IOWA STATE UNIVERSITY
OF SCIENCE AND TECHNOLOGY

2018 IOWA EVALUATION OF INSECTICIDES AND PLANT-INCORPORATED PROTECTANTS

CORN PESTS RESEARCH PROJECT

DEPARTMENT OF ENTOMOLOGY
AMES, IOWA 50011-3140

SUE BLODGETT, CHAIR

INSECT INVESTIGATED

Corn Rootworm
Diabrotica virgifera virgifera and *Diabrotica barberi*

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INTRODUCTION

In Iowa, the species of corn rootworm (CRW) that are of economic importance include western corn rootworm *Diabrotica virgifera virgifera* LeConte and northern corn rootworm *D. barberi* Smith and Lawrence, and these two species are the most damaging pests of corn, *Zea mays,* in the Unites States Corn Belt. Eggs are laid in the soil during the summer and hatch the following spring. Larval feeding on corn roots in June may diminish yield by reducing plant growth and drought tolerance, and by imposing harvest losses due to plant lodging. Adult emergence from the soil is underway by early July and continues through late summer. Additional crop losses may be caused by adult beetles feeding on corn silk and soft doughy kernels. In Iowa, crop rotation, where it fits cropping practices, remains the preferred method of management. However, it is also economically feasible to protect corn roots with soil-applied insecticides and plant incorporated protectants, which are transgenic corn hybrids that produce insecticidal toxins derived from *Bacillus thuringiensis* (Bt).

In additional to corn rootworm, several aboveground lepidopteran pests feed on corn in Iowa. These include the European corn borer *Ostrinia nubilalis*, black cutworm *Agrotis ipsilon*, fall armyworm *Spodoptera frugiperda,* and corn earworm *Helicoverpa zea*. Over the last two decades, Bt corn varieties have been made commercially available to protect corn from these pests.

OBJECTIVE

The goal of this research program is to serve the agricultural community of Iowa by monitoring and evaluating the performance of registered and pre-commercial insecticides and transgenic corn hybrids. To achieve this goal, we maintain a viable, proactive, progressive and scientifically sound product evaluation program.

TESTING PROCEDURES AND EVALUATIONS

Field Sites: Research plots were established at two Iowa State University research farms in 2018: 1) Johnson Farm (Ames), 2) Bruner Farm (Boone). At both locations, two sections of the study site are rotated annually as either research plots or late-planted trap crop. The seed planted for the trap crop is a mixed maturity blend with a greater proportion of late-maturing varieties. This trap crop constitutes a favorable environment for adult female CRW late in the season when other fields are maturing, and can result in a high abundance of CRW larvae the following season. Table 1 lists the studies conducted at each location.

METHODS

Field plot design: For all locations, the experimental design was a randomized complete block with four replications. Field plots were 30 feet in length.

Planting: Seeds were pre-bagged in the laboratory and then planted with a four-row John Deere Max Emerge™ 7100 Integral Rigid Frame Planter that had 30 inch row spacing. Seeds were planted at a depth of 2 inches with a spacing of 6 inches between seeds (35,600 seeds per acre). The standard planter fiberglass seed hoppers with attached finger-pickup mechanism were replaced with modified units. On these modified units, the metal plate that covered the fingers had been replaced with a 7/8 inch clear Plexiglas plate. Inserted through the Plexiglas was a small stainless-steel cylinder. The cylinder was positioned to deliver seed to the pickup fingers. At the beginning of each replication, pre-bagged seeds were dumped into the steel cylinder. At the beginning of each replication, a hydraulic motor (attached to the planter's drive shaft) was activated to deliver seed immediately into the ground. At the end of each replication, this same hydraulic motor was activated to expel any unplanted seed, and the finger pickup mechanism was visually inspected through the clear Plexiglas plate to ensure that no seed was present.

For some studies that only evaluated a single hybrid (see Tables 2,3,13-15), planting was accomplished with a two-row John Deere planter that had 30 inch row spacing and bulk seed hoppers. Seeds were planted at a depth of 2 inches with a spacing of 6 inches between seeds (35,600 seeds per acre).

Plant-incorporated protectants: Plant-incorporated protectants were evaluated in corn hybrids producing insecticidal toxins derived from the bacterium *Bacillus thuringiensis* (Bt), and these are described in Appendix III.

Seed treatments: All of the seed used in these studies contained an insecticidal seed treatment. These seed treatments target secondary pests, such as wireworm and seed corn maggot but may have some, limited efficacy against CRW larvae at levels higher than 250 mg active ingredient per kernel.

Liquid soil-applied insecticides: Ampex 1.71SC, AMV1118 CS-B 2.8CS, Capture LFR 1.5SC, Force EVO 2.1EC, and Index 2.8CS were applied in-furrow at planting with a compressed-air system built directly into the planter by Almaco manufacturing (Nevada, IA). All liquid products, with the exception of the 3RIVE3D treatments, were applied as ounces per 1000 row feet. All liquid insecticide was applied with a Teejet XR80015EVS spray nozzles at 21 psi to deliver 5 GPA of finished spray at a tractor speed of 4 mph. All 3RIVE3D treatments were applied at a rate of 40 oz per acre (0.3 GPA) using the 3RIVE3D application system.

All liquid insecticides used water as the carrier, except for studies listed in Tables 7 to 9, which used liquid fertilizer.

Before planting, two new spray nozzles were installed per row (T-Band & In-Furrow) and calibrated with water to ensure proper application of product.

Each of these liquid-application nozzles was checked for product and correct spray pattern, and was monitored during application to ensure that insecticides were applied correctly. Final incorporation was accomplished with drag chains mounted behind the closing wheels. All these products were applied in-furrow at a tractor speed of 4 mph at a rate of 5 gallons per acre.

SmartBox™ application of soil-applied insecticides: Aztec-HC 9.34G insecticide treatment was applied with modified SmartBox™ metering units mounted on the planter. The 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 that it could slide in and out of the same planter mounting brackets used for the Noble units. An inverted 1 L 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 both the in-furrow and T-band placement. A controller mounted in the tractor cab was used to operate all the SmartBox™ metering units. These units were managed using the AMVAC SmartBox System Manager. All treatments were applied at 4 mph using the "fixed speed mode" on the SmartBox™ controllers. These SmartBox™ metering units were calibrated before going to the field to deliver ounces of product per 1000 row feet.

General methodology: During planting, each row was constantly monitored to ensure that insecticides were applied correctly. Final incorporation was accomplished with drag chains mounted behind the closing wheels.

Evaluations

Stand counts: These were measured by laying a stand count chain length 17' 5" long (1/1000 of an acre for 30-inch row spacing) between the center two rows of a plot and counting the number of plants in both rows. Late season stand counts were measured following the same procedure as early season stand counts but using a two-inch PVC pipe cut to the length of 17'5" long. Measurements for both dates were averaged to provide a single value for stand counts.

Root injury: After the majority of corn rootworms had finished feeding, roots were dug to assess feeding injury. This took place from July 25 to August 16, 2018. Prior to leaving the field, excess soil was removed from roots and all roots were labeled with study name and plot number using a permanent marker. Roots were cleaned at the ISU Johnson Farm's root washing station. These roots were first soaked in water for 2 hours and then washed with a hose to remove any remaining soil. Roots were evaluated for rootworm feeding injury following the Iowa State 0 to 3 Node-Injury Scale:

Node-Injury Scale (0-3):

0.00 - No feeding injury (lowest rating that can be given).
1.00- One node (circle of roots), or the equivalent of an entire node, pruned to within 1.5 inches of the stalk or soil line.
2.00 - Two nodes pruned.
3.00 - Three or more nodes pruned. (highest rating that can be given)

Injury in between complete nodes pruned is scored as the percentage of the node missing (e.g., 1.50 = one and a half nodes pruned and 0.25 = one quarter of one node pruned). The linear node-injury scale allows injury to be expressed intuitively and has proved useful in evaluating minor injury.

For an interactive guide to the node-injury scale, see the website for the

Department of Entomology at Iowa State University.
http://www.ent.iastate.edu/dept/faculty/gassmann/rootworm

Yields: Studies that were taken to yield were machine harvested with a modified John Deere 9450 plot combine owned by Iowa State University. Weight (pounds) and percent moisture were recorded with a HarvestMaster high capacity grain gauge, using Mirus harvest software. These measurements were converted to bushels per acre of No. 2 shelled corn (56 lbs. per bushel at 15.5% moisture) in Microsoft Excel.

Data analysis

Data were analyzed with analysis of variance (ANOVA) procedures using SAS 9.4. When a significant treatment effect was present pairwise comparisons were made among means with an experimentwise error rate of $P < 0.05$. Root injury data and yield data were transformed using the square root function and log base 10 function, respectively to improve the fit of the data with the statistical assumptions of ANOVA.

Product consistency: Percent product consistency 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).

Results and Discussion

Studies reported here were conducted at two location in Iowa, both near Ames. Rootworm feeding pressure ranged from light to moderate. In some cases, untreated checks suffered slightly over 0.5 nodes of injury, but in other cases, untreated checks suffering more than a node of injury and injury.

A study conducted at both the Johnson Farm and Bruner Farm compared four methods for applying Capture. At the Johnson Farm location, the pressure was too light to observe any differences (Table 2). However, the pressure for the study conducted at the Bruner Farm was slightly higher (Table 13). In this study, Capture LFR applied in-furrow appeared to provide the best root protection.

In a study comparing various insecticides for management of rootworm larvae on non-rootworm-Bt corn, no statistical differences were observed among Aztec, Force, Capture, and a higher rate of Ampex, although numerical differences were observed (Table 4). Insecticidal seed treatments, and a lower rate of Ampex, had higher levels of root injury and in many cases did not differ from the untreated check. However, it should be noted that Ampex is not currently registered for management of corn rootworm larvae. For a second study of insecticides on non-rootworm Bt corn, significant reductions in root injury were observed Aztec, Force 3G and Capture (Table 8).

We conducted a study looking at insecticides on Bt and non-Bt corn that target corn rootworm (Table 10). In this study, injury to the untreated check was over 1 node, and all treatments had significantly lower injury than the check, with injury reduced to less than 0.3 nodes. There were no significant differences observed between Bt corn targeting corn rootworm and non-rootworm-Bt corn with soil-applied insecticide. Also, in no case, did the application of soil-applied insecticide to Bt corn targeting corn rootworm lead to a significant reduction in root injury.

ADDITIONAL INFORMATION

Agronomic information and field history are listed in **Appendix I**. Weather data from the test site or the nearest Iowa climatological station are listed in **Appendix II**. Information on materials tested is listed in **Appendix III**. Pictures of various research activities are in **Appendix IV**.

RESEARCH SUPPORT

Support for this research was provided by the Iowa State University Agriculture and Home Economics Experiment Station and by the following companies: AMVAC, FMC, Monsanto, Syngenta and Valent.

WAIVER OF ENDORSEMENT

This report deals with the relative ability of each treatment to protect corn from damage by insects. This information is not presented to endorse the use of any product and the name of Iowa State University should not appear in any advertising without prior written consent. Iowa State University, their respective officers, agents, or employees, have not made, and do not hereby make, any representation, warranty or covenant with respect to the use of these test results, nor will they be liable for any damages, losses, or claims, including those of an incidental or consequential nature, arising out of the use of these test results.

Table 1. Iowa evaluation of insecticides and plant-incorporated protectants.

Test Location	Types of Studies	Table Numbers	Entries/ Test	Rows/ Plot	Experimental Unit Size	
					Row Length (ft)	#Reps
Ames-Johnson Farm	1) Insecticides on non-RW Bt corn (study #1)	2-3	5	2	30	4
	2) Insecticides on non-RW Bt corn (study #2)	4-6	8	2	30	4
	3) Insecticides on non-RW Bt corn (study #3)	7-9	5	4	30	4
	4) Insecticides on RW Bt corn	10-12	12	4	30	4
Boone-Bruner Farm	1) Insecticides on non-RW Bt corn	13-15	5	2	30	4

[1]All these studies were conducted following corn rootworm trap crop, to ensure the presence of rootworm larvae in the study

Table 2. Average Root Injury and Product Consistency for Insecticide on Non-RW Bt Corn (Study #1): Johnson Farm, Ames[1]

Treatment[2]	Formulation	Rate[3]	Placement[4]	Node-Injury[5,6,8]	Product Consistency[7,8]
Capture LFR	1.5 SC	0.10	Furrow	0.16	80
Capture LFR	1.5 SC	0.10	Split Furrow	0.22	65
Capture 3RIVE3D	1.6 SC	0.10	Furrow	0.31	65
Capture 3RIVE3D	1.6 SC	0.10	Split Furrow	0.43	65
Control	-----	-----	-----------	0.53	40

[1] Planted May 8, 2018 evaluated August 17, 2018; there was an issue with the planter that led to big skips

[2] non-RW Bt = an absence of any Bt trait targeting corn rootworm; DeKalb non-RW Bt = DeKalb brand VT2P RIB (DeKalb 64-35)

[3] All Insecticides listed as pounds of a.i. per acre

[4] Furrow = insecticide applied in furrow at planting time; Split Furrow = new system that increases area of dispersal of product in the furrow

[5] Means based on 20 observations (5 roots/2 rows x 4 replications)

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

[7] Product consistency = Percentage of times nodal injury was 0.25 (¼ node eaten) or less

[8] No Significant difference between the treatment means for both Node-Injury and Product Consistency ($P \geq 0.05$)

Table 3. Average Stand Count for Insecticide on Non-RW Bt Corn (Study #1): Johnson Farm, Ames[1]

Treatment[2]	Formulation	Rate[3]	Placement[4]	Stand Counts[5,6]
Capture 3RIVE3D	1.6 SC	0.10	Furrow	23.69
Capture 3RIVE3D	1.6 SC	0.10	Split Furrow	21.63
Capture LFR	1.5 SC	0.10	Split Furrow	19.56
Control	-----	-----	-----------	18.69
Capture LFR	1.5 SC	0.10	Furrow	16.31

[1] Planted May 8, 2018; evaluated June 18 and October 11, 2018; there was an issue with the planter that led to big skips
[2] non-RW Bt = an absence of any Bt trait targeting corn rootworm; DeKalb non-RW Bt = DeKalb brand VT2P RIB (DeKalb 64-35)
[3] All Insecticides listed as pounds of a.i. per acre
[4] Furrow = insecticide applied in furrow at planting time; Split Furrow = new system that increases area of dispersal of product in the furrow
[5] Means based on 16 observations (2-row treatment x 17.4 row-feet/treatment x 4 replications x 2 evaluation dates)
[6] No Significant difference between the treatment means ($P \geq 0.05$)

Table 4. Average Root Injury and Product Consistency for Insecticide on Non-RW Bt Corn (Study #2): Johnson Farm, Ames[1]

Treatment[2]	Formulation	Rate[3]	Placement[4]	Node-Injury[5,6,8]	Product Consistency[7,8]
Aztec 4.67G	4.67 GR	3.00	Furrow	0.16a	75a
Ampex	1.71 SC	0.69	Furrow	0.36ab	45ab
Capture LFR	1.5 SC	0.98	Furrow	0.39ab	45ab
Force EVO	2.1 CS	0.57	Furrow	0.41ab	45ab
Poncho	600 FS	1.25	Seed Trt.	0.98bc	10b
Ampex	1.71 SC	0.46	Furrow	1.24cd	15b
Poncho	600 FS	0.50	Seed Trt.	1.40cd	5b
Control	-----	-----	------------	2.04d	0b

[1] Planted May 9, 2018; evaluated August 3, 2018
[2] non-RW Bt = an absence of any Bt trait targeting corn rootworm;
[3] Insecticides listed as ounces of formulated product per 1000 row feet. Ampex and Capture LFR = fl oz and Aztec 4.67G = oz Poncho listed as mg. a.i. per seed.
[4] Furrow = insecticide applied in furrow at planting time; Seed Trt. = insecticide applied to the seed coat
[5] Means based on 20 observations (5 roots/2 rows x 4 replications)
[6] Iowa State Node-Injury Scale (0-3). Number of full or partial nodes completely eaten
[7] Product consistency = Percentage of times nodal injury was 0.25 (¼ node eaten) or less
[8] Significant difference between the treatment means for both Node-Injury and Product Consistency ($P < 0.05$)

Table 5. Average Stand Count for Insecticide on Non-RW Bt Corn (Study #2): Johnson Farm, Ames[1]

Treatment[2]	Formulation	Rate[3]	Placement[4]	Stand Counts[5,6]
Force EVO	2.1 CS	0.57	Furrow	32.31
Ampex	1.71 SC	0.46	Furrow	32.25
Poncho	600 FS	0.50	Seed Trt.	31.94
Ampex	1.71 SC	0.69	Furrow	31.75
Capture LFR	1.5 SC	0.98	Furrow	31.63
Aztec 4.67G	4.67 GR	3.00	Furrow	31.44
Poncho	600 FS	1.25	Seed Trt.	30.94
Control	-----	-----	-----------	30.56

[1] Planted May 9, 2018; evaluated June 18 and October 10, 2018
[2] non-RW Bt = an absence of any Bt trait targeting corn rootworm;
[3] Insecticides listed as ounces of formulated product per 1000 row feet. Ampex and Capture LFR = fl oz and Aztec 4.67G = oz Poncho listed as mg. a.i. per seed.
[4] Furrow = insecticide applied in furrow at planting time; Seed Trt. = insecticide applied to the seed coat
[5] Means based on 16 observations (2-row treatment x 17.4 row-feet/treatment x 4 replications x 2 evaluation dates)
[6] No significant differences between means (ANOVA, $P \geq 0.05$)

Table 6. Average Yield for Insecticide on Non-RW Bt Corn (Study #2): Johnson Farm, Ames[1]

Treatment[2]	Formulation	Rate[3]	Placement[4]	Bushels/Acre[5,6,7]
Aztec 4.67G	4.67 GR	3.00	Furrow	275.62a
Ampex	1.71 SC	0.69	Furrow	248.59ab
Force EVO	2.1 CS	0.57	Furrow	246.45ab
Capture LFR	1.5 SC	0.98	Furrow	243.54ab
Ampex	1.71 SC	0.46	Furrow	242.37ab
Poncho	600 FS	1.25	Seed Trt.	236.38ab
Poncho	600 FS	0.50	Seed Trt.	232.18ab
Control	-----	-----	-----------	211.10b

[1] Planted May 9, 2018; machine harvested October 24, 2018 for crop destruct
[2] non-RW Bt = an absence of any Bt trait targeting corn rootworm;
[3] Insecticides listed as ounces of formulated product per 1000 row feet. Ampex and Capture LFR = fl oz and Aztec 4.67G = oz Poncho listed as mg. a.i. per seed.
[4] Furrow = insecticide applied in furrow at planting time; Seed Trt. = insecticide applied to the seed coat
[5] Means based on 16 observations (2-row treatment x 30 row-feet/treatment x 4 replications)
[6] Significant differences between means (ANOVA, $P < 0.05$)
[7] Yields converted to 15.5% Moisture

Table 7. Average Root Injury and Product Consistency for Insecticide on Non-RW Bt Corn (Study #3): Johnson Farm, Ames[1]

Treatment[2]	Formulation	Rate[3]	Placement[4]	Node-Injury[5,6,7]	Product Consistency[8,9]
Force 3G	3.0 GR	5.00	Furrow	0.21a	65
AMV118 CS-B	2.8 CS	0.72	Furrow	0.26a	60
Capture LFR	1.5 SC	0.98	Furrow	0.31a	65
Force EVO	2.1 EC	0.57	Furrow	0.34ab	55
Control	-----	-----	-----------	0.78b	20

[1] Planted May 10, 2018; evaluated August 14, 2018
[2] non-RW Bt = an absence of any Bt trait targeting corn rootworm; Dekalb non-RW Bt = Dekalb brand VT2P RIB (DKC 60-69)
[3] All insecticides listed as ounces of formulated product per 1000 row feet. AMV118 CS-B, Capture LFR, Force EVO = fl oz and Force 3G = oz
[4] Furrow = insecticide applied in furrow at planting time
[5] Means based on 20 observations (5 roots/2 rows x 4 replications)
[6] Iowa State Node-Injury Scale (0-3). Number of full or partial nodes completely eaten
[7] Significant differences between means (ANOVA, $P < 0.05$)
[8] Product consistency = Percentage of times nodal injury was 0.25 (¼ node eaten) or less
[9] No significant differences between means (ANOVA, $P \geq 0.05$)

Table 8. Average Stand Count for Insecticide on Non-RW Bt Corn (Study #3): Johnson Farm, Ames[1]

Treatment[2]	Formulation	Rate[3]	Placement[4]	Stand Counts[5,6]
Force EVO	2.1 EC	0.57	Furrow	31.50
Control	-----	-----	-----------	30.75
Capture LFR	1.5 SC	0.98	Furrow	30.13
Force 3G	3.0 GR	5.00	Furrow	29.88
AMV118 CS-B	2.8 CS	0.72	Furrow	29.69

[1] Planted May 10, 2018; evaluated June 18 and October 11, 2018
[2] non-RW Bt = an absence of any Bt trait targeting corn rootworm; Dekalb non-RW Bt = Dekalb brand VT2P RIB (DKC 60-69)
[3] All insecticides listed as ounces of formulated product per 1000 row feet. AMV118 CS-B, Capture LFR, Force EVO = fl oz and Force 3G = oz
[4] Furrow = insecticide applied in furrow at planting time
[5] Means based on 16 observations (2-row treatment x 17.4 row-feet/treatment x 4 replications x 2 evaluation dates)
[6] No significant differences between means (ANOVA, $P \geq 0.05$)

Table 9. Average Yield for Insecticide on Non-Bt Corn (Study #3): Johnson Farm, Ames[1]

Treatment[2]	Formulation	Rate[3]	Placement[4]	Bushels/Acre[5,6,7]
Force 3G	3.0 G	5.00	Furrow	272.81
Force EVO	2.1 EC	0.57	Furrow	266.67
AMV118 CS-B	2.8 CS	0.72	Furrow	265.65
Capture LFR	1.5 SC	0.98	Furrow	260.37
Control	-----	-----	-----------	258.20

[1] Planted May 10, 2018; machine harvested October 24, 2018 for crop destruct
[2] non-RW Bt = an absence of any Bt trait targeting corn rootworm; Dekalb non-RW Bt = Dekalb brand VT2P RIB (DKC 60-69)
[3] All insecticides listed as ounces of formulated product per 1000 row feet. AMV118 CS-B, Capture LFR, Force EVO = fl oz and Force 3G = oz
[4] Furrow = insecticide applied in furrow at planting time
[5] Means based on 4 observations (4-row treatment x 30 row-feet/treatment x 4 replications)
[6] No significant differences between means (ANOVA, $P \geq 0.05$)
[7] Yields converted to 15.5% Moisture

Table 10. Average Root Injury and Product Consistency for Insecticide on RW-Bt corn: Johnson Farm, Ames[1]

Treatment[2]	Formulation	Rate[3]	Placement[4]	Node-Injury[5,6,8]	Product Consistency[7,8]
Dekalb SSTX RIB + Aztec HC	9.34G	1.50	Furrow-SB	0.05a	95a
Pioneer AMXT + Index	2.80CS	0.72	Furrow	0.05a	100a
Pioneer AMX + Aztec HC	9.34G	1.50	Furrow-SB	0.06a	100a
Dekalb SSTX RIB + Index	2.80CS	0.72	Furrow	0.07a	95a
Dekalb SSTX RIB	-----	-----	-----------	0.08a	95a
Pioneer AMX + Index	2.80CS	0.72	Furrow	0.09a	100a
Pioneer AMXT + Aztec HC	9.34G	1.50	Furrow-SB	0.10a	95a
Pioneer AMX	-----	-----	-----------	0.12a	80ab
Pioneer AMXT	-----	-----	-----------	0.20a	85ab
Dekalb non-RW Bt + Index	2.80CS	0.72	Furrow	0.27a	50bc
Dekalb non-RW Bt + Aztec HC	9.34G	1.50	Furrow-SB	0.29a	65ab
Dekalb non-RW Bt	-----	-----	-----------	1.11b	15c

[1] Planted May 8 & 9, 2018; evaluated August 15, 2018
[2] non-RW Bt = an absence of any Bt trait targeting corn rootworm; DeKalb non-RW Bt = DeKalb brand VT2P RIB (DeKalb 64-35); DeKalb SSTX RIB = Dekalb brand Smartstax RIB (DKC 60-67); Pioneer AMX = Pioneer AcreMax Xtra (PO151AMX); Pioneer AMXT = Pioneer AcreMax Xtreme (P0339AMXT)
[3] All Insecticides listed as ounces of formulated product per 1000 row feet. Index = fl oz and Aztec HC = oz
[4] Furrow-SB = insecticide applied in furrow with SmartBox system at planting time; Furrow = insecticide applied in furrow at planting time
[5] Means based on 20 observations (5 roots/2 rows x 4 replications)
[6] Iowa State Node-Injury scale (0-3). Number of full or partial nodes completely eaten
[7] Product consistency = Percentage of times nodal injury was 0.25 (¼ node eaten) or less
[8] Significant difference between the treatment means for both Node-Injury and Product Consistency ($P < 0.05$)

Table 11. Average Stand Count for Insecticide on RW-Bt Corn: Johnson Farm, Ames[1]

Treatment[2]	Formulation	Rate[3]	Placement[4]	Stand Counts[5,6]
Dekalb SSTX RIB + Index	2.80CS	0.72	Furrow	33.63a
Pioneer AMX + Index	2.80CS	0.72	Furrow	33.50a
Dekalb SSTX RIB + Aztec HC	9.34GR	1.50	Furrow-SB	33.31a
Pioneer AMX	-----	-----	-----------	33.19ab
Dekalb SSTX RIB	-----	-----	-----------	32.94ab
Dekalb non-RW Bt + Aztec HC	9.34GR	1.50	Furrow-SB	32.88ab
Pioneer AMX + Aztec HC	9.34GR	1.50	Furrow-SB	32.81ab
Dekalb non-RW Bt	-----	-----	-----------	32.13abc
Dekalb non-RW Bt + Index	2.80CS	0.72	Furrow	31.69abc
Pioneer AMXT	-----	-----	-----------	30.38bc
Pioneer AMXT + Aztec HC	9.34GR	1.50	Furrow-SB	29.94c
Pioneer AMXT + Index	2.80CS	0.72	Furrow	29.50c

[1] Planted May 8 & 9, 2018; evaluated June 18 and October 11, 2018
[2] non-RW Bt = an absence of any Bt trait targeting corn rootworm; DeKalb non-RW Bt = DeKalb brand VT2P RIB (DeKalb 64-35); DeKalb SSTX RIB = Dekalb brand Smartstax RIB (DKC 60-67); Pioneer AMX = Pioneer AcreMax Xtra (PO151AMX); Pioneer AMXT = Pioneer AcreMax Xtreme (P0339AMXT)
[3] All Insecticides listed as ounces of formulated product per 1000 row feet. Index = fl oz and Aztec HC = oz
[4] Furrow-SB = insecticide applied in furrow with SmartBox system at planting time; Furrow = insecticide applied in furrow at planting time
[5] Means based on 16 observations (2-row treatment x 17.4 row-feet/treatment x 4 replications x 2 evaluation dates)
[6] Significant differences between means (ANOVA, $P < 0.05$)

Table 12. Average Yield for Insecticide on RW-Bt corn: Johnson Farm, Ames[1]

Treatment[2]	Formulation	Rate[3]	Placement[4]	Bushels/Acre[5,6,7]
Dekalb non-RW Bt + Aztec HC	9.34GR	1.50	Furrow-SB	257.42
Dekalb SSTX RIB + Index	2.80CS	0.72	Furrow	255.55
Dekalb non-RW Bt + Index	2.80CS	0.72	Furrow	255.05
Dekalb SSTX RIB	-----	-----	-----------	250.87
Dekalb SSTX RIB + Aztec HC	9.34GR	1.50	Furrow-SB	249.78
Dekalb non-RW Bt	-----	-----	-----------	246.94
Pioneer AMX + Index	2.80CS	0.72	Furrow	241.55
Pioneer AMX + Aztec HC	9.34GR	1.50	Furrow-SB	241.35
Pioneer AMXT + Index	2.80CS	0.72	Furrow	239.75
Pioneer AMXT + Aztec HC	9.34GR	1.50	Furrow-SB	232.97
Pioneer AMX	-----	-----	-----------	224.40
Pioneer AMXT	-----	-----	-----------	220.43

[1] Planted May 8 & 9, 2018; harvested October 24, 2018
[2] non-RW Bt = an absence of any Bt trait targeting corn rootworm; DeKalb non-RW Bt = DeKalb brand VT2P RIB (DeKalb 64-35); DeKalb SSTX RIB = Dekalb brand Smartstax RIB (DKC 60-67); Pioneer AMX = Pioneer AcreMax Xtra (PO151AMX); Pioneer AMXT = Pioneer AcreMax Xtreme (P0339AMXT)
[3] All Insecticides listed as ounces of formulated product per 1000 row feet. Index = fl oz and Aztec HC = oz
[4] Furrow-SB = insecticide applied in furrow with SmartBox system at planting time; Furrow = insecticide applied in furrow at planting time
[5] Means based on 4 observations (4-row treatment x 30 row-feet/treatment x 4 replications)
[6] No significant differences between means (ANOVA, $P \geq 0.05$)
[7] Yields converted to 15.5% Moisture

Table 13. Average Root Injury and Product Consistency for Insecticide on Non-RW Bt corn: Bruner Farm, Boone[1]

Treatment[2]	Formulation	Rate[3]	Placement[4]	Node-Injury[5,6,8]	Product Consistency[7,8]
Capture LFR	1.5 SC	0.10	Furrow	0.09a	90a
Capture LFR	1.5 SC	0.10	Split Furrow	0.11a	85a
Capture 3RIVE3D	1.6 SC	0.10	Split Furrow	0.15ab	80ab
Control	-----	-----	-----------	0.55b	30b
Capture 3RIVE3D	1.6 SC	0.10	Furrow	0.63b	40ab

[1] Planted May 10, 2018 evaluated July 25, 2018
[2] non-RW Bt = an absence of any Bt trait targeting corn rootworm; DeKalb non-RW Bt = DeKalb brand VT2P RIB (DeKalb 64-35)
[3] All Insecticides listed as pounds of a.i. per acre
[4] Furrow = insecticide applied in furrow at planting time; Split Furrow = new system that increases area of dispersal of product in the furrow
[5] Means based on 20 observations (5 roots/2 rows x 4 replications)
[6] Iowa State Node-Injury scale (0-3). Number of full or partial nodes completely eaten
[7] Product consistency = Percentage of times nodal injury was 0.25 (¼ node eaten) or less
[8] Significant differences between means (ANOVA, $P < 0.05$)

Table 14. Average Stand Count for Insecticide on Non-RW Bt Corn: Bruner Farm, Boone[1]

Treatment[2]	Formulation	Rate[3]	Placement[4]	Stand Counts[5,6]
Capture LFR	1.5 SC	0.10	Furrow	33.44
Capture 3RIVE3D	1.6 SC	0.10	Split Furrow	33.38
Capture 3RIVE3D	1.6 SC	0.10	Furrow	32.88
Capture LFR	1.5 SC	0.10	Split Furrow	32.63
Control	-----	-----	-----------	32.56

[1] Planted May 10, 2018 evaluated July 25, 2018
[2] non-RW Bt = an absence of any Bt trait targeting corn rootworm; DeKalb non-RW Bt = DeKalb brand VT2P RIB (DeKalb 64-35)
[3] All Insecticides listed as pounds of a.i. per acre
[4] Furrow = insecticide applied in furrow at planting time; Split Furrow = new system that increases area of dispersal of product in the furrow
[5] Means based on 16 observations (2-row treatment x 17.4 row-feet/treatment x 4 replications x 2 evaluation dates)
[6] No significant differences between means (ANOVA, $P \geq 0.05$)

Table 15. Average Yield for Insecticide on Non-RW Bt corn: Bruner Farm, Boone[1]

Treatment[2]	Formulation	Rate[3]	Placement[4]	Bushels/Acre[5,6,7]
Capture LFR	1.5 SC	0.10	Split Furrow	175.98
Capture 3RIVE3D	1.6 SC	0.10	Split Furrow	172.97
Control	-----	-----	-----------	165.29
Capture 3RIVE3D	1.6 SC	0.10	Furrow	163.56
Capture LFR	1.5 SC	0.10	Furrow	156.90

[1] Planted May 10, 2018 evaluated July 25, 2018
[2] non-RW Bt = an absence of any Bt trait targeting corn rootworm; DeKalb non-RW Bt = DeKalb brand VT2P RIB (DeKalb 64-35)
[3] All Insecticides listed as pounds of a.i. per acre
[4] Furrow = insecticide applied in furrow at planting time; Split Furrow = new system that increases area of dispersal of product in the furrow
[5] Means based on 4 observations (4-row treatment x 30 row-feet/treatment x 4 replications)
[6] No significant differences between means (ANOVA, P ≥ 0.05)
[7] Yields converted to 15.5% Moisture

APPENDIX I

Agronomic Information

2018
Field History Data

	Ames, IA-ISU Johnson Farm Corn Rootworm studies (following trap crop)	Boone, IA-ISU Bruner Farm Corn Rootworm studies (following trap crop)
Field History		
2017	Corn	Corn
2016	Corn	Corn
2015	Corn	Corn
2014	Corn	Corn
2013	Corn	Corn
Tillage	Fall 2017-disk ripper Spring 2018-field cultivation (2X)	Fall 2017-chopped stalks & Chisel plow; Spring 2018-field cultivation (2X)
Herbicides[1]	2 pintsSurestart II + 10 oz Harness-April 27-PRE; 3 oz/acre Capreno-June 9-POST	3 qts. Lumax-May 9-PRE; 1 oz. Impact-June 18-POST

Fertilizer[2]	N	P	K	S	Zn	N	P	K	S	Zn
Fall/2017	22	72	123	17	2	24	80	0	20	2
Preplant	200					200				

Soil Type	Clay loam & loam	Silty clay loam
Soil Organic Matter %	3.4	3.5
Soil pH	5.7	6.1

[1] Expressed as formulation per acre.
[2] Expressed as pounds per acre.

APPENDIX II

Weather Data

Ames & Boone[1] 2018 Rainfall and Temperature											
April				May				June			
Day	Temp.(F°) High	Temp.(F°) Low	Precip. (inches)	Day	Temp.(F°) High	Temp.(F°) Low	Precip. (inches)	Day	Temp.(F°) High	Temp.(F°) Low	Precip. (inches)
1	37	19		1	71	57	1.13	1	95	69	
2	40	19		2	64	56	0.38	2	77	59	0.72
3	33	14	0.13	3	68	55	0.62	3	80	55	
4	37	12		4	74	51	0.02	4	84	52	
5	51	27		5	82	50		5	91	61	
6	37	16		6	78	56		6	92	63	0.89
7	40	14		7	81	54		7	84	63	
8	31	22	0.14	8	82	56		8	86	68	
9	38	27	0.09	9	74	58	0.07	9	89	69	
10	57	24		10	73	55		10	74	65	0.26
11	60	36		11	62	47	0.03	11	78	63	0.86
12	63	37		12	58	46		12	86	65	
13	54	36	0.31	13	64	52	0.02	13	82	58	
14	37	26	0.83	14	81	58	0.04	14	78	56	3.88
15	29	22	0.33	15	81	56		15	91	67	
16	36	21	0.01	16	84	58		16	91	71	
17	48	26		17	84	60		17	92	74	
18	35	29	0.11	18	85	58		18	92	69	1.42
19	50	29		19	77	59	0.12	19	81	69	0.45
20	57	29		20	61	52	0.05	20	80	66	0.31
21	58	40		21	72	56	0.02	21	76	59	0.23
22	68	36		22	81	55	0.01	22	73	58	
23	72	42		23	88	64		23	79	59	
24	72	47		24	91	66		24	80	63	0.07
25	64	42		25	92	66	0.09	25	74	63	0.56
26	72	37		26	99	66		26	78	61	0.46
27	76	35		27	101	68		27	85	63	
28	60	36		28	99	71		28	87	67	
29	71	36		29	93	66	0.37	29	92	70	
30	85	49		30	82	64	0.01	30	90	69	1.60
				31	93	65					
Temp. Avg.	52.3	29.5	**Total(in.)**	**Temp. Avg.**	79.8	58.1	**Total(in.)**	**Temp. Avg.**	83.9	63.9	**Total(in.)**
	40.9		1.95		68.9		2.98		73.9		11.71
Normal	50.8		3.72	**Normal**	61.6		4.81	**Normal**	70.7		4.96
D.F.N.	-9.9		-1.77	**D.F.N.**	7.3		-1.83	**D.F.N.**	3.2		6.75

[1.] Weather station located 5 miles WSW of Ames at ISU AEA/Agronomy Farm. Low/High Temperatures & Rainfall amounts for Ames & Boone from Mesonet Weather Station website at: http://mesonet.agron.iastate.edu/agclimate/

Ames & Boone[1] 2018 Rainfall and Temperature											
July				August				September			
	Temp.(F°)		Precip.		Temp.(F°)		Precip.		Temp.(F°)		Precip.
Day	High	Low	(inches)	Day	High	Low	(inches)	Day	High	Low	(inches)
1	80	65	0.28	1	85	59	1.18	1	84	67	1.88
2	83	61		2	78	57		2	80	67	0.11
3	89	65		3	89	61		3	75	69	0.38
4	92	69	1.53	4	85	66	0.02	4	86	69	0.68
5	84	66	0.06	5	85	65	0.15	5	75	65	0.97
6	81	62		6	83	66	1.23	6	76	60	
7	81	61		7	81	64	0.61	7	67	56	
8	84	60		8	85	60		8	73	53	
9	91	63		9	89	67		9	74	51	
10	89	72		10	86	65		10	78	50	
11	92	69		11	87	65		11	81	55	
12	94	71		12	88	63		12	82	57	
13	90	72	0.11	13	89	64		13	85	59	
14	85	71	0.01	14	80	66	0.12	14	88	65	
15	88	69		15	84	68		15	93	66	
16	84	67		16	79	64	0.72	16	89	66	
17	88	65		17	84	64	0.01	17	94	66	
18	84	63		18	84	64		18	80	63	0.13
19	83	67	0.02	19	81	65	0.14	19	79	63	0.41
20	81	67		20	73	64	2.00	20	93	67	0.65
21	82	64		21	73	60		21	68	46	0.01
22	82	62		22	79	55		22	69	42	
23	85	64	0.01	23	77	55		23	77	47	
24	84	62	0.00	24	81	64		24	80	51	
25	84	63	0.34	25	88	62		25	62	45	0.75
26	78	58		26	83	68	0.01	26	66	44	
27	77	55		27	87	71	0.17	27	74	46	
28	77	58		28	81	59	0.96	28	55	39	
29	81	59		29	74	53		29	49	40	0.21
30	80	58		30	76	53		30	51	46	0.20
31	84	59		31	85	67	0.30				
Temp. Avg.	84.4	64.1	**Total(in.)**	**Temp. Avg.**	82.6	62.6	**Total(in.)**	**Temp. Avg.**	76.0	55.9	**Total(in.)**
	74.2		2.36		72.6		7.62		65.9		6.38
Normal	74		4.83	**Normal**	72.0		4.82	**Normal**	64.9		3.25
D.F.N.	0.2		-2.47	**D.F.N.**	0.6		2.80	**D.F.N.**	1.1		3.13

[1] Weather station located 5 miles WSW of Ames at ISU AEA/Agronomy Farm.

Ames & Boone[1] 2018 Rainfall and Temperature											
October											
	Temp.(F°)		Precip.		Temp.(F°)		Precip.		Temp.(F°)		Precip.
Day	High	Low	(inches)	Day	High	Low	(inches)	Day	High	Low	(inches)
1	54	47	1.56	1				1			
2	61	48		2				2			
3	88	47		3				3			
4	57	37		4				4			
5	55	48	0.20	5				5			
6	53	45	0.09	6				6			
7	55	45	0.68	7				7			
8	70	53	1.18	8				8			
9	69	56	0.25	9				9			
10	66	38		10				10			
11	46	33		11				11			
12	44	34		12				12			
13	56	39		13				13			
14	47	31	0.22	14				14			
15	48	30	0.09	15				15			
16	64	32		16				16			
17	55	35		17				17			
18	70	34		18				18			
19	69	47	0.09	19				19			
20	48	29		20				20			
21	63	26		21				21			
22	69	36		22				22			
23	56	31		23				23			
24	58	31		24				24			
25	53	42		25				25			
26	56	39		26				26			
27	68	35	0.02	27				27			
28	60	36		28				28			
29	64	35		29				29			
30	58	41		30				30			
31	59	37		31							
Temp. Avg.	59.3	38.6	**Total(in.)**	**Temp. Avg.**			**Total(in.)**	**Temp. Avg.**			**Total(in.)**
	48.9		4.38								
Normal	52.6		2.61	**Normal**				**Normal**			
D.F.N.	-3.6		1.77	**D.F.N.**				**D.F.N.**			

[1] Weather station located 5 miles WSW of Ames at ISU AEA/Agronomy Farm.

APPENDIX III

Materials Tested

Table 1. Conventional insecticides used in studies in 2018

Product name	Rate (ounces a.i. per 1000 row-feet; unless specified)	Active ingredient	Company
Aztec 4.67	3 oz. wt.	tebupirimphos & cyfluthrin	AMVAC Chem. Corp.
Aztec HC	1.5 oz. wt.	tebupirimphos & cyfluthrin	AMVAC Chem. Corp.
Ampex SC	0.46 & 0.69	clothianidin	Valent
Capture 3RIVE3D	0.46	bifenthrin	FMC
Capture LFR	0.98	bifenthrin	FMC
Force 3G	0.72	tefluthrin	Syngenta
Force EVO	0.46 & 0.57	tefluthrin	Syngenta
Index	0.72	chlorethoxyfos & bifenthrin	AMVAC
Poncho	0.50 and 1.25 mg ai/seed	clothianidin	Bayer Crop Science

Table 2. Rootworm active Bt Traits

Product name	**Events targeting rootworm**	**Toxin**	**Company**
Herculex	DAS-59122-7	Cry34/35Ab1	Pioneer & Dow AgroSciences
Pioneer AMX	DAS-59122-7	Cry34/35Ab1	DuPont-Pioneer
Pioneer AMXT	DAS-59122-7 + MIR604	Cry34/35Ab1 + mCry3A	DuPont-Pioneer
Pioneer OAM1	DAS-59122-7	Cry34/35Ab1	DuPont-Pioneer
Smartstax RIB	DAS-59122-7 + MON 88017	Cry34/35Ab1 + Cry3Bb1	Dow AgroSciences & Monsanto

APPENDIX IV

2018 Research Photos

Washing roots

Rating roots

Stand Counts