8
9/20/10	12.6	4.1

Table 4. Damage by caterpillars in harvested sweet corn ears in insecticide screening trial, 31 August 2010, Clark County, Ohio.

Trt no.	*Treatment (on 3- to 4-day spray schedule)*	*% of ears with no damaged kernels*[a, b]	*% of ears with no damage to kernels, husks, silks, shank*[a,b]	*Number of damaged kernels per ear*[a]				*Length of damage from ear tip (cm)*[a]	*Corn leaf aphid* [c]	*% ear fill*[a,b]
				Tip third of ear	*Middle third of ear*	*Butt third of ear*	*Total*			
5	Voliam Xpress	94 A	91 A	0.8 D	0.0 B	0.0 B	0.8 D	0.2 D	0.00	96 ABC
4	Hero	88 A	85 A	1.0 D	0.0 B	0.0 B	1.0 CD	0.4 D	0.00	96 ABC
3	Coragen early	86 A	82 AB	1.2 CD	0.0 B	0.0 B	1.2 CD	0.3 D	0.00	96 AB
1	Coragen mix	70 B	69 BC	2.3 CD	0.2 B	0.1 B	2.6 CD	1.3 C	0.00	95 BCD
2	Coragen late	68 B	60 C	2.7 CD	0.0 B	0.1 B	2.8 CD	1.9 BC	0.02	97 A
6	Warrior	60 B	58 C	3.1 C	0.1 B	0.1 B	3.2 C	1.5 BC	0.01	94 CD
7	Attribute (B.t.), no spray	21 C	18 D	6.0 B	0.2 B	0.2 B	6.4 B	2.3 B	0.00	97 AB
8	untreated	1 D	0 E	25.1 A	0.8 A	1.0 A	26.9 A	7.5 A	0.00	92 D
	P value	*<0.0001*	*<0.0001*	*<0.0001*	*0.03*	*0.0002*	*<0.0001*	*<0.0001*	*0.15*	*0.0147*

[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] *Corn leaf aphid rating: 0 = not infested; 1 = infested.*

Table 5. Density and species of caterpillars in sweet corn ears at harvest in insecticide screening trial, 31 August 2010, Clark County, Ohio.

Trt no.	*Treatment (on 3- to 4-day spray schedule)*	*Total number of caterpillars per ear*[a]	*Number of corn earworm per ear*[a]				*Number of European corn borer per ear*[a]	*Number of fall armyworm per ear*
			small	*medium*	*large*	*total*		
5	Voliam Xpress	0.05 C	0.00 C	0.02 C	0.00 C	0.02 B	0.02 C	0.00
4	Hero	0.02 C	0.00 C	0.00 C	0.00 C	0.00 B	0.01 C	0.01
3	Coragen early	0.09 C	0.02 C	0.01 C	0.00 C	0.04 B	0.05 C	0.00
1	Coragen mix	0.19 C	0.01 C	0.10 BC	0.02 C	0.14 B	0.04 C	0.01
2	Coragen late	0.29 C	0.04 C	0.01 C	0.05 BC	0.10 B	0.19 B	0.00
6	Warrior	0.16 C	0.01 C	0.08 BC	0.02 C	0.11 B	0.02 C	0.02
7	Attribute (B.t.), no spray	1.05 B	0.44 A	0.32 A	0.12 B	0.89 A	0.10 BC	0.06
8	untreated	1.83 A	0.19 B	0.19 B	0.43 A	0.81 A	0.94 A	0.08
	P value	*<0.0001*	*<0.0001*	*0.0004*	*<0.0001*	*<0.0001*	*<0.0001*	*0.15*

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

Table 6. Damage by caterpillars in harvested sweet corn ears in insecticide timing trial, 31 August 2010, Clark County, Ohio.

Trt no.	*Treatment*	*% of ears with no dam-aged ker-nels*[a,b]	*% of ears with no damage to kernels, husks, silks, or shank*[a,b]	*Number of damaged kernels per ear*[a]				*Length of dam-age from tip (cm)*[a]	*Corn leaf aphid*[c]	*% ear fill*[a, b]
				Tip third of ear	*Middle third of ear*	*Butt third of ear*	*Total*			
9	Warrior 2-day	84 A	81 A	0.7 D	0.2 B	0.1 B	1.0 D	1.0 C	0.00	96 A
10	Warrior 3-day	80 A	75 AB	1.6 CD	0.0 B	0.1 B	1.7 CD	1.1 C	0.00	94 BC
11	Warrior 4-day	65 AB	62 BC	3.4 BC	0.0 B	0.1 B	3.5 BC	1.6 BC	0.00	95 B
6	Warrior 3- to 4-day	60 B	58 C	3.1 BC	0.1 B	0.1 B	3.2 CD	1.5 BC	0.01	94 BC
12	Warrior 5-day	54 B	50 C	5.1 B	0.1 B	0.6 AB	5.8 B	2.7 B	0.01	95 B
8	untreated	1 C	0 D	25.1 A	0.8 A	1.0 A	26.9 A	7.5 A	0.00	92 C
	P value	*<0.0001*	*<0.0001*	*<0.0001*	*0.0164*	*0.09*	*<0.0001*	*<0.0001*	*0.45*	*0.0021*

[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] *Corn leaf aphid rating: 0 = not infested; 1 = infested.*

Table 7. Density and species of caterpillars in sweet corn ears at harvest in insecticide timing trial, 31 August 2010, Clark County, Ohio.

Trt no.	*Treatment*	*Total number of worms per ear*[a]	*Number of corn earworm per ear*[a]				*Number of European corn borer per ear*[a]	*Number of fall armyworm per ear*
			small	*medium*	*large*	*total*		
9	Warrior 2-day	0.02 B	0.00 B	0.01 CD	0.00 B	0.01 B	0.01 B	0.00
10	Warrior 3-day	0.14 B	0.02 B	0.00 D	0.04 B	0.06 B	0.08 B	0.00
11	Warrior 4-day	0.21 B	0.02 B	0.02 CD	0.08 B	0.12 B	0.08 B	0.01
6	Warrior 3- to 4-day	0.16 B	0.01 B	0.08 B	0.02 B	0.11 B	0.02 B	0.02
12	Warrior 5-day	0.21 B	0.02 B	0.05 BC	0.08 B	0.15 B	0.01 B	0.05
8	untreated	1.83 A	0.19 A	0.19 A	0.43 A	0.81 A	0.94 A	0.08
	P value	*<0.0001*	*0.0527*	*<0.0001*	*<0.0001*	*<0.0001*	*<0.0001*	*0.24*

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

Table 8. Insects and damage on sweet corn ears during early silking, 8/13/2010, in insecticide trial, Clark County, Ohio.

Treatment number	*Insecticides applied by time of evaluation*	*%[a,b] of silk clipped*	*Number[b] of silk-clipping beetles per ear*					*Number[b] of generalist predators per ear*		*Rating for corn leaf aphid[b,c]*
			Western corn root-worm	*North-ern corn root-worm*	*South-ern corn root-worm*	*Japa-nese bee-tle*	*total*	*Orius*	*Lady beetle larvae*	
9	Warrior on 8/10 & 8/12	0 C	0 B	0 C	0	0	0 B	0.02 D	0 B	0.05 CD
4	Hero on 8/10	0 C	0.05 B	0 C	0	0	0.05 B	0.7 C	0 B	0.08 BCD
6, 10, 11, 12	Warrior on 8/10	1 C	0.03 B	0.01 C	0	0.01	0.05 B	0.4 CD	0 B	0.17 A
5	Voliam Xpress on 8/10	1 C	0.02 B	0.02 BC	0	0	0.05 B	0.7 C	0 B	0.15 AB
1, 2	Asana on 8/10	3 C	0.11 B	0.02 BC	0	0	0.14 B	1.7 B	0 B	0.12 ABC
8	none (untreated)	29 B	1.72 A	0.10 B	0.08	0.02	1.92 A	1.9 AB	0.05 A	0 D
3	Coragen on 8/10	33 AB	1.68 A	0.20 A	0.08	0.02	1.98 A	2.2 A	0 B	0.08 BCD
7	none (BT)	38 A	1.70 A	0.02 BC	0.08	0	1.80 A	1.8 AB	0 B	0.02 D
P from ANOVA		*<0.0001*	*<0.0001*	*0.0003*	*0.062*	*0.53*	*<0.0001*	*<0.0001*	*0.0239*	*0.0044*

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

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

[c] Rating for corn leaf aphid on scale 0 to 2: 0 = none; 1 = light; 2 = heavy.