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Abstract

The purpose of this study was to evaluate the effectiveness of Bt corn and soil insecticides, either alone or in combination, for management of corn rootworm larvae. Evaluation of Bt hybrids included Agrisure 3111, Agrisure 3122, Herculex XTRA, Pioneer Optimum AcreMax1, Smartstax, and YieldGard VT3. Soil insecticides evaluated were Aztec 2.1G, Aztec-SB 4.67G, Capture LFR 1.5FL, Counter-S

Keywords

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Evaluation of Technologies for Management of Corn Rootworm Larvae in Northeast Iowa

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Introduction

The purpose of this study was to evaluate the effectiveness of Bt corn and soil insecticides, either alone or in combination, for management of corn rootworm larvae. Evaluation of Bt hybrids included Agrisure 3111, Agrisure 3122, Herculex XTRA, Pioneer Optimum AcreMax1, Smartstax, and YieldGard VT3. Soil insecticides evaluated were Aztec 2.1G, Aztec-SB 4.67G, Capture LFR 1.5FL, Counter-SB 20G, Force 3G, 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. A 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 experiment was a randomized complete block design with four replications. Treatments were two rows wide × 75 ft long. This study was planted on May 24 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 Aztec 2.1G and Force 3.0G were 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 and the Force 3.0G insecticide was applied with T-Band Placement. The Aztec-SB 4.67G, Counter-SB 20G, and SmartChoice-SB 5G insecticide treatments were applied with modified SmartBox™ metering units mounted on the planter. The commercial SmartBox™ 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 1.5FL insecticide was applied at planting with a compressed-air system built directly into the planter by Almaco manufacturing (Nevada, IA). Capture LFR 1.5FL was applied in-furrow and was mixed with starter fertilizer (10-34-0 NPK) as a carrier. This liquid product was applied as ounces/1,000 row feet using Teejet XR80015 spray nozzles at 21 psi to deliver 5 GPA of finished spray at a tractor speed of 4 mph.

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 19 June, early-season stand counts were measured in all treatments. These were measured by laying a one-inch PVC pipe cut

to a length of 17.5 ft (1/1,000 of an acre for 30-in. row spacing) between the two rows and counting the number of plants. Stand counts were taken again on October 24.

Measurements for both dates were averaged to provide a single value for stand counts (Table 2).

On August 12, five root systems were dug/replication from all treatments for a total of twenty 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 October 24, lodging counts (Table 3) were taken. A plant was considered lodged if it was leaning at least 30 degrees from vertical.

This study was machine harvested on November 9 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% moisture) (Table 3).

Percent product consistency (Table 1) was calculated as the percentage of times a treatment limited feeding injury to 0.25 nodes 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

There was moderate rootworm pressure with injury to the untreated checks ranging from 0.7 to 1.75 nodes of root injury (Table 1). Although differences in yield were observed among treatments (Table 4), this was likely caused in large part by significant differences in stand counts among treatments (Table 2). However, the data on root injury still provide a valuable comparison among products.

Importantly, this research site contains western corn rootworm with resistance to Cry3Bb1 and mCry3A, and this appeared to have some effects on product performance. For example, injury to Agrisure3111GT (mCry3A) corn was moderate and did not differ statistically from the untreated check. However, corn pyramided with multiple Bt traits targeting rootworm (Agrisure 3122 and SmartStax) performed well as did soil-applied insecticide (Aztec) on non-rootworm Bt corn. These results indicate that planting of rootworm pyramids or using a soil-applied insecticide at planting with non-rootworm Bt corn are good management options in areas where Cry3 resistance is suspected.

Acknowledgements

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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. Comparison of corn rootworm management for noted injury and product consistency, Nashua, Iowa.¹

Treatment ²	Form.	Rate ³	Placement ⁴	Node-injury ^{5,6,7}	Product consistency ^{8,9}
Agrisure 3122 + Force	3G	0.15	T-Band	0.05 a	100 a
Agrisure 3122 RIB + Counter-SB	20G	0.90	SB/In-Furrow	0.05 ab	100 a
Agrisure 3122 RIB	-----	-----	-----	0.05 abc	100 a
Pioneer OAM1 + Capture LFR + SF	1.5SC	0.10	In-Furrow	0.05 abc	85 ab
DeKalb Smartstax	-----	-----	-----	0.06 abc	100 a
Pioneer OAM1 + Aztec	2.1G	0.14	In-Furrow	0.06 abc	95 ab
Pioneer OAM1 + SmartChoice-SB	5G	0.25	SB/In-Furrow	0.07 abc	100 a
Pioneer HXX	-----	-----	-----	0.07 abc	100 a
Agrisure 3111 + Force	3G	0.15	T-Band	0.09 abc	95 ab
Agrisure 3122	-----	-----	-----	0.09 abc	95 ab
DeKalb VT3 + Aztec	2.1G	0.14	In-Furrow	0.11 abc	90 ab
Pioneer OAM1	-----	-----	-----	0.19 abcde	75 ab
DeKalb VT3 PRO RIB + Aztec-SB	4.67G	0.14	SB/In-Furrow	0.16 abcd	85 ab
DeKalb non-RW Bt + Aztec	2.1G	0.14	In-Furrow	0.17 abcd	85 ab
DeKalb VT3 + Starter Fertilizer	-----	-----	In-Furrow	0.18 abcde	85 ab
Pioneer OAM1 + Starter Fertilizer	-----	-----	In-Furrow	0.31 abcdef	85 ab
DeKalb VT3 + Capture LFR + SF	1.5SC	0.10	In-Furrow	0.32 bcdef	65 abc
DeKalb VT3	-----	-----	-----	0.37 bcdef	60 abc
Agrisure 3111 + Capture LFR + SF	1.5SC	0.10	T-Band	0.38 bcdef	75 ab
DeKalb VT3 PRO RIB	-----	-----	-----	0.50 def	50 abc
Agrisure 3111	-----	-----	-----	0.53 ef	45 bc
Agrisure non-RW Bt	-----	-----	-----	0.69 fg	40 abc
DeKalb non-RW Bt	-----	-----	-----	1.07 g	25 cd
Pioneer non-RW Bt	-----	-----	-----	1.75 h	5 d

¹Planted May 24, 2013; evaluated August 13, 2013.

²Non-RW Bt=an absence of any Bt trait targeting corn rootworm; SF=starter fertilizer (10-34-0 NPK) used as carrier with Insecticide; DeKalb Smartstax=DeKalb Smartstax (DKC 59-90); DeKalb VT3=YieldGard VT Triple (DKC59-88); DeKalb VT3 PRO RIB=DeKalb brand VT3 PRO RIB (DKC 61-86); DeKalb-non-RW Bt=DeKalb brand RR Isoline (DKC 59-89); Pioneer OAM1=Pioneer Optimum AcreMax1 (P0533AM1); Pioneer non-RW Bt=Pioneer Herculex 1 (P0533HR); Pioneer HXX=Pioneer Herculex XTRA (P0533HXX); Agrisure non-RW Bt=Syngenta Agrisure (Agrisure N68B-GT, Glyphosate Tolerant); Agrisure 3111=Syngenta Agrisure (Agrisure N68-3111); Agrisure 3122=Syngenta Agrisure (Agrisure N68-3122); Agrisure 3122 RIB=Syngenta Agrisure RIB (Agrisure N68-3122 RIB).

³Insecticide listed as ounces a.i./1,000 row-ft.

⁴In-Furrow and T-Band=insecticide applied at planting time; SB=SmartBox application at planting time.

⁵Chemical and check means based on 20 observations (5 roots/2 rows × 4 replications).

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

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

⁸Product consistency=percentage of times nodal injury was 0.25 (1/4 node eaten) or less.

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

Table 2. Comparison of rootworm management for stand count, Nashua, Iowa.¹

Treatment²	Form.	Rate³	Placement⁴	Stand count^{5,6}
DeKalb VT3 PRO RIB + Aztec-SB	4.67G	0.14	SB/In-Furrow	33.25 a
DeKalb VT3 + Azte	2.1G	0.14	In-Furrow	32.75 ab
DeKalb Smartstax	-----	-----	-----	32.50 abc
DeKalb VT3 + Capture LFR + SF	1.5SC	0.10	In-Furrow	32.00 abcd
DeKalb VT3	-----	-----	-----	32.00 abcd
DeKalb VT3 + Starter Fertilizer	-----	-----	In-Furrow	31.75 abcde
Pioneer OAM1	-----	-----	-----	31.75 abcde
DeKalb VT3 PRO RIB	-----	-----	-----	31.50 abcde
DeKalb non-RW Bt	-----	-----	-----	31.00 abcdef
DeKalb non-RW Bt + Aztec	2.1G	0.14	In-Furrow	31.00 abcdef
Pioneer HXX	-----	-----	-----	30.50 abcdef
Agrisure 3111 + Force	3G	0.15	T-Band	30.50 abcdef
Agrisure 3111 + Capture LFR + SF	1.5SC	0.10	T-Band	30.25 abcdef
Pioneer OAM1 + Capture LFR + SF	1.5SC	0.10	In-Furrow	30.00 bcdefg
Pioneer non-RW Bt	-----	-----	-----	29.75 bcdefg
Agrisure non-RW Bt	-----	-----	-----	29.25 defg
Agrisure 3122 RIB	-----	-----	-----	29.25 defg
Agrisure 3111	-----	-----	-----	29.25 cdefg
Pioneer OAM1 + Aztec	2.1G	0.14	In-Furrow	29.00 defg
Agrisure 3122 + Force	3G	0.15	T-Band	28.75 efg
Agrisure 3122	-----	-----	-----	28.25 fg
Pioneer OAM1 + Starter Fertilizer	-----	-----	In-Furrow	28.50 fg
Agrisure 3122 RIB + Counter-SB	20G	0.90	SB/In-Furrow	27.25 g
Pioneer OAM1 + SmartChoice-SB	5G	0.25	SB/In-Furrow	26.75 g

¹Planted May 24, 2013; evaluated June 19 and October 24, 2013.

²Non-RW Bt=an absence of any Bt trait targeting corn rootworm; SF=starter fertilizer (10-34-0 NPK) used as carrier with Insecticide; DeKalb Smartstax=DeKalb Smartstax (DKC 59-90); DeKalb VT3=YieldGard VT Triple (DKC59-88); DeKalb VT3 PRO RIB=DeKalb brand VT3 PRO RIB (DKC 61-86); DeKalb-non-RW Bt=DeKalb brand RR Isoline (DKC 59-89); Pioneer OAM1=Pioneer Optimum AcreMax1 (P0533AM1); Pioneer non-RW Bt=Pioneer Herculex 1 (P0533HR); Pioneer HXX=Pioneer Herculex XTRA (P0533HXX); Agrisure non-RW Bt=Syngenta Agrisure (Agrisure N68B-GT, Glyphosate Tolerant); Agrisure 3111=Syngenta Agrisure (Agrisure N68-3111); Agrisure 3122=Syngenta Agrisure (Agrisure N68-3122); Agrisure 3122 RIB=Syngenta Agrisure RIB (Agrisure N68-3122 RIB).

³Insecticide listed as ounces a.i./1,000 row-ft.

⁴In-Furrow and T-Band=insecticide applied at planting time; SB=SmartBox application at planting time.

⁵Means based on 16 observations (2-row treatment × 17.5 row-ft/treatment × 4 replications × 2 evaluation dates).

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

Table 3. Comparison of rootworm management for lodging, Nashua, Iowa.¹

Treatment²	Form.	Rate³	Placement⁴	Lodging^{5,6}
Pioneer OAM1 + Capture LFR + SF	1.5SC	0.10	In-Furrow	0 a
Pioneer OAM1 + SmartChoice-SB	5G	0.25	SB/In-Furrow	0 a
Pioneer OAM1 + Starter Fertilizer	-----	-----	In-Furrow	0 a
DeKalb VT3 + Aztec	2.1G	0.14	In-Furrow	0 a
DeKalb Smartstax	-----	-----	-----	0 a
DeKalb VT3 PRO RIB + Aztec-SB	4.67G	0.14	SB/In-Furrow	0 a
Agrisure 3111 + Capture LFR + SF	1.5SC	0.10	T-Band	0 a
Agrisure 3122 RIB	-----	-----	-----	0 a
Agrisure 3122 RIB + Counter-SB	20G	0.90	SB/In-Furrow	0 a
Pioneer OAM1 + Aztec	2.1G	0.14	In-Furrow	1 a
DeKalb non-RW Bt + Aztec	2.1G	0.14	In-Furrow	1 a
DeKalb VT3 + Capture LFR + SF	1.5SC	0.10	In-Furrow	1 a
Agrisure 3122 + Force	3G	0.15	T-Band	1 a
Agrisure 3111 + Force	3G	0.15	T-Band	1 a
Agrisure 3111	-----	-----	-----	1 a
Agrisure 3122	-----	-----	-----	1 a
DeKalb VT3 + Starter Fertilizer	-----	-----	In-Furrow	2 a
Pioneer OAM1	-----	-----	-----	2 a
Agrisure non-RW Bt	-----	-----	-----	2 a
Pioneer HXX	-----	-----	-----	4 a
DeKalb VT3	-----	-----	-----	4 a
DeKalb VT3 PRO RIB	-----	-----	-----	7 a
DeKalb non-RW Bt	-----	-----	-----	8 a
Pioneer non-RW Bt	-----	-----	-----	23 b

¹Planted May 24, 2013; evaluated October 24, 2013.

²Non-RW Bt=an absence of any Bt trait targeting corn rootworm; SF=starter fertilizer (10-34-0 NPK) used as carrier with Insecticide; DeKalb Smartstax=DeKalb Smartstax (DKC 59-90); DeKalb VT3=YieldGard VT Triple (DKC59-88); DeKalb VT3 PRO RIB=DeKalb brand VT3 PRO RIB (DKC 61-86); DeKalb-non-RW Bt=DeKalb brand RR Isoline (DKC 59-89); Pioneer OAM1=Pioneer Optimum AcreMax1 (P0533AM1); Pioneer non-RW Bt=Pioneer Herculex 1 (P0533HR); Pioneer HXX=Pioneer Herculex XTRA (P0533HXX); Agrisure non-RW Bt=Syngenta Agrisure (Agrisure N68B-GT, Glyphosate Tolerant); Agrisure 3111=Syngenta Agrisure (Agrisure N68-3111); Agrisure 3122=Syngenta Agrisure (Agrisure N68-3122); Agrisure 3122 RIB=Syngenta Agrisure RIB (Agrisure N68-3122 RIB).

³Insecticide listed as ounces a.i./1,000 row-ft.

⁴In-Furrow and T-Band=insecticide applied at planting time; SB=SmartBox application at planting time.

⁵Means based on 8 observations (2-row treatment x 17.5 row-feet/treatment x 4 replications)

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

Table 4. Comparison of rootworm management for yield, Nashua, Iowa.¹

Treatment ²	Form.	Rate ³	Placement ⁴	Bushels/ acre ^{5,6,7}
DeKalb Smartstax	-----	-----	-----	219 a
Agrisure 3111 + Capture LFR + SF	1.5SC	0.10	T-Band	214 ab
DeKalb VT3 PRO RIB	-----	-----	-----	210 ab
DeKalb VT3 + Capture LFR + SF	1.5SC	0.10	In-Furrow	208 abc
DeKalb VT3 + Aztec	2.1G	0.14	In-Furrow	202 abcd
Agrisure 3122 + Force	3G	0.15	T-Band	197 abcd
DeKalb VT3 PRO RIB + Aztec-SB	4.67G	0.14	SB/In-Furrow	197 abcd
DeKalb VT3 + Starter Fertilizer	-----	-----	In-Furrow	195 abcd
Pioneer OAM1 + Capture LFR + SF	1.5SC	0.10	In-Furrow	194 abcd
Agrisure 3111 + Force	3G	0.15	T-Band	194 abcd
DeKalb non-RW Bt + Aztec	2.1G	0.14	In-Furrow	193 abcd
Pioneer HXX	-----	-----	-----	193 abcd
DeKalb VT3	-----	-----	-----	192 abcd
Agrisure 3122 RIB + Counter-SB	20G	0.90	SB/In-Furrow	192 abcd
Agrisure 3111	-----	-----	-----	190 abcd
Agrisure 3122 RIB	-----	-----	-----	185 bcd
Pioneer OAM1 + SmartChoice-SB	5G	0.25	SB/In-Furrow	184 bcd
Agrisure 3122	-----	-----	-----	180 cd
Pioneer OAM1 + Starter Fertilizer	-----	-----	In-Furrow	178 cd
Pioneer OAM1 + Aztec	2.1G	0.14	In-Furrow	178 cd
Agrisure non-RW BT	-----	-----	-----	176 d
DeKalb non-RW Bt	-----	-----	-----	175 d
Pioneer OAM1	-----	-----	-----	173 d
Pioneer non-RW Bt	-----	-----	-----	148 e

¹Planted May 24, 2013; machine harvested November 9, 2013.

²Non-RW Bt=an absence of any Bt trait targeting corn rootworm; SF=Starter Fertilizer (10-34-0 NPK) used as carrier with Insecticide; DeKalb Smartstax=DeKalb Smartstax (DKC 59-90); DeKalb VT3=YieldGard VT Triple (DKC59-88); DeKalb VT3 PRO RIB=DeKalb brand VT3 PRO RIB (DKC 61-86); DeKalb-non-RW Bt=DeKalb brand RR Isoline (DKC 59-89); Pioneer OAM1=Pioneer Optimum AcreMax1 (P0533AM1); Pioneer non-RW Bt=Pioneer Herculex 1 (P0533HR); Pioneer HXX=Pioneer Herculex XTRA (P0533HXX); Agrisure non-RW Bt=Syngenta Agrisure (Agrisure N68B-GT, Glyphosate Tolerant); Agrisure 3111=Syngenta Agrisure (Agrisure N68-3111); Agrisure 3122=Syngenta Agrisure (Agrisure N68-3122); Agrisure 3122 RIB=Syngenta Agrisure RIB (Agrisure N68-3122 RIB).

³Insecticide listed as ounces a.i./1,000 row-ft.

⁴In-Furrow and T-Band=insecticide applied at planting time; SB=SmartBox application at planting time.

⁵Means based on 4 observations (2-row treatment × 68 row-ft/treatment × 4 replications).

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

⁷Yields converted to 15% moisture.