Managing corn earworm using GMO varieties, conventional and OMRI-listed insecticides in sweet corn

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Corn earworm (CEW) is a major threat to sweet corn production in New York as infestations have become challenging to control when pressure is high. Management of CEW relies on properly timed foliar applications of insecticides during the green silk stage. In seasons when CEW pressure is high, poor control may result because either the population is resistant to the insecticides applied (e.g., pyrethroids) against them, the applications are not well-timed, are not frequent enough, or all three. Research is needed to identify effective insecticides and proper timing of applications for CEW control. Moreover, there is increasing interest in growing sweet corn grown organically, so information about the efficacy of insecticide products listed by the Organic Materials Review Institute (OMRI) is needed. There is also great interest in relying less on foliar insecticide applications for managing CEW and taking advantage of GM-sweet corn that is resistant to CEW. While GM-sweet corn is not currently a viable option for the processing industry, it is an excellent option for the fresh-market industry. Below describes the objectives of research conducted in 2017 that addressed these questions for improving CEW control in sweet corn:

OBJECTIVES

(1) Evaluate combinations of conventional insecticide product and application timings
(2) Evaluate efficacy of selected OMRI-listed products
(3) Evaluate the performance of single- and multiple Bt-gene sweet corn varieties

I. Evaluate various conventional insecticide product by application timing combinations for CEW control

Table 1. Various insecticide by application timing strategies evaluated for control of corn earworm in sweet corn in Geneva, NY in 2017.

Trt #	Product*	Timing	Start time	End time	Rate
1	Coragen	Standard IPM	50% silk	Harvest	5 fl oz/acre
2	Coragen	One application	50% tassel	50% tassel	5 fl oz/acre
3	Coragen	3d interval	50% tassel	25% dry silk	5 fl oz/acre
4	Coragen	5d interval	50% tassel	25% dry silk	5 fl oz/acre
5	Besiege	Standard IPM	50% silk	Harvest	6 fl oz/acre
6	Besiege	One application	50% tassel	50% tassel	6 fl oz/acre
7	Besiege	3d interval	50% tassel	25% dry silk	6 fl oz/acre
8	Besiege	5d interval	50% tassel	25% dry silk	6 fl oz/acre
9	Warrior II	Standard IPM	50% silk	Harvest	1.92 fl oz/acre
10	Warrior II	One application	50% tassel	50% tassel	1.92 fl oz/acre
11	Warrior II	3d interval	50% tassel	25% dry silk	1.92 fl oz/acre
12	Warrior II	5d interval	50% tassel	25% dry silk	1.92 fl oz/acre
13	Untreated	-	-	-	-

New insecticide spray timings were evaluated in which the initial application was applied when 50% of the plants were tasseling, rather than 50% of the ears silking. Additional applications were either not made or made following a 3- or 5-day interval until a majority of the ears had silks that were 25% brown and dry. Because diamide insecticides have longer residual activity than pyrethroids, Coragen (chlorantraniliprole), Besiege (chlorantraniliprole + lambda-cyhalothrin) and Warrior II w/Zeon Technology (lambda-cyhalothrin) were compared. Treatment structure was a 4 x 3 factorial with application timing as the first factor (4 timings: standard application timing, one single application at 50% tassel, initial application at

50% tassel followed by additional sprays every 3-d or 5-d) and insecticide as the second factor (3 insecticides: Coragen, Besiege and Warrior II w/Zeon Technology) (**Table 1**). These 12 treatments plus an untreated control were arranged in a randomized complete block design and replicated 5 times. Plots consisted of three 20-ft rows @ 30 in spacing; seeds of the processing cultivar, cv. '2390', were planted at 8-inch spacing. Three weeks after first silk, 50 primary ears from the middle two rows were randomly harvested and evaluated for CEW presence and/or damage as well as other caterpillar pests.

CEW pressure was very low in this trial. Consequently, it was not possible to statistically discern the best insecticide by application timing treatment (**Table 2**). However, all insecticides applied more than one time, regardless of when the initial application was made relative to the phenology of the crop, performed numerically better than treatments applied a single time at 50% tassel (**Table 2**).

Table 2. Mean percentage (± SEM) of undamaged, market-sized ears in various insecticide by application timing treatments made in sweet corn in Geneva, NY in 2017. Treatments are listed in descending order of performance based on the percentage of non-damaged, market-sized ears.

Trt #	Treatment	Number of applications	Mean undamaged "clean" ears (%)[a]
12	Warrior II, 5d interval from 50% tassel to 25% dry silk	3	98.8 ± 0.5 a
11	Warrior II, 3d interval from 50% tassel to 25% dry silk	5	98.4 ± 0.7 a
3	Coragen, 3d interval from 50% tassel to 25% dry silk	5	98.0 ± 1.2 a
4	Coragen, 5d interval from 50% tassel to 25% dry silk	3	96.8 ± 1.6 a
8	Besiege, 5d interval from 50% tassel to 25% dry silk	3	96.8 ± 1.0 a
1	Coragen, 50% ears silking to harvest	1	96.4 ± 1.2 a
5	Besiege, 50% ears silking to harvest	1	95.6 ± 2.0 ab
7	Besiege, 3d interval from 50% tassel to 25% dry silk	5	94.8 ± 2.1 ab
9	Warrior II, 50% ears silking to harvest	1	93.2 ± 3.4 ab
6	Besiege, 1 spray @ 50% tassel	1	92.8 ± 2.4 ab
13	Untreated	0	90.8 ± 2.1 ab
10	Warrior II, 1 spray @ 50% tassel	1	88.0 ± 3.6 ab
2	Coragen, 1 spray @ 50% tassel	1	84.8 ± 4.2 b

[a] Means followed by the same letter are not significantly different ($P>0.05$).

CONCLUSION

While there was a trend for multiple applications of insecticides to provide better control of CEW than a single application at 50% tassel, additional research is needed before recommending an optimal strategy for corn earworm management.

II. Evaluate efficacy of selected OMRI-listed products for CEW control

OMRI-listed insecticides were evaluated for their efficacy against CEW and other caterpillar pests in fresh-market sweet corn, cv. 'AP 426 F1', in Geneva, NY in 2017. On 6 July, seeds were planted in two-row, 25-ft long plots. This experiment included 10 treatments (including the untreated control) **(Table 3)**. Coragen SC (not listed by OMRI) was included as a conventional standard. All treatments were arranged in a randomized complete block design with each treatment replicated 5 times.

Table 3. Insecticide products and rates evaluated for control of CEW in sweet corn in Geneva, NY in 2017. *Coragen is not listed by OMRI.

Trt #	Treatment	Active ingredient	Rate
1	Untreated control	-	-
2	Azera	pyrethrin+azadirachtin	40 fl oz/A
3	Entrust	spinosad	5 fl oz/A
4	Entrust	spinosad	10 fl oz/A **(not labelled)**
5	Agree WG	*B.t. aizawai*	2 lbs/A
6	Javelin	*B.t. kurstaki*	1.5 lbs/A
7	Gemstar	OBs of *NPV*	10 fl oz/A
8	Entrust + Agree	spinosad + *B.t. aizawai*	5 fl oz/A + 2 lbs/A
9	Entrust + Javelin	spinosad + *B.t. kurstaki*	5 fl oz/A + 1.5 lbs/A
10	Coragen SC*	chlorantraniliprole	5 fl oz/A

Treatments were applied using a CO_2–pressurized backpack sprayer and boom equipped with two, flat-fan nozzles (XR-Teejet 8002) calibrated to deliver 25 gallons per acre at 40 psi. Nozzles were separated by 20 inches and directed horizontally toward the primary ear and applied to only one row at a time. All treatments included the OMRI-listed surfactant, NuFilm P @ 8 fl oz/acre. All treatments were initially sprayed on 4 September when 49% of the ears had produced fresh silk. Additional applications were made on 9 and 15 September. All silks were brown and dry shortly after the last application. On 2 October, 40 primary, market-sized ears were harvested within each plot. Efficacy of treatments was evaluated by recording the number of ears damaged. Additionally, the location of damage on each ear was recorded as either tip only (the top inch or where developed kernels had made a complete ring) or below the tip/base of the ear (any damage that extended from below 1 inch of the ear tip to the ear base). Ears with damage to both the tip and below the tip were categorized as below the tip/base of the ear.

The CEW infestation was low and caused only 15% ear damage in the untreated control **(Table 4)**. Entrust applied at a high rate (Treatment #4) significantly reduced the percentage of total damaged ears compared with the percentage in the untreated control. None of the other treatments significantly reduced the percentage of damage ears compared with damage in the untreated control. Surprisingly, this included Coragen. However, Coragen and all treatments that included Entrust (either alone or in mixes with *Bt* products) reduced the percentage of damaged ears compared with those treated only with *Bt* products (Agree and Javelin) or the nuclear polyhedrosis virus of *H. zea* product (Gemstar) (**Table 4**). There was no apparent advantage of co-applying the *Bt* products with the lower rate of Entrust (5 fl oz rate) for reducing damage.

The high rate of Entrust (Treatment #4) was applied at a rate of 10 fl oz/acre and the total amount of Entrust applied to the crop was 30 fl oz/acre; both of these amounts exceeded the maximum allowable per application (6 fl oz/acre) and maximum allowable per crop per season (29 fl oz/acre). This trial should be repeated to determine if there is a consistent advantage of using a 10 fl oz/acre rate versus a 5 fl oz/acre rate. If so, information may help the registrant modify the existing label.

Table 4. Mean percent of market-sized ears damaged primarily by corn earworm in fresh-market sweet corn planted on 6 July 2017 in Geneva, NY.

Trt #	Product [b]	Mean percent damaged ears (%)[a]		
		Total	Tip only	Below tip/base of the ear
1	Untreated control	15.0 abc	8.5 a-d	6.5
2	Azera	13.5 a-d	9.0 a-d	4.5
3	Entrust (5 fl oz)	4.0 cd	2.5 d	1.5
4	Entrust (10 fl oz)	0.9 d	0.9 d	0.0
5	Agree WG	21.0 a	12.5 abc	8.5
6	Javelin	19.5 a	14.5 a	5.0
7	Gemstar	18.0 ab	13.0 ab	5.0
8	Entrust + Agree	5.0 bcd	3.5 cd	1.5
9	Entrust + Javelin	4.5 cd	4.0 bcd	0.5
10	Coragen SC	1.5 cd	1.0 d	0.5
	P Value	<0.0001	<0.0001	0.0544

[a] Means followed by the same letter within a column are not significantly different (*P*> 0.05; Tukey's Studentized Range [HSD] Test; n= 5). If the *P* value for the overall test was not significant (>0.05), no letters were included.

Ear damage tended to be localized more at the tip than below the tip (**Table 4**). Coragen and Entrust applied either alone or in combination with the *Bt* products had the least amount of tip damage compared with the other products, but overall tip damage did not differ from tip damage in the untreated control. Tip damage levels in treatments that received either *Bt* products alone or Gemstar tended to be greater than damage levels in treatments that included either Entrust or Coragen (**Table 4**). Ear damage located below the tip/based of the ear tended to be highest in the untreated control as well as treatments that received either Azera, *Bt* products or Gemstar, but damage levels were not significantly higher than those in the other treatments.

CONCLUSION

Entrust was the best OMRI-listed product for protecting sweet corn from CEW. Entrust at 10 fl oz/acre impressively provided an equivalent level of control as that provided by the conventional product, Coragen. Future research is needed to determine the repeatability of Entrust's performance against CEW, especially at the highest labelled rate.

III. Evaluate the performance of single- and multiple Bt-gene sweet corn varieties

Two types of Bt sweet corn hybrids from Syngenta Seeds were evaluated for their efficacy against CEW and other caterpillar pests in Geneva, NY in 2017. Attribute® hybrids (expressing Cry1Ab toxin – cv. 'BC0805'), Attribute® II hybrids (expressing Cry1Ab and Vip3A – cv., 'Remedy') and the non-expressing isoline, cv. 'Providence', were evaluated. On 6 July, seeds were planted in four-row, 100-ft long plots. This experiment included 3 treatments that were arranged in a randomized complete block design with each treatment replicated 4 times **(Table 5)**. On 27 September, 100 primary, market-sized ears were harvested within the center rows of each plot. Efficacy of treatments was evaluated as described in the study addressed in Objective 2. In addition to this trial, the same protocol was followed by colleagues located in seven states (NC, VA, WV, MD, DE, NJ, and NY), for a total of 17-18 trials in total in 2017.

The caterpillar pest infestation in Geneva was moderate and caused 19% ear damage (81% clean ears) in the non-Bt isoline **(Table 5)**. In contrast, overall ear damage by caterpillar pests in trials in other states participating in the trial in 2017 was much higher and averaged 87.4% (only 12.6% clean ears) (**Table 5**). In Geneva, CEW was by far the major pest, followed by ECB and then FAW. Averaged across the other states, CEW was also the major pest, but followed by FAW and then ECB.

In Geneva, the percentage of clean ears in Remedy was significantly greater than the percentages of clean ears in both BC0805 and the non-Bt isoline (**Table 5**). The percentage of clean ears in BC0805 also was significantly greater than those in the non-Bt isoline. Unlike BC0805, there were significantly fewer ears damaged by CEW in Remedy than in the non-Bt isoline, indicating that inclusion of the Vip3 gene is responsible for the enhanced control of CEW. Both Bt cultivars provided excellent and equivalent control of ECB (**Table 5**). Too few FAW infested corn in our trial to compare the two Bt cultivars.

Of 18 field trials across seven states in 2017 comparing Attribute® II hybrids (e.g., Remedy) with non-Bt hybrids, less than 1.5% of the ears were damaged, indicating near 100% control efficacy of all ear-invading worms including CEW (**Table 5**). In contrast, Attribute® hybrids (e.g., BC0805) averaged 21% damage, primarily caused by CEW, which is not commercially acceptable.

Table 5. Summary of insect control efficacy of different Bt sweet corn hybrids compared with the non-expressing isoline in Geneva, NY in 2017. Data in parentheses was compiled from 17-18 individual field trials conducted at 15 locations across seven states (NC, VA, WV, MD, DE, NJ, and NY) in 2017.

Hybrid[a]	Bt traits expressed	% clean ears	% ears damaged by CEW	% ears damaged by ECB	% ears damaged by FAW
Remedy	Cry1Ab+Vip3A	99.5 a (98.7)	0.5 b (0.6)	0.0 b (0.0)	0.0 (0.1)
BC0805	Cry1Ab	91.8 b (23.8)	7.8 a (79.0)	0.3 b (0.1)	0.5 (1.9)
Providence	Non-Bt isoline	81.0 c (12.6)	12.3 a (84.4)	6.3 a (3.6)	0.8 (6.1)

[a] Means followed by the same letter within a column are not significantly different (*P*> 0.05; Tukey's Studentized Range [HSD] Test: n= 4). If the *P* value for the overall test was not significant (>0.05), no letters were included.

CONCLUSION

Attribute® II sweet corn provides excellent control of all foliage feeding and ear-invading caterpillars, thus no insecticidal sprays are required, except for secondary pests such as sap beetles, rootworm adults and Japanese beetles.