

# Evaluation of Bt Corn and Soil-Applied Insecticides for Management of Corn Rootworm Larvae

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### Introduction

The purpose of this study was to evaluate the effectiveness of Bt corn and soil insecticide, either alone or in combination, for management of larval corn rootworm. Evaluation of Bt hybrids included Agrisure 3000GT, Agrisure 3111, Agrisure 3122 RIB, DeKalb YieldGard VT Triple RIB, and Pioneer Optimum AcreMax1. Soil insecticides evaluated were Aztec-SB 4.67G, Capture LFR 1.5SC, Force 250CS, and Precept 3G.

### Materials and Methods

The study was conducted in a field that had been planted the previous year with a trap crop, which is a mixed-maturity blend with a greater proportion of late-maturing varieties. This trap crop constitutes a favorable environment for adult female rootworm late in the season when other fields are maturing, and results in a high abundance of rootworm larvae the following year. The study was a randomized complete block design with four replications. Treatments were two rows wide, and 75 ft in length. This study was planted April 29 at a population of 35,600 seeds/acre. Seeds were pre-bagged and planted with a four-row John Deere Max Emerge™ 7100 integral planter that had 30-in. row spacing.

The granular insecticides Precept 3G was applied with modified Noble® metering units mounted on the planter. The Noble units were calibrated in the laboratory to accurately deliver material at a tractor speed of 4 mph. The Precept 3G insecticide was applied with

in-furrow and T-Band placement. The Aztec-SB 4.67G insecticide treatments were applied with modified SmartBox™ metering units mounted on the planter. These commercial SmartBox™ units were removed from their large-base containers and sandwiched between a flat metal plate on the bottom and a custom-made, threaded plastic cap on the top. The bottom plate had been fabricated so it could slide in and out of the same planter mounting brackets used for the noble units. An inverted 1-liter Nalgene bottle attached to the top provided a secure and sealed container for insecticide for the SmartBox™ units. Clear plastic tubes directed the granular insecticides to the in-furrow placement. The liquid product Capture LFR 1.5SC was applied in-furrow and Force 250CS insecticide was applied T-Band at planting with a compressed-air system built directly into the planter by Almaco manufacturing (Nevada, IA). Capture LFR and Force CS were applied as ounces per 1,000 row feet using Teejet XR80015EVS spray nozzles at 21 psi to deliver 5 GPA of finished spray at a tractor speed of 4 mph. Both liquid products Capture LFR 1.5SC and Force 250CS used water as the carrier.

Eleven-inch poly-bristle skirts were attached to the frame of the planter and positioned so the bristle tips touched the ground. Each row was constantly monitored to ensure insecticides were applied correctly. Final incorporation was accomplished with drag chains mounted behind the closing wheels.

On June 4, early-season stand counts were measured in all treatments. These were measured by laying a stand count chain length 17.5 ft long (1/1,000 of an acre for 30-in. row spacing) between the two corn rows and counting the number of plants in both rows.

Late-season stand counts were measured September 24 following the same procedure as early-season stand counts. Measurements for both dates were averaged to provide a single value for stand counts (Table 2).

On August 3, five root systems were dug per replication from all treatments for a total of 20 roots/treatment. Prior to leaving the field, excess soil was removed and all roots were labeled with study name, plot number, and row. Roots were transported to the Insectary Building at Iowa State University where they were soaked in water and then washed with a pressurized hose to remove any remaining soil. Roots then were evaluated for rootworm feeding injury following the Iowa State Node-Injury Scale (0–3) (Table 1).

On September 24, lodging counts were taken (Table 3). A plant was considered lodged if it was leaning at least 30 degrees from vertical.

This study was machine harvested October 16 with a modified John Deere 9450 plot combine. Weights (pounds) and percent moisture were recorded from Avery-Weigh Tronix load cell bars with an XL900 weigh scale indicator and a Shivvers 5010 Moisture meter data collector. These measurements were converted to bushels/acre of No. 2 shelled corn (56 lb/bushel) at 15.5 percent moisture (Table 4).

Percent product consistency (Table 1) was calculated as the percentage of times a treatment limited feeding injury to 0.25 node or less (greater injury can result in economic yield loss, especially when plants are moisture stressed).

All data were analyzed with standard ANOVA procedures using SAS 9.3. When a significant treatment effect was present, pairwise comparisons made among means with an experiment-wise error rate of  $P < 0.05$ .

## Results and Discussion

Generally, the economic injury level for root feeding by corn rootworm larvae ranges from 0.25 to 0.5 nodes depending on the level of environmental stress, in particular, stress from high heat and low soil moisture. When feeding exceeds the economic injury level, it is typically profitable to institute additional or alternative management efforts to reduce root injury.

In this study, feeding on untreated checks was greater than 1.75 nodes. Root injury of under 0.5 nodes was observed for non-rootworm Bt corn with soil-applied insecticide and for Bt corn that contained Cry34/35Ab1 (Agrisure 3122). Because of resistance by western corn rootworm to Cry3Bb1 and mCry3A, high levels of root injury were observed for Agrisure 3000GT, Agrisure 3111, and VT3, all of which rely on either Cry3Bb1 or mCry3A alone to protect corn roots from injury.

Patterns of product consistency and lodging closely mirrored mean root injury. Few differences in yield were observed, which likely resulted from favorable environmental conditions mitigating the effects of root injury on yield.

## Acknowledgements

We thank AMVAC, Monsanto, and Syngenta for providing the funding for this study. We thank Ken Pecinovsky and his staff for their work on this study.

## Additional Information

Annual reports for the Iowa Evaluation of Insecticides and Plant-Incorporated Protectants are available online through the Department of Entomology at Iowa State University:  
<http://www.ent.iastate.edu/dept/faculty/gassmann/rootworm>

**Table 1. Root injury and product consistency for comparison among multiple products at the ISU Northeast Research Farm, Nashua, IA.<sup>1</sup>**

Treatment <sup>2</sup>	Form.	Rate <sup>3</sup>	Placement <sup>4</sup>	Node-injury <sup>5,6,7</sup>	Product consistency <sup>8,9</sup>
Agrisure 3122 RIB	-----	-----	-----	0.06a	100a
Agrisure 3122 RIB + Force	250CS	0.57	T-Band	0.06a	100a
Agrisure 3000GT + Force	250CS	0.57	T-Band	0.12ab	95a
Pioneer OAM1	-----	-----	-----	0.14ab	90a
Pioneer OAM1 + Aztec-SB	4.67G	0.14	SB/Furrow	0.22ab	85a
Agrisure 3111 + Aztec-SB	4.67G	0.14	SB/Furrow	0.23ab	75ab
Pioneer non-RW Bt + Precept	3G	0.13	Furrow	0.28abc	75ab
Agrisure 3000GT + Capture LFR	1.5SC	0.10	Furrow	0.35 bc	55abc
Agrisure non-RW Bt + Capture LFR	1.5SC	0.10	Furrow	0.37abc	75ab
Pioneer non-RW Bt + Aztec-SB	4.67G	0.14	SB/Furrow	0.38abc	70ab
DeKalb VT3 RIB + Aztec-SB	4.67G	0.14	SB/Furrow	0.62 cd	45abc
DeKalb VT3 RIB	-----	-----	-----	1.04 de	30 cde
Agrisure 3111	-----	-----	-----	1.12 e	10 de
Pioneer non-RW Bt + Precept	3G	0.13	T-Band	1.16 de	30 bcd
Agrisure 3000GT	-----	-----	-----	1.43 ef	5 de
Pioneer non-RW Bt	-----	-----	-----	1.89 f <sup>10</sup>	0 e
Agrisure non-RW Bt <sup>12</sup>	-----	-----	-----	1.99 f	0 e
Agrisure non-RW Bt <sup>11</sup>	-----	-----	-----	2.06 f	0 e

<sup>1</sup>Planted April 29, 2015; evaluated August 4, 2015.

<sup>2</sup>Non-RW Bt = an absence of any Bt trait targeting corn rootworm; \*DeKalb VT3 RIB = YieldGard VT Triple RIB (DKC 58-83 RIB); Pioneer OAM1 = Pioneer Optimum AcreMax1 (P0533AM1); Pioneer non-RW Bt = Pioneer Herculex 1 (P0533HR); Agrisure 3111 = Syngenta Agrisure Viptera 3111 (N68B-3111), Agrisure 3122 RIB = Syngenta Agrisure RIB (Agrisure N53W-3122 RIB); Agrisure 3000GT = Syngenta Agrisure (Agrisure N53W-3000GT).

<sup>3</sup>Insecticide listed as ounces a.i./1,000 row-feet.

<sup>4</sup>Furrow & T-Band = insecticide applied at planting time; SB = SmartBox application at planting time.

<sup>5</sup>Chemical and check means based on 20 observations (5 roots/2 rows x 4 replications).

<sup>6</sup>Iowa State Node-Injury scale (0-3). Number of full or partial nodes completely eaten.

<sup>7</sup>Means sharing a common letter do not differ significantly according to Ryan's Q Test ( $P \leq 0.05$ ).

<sup>8</sup>Product consistency = Percentage of times nodal injury was 0.25 ( $\frac{1}{4}$  node eaten) or less.

<sup>9</sup>Means sharing a common letter do not differ significantly according to Ryan's Q Test ( $P \leq 0.05$ ).

<sup>10</sup>This check mean based on 39 observations.

<sup>11</sup>Syngenta Agrisure GT hybrid (Agrisure N53-W3, Glyphosate Tolerant), near isoline of Agrisure N53-3122 RIB and N53-3000GT.

<sup>12</sup>Syngenta Agrisure GT hybrid (Agrisure N68B-GT, Glyphosate Tolerant), near isoline of Agrisure N68-3111.

**Table 2. Stand counts for comparison among multiple products at the ISU Northeast Research Farm, Nashua, IA.<sup>1</sup>**

Treatment <sup>2</sup>	Form.	Rate <sup>3</sup>	Placement <sup>4</sup>	Stand counts <sup>5,6</sup>
Agrisure non-RW Bt + Capture LFR	1.5SC	0.10	Furrow	37.25a
Pioneer OAM1 + Aztec-SB	4.67G	0.14	SB/Furrow	36.75ab
Pioneer non-RW Bt + Precept	3G	0.13	Furrow	36.50ab
Pioneer OAM1	-----	-----	-----	36.50ab
DeKalb VT3 RIB	-----	-----	-----	36.25ab
Agrisure 3111 + Aztec-SB	4.67G	0.14	SB/Furrow	36.25ab
DeKalb VT3 RIB + Aztec-SB	4.67G	0.14	SB/Furrow	36.00ab
Agrisure 3000GT + Capture LFR	1.5SC	0.10	Furrow	36.00ab
Pioneer non-RW Bt + Precept	3G	0.13	T-Band	35.75ab
Agrisure non-RW Bt <sup>8</sup>	-----	-----	-----	35.75ab
Agrisure 3000GT + Force	250CS	0.57	T-Band	35.50ab
Agrisure 3111	-----	-----	-----	35.25ab
Agrisure 3122 RIB + Force	250CS	0.57	T-Band	35.25ab
Pioneer non-RW Bt + Aztec-SB	4.67G	0.14	SB/Furrow	35.25ab
Pioneer non-RW Bt	-----	-----	-----	34.75ab <sup>7</sup>
Agrisure 3122 RIB	-----	-----	-----	34.50ab
Agrisure 3000GT	-----	-----	-----	34.25ab
Agrisure non-RW Bt <sup>9</sup>	-----	-----	-----	33.50 b

<sup>1</sup>Planted April 29, 2015; evaluated June 4 and September 24, 2015.

<sup>2</sup>Non-RW Bt = an absence of any Bt trait targeting corn rootworm; \*DeKalb VT3 RIB = YieldGard VT Triple RIB (DKC 58-83 RIB); Pioneer OAM1 = Pioneer Optimum AcreMax1 (P0533AM1); Pioneer non-RW Bt = Pioneer Herculex 1 (P0533HR); Agrisure 3111 = Syngenta Agrisure Viptera 3111 (N68B-3111); Agrisure 3122 RIB = Syngenta Agrisure RIB (Agrisure N53W-3122 RIB); Agrisure 3000GT = Syngenta Agrisure (Agrisure N53W-3000GT).

<sup>3</sup>Insecticide listed as ounces a.i./1,000 row-feet.

<sup>4</sup>Furrow & T-Band = insecticide applied at planting time; SB = SmartBox application at planting time.

<sup>5</sup>Chemical and check means based on 16 observations (2-row treatment x 17.5 row-feet/treatment x 4 replications x 2 evaluation dates).

<sup>6</sup>Means sharing a common letter do not differ significantly according to Ryan's Q Test ( $P \leq 0.05$ ).

<sup>7</sup>This check mean based on 32 observations.

<sup>8</sup>Syngenta Agrisure GT hybrid (Agrisure N53-W3, Glyphosate Tolerant), near isoline of Agrisure N53-3122 RIB and N53-3000GT.

<sup>9</sup>Syngenta Agrisure GT hybrid (Agrisure N68B-GT, Glyphosate Tolerant), near isoline of Agrisure N68-3111.

**Table 3. Lodging for comparison among multiple products at the ISU Northeast Research Farm, Nashua, IA.<sup>1</sup>**

<b>Treatment<sup>2</sup></b>	<b>Form.</b>	<b>Rate<sup>3</sup></b>	<b>Placement<sup>4</sup></b>	<b>Lodging<sup>5,6</sup></b>
Agrisure 3122 RIB	-----	-----	-----	0a
Agrisure 3122 RIB + Force	250CS	0.57	T-Band	0a
Agrisure 3000GT + Force	250CS	0.57	T-Band	0a
DeKalb VT3 RIB + Aztec-SB	4.67G	0.14	SB/Furrow	0a
Pioneer non-RW Bt + Aztec-SB	4.67G	0.14	SB/Furrow	0a
Agrisure non-RW Bt + Capture LFR	1.5SC	0.10	Furrow	0a
Pioneer OAM1	-----	-----	-----	1a
Pioneer OAM1 + Aztec-SB	4.67G	0.14	SB/Furrow	1a
Agrisure 3000GT + Capture LFR	1.5SC	0.10	Furrow	1a
Pioneer non-RW Bt + Precept	3G	0.13	Furrow	1a
Agrisure 3111 + Aztec-SB	4.67G	0.14	SB/Furrow	3a
DeKalb VT3 RIB	-----	-----	-----	11ab
Agrisure 3111	-----	-----	-----	12ab
Pioneer non-RW Bt + Precept	3G	0.13	T-Band	12ab
Agrisure non-RW Bt <sup>8</sup>	-----	-----	-----	18 bc
Agrisure 3000GT	-----	-----	-----	22 bc
Pioneer non-RW Bt	-----	-----	-----	30 bc <sup>7</sup>
Agrisure non-RW Bt <sup>9</sup>	-----	-----	-----	38 c

<sup>1</sup>Planted April 29, 2015; evaluated September 24, 2015

<sup>2</sup>Non-RW Bt = an absence of any Bt trait targeting corn rootworm; \*DeKalb VT3 RIB = YieldGard VT Triple RIB (DKC 58-83 RIB); Pioneer OAM1 = Pioneer Optimum AcreMax1 (P0533AM1); Pioneer non-RW Bt = Pioneer Herculex 1 (P0533HR); Agrisure 3111 = Syngenta Agrisure Viptera 3111 (N68B-3111); Agrisure 3122 RIB = Syngenta Agrisure RIB (Agrisure N53W-3122 RIB); Agrisure 3000GT = Syngenta Agrisure (Agrisure N53W-3000GT).

<sup>3</sup>Insecticide listed as ounces a.i./1,000 row-feet.

<sup>4</sup>Furrow & T-Band = insecticide applied at planting time; SB = SmartBox application at planting time.

<sup>5</sup>Chemical and check means based on 8 observations (2-row treatment x 17.5 row-feet/treatment x 4 replications).

<sup>6</sup>Means sharing a common letter do not differ significantly according to Ryan's Q Test ( $P \leq 0.05$ ).

<sup>7</sup>This check mean based on 16 observations.

<sup>8</sup>Syngenta Agrisure GT hybrid (Agrisure N53-W3, Glyphosate Tolerant), near isoline of Agrisure N53-3122 RIB and N53-3000GT.

<sup>9</sup>Syngenta Agrisure GT hybrid (Agrisure N68B-GT, Glyphosate Tolerant), near isoline of Agrisure N68-3111.

**Table 4. Yield for comparison among multiple products at the ISU Northeast Research Farm, Nashua, IA.<sup>1</sup>**

Treatment <sup>2</sup>	Form.	Rate <sup>3</sup>	Placement <sup>4</sup>	Bushels/ acre <sup>5,6,7</sup>
Agrisure 3111 + Aztec-SB	4.67G	0.14	SB/Furrow	217a
Pioneer OAM1	-----	-----	-----	201ab
Agrisure 3000GT + Force	250CS	0.57	T-Band	200ab
DeKalb VT3 RIB	-----	-----	-----	197ab
Agrisure 3111	-----	-----	-----	196ab
DeKalb VT3 RIB + Aztec-SB	4.67G	0.14	SB/Furrow	194ab
Agrisure non-RW Bt + Capture LFR	1.5SC	0.10	Furrow	193ab
Pioneer OAM1 + Aztec-SB	4.67G	0.14	SB/Furrow	192ab
Pioneer non-RW Bt + Precept	3G	0.13	Furrow	192ab
Agrisure 3122 RIB + Force	250CS	0.57	T-Band	189ab
Pioneer non-RW Bt + Aztec-SB	4.67G	0.14	SB/Furrow	188ab
Agrisure 3000GT + Capture LFR	1.5SC	0.10	Furrow	185ab
Agrisure non-RW Bt <sup>10</sup>	-----	-----	-----	182ab
Agrisure 3000GT	-----	-----	-----	181ab
Pioneer non-RW Bt + Precept	3G	0.13	T-Band	176ab
Agrisure 3122 RIB	-----	-----	-----	173ab
Agrisure non-RW Bt <sup>9</sup>	-----	-----	-----	168ab
Pioneer non-RW Bt	-----	-----	-----	165 b <sup>8</sup>

<sup>1</sup>Planted April 29, 2015; machine harvested October 16, 2015.

<sup>2</sup>Non-RW Bt = an absence of any Bt trait targeting corn rootworm; \*DeKalb VT3 RIB = YieldGard VT Triple RIB (DKC 58-83 RIB); Pioneer OAM1 = Pioneer Optimum AcreMax1 (P0533AM1); Pioneer non-RW Bt = Pioneer Herculex 1 (P0533HR); Agrisure 3111 = Syngenta Agrisure Viptera 3111 (N68B-3111); Agrisure 3122 RIB = Syngenta Agrisure RIB (Agrisure N53W-3122 RIB); Agrisure 3000GT = Syngenta Agrisure (Agrisure N53W-3000GT).

<sup>3</sup>Insecticide listed as ounces a.i./1,000 row-feet.

<sup>4</sup>Furrow & T-Band = insecticide applied at planting time; SB = SmartBox application at planting time.

<sup>5</sup>Chemical and check means based on 4 observations (2-row treatment x 68 row-feet/treatment x 4 replications).

<sup>6</sup>Means sharing a common letter do not differ significantly according to Ryan's Q Test ( $P \leq 0.05$ ).

<sup>7</sup>Yields converted to 15.5% moisture.

<sup>8</sup>This check mean based on 8 observations.

<sup>9</sup>Syngenta Agrisure GT hybrid (Agrisure N53-W3, Glyphosate Tolerant), near isoline of Agrisure N53-3122 RIB and N53-3000GT.

<sup>10</sup>Syngenta Agrisure GT hybrid (Agrisure N68B-GT, Glyphosate Tolerant), near isoline of Agrisure N68-3111.