Evaluation of Soil-Applied Insecticide and Bt Corn for Management of Larval Corn Rootworm in Northeast Iowa

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The purpose of this study was to evaluate the effectiveness of Bt corn targeting corn rootworm and soil insecticide, either alone or in combination, for management of larval corn rootworm injury. The Bt trait packages evaluated in this study were: DeKalb Smartstax RIB, Pioneer Qrome, and Syngenta Duracade. All three of these hybrids contain two Bt traits that target corn rootworm larvae. Also evaluated was the soil-applied insecticide Aztec HC. Pioneer AcreMax (AM) was included in this study as a non-rootworm Bt check.

Materials and Methods

Study location. The study was conducted at the Northeast Research and Demonstration Farm (NERF). The field site 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.

Field plot design. This study was a randomized complete block design with four replications. Treatments were two rows wide, and 35 feet in length. Plots were cut down to 30 feet in length after planting.

Planting. This study was planted May 13 using a four-row John Deere Max Emerge™ 7100 Integral Rigid Frame Planter with 30-in. row spacing. Planting was at a depth of 2 in., with a spacing of 6 in. between seeds (35,600 seeds per acre).

SmartBox soil-applied insecticide. Aztec-HC 9.34G insecticide was applied in-furrow 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. An inverted 1-L plastic bottle attached to the top provided a secure and sealed container for insecticide used by the SmartBox units. Clear plastic tubes directed the granular insecticides to the in-furrow placement. Rows were monitored during application to ensure that all insecticides were applied correctly. Final incorporation was accomplished with drag chains mounted behind the closing wheels.

Stand counts. On June 9 early season stand counts were measured in all treatments. These were measured by using a 2 in. PVC pipe cut to the length of 17.4 ft. (1/1,000 of an acre for 30 in. row spacing) that was placed between two rows of corn, and the number of plants in both rows then counted. Late season stand counts were measured October 6 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).

Root injury. After the majority of corn rootworm larvae had finished feeding on corn roots, roots were dug to assess feeding injury. Roots were dug on July 29, 2021. Prior to leaving the field, all roots were labeled with study name and plot number using a permanent marker. On August 5 roots were cleaned at the ISU Johnson Farm's root washing station. Roots first were soaked in water for 2-8 hours, then washed with a hose to remove any remaining soil. After being washed, roots were evaluated for rootworm feeding injury following the Iowa State Node Injury Scale (0-3) (Table 1).

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 in. 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 was noted as the proportion of the node injured (1.50 = one and a half nodes pruned and 0.25 = one quarter of one node pruned).

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

Yields. This study was machine harvested October 20, 2021. with a modified John Deere 9450 plot combine owned by Iowa State University. Weight (pounds) and percent moisture were recorded using a Shivvers brand 5010 moisture meter and Avery-WeighTronix weigh system with a 915 weigh scale indicator harvest data collection system. These measurements were converted to bushels per acre of No. 2 shelled corn (56 pounds per bushel) at 15.5% moisture in Microsoft Excel (Table 3).

Data analysis. Data were analyzed with analysis of variance (ANOVA) in SAS Enterprise Guide 7.1. The treatment means were compared using LSMEAN procedure with an experiment wise error rate of $P < 0.05$.

Results and Discussion

Rootworm pressure was very high at this location, with the untreated check (Pioneer AM) suffering 1.71 nodes of feeding injury. On average, each node of roots lost to rootworm feeding reduces yield by approximately 15%.

The large rootworm populations likely arose from three primary factors. First, average to above average rootworm populations in 2020 provided a source of rootworm eggs in this field for the 2021 growing season. Second, adequate snow cover during the winter reduced egg mortality. Finally, dry conditions during June increased the ability of newly hatched rootworm larvae to establish on corn roots and initiate feeding.

In general, rainfall in June and July was well below average (less than half of the precipitation in a typical year) and this likely reduced the effectiveness of soil-applied insecticide to limit rootworm feeding injury. The application of Aztec to Pioneer AM (a non-rootworm Bt hybrid) reduced feeding injury by 0.7 nodes, but on average, this treatment still suffered approximately a node of feeding injury (Table 1).

Table 1. Average Root Injury and Product Consistency. NERF, Floyd Co.[a]

Treatment[b]	Formulation	Rate[c]	Placement[d]	Node-Injury[e,f]	Product Consistency[g,h]
Pioneer Qrome + Aztec HC	9.34G	1.50	Furrow-SB	0.40a	35a
Dekalb SSTX RIB + Aztec HC	9.34G	1.50	Furrow-SB	0.54ab	20ab
Syngenta Duracade + Aztec HC	9.34G	1.50	Furrow-SB	0.75b	10ab
Dekalb SSTX RIB				0.98cd	10ab
Pioneer AM + Aztec HC	9.34G	1.50	Furrow-SB	0.99cd	0b
Pioneer Qrome				1.10d	10ab
Pioneer AM				1.71e	0b
Syngenta Duracade				1.83e	0b

[a] Planted May 13, evaluated August 5
[b] Non-RW Bt = an absence of any Bt trait targeting corn rootworm; Pioneer non-RW Bt= Pioneer AcreMax (P0157 AM); DeKalb SSTX RIB = Dekalb brand Smartstax RIB (DKC 54-38); Pioneer Qrome = (0622Q); Syngenta Duracade = (G06Z97-5122-EZ1)
[c] All Insecticides listed as ounces per 1000 row ft
[d] Furrow-SB = insecticide applied in furrow with SmartBox system at planting time
[e] Means based on 20 observations (5 roots/2 rows x 4 replications)
[f] Iowa State Node-Injury scale (0-3). Number of full or partial nodes completely eaten
[g] Product consistency=percentage of times nodal injury was 0.25 (¼ node eaten) or less
[h] Significant difference between the treatment means for both Node-Injury and Product Consistency (ANOVA, $P < 0.05$)

Table 2. Average Stand Count. NERF, Floyd Co.[a]

Treatment[b]	Formulation	Rate[c]	Placement[d]	Stand Counts[e,f]
Syngenta Duracade + Aztec HC	9.34GR	1.50	Furrow-SB	32.5a
Dekalb SSTX RIB				32.5a
Dekalb SSTX RIB + Aztec HC	9.34GR	1.50	Furrow-SB	32.5a
Pioneer AM				32.0a
Pioneer AM + Aztec HC	9.34GR	1.50	Furrow-SB	31.8ab
Pioneer Qrome + Aztec HC	9.34GR	1.50	Furrow-SB	31.4ab
Syngenta Duracade				30.8ab
Pioneer Qrome				29.8b

[a] Planted May 13, evaluated June 9 and October 6
[b] Non-RW Bt = an absence of any Bt trait targeting corn rootworm; Pioneer non-RW Bt= Pioneer AcreMax (P0157 AM); DeKalb SSTX RIB = Dekalb brand Smartstax RIB (DKC 54-38); Pioneer Qrome = (0622Q); Syngenta Duracade = (G06Z97-5122-EZ1)
[c] All insecticides listed as ounces per 1000 row ft.
[d] Furrow-SB = insecticide applied in furrow with SmartBox system at planting time
[e] Data presented as plants per 1/1000 of an acre
[f] Significant differences between means (ANOVA, $P < 0.05$)

Further compounding rootworm management challenges in Iowa, some western corn rootworm populations have evolved resistance to all commercially available Bt traits. The effects of Bt resistance were apparent in this study, with all rootworm-traited Bt hybrids (Duracade, Qrome, and SmartStax) suffering approximately one node, or more, of feeding injury (Table 1). While Duracade contains a combination of Cry3 traits (mCry3A and eCry3.1Ab), both SmartStax and Qrome contain a combination of Cry34/35Ab1 and Cry3. Because the rootworm population in this study was likely resistant to all of these Bt traits, all Bt hybrids suffered a node or more of feeding injury. The cut-off for greater than expected injury to a pyramided rootworm hybrid, one that contains two traits for rootworm management, is 0.50 nodes. All of the rootworm traited hybrids evaluated in this study were pyramids for rootworm management and experienced greater than expected injury.

In general, management of corn rootworm in Iowa should focus on a diversified approach that reduces the likelihood of encountering large rootworm populations, such as the one observed in this study. The use of crop rotation is highly effective at reducing the abundance of corn rootworm. Additionally, the application of soil-applied insecticide to non-Bt corn typically provides an acceptable level of root protection (with injury of less than 0.50 nodes), although the dry conditions present during this study likely diminished the effectiveness of soil-applied insecticides. It is noteworthy that yields for soil-applied insecticide on non-rootworm Bt corn did not differ significantly from soil-insecticide applied to Bt corn (Table 3).

The most sustainable and profitable approach for long-term rootworm management is a diversified approach that includes crop rotation, soil-applied insecticide on non-rootworm Bt corn, and the use of transgenic corn targeting rootworm. Due to resistance to all Bt traits in the rootworm population evaluated in this study, use of a Bt hybrid is unlikely to provide sufficient root protection. The only suitable transgenic hybrid is likely to be one that manages rootworm through the use of RNA interference. It is important to keep in mind that continuous corn cultivation coupled with continuous use of the same Bt traits can lead to large populations of Bt-resistant rootworm, which can substantially reduce management options and reduce the effectiveness of management to preserve yield.

Table 3. Average Yield. NERF, Floyd Co.[a]

Treatment[b]	Formulation	Rate[c]	Placement[d]	Stand Counts[e],[f]
Dekalb SSTX + Aztec HC	9.34GR	1.50	Furrow-SB	199.1a
Syngenta Duracade + Aztec HC	9.34GR	1.50	Furrow-SB	197.4a
Pioneer Qrome + Aztec HC	9.34GR	1.50	Furrow-SB	176.1a
Pioneer Qrome				170.7a
Pioneer AM + Aztec HC	9.34GR	1.50	Furrow-SB	166.8a
Dekalb SSTX				163.6a
Syngenta Duracade				120.3b
Pioneer AM				92.8b

[a] Planted May 13, harvested October 20
[b] Non-RW Bt = an absence of any Bt trait targeting corn rootworm; Pioneer non-RW Bt = Pioneer AcreMax (P0157 AM); DeKalb SSTX RIB = Dekalb brand Smartstax RIB (DKC 54-38); Pioneer Qrome = (0622Q); Syngenta Duracade = (G06Z97-5122-EZ1)
[c] All Insecticides listed as ounces per 1000 row ft.
[d] Furrow-SB = insecticide applied in furrow with SmartBox system at planting time
[e] Means based on four observations (2-row treatment x 30 row-feet/treatment x four replications)
[f] Significant differences between means (ANOVA, $P < 0.05$)
[g] Yields converted to 15.5% moisture

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Additional Information

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