Managing insecticide resistance in corn earworm on sweet corn

Final report to the Ohio Vegetable & Small Fruit Research & Development Program, 4 January 2010

Celeste Welty, Jim Jasinski, Bob Precheur

Ohio State University

Background: There has been concern by Ohio growers about the development of resistance to pyrethroids in corn earworm populations during the past few years. This is the third year that we have evaluated pyrethroid and non-pyrethroid alternatives for corn earworm management. Insecticides were evaluated primarily against corn earworm but also against European corn borer and fall armyworm as well as silk-clipping beetles and corn leaf aphid, which usually infest sweet corn concurrently. The objectives of this project were to continue to monitor the development of resistance to pyrethroid insecticides in Ohio populations of corn earworm, and evaluate non-pyrethroid alternatives as replacements for the standard pyrethroid spray schedule.

Methods: The 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 fifteen treatments were set up in a randomized complete block design. Thirteen treatments used a standard hybrid ('Providence'), and two treatments used its 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 27 June. Corn earworm moths were monitored by pheromone lures (Hercon brand) in one Hartstack trap; lures were changed every 2 weeks.

The spray program was initiated once silks appeared on approximately 20% of plants. Sprays were applied six times at 3- to 5-day intervals based on maximum daily temperature and moth catch in the trap. The application dates were 24, 27, 30 August, and 3, 7, 12 September. Sprays were applied by a "Hi-Boy"-style Spider sprayer (West Texas Lee Company, Inc., Idalou TX) that applied 35 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. Formulations and rates of insecticides used were: Belt 4SC (flubendiamide), 3 fl oz/A + MSO 0.5%; Baythroid XL 1EC (beta-cyfluthrin), 2.4 fl oz/A; Coragen 1.67SC (chlorantraniliprole), 5 fl oz/A + MSO 0.5%; Asana XL (esfenvalerate), 9.6 fl oz/A; Lannate LV 2.4WSL (methomyl), 24 fl oz/A; Radiant 1SC (spinetoram), 6 fl oz/A; Voliam Xpress 0.417+0.835 ZC (lambda-cyhalothrin + chlorantraniliprole), 7 fl oz/A, and 9 fl oz/A; Hero 1.24EC (bifenthrin + zeta-cypermethrin), 8 fl oz/A; Mustang Max 0.8EC (zeta-cypermethrin), 4 oz/A; Warrior II 2.08CS (lambda-cyhalothrin), 1.92 fl oz/A, and 1.26 fl oz/A; Brigade 2EC (bifenthrin), 2.56 fl oz/A, and 6.4 fl oz/A. Coragen and Voliam Xpress are not yet registered for use on sweet corn; all other products are registered for this use. The sequence of products used in each spray for each treatment is shown in Table 2.

Silk-clipping damage was evaluated in 10 ears per plot on 27 August (before the second spray) and 3 September (before the fourth spray). Samples of 20 ears from the center two rows per plot were harvested and evaluated on 15 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. 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 was slow to develop due to cooler than normal summer weather, but it began silking during the same week that the corn earworm moth population migrated into Ohio, thus there was heavy pest pressure during the critical silking period. During the silking period in late August and early September, the moth catch in the pheromone trap ranged from 1 to 63 moths per night (Table 1). The corn earworm population in 2009 was larger than in 2008 but smaller than in 2007.

All insecticide treatments 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, or husks (a conservative measure); the number of damaged kernels per ear; and the length of kernel damage from ear tip (Table 3). The percentage of ears with no kernel damage was 9% in the untreated control, and ranged from a high of 99% in the Voliam Xpress 9 oz treatment and Brigade/Warrior treatment to a low of 64% in the Belt treatment (Table 3). The percentage of ears with no damage to kernels, silks, or husks was zero percent in the untreated control, and ranged from a high of 95% in the Brigade/Warrior treatment to a low of 45% in the Attribute treatment (Table 3). The number of kernels damaged was 16 per ear in the untreated control, and ranged from 0.1 kernels per ear in the Voliam Xpress 9 oz treatment and Brigade/Warrior treatment to 3.1 kernels per ear in the Belt treatment (Table 3). The length of kernel damage from ear tip was 3.6 cm in the untreated control, and ranged from 0.1 cm in the five best treatments to 1.1 cm in the Warrior 1.26 oz treatment (Table 3). Belt alternated with Baythroid was numerically better but not statistically better than Belt alone, by all four damage measures. Coragen/Asana/Lannate was numerically better but not statistically better than Coragen alone, by all four damage measures. Radiant provided control very similar to Coragen alone. Warrior II at the maximum label rate of 1.92 oz/A was significantly better than at the minimum label rate of 1.26 oz/A for three of the four damage measures. Voliam Xpress at 9 oz/A was not significantly better than the 7 oz rate for any of the four damage measures. The BT hybrid 'Attribute 0805' with two sprays of Brigade was significantly better than 'Attribute 0805' without sprays, for one of the four damage measures. Among the five treatments that were pyrethroids alone, the best was Brigade/Warrior.

Although corn earworm was the dominant pest species, European corn borer and fall armyworm were also present at low density. There were approximately nine times as many corn earworm larvae per ear as European corn borer or fall armyworm larvae in untreated plots at harvest (Table 4). The number of larvae per ear was significantly lower in all treated plots than in the untreated control for each of the three species separately and for the sum of species (Table 4). The total number of larvae per ear ranged from a low of 0.00 in the Coragen/Asana/Lannate treatment to 0.79 in the 'Attribute' treatment, compared to 1.59 larvae in the untreated control.

The most common species of silk-clipping beetle found by scouting was western corn rootworm beetle, but a few northern corn rootworm beetles and Japanese beetles were found. On 27 August, no significant differences among treatments were found in the percentage of silk clipped but significant differences were found in the number of beetles per ear (Table 5). On 3 September, both the percentage clipped and the number of beetles differed significantly among treatments; clipping was zero or negligible (<5%) in 10 treatments and higher (>5%) in 5 treatments (Table 5). Any treatment that included a pyrethroid in any of the first three sprays had negligible silk-clipping damage. The percentage of ear fill at harvest was assessed but no significant treatment differences were found (Table 5), which suggests that clipping occurred after pollination was complete.

Corn leaf aphid populations evaluated at the same time as silk clipping showed significant treatment differences on both scouting dates as well as at harvest. Infestation ranged from 2 to 58% of ears on 27 August, from 0 to 55% of ears on 3 September, and from 0 to 79% of ears at harvest (Table 6). In general, any treatment that included a pyrethroid had low incidence of aphid infestation. It was not determined whether differences were due to direct toxicity to the aphids or to indirect effects via toxicity to natural enemies of the aphids.

Conclusions: Pyrethroids were still effective in 2009 for control of corn earworm when used at maximum rates. Coragen alone and Radiant alone are good alternatives to pyrethroids for corn earworm control, and Belt alone is a fair alternative, but none of these provide control of silk clipping beetles or corn leaf aphid. Coragen or Belt used in a program with pyrethoids provided good control of caterpillars as well as silk clipping beetles and corn leaf aphid.

Acknowledgements: We appreciated assistance with planting from Clarence Renk, with spraying from Bryan Reeb and Joe Davlin, and with harvest from Marie Burleson, Michelle LaCount, Bruce Eisley and Marsha Martin. Seed was provided by Syngenta. Insecticides and funding were provided by Bayer, Dow, DuPont, FMC, and Syngenta. Funding was also provided by the Ohio Vegetable and Small Fruit Research and Development Program.

Table 1. Number of corn earworm moths caught in a pheromone trap next to sweet corn trial field, Clark County, Ohio, 2009.

Date	*Number of moths*	*Mean number moths per day*
30 June	0	0.0
6 July	0	0.0
8 July	0	0.0
10 July	0	0.0
15 July	0	0.0
17 July	0	0.0
20 July	0	0.0
24 July	0	0.0
28 July	2	0.5
30 July	0	0.0
5 August	0	0.0
11 August	2	0.3
17 August	6	1.0
21 August	13	3.3
24 August	179	59.7
27 August	188	62.7
31 August	33	8.3
3 September	15	5.0
8 September	17	3.4
12 September	3	0.8

Table 2. Sequence of insecticides used on two sweet corn hybrids in 15 treatments, Clark County, Ohio, 2009.

	Hybrid	*Spray 1*	*Spray 2*	*Spray 3*	*Spray 4*	*Spray 5*	*Spray 6*
1	Providence	Belt, 3 fl oz/A + MSO 0.5%	Belt, 3 fl oz/A + MSO 0.5%	Belt, 3 fl oz/A + MSO 0.5%	Belt, 3 fl oz/A + MSO 0.5%	Belt, 3 fl oz/A + MSO 0.5%	Belt, 3 fl oz/A + MSO 0.5%
2	Providence	Belt, 3 fl oz/A + MSO 0.5%	Baythroid XL, 2.4 fl oz/A	Belt, 3 fl oz/A + MSO 0.5%	Baythroid XL, 2.4 fl oz/A	Belt, 3 fl oz/A + MSO 0.5%	Baythroid XL, 2.4 fl oz/A
3	Providence	Coragen, 5 fl oz/A + MSO 0.5%	Coragen, 5 fl oz/A + MSO 0.5%	Coragen, 5 fl oz/A + MSO 0.5%	Coragen, 5 fl oz/A + MSO 0.5%	Coragen, 5 fl oz/A + MSO 0.5%	Coragen, 5 fl oz/A + MSO 0.5%
4	Providence	Coragen, 5 fl oz/A + MSO 0.5%	Coragen, 5 fl oz/A + MSO 0.5%	Asana XL, 9.6 fl oz/A	Lannate LV, 24 fl oz/A	Asana XL, 9.6 fl oz/A	Lannate LV, 24 fl oz/A
5	Providence	Radiant, 6 fl oz/A	Radiant, 6 fl oz/A	Radiant, 6 fl oz/A	Radiant, 6 fl oz/A	Radiant, 6 fl oz/A	Radiant, 6 fl oz/A
6	Providence	Voliam Xpress, 7 fl oz/A	Voliam Xpress, 7 fl oz/A	Voliam Xpress, 7 fl oz/A	Voliam Xpress, 7 fl oz/A	Voliam Xpress, 7 fl oz/A	Voliam Xpress, 7 fl oz/A
7	Providence	Voliam Xpress, 9 fl oz/A	Voliam Xpress, 9 fl oz/A	Voliam Xpress, 9 fl oz/A	Voliam Xpress, 9 fl oz/A	Voliam Xpress, 9 fl oz/A	Voliam Xpress, 9 fl oz/A
8	Providence	Hero, 8 fl oz/A	Hero, 8 fl oz/A	Hero, 8 fl oz/A	Mustang Max, 4 oz/A	Mustang Max, 4 oz/A	Mustang Max, 4 oz/A
9	Providence	Warrior II, 1.92 fl oz/A	Warrior II, 1.92 fl oz/A	Warrior II, 1.92 fl oz/A	Warrior II, 1.92 fl oz/A	Warrior II, 1.92 fl oz/A	Warrior II, 1.92 fl oz/A
10	Providence	Warrior II, 1.26 fl oz/A	Warrior II, 1.26 fl oz/A	Warrior II, 1.26 fl oz/A	Warrior II, 1.26 fl oz/A	Warrior II, 1.26 fl oz/A	Warrior II, 1.26 fl oz/A
11	Providence	Brigade, 2.56 fl oz/A	Brigade, 2.56 fl oz/A	Brigade, 2.56 fl oz/A	Brigade, 2.56 fl oz/A	Brigade, 2.56 fl oz/A	-
12	Providence	Brigade, 6.4 fl oz/A	Brigade, 6.4 fl oz/A	Warrior II, 1.92 fl oz/A	Warrior II, 1.92 fl oz/A	Warrior II, 1.92 fl oz/A	Warrior II, 1.92 fl oz/A
13	Attribute BC 0805	-	-	-	-	Brigade, 6.4 fl oz/A	Brigade, 6.4 fl oz/A
14	Attribute BC 0805	-	-	-	-	-	-
15	Providence	-	-	-	-	-	-

Table 3. Damage by caterpillars in harvested sweet corn ears, 15 September 2009, Clark County, Ohio.

Treatment (ranked by % of ears with no kernel damage)	*% of ears with no kernel damage*[1]	*% of ears with no damage to kernels, silks, or husks*[1]	*Number of kernels damaged per ear*[1]	*Length of kernel damage at ear tip (cm)*[1]
Voliam Xpress, 9 oz/A (6 sprays)	99 A	92 AB	0.1 C	0.1 E
Brigade 6.4 oz/A (2 sprays) then Warrior II, 1.92 oz/A (4 sprays)	99 A	95 A	0.1 C	0.1 E
Voliam Xpress, 7 oz/A (6 sprays)	98 A	94 A	0.3 C	0.1 E
Warrior II, 1.92 oz/A (6 sprays)	94 AB	88 ABC	0.7 C	0.1 E
Coragen 5 oz/A + MSO 0.5% (2 sprays) then Asana 9.6 oz/A (2 sprays) alternated with Lannate 24 oz/A (2 sprays)	92 AB	88 ABCD	1.0 C	0.1 E
Hero, 8 oz/A (3 sprays) then Mustang Max 4 oz/A (3 sprays)	90 BC	74 CDEF	0.8 C	0.6 BCDE
Brigade 2.56 oz/A (first 5 sprays)	85 BCD	81 BCDE	1.2 BC	0.4 DE
Coragen 5 oz/A + MSO 0.5% (6 sprays)	84 BCD	78 CDEF	1.3 BC	0.3 DE
Radiant 6 oz/A (6 sprays)	80 CDE	71 DEFG	1.8 BC	0.6 BCDE
BT hybrid ‘Attribute 0805’ + Brigade 6.4 oz/A (last 2 sprays only)	80 CDEF	70 EFG	1.1 C	0.4 CDE
Belt 3 oz/A + MSO 0.5% (3 sprays) alternating with Baythroid XL 2.4 oz/A (3 sprays)	79 CDEF	69 EFG	2.1 BC	0.5 BCDE
Warrior II, 1.26 oz/A (6 sprays)	75 DEF	61 FGH	2.0 BC	1.1 B
BT hybrid ‘Attribute 0805’ + no sprays	66 EF	45 H	2.0 BC	1.0 BC
Belt 3 oz/A + MSO 0.5% (6 sprays)	64 F	54 GH	3.1 B	0.8 BCD
untreated	9 G	0 I	16.0 A	3.6 A
Probability value for treatment effect	*<0.0001*	*<0.0001*	*<0.0001*	*<0.0001*

[1] Within each column, means followed by the same letter are not significantly different (*P*>0.05), by LSD.

Table 4. Density and species of caterpillars in sweet corn ears at harvest, 15 September 2009, Clark County, Ohio.

Treatment (ranked by total of three species)	*Number of larvae per ear*[1]			
	Corn earworm	*European corn borer*	*Fall armyworm*	*Total*
Coragen 5 oz/A + MSO 0.5% (2 sprays) then Asana 9.6 oz/A (2 sprays) alternated with Lannate 24 oz/A (2 sprays)	0.00 E	0.00 B	0.00 C	0.00 E
Voliam Xpress, 9 oz/A (6 sprays)	0.01 E	0.00 B	0.00 C	0.01 E
Brigade 6.4 oz/A (2 sprays) then Warrior II, 1.92 oz/A (4 sprays)	0.02 DE	0.00 B	0.01 C	0.04 E
Hero, 8 oz/A (3 sprays) then Mustang Max 4 oz/A (3 sprays)	0.02 DE	0.00 B	0.01 C	0.04 E
Voliam Xpress, 7 oz/A (6 sprays)	0.04 DE	0.00 B	0.00 C	0.04 E
Warrior II, 1.92 oz/A (6 sprays)	0.09 DE	0.00 B	0.00 C	0.09 DE
Brigade 2.56 oz/A (first 5 sprays)	0.09 DE	0.00 B	0.01 C	0.10 CDE
Coragen 5 oz/A + MSO 0.5% (6 sprays)	0.14 CDE	0.00 B	0.00 C	0.14 CDE
Radiant 6 oz/A (6 sprays)	0.15 CDE	0.00 B	0.01 C	0.16 CDE
Belt 3 oz/A + MSO 0.5% (3 sprays) alternating with Baythroid XL 2.4 oz/A (3 sprays)	0.15 CDE	0.02 B	0.00 C	0.18 CDE
Warrior II, 1.26 oz/A (6 sprays)	0.21 CDE	0.03 B	0.01 C	0.25 CDE
Belt 3 oz/A + MSO 0.5% (6 sprays)	0.39 C	0.00 B	0.01 C	0.40 CD
BT hybrid ‘Attribute 0805’ + Brigade 6.4 oz/A (last 2 sprays)	0.31 CD	0.00 B	0.10 AB	0.41 C
BT hybrid ‘Attribute 0805’ + no sprays	0.74 B	0.00 B	0.05 BC	0.79 B
untreated	1.31 A	0.14 A	0.14 A	1.59 A
Probability value for treatment effect	*<0.0001*	*<0.0001*	*0.0012*	*<0.0001*

[1] Within each column, means followed by the same letter are not significantly different (P>0.05), by LSD.

Table 5. Silk clipping damage by beetles in sweet corn, 2009, Clark County, Ohio.

Treatment (ranked by % of silk clipped on 3 September)	*27 August (before 2nd spray)*		*3 September (before 4th spray)*		*15 Sep.: % ear fill at harvest*
	% of silk clipped	*Number of beetles per ear*[1, 2]	*% of silk clipped*[1]	*Number of beetles per ear*[1, 2]	
Brigade 2.56 oz/A (first 5 sprays)	0.0	0.00 E	0.0 C	0.00 C	98.9
Warrior II, 1.92 oz/A (6 sprays)	0.0	0.00 E	0.0 C	0.00 C	98.4
Brigade 6.4 oz/A (2 sprays) then Warrior II, 1.92 oz/A (4 sprays)	0.0	0.00 E	0.0 C	0.00 C	99.0
Voliam Xpress, 7 oz/A (6 sprays)	0.0	0.02 DE	0.6 C	0.00 C	99.5
Voliam Xpress, 9 oz/A (6 sprays)	0.0	0.00 E	0.6 C	0.00 C	99.6
Coragen 5 oz/A + MSO 0.5% (2 sprays) then Asana 9.6 oz/A (2 sprays) alternated with Lannate 24 oz/A (2 sprays)	0.0	0.20 CDE	1.9 C	0.00 C	99.5
Hero, 8 oz/A (3 sprays) then Mustang Max 4 oz/A (3 sprays)	0.0	0.00 E	1.9 C	0.00 C	99.2
Warrior II, 1.26 oz/A (6 sprays)	0.0	0.00 E	2.5 C	0.00 C	99.3
Belt 3 oz/A + MSO 0.5% (3 sprays) alternating with Baythroid XL 2.4 oz/A (3 sprays)	0.0	0.18 CDE	2.5 C	0.00 C	99.1
Belt 3 oz/A + MSO 0.5% (6 sprays)	3.1	0.38 ABC	3.8 C	0.12 BC	99.1
Radiant 6 oz/A (6 sprays)	0.0	0.25 BCD	8.1 BC	0.10 BC	99.1
Coragen 5 oz/A + MSO 0.5% (6 sprays)	0.6	0.25 BCD	15.0 AB	0.22 AB	99.5
BT hybrid ‘Attribute 0805’ + no sprays	1.9	0.38 ABC	16.2 AB	0.28 AB	99.4
untreated	0.6	0.48 AB	18.8 AB	0.35 A	98.7
BT hybrid ‘Attribute 0805’ + Brigade 6.4 oz/A (last 2 sprays)	4.4	0.58 A	20.0 A	0.25 AB	98.9
Probability value for treatment effect	*0.35*	*<0.0001*	*0.0005*	*0.0053*	*0.79*

[1] Within each column, means followed by the same letter are not significantly different ($P>0.05$), by LSD.

[2] The most common species of silk-clipping beetle was western corn rootworm beetle, but a few northern corn rootworm beetles and Japanese beetles were found.

Table 6. Corn leaf aphid on sweet corn ears during silking and at harvest, 2009, Clark County, Ohio.

Treatment (ranked by percentage infested at harvest)	*% of ears infested*[1]		
	27 Aug. (before 2nd spray)	*3 Sep. (before 4th spray)*	*15 Sep. (harvest)*
Brigade 2.56 oz/A (first 5 sprays)	10 DE	0 E	0 G
Warrior II, 1.26 oz/A (6 sprays)	8 DE	0 E	2 G
Brigade 6.4 fl oz/A (2 sprays) then Warrior II, 1.92 oz/A (4 sprays)	8 DE	0 E	2 FG
Voliam Xpress, 9 oz/A (6 sprays)	5 DE	0 E	4 EFG
Hero, 8 oz/A (3 sprays) then Mustang Max 4 oz/A (3 sprays)	8 CDE	0 E	4 EFG
Warrior II, 1.92 oz/A (6 sprays)	2 E	0 E	5 DEFG
Voliam Xpress, 7 oz/A (6 sprays)	10 CDE	0 E	9 DEFG
Belt 3 oz/A + MSO 0.5% (3 sprays) alternating with Baythroid XL 2.4 oz/A (3 sprays)	15 CDE	10 CD	15 CDEF
Coragen 5 oz/A + MSO 0.5% (2 sprays) then Asana 9.6 oz/A (2 sprays) alternated with Lannate 24 oz/A (2 sprays)	18 BCD	42 AB	16 CDE
BT hybrid 'Attribute 0805' + Brigade 6.4 oz/A (last 2 sprays)	2 E	5 DE	26 CD
BT hybrid 'Attribute 0805' + no sprays	5 DE	0 E	39 BC
untreated	28 ABC	28 BC	55 AB
Belt 3 oz/A + MSO 0.5% (6 sprays)	42 AB	40 AB	55 AB
Coragen 5 oz/A + MSO 0.5% (6 sprays)	58 A	55 A	78 A
Radiant 6 oz/A (6 sprays)	18 BCD	40 AB	79 A
Probability value for treatment effect	*0.0003*	*<0.0001*	*<0.0001*

[1] Within each column, means followed by the same letter are not significantly different (P>0.05), by LSD.