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Abstract
The purpose of this study was to evaluate the effectiveness of Bt corn, with and without soil insecticides, for management of corn rootworm. Evaluation of Bt hybrids included Agrisure 3122 RIB, DeKalb YieldGard VT3, and Pioneer Optimum AcreMax1. Evaluation of at-planting, soil-applied insecticides included Aztec 2.1G, Aztec-SB 4.67G, Counter-SB 20G, and SmartChoice-SB 5G.

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Introduction

The purpose of this study was to evaluate the effectiveness of Bt corn, with and without soil insecticides, for management of corn rootworm. Evaluation of Bt hybrids included Agrisure 3122 RIB, DeKalb YieldGard VT3, and Pioneer Optimum AcreMax1. Evaluation of at-planting, soil-applied insecticides included Aztec 2.1G, Aztec-SB 4.67G, Counter-SB 20G, and SmartChoice-SB 5G.

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 on May 19 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 insecticide Aztec 2.1G 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 Aztec 2.1G insecticide was applied with in-furrow placement. SmartChoice-SB 5G, Counter-SB 20G, and Aztec-SB 4.67G was 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 be used interchangeably with 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 insecticide container for the SmartBox™ units. Clear plastic tubes directed the granular insecticides to the in-furrow placement.

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 that insecticides were applied correctly. Final incorporation was accomplished with drag chains mounted behind the closing wheels.

On June 6, early season stand counts were measured in all treatments. These were measured by laying a stand count chain (length = 17.5 ft, which is 1/1,000 of an acre for 30-in. row spacing) between the two rows of corn in each treatment and counting the number of plants in both rows. Late season stand counts were measured on September 23 by laying a one-inch PVC pipe (length = 17.5 ft) between the two rows of corn in each treatment and counting the number of plants in both rows. Measurements for both dates were averaged to provide a single value for stand counts (Table 2).

On August 5, 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 using a permanent marker. 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 were evaluated for rootworm feeding injury following the Iowa State University Node Injury Scale (0–3) (Table 1).

On September 23, lodging was scored for the same plants evaluated during stand counts (Table 3). A plant was considered lodged if it was leaning at least 30 degrees from vertical.

This study was machine harvested on October 28 with a modified John Deere 9450 plot combine. Weight (pounds) and percent moisture were recorded from a HarvestMaster brand harvest data collection system. These measurements were converted to bushels/acre of No. 2 shelled corn (56 lb/bushel) at 15.5 percent moisture in Excel (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 were made among means with an experiment-wise error rate of $P < 0.05$.

Results and Discussion

Because of below average winter temperatures and wet soils early in the growing season, mortality of rootworm eggs and larvae was greater than normal, and in general, rootworm larval feeding was reduced across much of Iowa in 2014. This was the case at the ISU Johnson Farm, with injury to the untreated controls averaging between 1.15 and 0.24 nodes (Table 1).

We found all rootworm treatments, whether Bt traits or soil-applied insecticides, reduced injury below that observed for the untreated checks, although the effects were not always statistically significant (Table 1).

Additionally, adding soil-applied insecticide to a Bt trait did not result in a significant reduction of injury. For this field location, the optimal management strategy, in terms of achieving adequate protection of roots at the least cost to the farmer, would have been to use either a Bt trait for rootworm without adding soil-applied insecticide or to use a soil-applied insecticide on non-CRW Bt corn.

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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. Node injury and product consistency for comparison among multiple products: ISU Johnson Farm, Ames.[1]

Treatment[2]	Form.	Rate[3]	Placement[4]	Node-injury[5,6,7]	Product consistency[8,9]
Pioneer OAM1	-------	-------	-------	0.01a	100a
DeKalb VT3 + Aztec-SB	4.67G	0.14	SB/Furrow	0.02a	100a
Agrisure 3122 RIB + Counter-SB	20G	0.90	SB/Furrow	0.02a	100a
Pioneer OAM1 + SmartChoice-SB	5G	0.25	SB/Furrow	0.03a	100a
Agrisure 3122 RIB	-------	-------	-------	0.05a	100a
DeKalb non-RW Bt + Aztec	2.1G	0.14	Furrow	0.20ab	85ab
DeKalb VT3	-------	-------	-------	0.20ab	75ab
DeKalb non-RW Bt	-------	-------	-------	0.24ab	80ab
Agrisure non-RW Bt	-------	-------	-------	0.57 b	60ab
Pioneer non-RW Bt	-------	-------	-------	1.15 c	35 b

[1]Planted May 19, 2014; evaluated August 5, 2014.
[2]Non-RW Bt = an absence of any Bt trait targeting corn rootworm; DeKalb VT3 = YieldGard VT Triple (DKC58-83); DeKalb-non-RW Bt = DeKalb brand VT2PRO Isoline (DKC 58-89); Pioneer OAM1 = Pioneer Optimum AcreMax1 (P0533AM1); Pioneer non-RW Bt = Pioneer Herculex 1 (P0533HR); Agrisure non-RW Bt = Syngenta Agrisure GT (Agrisure N53-W3, Glyphosate Tolerant); Agrisure 3122 RIB = Syngenta Agrisure RIB (Agrisure N52W-3122 RIB).
[3]Insecticide listed as ounces a.i. per 1,000 row-feet.
[4]Furrow = insecticide applied at planting time; SB = SmartBox application at planting time.
[5]Chemical and check means based on 20 observations (5 roots/2 rows × 4 replications).
[6]Iowa State Node-Injury scale (0–3). Number of full or partial nodes completely eaten.
[7]Means sharing a common letter do not differ significantly according to Ryan's Q Test ($P \leq 0.05$).
[8]Product consistency = percentage of times nodal injury was 0.25 (¼ node eaten) or less.
[9]Means sharing a common letter do not differ significantly according to Ryan's Q Test ($P \leq 0.05$).

Table 2. Stand counts for comparison among multiple products: ISU Johnson Farm, Ames.[1]

Treatment[2]	Form.	Rate[3]	Placement[4]	Stand count[5,6]
DeKalb VT3	-------	-------	-------	38.00a
DeKalb VT3 + Aztec-SB	4.67G	0.14	SB/Furrow	37.25ab
DeKalb non-RW Bt + Aztec	2.1G	0.14	Furrow	36.75abc
DeKalb non-RW Bt	-------	-------	-------	36.50abc
Pioneer OAM1 + SmartChoice-SB	5G	0.25	SB/Furrow	36.00abc
Pioneer non-RW Bt	-------	-------	-------	36.00abc
Pioneer OAM1	-------	-------	-------	35.75abc
Agrisure 3122 RIB	-------	-------	-------	34.75abc
Agrisure non-RW Bt	-------	-------	-------	34.50 bc
Agrisure 3122 RIB + Counter-SB	20G	0.90	SB/Furrow	33.75 c

[1]Planted May 19, 2014; evaluated June 6 and September 23, 2014.
[2]Non-RW Bt = an absence of any Bt trait targeting corn rootworm; DeKalb VT3 = YieldGard VT Triple (DKC58-83); DeKalb-non-RW Bt = DeKalb brand VT2PRO Isoline (DKC 58-89); Pioneer OAM1 = Pioneer Optimum AcreMax1 (P0533AM1); Pioneer non-RW Bt = Pioneer Herculex 1 (P0533HR); Agrisure non-RW Bt = Syngenta Agrisure GT (Agrisure N53-W3, Glyphosate Tolerant); Agrisure 3122 RIB = Syngenta Agrisure RIB (Agrisure N52W-3122 RIB).
[3]Insecticide listed as ounces a.i. per 1,000 row-feet.
[4]Furrow = insecticide applied at planting time; SB = SmartBox application at planting time.
[5]Chemical and check means based on 16 observations (2-row treatment × 17.5 row-feet/treatment × 4 replications × 2 evaluation dates).
[6]Means sharing a common letter do not differ significantly according to Ryan's Q Test ($P \leq 0.05$).

Table 3. Lodging for comparison among multiple products: ISU Johnson Farm, Ames.[1]

Treatment[2]	Form.	Rate[3]	Placement[4]	Lodging[5,6]
DeKalb non-RW Bt	-------	-------	-------	0
DeKalb non-RW Bt + Aztec	2.1G	0.14	Furrow	0
DeKalb VT3	-------	-------	-------	0
DeKalb VT3 + Aztec-SB	4.67G	0.14	SB/Furrow	0
Agrisure 3122 RIB	-------	-------	-------	0
Agrisure 3122 RIB + Counter-SB	20G	0.90	SB/Furrow	0
Pioneer OAM1	-------	-------	-------	0
Pioneer OAM1 + SmartChoice-SB	5G	0.25	SB/Furrow	0
Pioneer non-RW Bt	-------	-------	-------	6
Agrisure non-RW Bt	-------	-------	-------	11

[1]Planted May 19, 2014; evaluated September 23, 2014.
[2]Non-RW Bt = an absence of any Bt trait targeting corn rootworm; DeKalb VT3 = YieldGard VT Triple (DKC58-83); DeKalb-non-RW Bt = DeKalb brand VT2PRO Isoline (DKC 58-89); Pioneer OAM1 = Pioneer Optimum AcreMax1 (P0533AM1); Pioneer non-RW Bt = Pioneer Herculex 1 (P0533HR); Agrisure non-RW Bt = Syngenta Agrisure GT (Agrisure N53-W3, Glyphosate Tolerant); Agrisure 3122 RIB = Syngenta Agrisure RIB (Agrisure N52W-3122 RIB).
[3]Insecticide listed as ounces a.i. per 1,000 row-feet.
[4]Furrow = insecticide applied at planting time; SB = SmartBox application at planting time.
[5]Chemical and check means based on eight observations (2-row treatment × 17.5 row-feet/treatment × 4 replications).
[6]No significant differences between means (ANOVA, $P \leq 0.05$).

Table 4. Yield for comparison among multiple products: ISU Johnson Farm, Ames.[1]

Treatment[2]	Form.	Rate[3]	Placement[4]	Bushels/acre[5,6,7]
DeKalb non-RW Bt + Aztec	2.1G	0.14	Furrow	203a
DeKalb VT3	-------	-------	-------	189a
DeKalb non-RW Bt	-------	-------	-------	174ab
Agrisure 3122 RIB	-------	-------	-------	172ab
Pioneer OAM1 + SmartChoice-SB	5G	0.25	SB/Furrow	168ab
DeKalb VT3 + Aztec-SB	4.67G	0.14	SB/Furrow	146ab
Pioneer non-RW Bt	-------	-------	-------	139ab
Agrisure non-RW Bt	-------	-------	-------	133ab
Agrisure 3122 RIB + Counter-SB	20G	0.90	SB/Furrow	124ab
Pioneer OAM1	-------	-------	-------	105 b

[1]Planted May 19, 2014; machine harvested October 28, 2014.
[2]Non-RW Bt = an absence of any Bt trait targeting corn rootworm; DeKalb VT3 = YieldGard VT Triple (DKC58-83); DeKalb-non-RW Bt = DeKalb brand VT2PRO Isoline (DKC 58-89); Pioneer OAM1 = Pioneer Optimum AcreMax1 (P0533AM1); Pioneer non-RW Bt = Pioneer Herculex 1 (P0533HR); Agrisure non-RW Bt = Syngenta Agrisure GT (Agrisure N53-W3, Glyphosate Tolerant); Agrisure 3122 RIB = Syngenta Agrisure RIB (Agrisure N52W-3122 RIB).
[3]Insecticide listed as ounces a.i. per 1,000 row-feet.
[4]Furrow = insecticide applied at planting time; SB = SmartBox application at planting time.
[5]Chemical and check means based on four observations (2-row treatment × 68 row-feet/treatment × 4 replications).
[6]Means sharing a common letter do not differ significantly according to Ryan's Q Test ($P \leq 0.05$).
[7]Yields converted to15.5% moisture.