

2023 Applied Research Results Field Crop Disease and Insect Management

Evaluations of insect and disease control tactics for corn, soybean, and wheat Statewide surveys of corn and soybean pests





A digital copy of this guide can be viewed or downloaded at: <u>https://go.illinois.edu/2023PestPathogenARB</u> (Available online by February 2024)

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Regional moth trap network: <u>https://corn.ipmpipe.org/insects</u>	
Illinois Extension field crop production resources: https://go.illinois.edu/cropcentral	
Previous editions of this report: https://go.illinois.edu/pestmanagementresearchreport	

2023 Crop Production Summary

Giovani Preza Fontes Assistant Professor, Field Crops Extension Agronomist

Illinois producers planted 650,000 acres of winter wheat in the fall of 2021 and harvested 560,000 acres in 2022, with an average yield of 79 bushels per acre. Boosted by high world wheat prices, high wheat and good double-crop soybean yields, and dry fall weather, planted acreage jumped to an estimated 940,000 acres for the 2023 crop. The crop was planted at about the normal time last fall, with 50% planted by October 17. Crop growth and development were ahead of normal, given the warm and dry weather in most of the spring. Statewide wheat heading was at 74% compared to the 5-year average of 56%, with ratings 62% good + excellent. Wheat harvest began in the second half of June and ended in the first half of July. Based on the USDA Illinois Small Grains Summary report released on September 29, winter wheat harvested area in 2023 is estimated at 78,000 acres, up 39% from the previous year. Illinois winter wheat yield is forecasted to be at a record 87 bushels per acre, up 8 bushels per acre from 2022 (Table 1).

The first two months of the 2023 corn and soybean growing season were much like the first two months of the 2022 growing season, with a few key differences. The 2023 crop was planted earlier and into somewhat drier soils – some producers waited to plant during part of the second half of April until the weather warmed up. By May 7, 73% of the corn and 66% of the soybeans had been planted, compared to the 14% for corn and 10% for soybeans from May 7, 2022.

On one hand, early dryness benefited plant stands and soil oxygen levels, with no standing water damage, good root development for both corn and soybeans, and low levels of soilborne and foliar diseases. On the other hand, dryness also limited crop height and, to some extent, leaf area in upper leaves. Fortunately, early-season dryness was relieved by rainfall in late July and early August, greatly enhancing pollination success in corn and adding some nodes and pods to soybean plants. In most fields, crop canopy recovered some, with a dark green color that we associate with good yield potential. Weather and soil conditions were average to above average during grain-filling period. Harvest began in the second half of September and ended by mid-November. Based on the December USDA Crop Production report, corn production from Illinois for 2023 was 2.23 billion bushels, averaging 203 bushels per acre (Table 1). Soybean production was 628 million bushels, averaging 61 bushels per acre.

Soybean	2023 ^a	2022	2021	2020	2019
Acres planted	10,350,000	10,800,000	10,600,000	10,300,000	9,950,000
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Acres harvested	10,300,000	10,750,000	10,550,000	10,250,000	9,860,000
Yield (bushels per acre)	61	63	64	60	54
Price received (per	\$12.90 ^a	\$14.00	\$13.50	\$10.90	\$8.84
bushel)					
Corn	2023 ^a	2022 ^a	2021	2020	2019
Acres planted	11,200,000	10,800,000	11,000,000	11,300,000	10,500,000
Acres harvested (grain)	11,000,000	10,600,000	10,800,000	11,100,000	10,200,000
Yield (bushels per acre)	203	214	207	191	181
Price received (per	\$4.85 ^a	\$6.70	\$5.96	\$4.46	\$3.55
bushel)					
Wheat	2023 ^a	2022 ^a	2021	2020	2019
Acres planted	650,000	650,000	670,000	570,000	650,000
Acres harvested	560,000	560,000	610,000	520,000	550,000
Yield (bushels per acre)	79	79	79	68	67
Price received (per	\$7.30 ^a	\$9.10	\$6.43	\$5.39	\$5.06
bushel)					

Production Overview from 2019 to 2023

^a 2023 prices are projections from the December 2023 USDA World Agricultural Supply and Demand Estimates for the marketing year beginning September 2023; prices from 2019-2022 are the historical marketing year averages for the price received.

Data obtained from the USDA-NASS Quick Stats database (<u>https://quickstats.nass.usda.gov</u>); accessed December 4, 2023.

2023 Growing Season Weather & Climate Summary

Trent Ford, Illinois State Climatologist, Illinois State Water Survey, Prairie Research Institute

Another weather year in the books, and as with other years, 2023 brought its own interesting characteristics and events. From drought to extreme rainfall, way too many tornadoes, and some serious wildfire smoke, in this article I will review the 2023 growing season from a climate perspective.

A Cool & Wet Start to Spring

Although March wasn't extremely cold, it did feel more like an extension of winter than the start of spring. March average temperatures were around 1 degree below normal across the state, and – combined with abundant precipitation – didn't make for the best planting and spring fieldwork conditions in Illinois. The first month of spring was a top-10 wettest in parts of southern and eastern Illinois, including in Randolph and Edgar Counties. Unfortunately, the abundant rainfall came to us care of several rounds of severe storms, which produced a record 49 tornadoes in March. For perspective, Illinois typically sees between 50 and 60 tornadoes per year. The same storm systems also brought heavy snow to parts of northern Illinois. Rockford's 14.1 inches was the most March snowfall there since 1972.

April Fools Indeed

April started with very mild temperatures and extremely dry conditions across the state. In fact, April 8th to 13th was completely dry in Illinois, meaning exactly 0 inches of rain anywhere in the state over that 6-day period. Meanwhile, many parts of the state saw high temperatures well into the 80s in the first week of April. The warm and dry weather allowed many folks to make significant progress on planting and spring fieldwork. However, the weather pattern flipped midmonth, and left us with cold and wet conditions until the first week of May. Much of southern and central Illinois didn't see their last spring freeze until the last week of April this year, between 1 and 3 weeks later than normal. Meanwhile, most of the state picked up between 2 and 5 inches of rain in the latter half of April, and northern Illinois had some late measurable snow. The switch to cold and wet weather in late April created less than ideal fieldwork conditions and forced some folks to replant in May. The difference between a successful planting in early- to mid-April and a late planting or replant in May was magnified by summer drought this year. May finally brought consistently mild – if not warm – temperatures across Illinois, which was welcomed by most folks wanting to wrap up spring fieldwork activities. Figure 1 shows monthly temperature departures from normal from this past spring.

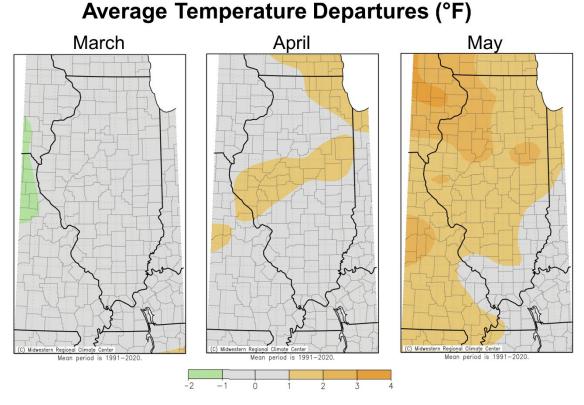
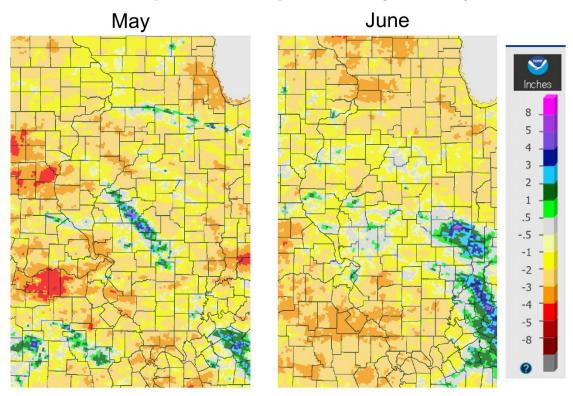


Figure 1. Maps show monthly average temperature departures from average for (left) March, (middle) April, and (right) May in Illinois.

Dude, Where's My Rain?

The dry weather in the first half of April was welcomed after a wet and cool start to spring. Dryness in the first half of May equally helped strong root growth to both reduce crop vulnerability to wind and improve access to deeper soil moisture. However, continued dryness in the last two weeks of May began to create some concern, as much of the state had virtually no rain between May 16th and May 31st. May ended about 2 inches drier than normal statewide and was a top 10 driest May on record in much of northeast Illinois, including the 3rd driest on record in Cook and Lake Counties (Figure 2a). June continued the dry trend with most of the state seeing less than 1.5 inches of rain through the first 28 days of June. The climatologically wettest month of the year in Illinois ended more than 2 inches drier than normal across the state, and was the driest June since 2012 (Figure 2b). The month was a top 10 driest June on record in dozens of counties, and the 3rd driest on record in Johnson, Pope, Perry, and Pulaski Counties.



Total Precipitation Departures (inches)

Figure 2. Maps show total precipitation departures from average in (left) May and (right) June in Illinois.

Drought in May and June dried topsoil and rootzone soils quickly and began to push stream and pond levels well below normal as water tables dropped across the state. For the most part, the drought did not progress to affect rural well or municipal water supply, but many producers' stock ponds dropped to unsuitably low levels, creating issues with water supply and water quality for livestock (Figure 3). Producers were also challenged by poor pasture regrowth, forcing many to supplement with feed hay at high economic and labor costs.



Figure 3. Photo of a depleted stock pond in Champaign County, Illinois, taken in mid-June. Photo source: Trent Ford, June 25.

Flash Drought

Drought is usually not much fun, but it is one hazard that typically develops and intensifies slowly. "Flash drought" is a concept describing a drought event that develops much more rapidly than a conventional drought. Flash droughts are typically caused by a combination of very little rainfall and high temperatures and evaporation, which work together to quickly deplete rootzone soil moisture. Much of central and western Illinois experienced a flash drought this summer. The U.S. Drought Monitor captured this rapid drought onset with 2-3 category increases in drought severity in 4 to 6 weeks between mid-May and late June (Figure 4).

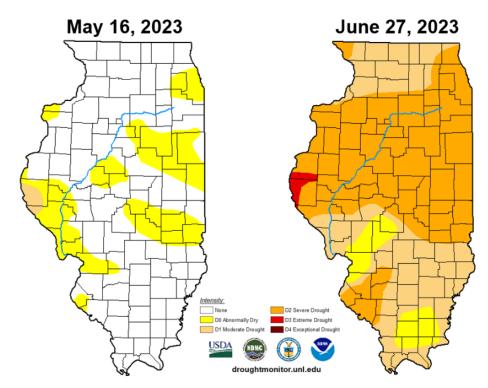
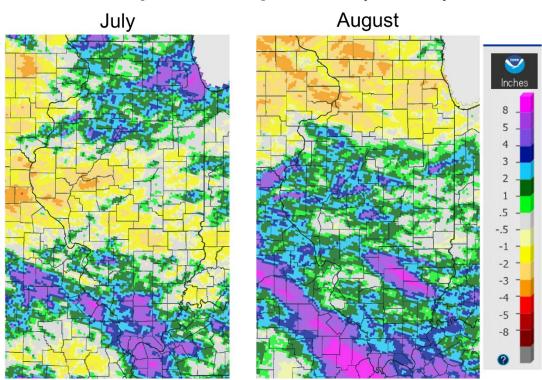


Figure 4. Maps show the U.S. Drought Monitor drought conditions in (left) mid-May and (right) late June in Illinois.

July and August Bring Rain When It's Most Needed

Things were not looking good as of July 1st; soils were dry, streamflow was near record low in some places, and pasture conditions were very poor in many parts of the state. Thankfully, July brought some better rain to parts of the drought-stricken Midwest. July precipitation was slightly-to-much above normal in most of the state, except for far western Illinois (Figure 5a). Incredibly, Cook County experienced its wettest July on record (going back to 1895) following its third driest June on record. Southern Illinois also saw a few very heavy rain events in July, including 8 inches in less than 24 hours in parts of Alexander and Pulaski Counties. Unfortunately, the beneficial rainfall also came with severe weather, including a derecho in late June that caused significant crop and infrastructure damage in west-central Illinois. One personal weather station in Taylorville measured a 101-mph wind from the derecho, and parts of Springfield were without consistent power for over a week. Meanwhile, Illinois added 23 tornadoes to its annual tally in July, pushing the state ahead of all others for 2023 tornadoes... not really a title we like to hold.

A more active storm track in August helped continue agricultural drought relief, especially in southern and central Illinois. In total, August brought over 4 inches of rain to most places south of Interstate 80, and some isolated 10+ inch totals in south-central Illinois (Figure 5b). While most of northern Illinois was drier than normal in August, the 1 to 3 inches of rain the region did get went a long way to limiting drought stress on crops.



Total Precipitation Departures (inches)

Figure 5. Maps show total precipitation departures from 1991-2020 normal in March, April, and May 2022.

A Good Fall for Harvest

Sometime around Labor Day we start to witness a change in desire from rain for the crop to dryness for the harvest. Of course, mother nature doesn't much care what we desire, but this year most of the fall season did bring good harvest weather. Both September and October were around 2 degrees warmer than normal, and November was just slightly warmer than normal. While Illinois did get its fair share of very cold conditions (it's fall, after all), the periods of extreme cold were sporadic and fleeting. Meanwhile, September and most of October were slightly to somewhat drier than normal, allowing for good harvest progress across the state. Additionally, the milder temperatures and drier weather before the last week of October was great for agritourism and specialty crop harvest. October had a very chilly and wet end, which postponed harvest in northern Illinois for a few days to a week. But a very dry November helped finish most harvest and fall field activity before Thanksgiving.

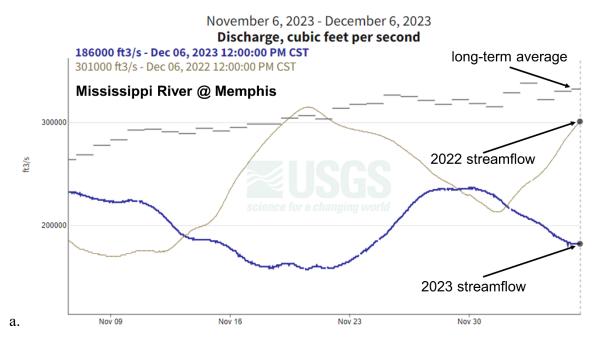
A Bad Fall for Drought

The good harvest weather this fall did not help our persistent drought conditions. It's important to distinguish agricultural drought from hydrological drought, especially in a year like 2023. Because of timely July and August rain, the commodity and specialty crop impacts from the 2023 drought were limited, relative to infamous droughts of record like 2012 and 1988. Late-planted or re-planted corn and beans this year generally did not do as well as their earlier planted counterparts because of less vigorous root growth ahead of the very dry weather in May and

June. But, in general we will not look back on 2023 with the same disposition as the most intense agricultural droughts in Illinois' history. While the timely July and August rain largely saved the 2023 crop, it did very little to assuage low stream, pond, and water table levels. These hydrological conditions were more affected by the state's nearly 10-inch water deficit accumulated between April and November this year.

Among the hydrological drought impacts was another harvest season with problematic low levels along the Mississippi River and reduction in barge traffic. The Mississippi River hit record low discharge for the second consecutive year, and current streamflow remains well below 2022 conditions (Figure 6a). More locally, the extended dryness penetrated below the rootzone and has affected water table levels across the state. The Water & Atmospheric Resources Monitoring program (WARM, <u>https://warm.isws.illinois.edu/warm/</u>) site at the SIU research farm near Belleville shows water table levels on December 1st were the deepest on record (going back to 2000) and were more than 10 feet deeper than average (Figure 6b).

The water table levels affect baseflow in streams, pond and lake levels, and generally slow the recovery from hydrological drought. The legacy effects of the 2023 and 2022 droughts take much longer to recover than topsoil moisture and are important conditions to monitors through the winter into spring 2024. Neither our existing dry soils nor the potential for a dry winter necessarily guarantee we will be dealing with drought conditions next spring or summer. But those drier conditions can hasten drought onset and impacts with poorly timed dry spells in the next growing season.



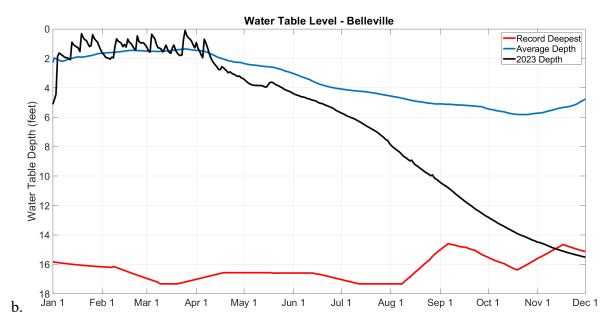


Figure 6. The top panel shows streamflow on the Mississippi River at Memphis this year compared with 2022 and the long-term average. The bottom panel shows water table levels at the WARM station in Belleville compared to the average depths and record depths.

2023 Illinois Statewide Insect Survey

Kelly Estes State Survey Coordinator, Illinois Cooperative Agriculture Pest Survey Program University of Illinois Illinois Natural History Survey

The Illinois Statewide Insect Survey has occurred in twelve of the last thirteen years (2011, 2013-2023). Methods of the survey have remained the same throughout the years, sampling in July and August each year, with the goal of estimating densities of common insect pests in corn and soybean cropping systems throughout the nine crop reporting districts in Illinois.

Within each crop reporting district 4-5 counties are surveyed, with 5 corn and 5 soybean fields sampled in each county. Within the soybean fields surveyed, 100 sweeps were performed on both the exterior of the field (outer 2 rows) and interior (at least 12 rows beyond the field edge) using a 38-cm (15-in) diameter sweep net. The insects collected in sweep samples were identified and counted to provide an estimate of the number of insects per 100 sweeps (Tables 1 and 2).

District	Bean Leaf Beetle	Grape Colaspis	Japanese Beetle	Northern CRW	Southern CRW	Western CRW	Grasshopper	Cloverworm/ Loopers	Stink Bugs	Dectes Stem Borer
Northwest	0.00	0.32	8.48	0.08	0.00	0.56	1.20	0.24	0.24	0.00
Northeast	0.20	0.00	11.30	0.20	0.00	0.60	1.30	0.20	0.20	0.00
West	0.24	0.64	13.64	0.96	0.16	0.16	3.16	0.32	0.16	0.00
Central	0.32	0.72	14.96	0.24	0.16	0.00	2.32	0.80	0.08	0.16
East	1.80	1.00	19.10	0.00	0.00	0.30	3.80	0.20	0.10	0.00
West Southwest	0.00	0.64	23.68	0.00	0.16	0.32	5.60	0.72	0.48	0.08
East Southeast	2.32	5.60	43.04	0.00	0.32	0.16	3.60	1.60	0.32	0.08
Southwest	1.40	5.50	13.50	0.00	0.20	0.00	1.30	0.80	0.30	2.10
Southeast	0.10	4.20	2.10	0.00	0.20	0.10	1.30	0.30	0.40	4.40
STATE AVE	0.71	2.07	16.64	0.16	0.13	0.24	2.62	0.58	0.25	0.76

Table 1. Average number of insects per 100 sweeps in the exterior of the field (2023).

District	Bean Leaf Beetle	Grape Colaspis	Japanese Beetle	Northern CRW	Southern CRW	Western CRW	Grasshopper	Cloverworm/ Loopers	Stink Bugs	Dectes Stem Borer
Northwest	0.08	0.24	11.2	0.08	0.00	0.32	0.88	0.24	0.40	0.00
Northeast	0.00	0.00	12.10	0.20	0.00	1.00	0.40	0.30	0.00	0.00
West	0.32	2.08	21.92	0.16	0.00	0.48	2.56	0.48	0.00	0.00
Central	0.16	0.24	7.52	0.48	0.16	0.24	1.84	1.36	0.88	0.16
East	1.80	0.30	13.38	0.00	0.20	0.10	2.08	0.90	0.60	0.00
West Southwest	0.08	0.88	19.84	0.00	0.40	0.60	3.32	0.40	0.24	0.00
East Southeast	2.16	3.92	20.40	0.08	0.08	0.40	3.60	1.68	0.40	0.00
Southwest	1.13	10.03	14.98	0.10	0.50	0.00	3.40	1.88	0.85	2.93
Southeast	0.50	2.20	5.20	0.00	0.30	0.00	2.40	0.20	0.10	5.30
STATE AVE	0.08	0.24	11.2	0.08	0.00	0.32	0.88	0.24	0.40	0.00

Table 2. Average number of insects per 100 sweeps in the interior of the field (2023).

Insect populations varied greatly by species and locations across the state in 2023 (Table 3). Variation also occurred between fields within counties. Fields are randomly selected in this survey and pest management strategies are unknown. Other factors such as climate and recent weather events may also impact insect populations.

Overall, bean leaf beetle, grape colaspis, and stink bug numbers remained low throughout the season. Despite recording low counts during the survey, grasshopper, green cloverworm and soybean looper numbers saw late season increases. Field reports in August and September indicated populations of green cloverworm and soybean looper were much high later in the growing season.

In 2023, Japanese beetle populations were moderate throughout much of the state at the time of the survey (Table 3). Though district averages may not have reflected high counts of Japanese beetles similar to the large numbers in 2017 and 2018, counties in both west-southwest and east south-east crop reporting districts, including Christian, Montgomery, Coles, Cumberland and Clark, reported some of the highest Japanese beetle densities. It is worth noting that Ford county also recorded high Japanese beetle counts as well (52 beetles per 100 sweeps).

District	2011	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Northwest	31.7	28.4	14.5	13.4	21.8	54.0	175.7	52.6	67.1	119.8	48.4	8.5
Northeast	13.0	13.8	18.3	12.9	1.3	31.8	36.5	23.3	7.3	20.2	39.3	11.3
West	9.5	5.0	2.1	17.5	89.4	133.6	151.7	26.3	21.9	37.4	07.6	13.6
Central	24.1	0.9	0.7	2.7	2.0	10.0	30.6	17.5	15.9	6.0	7.5	15.0
East	5.3	2.2	0.4	2.0	0.8	2.7	25.4	51.3	9.4	7.2	10.5	19.1
West Southwest	7.0	2.4	7.3	22.2	10.5	20.8	85.3	20.2	11.9	12.6	35.2	43.0
East Southeast	2.0	0.5	0.4	2.7	2.0	4.4	27.5	10.6	15.7	4.8	9.8	43.0
Southwest	2.7	0.4	0.2	2.1	12.0	0.0	12.0	3.9	2.7	3.4	2.1	13.5
Southeast	2.5	0.5	0.8	2.5	7.7	0.4	13.0	3.3	13.7	3.3	4.6	2.1
STATE AVE	25.4	6.0	5.0	8.7	16.4	28.3	47.8	19.6	18.4	23.9	29.4	16.6

Table 3. Average number of Japanese beetles per 100 sweeps, 2011-2023).

Dectes Stem Borer (Figure 1) continues to be well established in the southern third of Illinois. Wayne, Perry, Saline and Hamilton continue to have higher numbers of Dectes stem borer in sweeps compared to surrounding counties and the rest of the state. Results also varied from field to field and county to county, but it is evident that Dectes stem borer is well established in southern Illinois.

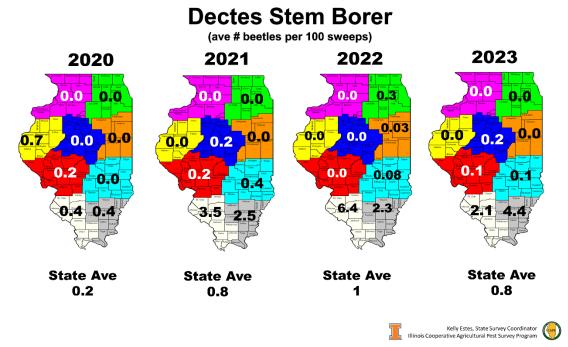


Figure 7. State maps with average number of Dectes Stem Borer in soybeans per 100 sweeps for each crop reporting district (2020-2022).

District	2020	2021	2022	2023
Northwest	0.0	0.0	0.0	0.0
Northeast	0.0	0.0	0.3	0.0
West	0.7	0.0	0.0	0.0
Central	0.0	0.2	0.0	0.2
East	0.0	0.0	0.03	0.0
West Southwest	0.2	0.2	0.0	0.1
East Southeast	0.0	0.4	0.08	0.1
Southwest	0.4	3.5	6.4	2.1
Southeast	0.4	2.5	2.3	4.4
STATE AVE	0.2	0.8	1.0	0.8

Table 4. Average number of Dectes stem borer in soybeans per 100 sweeps (2020-2023;duplicates Figure 1).

In addition to sweep samples in soybeans, cornfields were also sampled for western corn rootworm by counting the number of beetles on 20 consecutive plants beyond the end rows of a given field. A beetle per plant average was then calculated for each field. Like recent years, western corn rootworm beetle populations remained low in several areas of the state, but higher numbers were observed in northwest Illinois (Table 6). Carroll, Lee and Whiteside counties reported higher numbers of western corn rootworm beetles in per-plant counts in northwest Illinois, along with Dekalb in the northeast. Warren county in the west recorded an average of 0.75 beetles per plant.

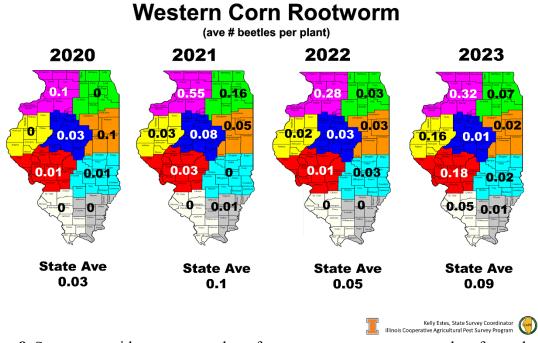


Figure 8. State maps with average number of western corn rootworm per plant for each crop reporting district (2020-2022).

District	2020	2021	2022	2023
Northwest	0.0	0.0	0.0	0.0
Northeast	0.0	0.0	0.3	0.0
West	0.7	0.0	0.0	0.0
Central	0.0	0.2	0.0	0.2
East	0.0	0.0	0.03	0.0
West Southwest	0.2	0.2	0.0	0.1
East Southeast	0.0	0.4	0.08	0.1
Southwest	0.4	3.5	6.4	2.1
Southeast	0.4	2.5	2.3	4.4
STATE AVE	0.2	0.8	1.0	0.8

Table 5. Average number of western corn rootworm beetles per plant in corn (2020-2023;duplicates Figure 2).

District	2011	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Northwest	0.26	0.33	0.05	0.02	0.02	0.10	0.04	0.08	0.13	0.55	0.28	0.32
Northeast	0.15	0.20	0.02	0.00	0.02	1.95	0.35	0.00	0.00	0.16	0.03	0.07
West	0.01	0.10	0.01	0.01	0.00	0.75	0.00	0.00	0.00	0.03	0.02	0.16
Central	0.35	0.37	0.74	0.02	0.05	0.30	0.12	0.12	0.03	0.08	0.03	0.01
East	0.31	0.81	0.51	0.01	0.01	0.40	0.02	0.12	0.05	0.05	0.03	0.02
West Southwest	0.01	0.20	0.06	0.00	0.01	0.70	0.35	0.52	0.01	0.03	0.01	0.18
East Southeast	0.02	0.01	0.00	0.00	0.00	0.00	0.03	0.05	0.01	0.00	0.03	0.02
Southwest	0.00	0.00	0.00	0.01	0.01	0.15	0.00	0.00	0.00	0.00	0.00	0.05
Southeast	0.00	0.03	0.01	0.00	0.02	0.20	0.03	0.00	0.00	0.01	0.00	0.01
STATE AVE	0.12	0.23	0.16	0.01	0.01	0.51	0.11	0.01	0.03	0.10	0.05	0.09

Table 6. Mean number of western corn rootworm beetles per plant in corn by crop reporting district and year (2011-2023).

Funding for survey activities was provided by the USDA National Institute of Food and Agriculture. This survey would not be possible without the hard work and contributions of many people, including Cooperative Agriculture Pest Survey Program interns.

Soybean Gall Midge Survey - Illinois 2023

N. J. Seiter and K. A. Estes

Objective: inspect soybean fields throughout Illinois to facilitate early detection of the soybean gall midge, *Resseliella maxima*, a new pest of soybean that has not been found in Illinois

Outcome: We inspected 312 soybean fields in 59 counties and found no evidence of soybean gall midge in Illinois.

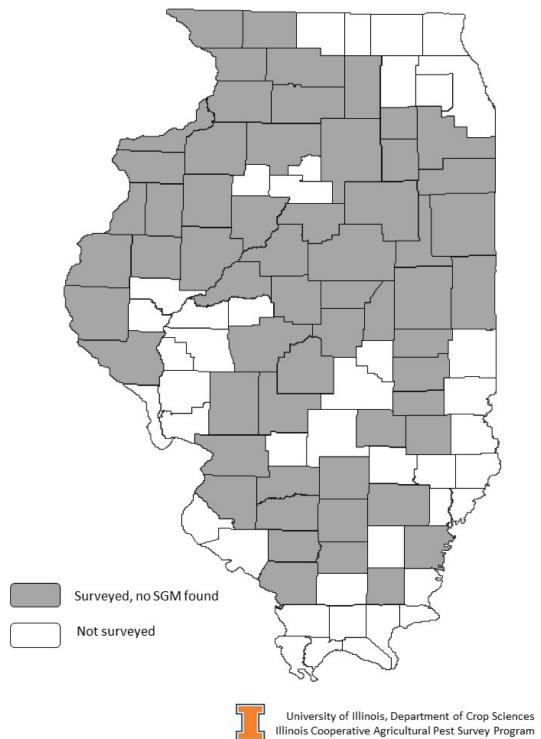
Survey methods: Our survey efforts were conducted in two phases. The majority (276) of fields we examined for soybean gall midge were sampled as part of the Illinois Statewide Insect Survey; plants were assessed along the edge of every soybean field every 60-100 feet for signs of soybean gall midge infestation (dead/wilting plants and discolored stems). We conducted an additional survey of 36 fields in 9 counties (Hancock, Henderson, Mercer, Rock Island, Henry, Whiteside, Carroll, Stephenson, and Jo Daviess) along the northwestern border of Illinois with Missouri, Iowa, and Wisconsin. (This transect was chosen due to the relative proximity to areas in Iowa where soybean gall midge is known to occur; the closest positive report of this insect in Iowa was approximately 100 miles from the Illinois border. Areas with economically damaging populations of soybean gall midge are still further west). Fields were selected approximately every 5-10 miles in a transect along the state border that had rotation patterns that placed them at elevated risk of soybean gall midge infestation (adjacent soybean fields and dense uncultivated vegetation in near proximity). (Note: whenever possible, these were soybean fields that were adjacent to the soybean fields we sampled for gall midge in 2022 as part of the same survey). Fields in this survey were examined for signs of gall midge infestation for a timed period of 5 minutes per field along the field edge adjacent to soybean grown the previous year (the most likely location to observe initial soybean gall midge activity). The epidermis of the stem was removed from areas showing potential signs of infestation to look for larvae. No soybean gall midge larvae were found during either survey.

Acknowledgements: We thank Dr. Justin McMechan (University of Nebraska) for coordinating survey efforts and developing the monitoring protocol we used.

Funding: Funding for this survey was provided by the Illinois Soybean Association and the North Central Soybean Research Program.

For continuously updated information on where soybean gall midge has been found in the U.S. and how to manage it, visit <u>www.soybeangallmidge.org</u>

2023 Soybean Gall Midge Field Survey



CAPS

Figure 9. Map showing Illinois counties which were sampled for soybean gall midge. This insect has not been found in Illinois.

2023 University of Illinois Plant Clinic Agronomic Sample Summary

Diane Plewa, Alison Colgrove, Esneider Mahecha University of Illinois Plant Clinic

The University of Illinois Plant Clinic received 2,564 samples in 2023. These samples include field crop, nursery, and ornamental plant samples, along with Amaranth weeds submitted for herbicide resistance screening, seed lots submitted to test for the presence of Palmer amaranth, soil samples submitted for vermiform nematode identification and SCN egg counts and typing, and seed screening to test for SCN resistance. Plant Clinic staff use a combination of traditional laboratory methods including incubation, culturing, microscopy, and bioassays, and newer techniques such as serological and molecular assays for diagnosis and identification.

2,255 field crop samples were received, comprising approximately 87.9% of all samples in 2023. These samples consisted of plant samples submitted for pest and pathogen identification, soil samples submitted for nematode identification and enumeration, Amaranth weed samples submitted for herbicide resistance testing, and seed lots submitted to test for the presence of Palmer amaranth. 1,263 soil samples for nematode testing and 952 plant samples for pest and pathogen diagnosis were received. Of those 952 plant samples, 409 were corn, 406 were soybean, 131 were industrial hemp, and 6 were wheat. These samples included field crop samples submitted by farmers, crop consultants, and researchers, and samples processed for phytosanitary certification. Most of the corn, soybean, and wheat samples originated from within Illinois while many of the hemp samples came from other states in the Midwest as part of a regional research project. Overall, disease incidence was lower compared to previous years probably due to the dry conditions experienced by much of the state during the growing season. Many diseases are favored by moderate, humid conditions and we tend to see reduced impact in hot, dry weather. We saw an increased number of samples (both agronomic and horticultural) with symptoms consistent with plant growth regulator herbicide damage. This could be due to environmental conditions favoring off-target movement during applications, and growers being more familiar with the symptoms and choosing those plants to submit as samples.

The most common corn diseases diagnosed were Gray Leaf Spot (32% of corn samples were infected with this disease), Common Smut (23%), Northern Corn Leaf Blight (15%), Physoderma Brown Spot (14%), and Yellow Leaf Blight (14%). Due to the hot, dry weather which resulted in droughts across parts of the state, diseases in general were reduced compared to last year. Both Southern Rust and Corn Tar Spot were rare this year, though more prevalent than last year. 25 samples of Corn Tar Spot were confirmed from Adams, Cass, Champaign, DeKalb, Grundy, Henry, Lawrence, Mason, Montgomery, Schuyler, Tazewell, and Wayne counties. Of the corn vermiform soil samples submitted, Spiral nematodes were the most frequently detected (81% of samples submitted), followed by Lesion (77%), followed by Lance (46%), Dagger (34%) and Stunt (27%).

For soybean samples, the most common diseases diagnosed were Soybean Vein Necrosis Virus (39%), Downy Mildew (38%), Purple Seed Stain and Leaf Blight (20%), Phytophthora (20%),

and Sudden Death Syndrome (14%). Red Crown Rot, a fairly new disease described in Illinois, was confirmed on 8 samples from Bond, Champaign, Coles, Marion, Monroe, Montgomery, and Piatt counties. Soybean Rust was not diagnosed on any of the soybean samples submitted to the Plant Clinic. We continue to see moderate to high numbers of SCN eggs found in fields across the state sufficient to cause yield loss. Yield loss is usually most severe on lighter, sandy soils, but drastic losses have been observed even in the heavy clay-loam soils typical of much of the soybean acreage in Illinois. SCN Type 2 is the most common in Illinois, though Type 1 is increasing in prevalence, continuing the trend seen in previous years.

The hemp (*Cannabis sativa*) samples submitted are part of a research grant investigating seed and fiber hemp production in the Midwest. Samples submitted ranged from seedlings to fully mature plants, along with soil samples for nematode testing. These samples were collected from research stations, growers' farms, and commercial companies spanning Indiana, Michigan, Wisconsin, and Illinois. At the end of the season, the pathogens *Botrytis* spp. and *Fusarium* spp. were the most prevalent causing Botrytis and Fusarium bud rots. Additionally, fungal stem pathogens such as *Macrophomina phaseolina* and *Sclerotinia sclerotiorum*, causal agents of charcoal rot and white mold, were identified. Among the soil samples, lesion and spiral nematodes were consistently detected. Both of these are common pathogens in Midwest corn cultivation. This investigation into prevalent diseases in Midwest hemp crops marks an initial step in determining the frequency of these pathogens and their potential impact on seed and fiber yields. Data from this project will be published in next year's Annual Applied Research Report.

This year, samples submitted for agronomic nematode analysis consisted of soil samples for soybean cyst nematode (SCN) egg counts, vermiform nematode analysis, and HG Type and SCN Type testing. One new project is a partnership with the Illinois Soybean Association (ISA) to provide Illinois soybean producers with SCN Egg Count analysis on their soil samples at no charge to them. Producers can contact freeSCNtesting@illinois.edu to receive a kit with sampling instructions and information to receive free shipping for sending the samples to the Plant Clinic. Close to 1000 samples have already been received since the project began in October 2023 and will run through August 2024. SCN egg counts (measured as the number of eggs per 100 cubic centimeters of soil) provide a snapshot of the status of SCN in a field and can help inform the producer's management plan. A low count indicates that the management plan is successfully incorporating best practices for SCN management, which should include rotation with a non-host (including corn or wheat), use of SCN resistant soybean varieties, as well as monitoring their SCN egg count. Because SCN is known to be prevalent in Illinois soybean fields and to cause significant yield losses especially at high levels, it is important for Illinois soybean farmers to test their fields to determine if they have a problem with SCN in their soybean fields and if their management plan should be re-evaluated. If SCN egg counts ae found to be moderate to high, the next step would be to perform the SCN Type Test (which involves a greenhouse bioassay with resistant soybeans and a susceptible check) to test the nematodes from the soil sample to measure the degree of virulence of the field population of SCN on the resistant lines and determine which type of resistant soybean would be effective against that field population.

Besides providing important assistance to Illinois farmers, this project provides the Illinois Soybean Association, the Plant Clinic, soybean researchers, and seed companies with a valuable survey of the status of SCN in Illinois. Data from this survey will be published in next year's Annual Applied Research Report.

For more information about the University of Illinois Plant Clinic, please see our website at <u>https://go.illinois.edu/plantclinic</u>.

Evaluations of insecticides and Bt hybrids for control of corn rootworm in Illinois, 2023

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Materials and Methods: Field experiments were established using randomized complete block designs, with 4 replicate blocks per experiment. The previous crop was a "trap crop" for corn rootworm beetles, which consisted of late-planted, non-Bt corn (seeding rate 22,000 seeds per acre) inter-seeded with a mixture of sugar pumpkins, jack-o-lantern pumpkins, and buttercup squash (seeding rate 2 lbs. per acre). Treatments (4-8 per experiment) were different control tactics applied at planting, including in-furrow liquid and granular insecticides, insecticide seed treatments, and corn hybrids expressing different combinations of biotech traits for insect control (i.e., Bt proteins or double-stranded RNA). The experimental units were plots of corn that varied in size, seeding rate, and other agronomic characteristics (see "Plot information" table for each experiment). Stand was evaluated at least once during the early vegetative stages from two or more 17.5 row-ft sections per plot. Larval corn rootworm damage was rated in each plot near silking (growth stage R1) by digging 5 root masses per plot from non-harvest rows, removing all soil using an electric high-pressure water sprayer, and rating damage using the 0-3 Node-injury scale (Oleson et al. 2005, J. Econ. Entomol. 98: 1-8. https://doi.org/10.1093/jee/98.1.1). Percent root lodging (i.e., "goose-necking") was estimated at maturity (R6). Yields were assessed by harvesting the center 2 rows using one of two small-plot combines (Massey Ferguson 8XP, Kincaid Equipment, Haven, KS) with built-in weight and moisture monitors (HarvestMaster, Logan, UT).

Data Analysis. Percent consistency of root ratings for each plot was set equal to the percentage of roots that were assigned a node-injury rating of less than 0.25 (i.e. less than 25% of one node pruned by corn rootworm larval injury). Weights per plot were corrected to 15.5% moisture, then converted to bushels per acre using the standard bushel weight of 56 pounds. Consistency and lodging were analyzed as proportions but are reported as percentages. All dependent variables for each experiment were analyzed separately using a generalized linear mixed model (PROC GLIMMIX, SAS Version 9.4, SAS Institute, Cary, NC) where treatment was considered a fixed effect and replicate block was considered a random effect. The probability distribution used in the analysis is provided in a table for each individual experiment.

Acknowledgements: We thank Tim Lecher and Lane Simpson (Agricultural and Biological Engineering Farm, Urbana, IL) and Greg Steckel and Marty Johnson (Northwest Illinois Agricultural Research and Demonstration Center, Monmouth, IL) for assisting with planting, plot maintenance, and harvest. We thank graduate students Yony Callohuari Quispe, Sagnika Das, and Will Foulke, research assistants Grayce Montano and China Carr, and undergraduate students Fay Siringoringo and Solomon Davenport for assisting with plot maintenance and data collection. In addition, we thank Dr. Joseph Spencer (Illinois Natural History Survey) and his undergraduate research assistants for their help with root damage assessments.

Funding: See note on individual trials

A. Evaluation of CRW Trait Hybrids With or Without a Soil Insecticide at Two Locations

Location 1: University of Illinois Agricultural and Biological Engineering Farm, Urbana, IL (40.067924, -88.210471)

Location 2: University of Illinois Northwestern Illinois Agricultural Research and Demonstration Center, Monmouth, IL (40.933535, -90.725389)

Objective: To compare the performance of pyramided Bt traits and an RNA-interference trait with or without a soil insecticide for control of corn rootworm (western corn rootworm, *Diabrotica virgifera virgifera* and northern corn rootworm, *Diabrotica barberi*) larval damage. The corn rootworm population at Urbana was almost exclusively western corn rootworm, while Monmouth had a mix of western (majority) and northern corn rootworm.

Summary:

<u>Urbana</u>: Node injury ratings for all CRW trait packages tested were reduced when a soil insecticide was applied. Only SmartStax PRO resulted in node injury ratings that were reduced compared with the non-CRW trait control (VT Double Pro). These results are indicative of high levels of resistance to both Cry3Bb1 and Cry34/35Ab1, which has previously been identified at this site. Yields were poor and compromised by drought stress at this location, but generally reflected differences in corn rootworm injury.

<u>Monmouth</u>: While root pruning injury was low, reductions in root pruning were observed when a soil insecticide was applied for all trait packages tested except SmartStax. All trait packages tested other than Duracade resulted in reduced root injury scores compared with the non-CRW trait control when no insecticide was applied. Reductions in stand were apparently related to variety rather than insect damage, and were not reflected by corresponding differences in yields (which were similar among all treatments).

Funding: Pesticide materials were provided by Syngenta; seed was provided by Bayer CropScience and Syngenta.

Seed coatings	DKC 111-35 ^a Clothianidin (0.50mg ai/seed) [Acceleron FALEH2Q]
_	DKC 61-40 ^a Clothianidin (0.50mg ai/seed) [Acceleron FALH2VQ]
	DKC 111-33 Clothianidin (0.50mg ai/seed) [Acceleron FALEH2VQ]
	G10L16-5222A-EZ ^b Thiamethoxam 0.5 mg/seed (Avicta Complete
	500 + Vibrance)
Previous crop	Trap crop: late-planted, non-Bt field corn inter-seeded with
	pumpkins
Soil type	Urbana: Drummer silt loam
	Monmouth: Muscatune silt loam
Tillage	Conventional
Row spacing	30 inches
Seeding Rate	Urbana: 35,000 seeds per acre; Monmouth: 36,000 seeds per acre
Soil insecticide	Trts. 2, 4, 6, 8: Liquid in-furrow, 5 gal/acre application volume,
application	water is carrier. Material was Force Evo ^c (tefluthrin, 2.1 lb a.i. per
	gallon, emulsifiable concentrate)
Planting date	Urbana: 11 May 2023; Monmouth: 18 May 2023
Emergence date	Urbana: 17 May 2023; Monmouth: not observed
Herbicide program	Pre-emerge: 32% UAN (0.28 T/ac), Harness Xtra ^a (0.5 gal/ac)
(Urbana)	Post-emerge: Roundup PowerMAX ^a (32 oz/ac), Warrant ^a (2 qt/ac)
Herbicide program	Pre-emerge: Corvus ^a (5.5 oz/a)
(Monmouth)	Post-emerge: Roundup PowerMAX ^a (16 oz/ac) + Armezon Pro ^d (16
	oz/a)
Plot size	Urbana: 4 rows (10 ft) wide by 30 ft long, 5 ft unplanted alleys
	Monmouth: 4 rows (10 ft) wide by 50 ft long, 5 ft unplanted alleys

Table A-1. Plot information

^a Bayer CropScience, St. Louis, MO; ^b Golden Harvest Seeds, Syngenta, Minnetonka, MN; ^c Syngenta Crop Protection, Greensboro, NC; ^d BASF Corporation, Research Triangle Park, NC

Table A-2.	Corn	rootworm	treatments
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Trt	Soil Insecticide	Seed Variety	CRW Trait
1	VT Double Pro	DKC 111-35 ^a	None
2	VT Double Pro	DKC 111-35	None
	+ Force Evo ^b (8 fl oz/a)		
3	SmartStax	DKC 61-40 ^a	Cry3Bb1 + Cry34/35Ab1
4	SmartStax	DKC 61-40	Cry3Bb1 + Cry34/35Ab1
	+ Force Evo (8 fl oz/a)		
5	SmartStax Pro	DKC 111-33 ^a	Cry3Bb1 + Cry34/35Ab1 + DvSnf7
6	SmartStax Pro	DKC 111-33	Cry3Bb1 + Cry34/35Ab1 + DvSnf7
	+ Force Evo (8 fl oz/a)		
7	Duracade	G10L16-5222A-EZ °	mCry3A + eCry3.1Ab
8	Duracade	G10L16-5222A-EZ	mCry3A + eCry3.1Ab
	+ Force Evo (8 fl oz/a)		

^a Dekalb, Bayer Crop Science, St. Louis, MO; ^b 2.1 lb tefluthrin per gallon emulsifiable concentrate, Syngenta Crop Protection, Greensboro, NC; ^c Golden Harvest Seeds, Syngenta, Minnetonka, MN

Table A-3. Generalized linear mixed model statistics for field experiment conducted at Urbana, IL. Each analysis had 28 total degrees of freedom (Treatment = 7 df, Error = 21 df). Probability distribution is indicated in parentheses.

Dependent Variable	Date	F	Р
Plant stand (lognormal)	22 May	1.21	0.336
	30 May	1.03	0.442
	8 June	1.19	0.348
Root injury rating (gamma)	21 July	22.69	$< 0.001^{a}$
Proportion consistency (normal)	21 July	12.46	$< 0.001^{a}$
Proportion gooseneck lodging (normal)	23 Oct.	b	
Yield (lognormal)	24 Oct.	13.03	$< 0.001^{a}$

^a Effect is significant at $\alpha = 0.05$

Table A-4. Generalized linear mixed model statistics for field experiment conducted at Monmouth, IL. Each analysis had 28 total degrees of freedom (Treatment = 7 df, Error = 21 df). Probability distribution is indicated in parentheses.

Dependent Variable	Date	F	Р
Plant stand (lognormal)	22 June	8.74	< 0.001 ^a
Root injury rating (gamma)	24 July	21.45	$< 0.001^{a}$
Proportion consistency (normal)	24 July	10.13	$< 0.001^{a}$
Proportion gooseneck lodging (normal)	12 Oct.	0.60	0.746
Yield (lognormal)	20 Oct.	2.22	0.074

^a Effect is significant at $\alpha = 0.05$; ^b Analysis not performed (all data = 0)

Table A-5. Response variables for the field experiment located at **Urbana**. Mean (\pm Standard error [SE]) stand in number of plants per 17.5 ft. of row, node-injury rating (0-3 scale) of corn rootworm larval feeding injury, percent consistency (percentage of roots with a node-injury rating of less than 0.25), percent "gooseneck" (root) lodging, and yield in bushels per acre corrected to 15.5% moisture.

			Node-injury Percent		Percent	
		Stand (V3)	rating (R1)	consistency (R1)	lodging (R6)	Yield
Trt	Treatment	8 June 2023	21 July 2023	21 July 2023	23 Oct. 2023	24 Oct. 2023
1	VT Double Pro	$37.3\pm0.7\ a^a$	$0.81 \pm 0.13 \text{ ab}$	$20 \pm 8 \text{ cd}$	0 ± 0 a	$107 \pm 10 \text{ de}$
2	VT Double Pro	$37.4 \pm 0.5 \text{ a}$	$0.48\pm0.11~bc$	45 ± 13 bc	0 ± 0 a	$117 \pm 15 \text{ cd}$
	+ Force Evo (8 fl oz/a)					
3	SmartStax	35.0 ± 0.8 a	0.69 ± 0.13 ab	30 ± 10 bcd	0 ± 0 a	111 ± 8 d
4	SmartStax	$37.3 \pm 0.6 \text{ a}$	$0.10\pm0.03\ d$	90 ± 6 a	0 ± 0 a	$134 \pm 4 bc$
	+ Force Evo (8 fl oz/a)					
5	SmartStax Pro	$34.8\pm0.9\ a$	$0.30\pm0.07~c$	55 ± 13 b	0 ± 0 a	$152 \pm 9 \text{ ab}$
6	SmartStax Pro	36.1 ± 0.7 a	$0.07\pm0.04\ d$	$95\pm5~a$	0 ± 0 a	159 ± 7 a
	+ Force Evo (8 fl oz/a)					
7	Duracade	36.8 ± 0.8 a	1.25 ± 0.17 a	$5 \pm 5 d$	0 ± 0 a	$94 \pm 12 \text{ e}$
8	Duracade	36.3 ± 1.0 a	$0.33\pm0.07~\text{c}$	55 ± 15 b	0 ± 0 a	$112 \pm 7 d$
	+ Force Evo (8 fl oz/a)					

^a Means followed by the same letter within a column are not different based on the Fisher method of least significant difference ($\alpha = 0.05$)

Table A-6. Response variables for the field experiment located at **Monmouth**. Mean (\pm Standard error [SE]) stand in number of plants per 17.5 ft. of row, node-injury rating (0-3 scale) of corn rootworm larval feeding injury, percent consistency (percentage of roots with a node-injury rating of less than 0.25), percent "gooseneck" (root) lodging, and yield in bushels per acre corrected to 15.5% moisture.

		Stand (V7)	Node-injury rating (R1)	Percent consistency (R1)	Percent lodging (R6)	Yield
Trt	Treatment	22 June 2023	24 July 2023	24 July 2023	12 Oct. 2023	20 Oct. 2023
1	VT Double Pro	$35.6\pm0.3\ ab^a$	0.31 ± 0.04 a	$45\pm15~b$	0.3 ± 0.3 a	271 ± 8 a
2	VT Double Pro					
	+ Force Evo (8 fl oz/a)	$36.3\pm0.3~a$	0.12 ± 0.05 bc	90 ± 10 a	0.0 ± 0.0 a	277 ± 9 a
3	SmartStax	$36.0 \pm 0.7 \text{ a}$	$0.09\pm0.03~bc$	95 ± 5 a	$0.3 \pm 0.3 \; a$	270 ± 4 a
4	SmartStax					
	+ Force Evo (8 fl oz/a)	$36.0\pm0.6\;a$	$0.07\pm0.02~\mathrm{c}$	$95\pm5~a$	$0.8\pm0.8~\mathrm{a}$	286 ± 16 a
5	SmartStax Pro	$36.9 \pm 0.5 a$	$0.08\pm0.02~bc$	90 ± 6 a	0.0 ± 0.0 a	293 ± 11 a
6	SmartStax Pro					
	+ Force Evo (8 fl oz/a)	$36.5 \pm 0.3 \text{ a}$	$0.01\pm0.01~d$	100 ± 0 a	0.3 ± 0.3 a	291 ± 3 a
7	Duracade	$34.3\pm0.6\ b$	0.54 ± 0.08 a	25 ± 10 b	$0.3 \pm 0.3 \; a$	253 ± 11 a
8	Duracade					
	+ Force Evo (8 fl oz/a)	$32.3\pm0.4\ c$	$0.14\pm0.03\ b$	75 ± 10 a	0.0 ± 0.0 a	267 ± 7 a

^a Means followed by the same letter within a column are not different based on the Fisher method of least significant difference ($\alpha = 0.05$)

B. Evaluation of In-furrow soil-applied insecticides with untreated corn seed

Location: University of Illinois Agricultural and Biological Engineering Farm, Urbana, IL (40.067954, -88.210675)

Objective: To compare the performance of common soil insecticides used for control of corn rootworm (particularly western corn rootworm, *Diabrotica virgifera virgifera*) larval damage when used in combination with seed that lacked an insecticide seed treatment.

Summary: All insecticides we tested resulted in reduced node-injury ratings compared with the untreated plots; Force Evo and Aztec HC resulted in lower node-injury ratings than Ethos XB. While yields were poor in this experiment due to the combination of drought stress and corn rootworm feeding injury, all insecticide treatments resulted in yields that were higher than in the untreated plots.

Funding: Pesticide materials for this trial were provided by AMVAC Chemical Corporation, FMC Corporation, and Syngenta Crop Protection; seed was provided by Bayer Crop Science.

Variety	G07G63-AA ^a Agrisure Above (no CRW traits)
Seed coatings	Fungicide-only (Vayantis plus Vibrance Cinco ^b)
Previous crop	Trap crop: late-planted, non-Bt field corn inter-seeded with pumpkins
Soil type	Drummer silty clay loam
Tillage	Conventional
Row spacing	30 inches
Seeding Rate	35,000 seeds per acre
Soil insecticide	Trts. 2-3 Liquid in-furrow, 5 gal/acre application volume, carrier is water
application	Trt 4 Granular in-furrow, SmartBox ^c research-scale granular applicator
Planting date	May 11 2023
Emergence date	May 17 2023
Herbicide	Pre-emerge: 32% UAN (0.28 T/ac), Harness Xtra ^d (0.5 gal/ac)
	Post-emerge: Roundup PowerMAX ^d (32 oz/ac), Warrant ^d (2 qt/ac)
Plot size	4 rows (10 ft) wide by 30 ft long, 5 ft unplanted alleys
A California II and Cal	de Samaante Minnetenber MOL & Samaante Crean Protection Creanshane

Table B-1. Plot information

^a Golden Harvest Seeds, Syngenta, Minnetonka, MN; ^b Syngenta Crop Protection, Greensboro, NC; ^c AMVAC Chemical Corporation, Newport Beach, CA; ^d Bayer CropScience, St. Louis, MO

 Table B-2. Corn rootworm treatments

Trt	Soil Insecticide	Active Ingredient				
1	None					
2	Ethos XB ^a (10 fl oz/a)	Bifenthrin, 1.5 lb AI per gallon + <i>Bacillus</i> <i>amyloliquefaciens</i> strain D747 1×10^{10} colony- forming units per ml, suspension concentrate				
3	Force Evo ^b (8 fl oz/a)	Tefluthrin, 2.1 lb AI per gallon, emulsifiable concentrate				
4	Aztec HC ^c (1.5 oz wt/1000 row-ft)	8.9% tebupirimphos + 0.44% cyfluthrin, high concentration granules				
^a FMC Corporation Dhiladalphia DA: ^b Synganta Crap Protection Grapshara NC: ^c AMVAC						

^a FMC Corporation, Philadelphia, PA; ^b Syngenta Crop Protection, Greensboro, NC; ^c AMVAC Chemical Corporation, Los Angeles

Table B-3. Generalized linear mixed model statistics. Each analysis had 13 total degrees of freedom (Treatment = 3 df, Error = 10 df). Probability distribution is indicated in parentheses.

Date	F	Р
22 May	0.41	0.725
30 May	0.12	0.948
21 July	72.20	$< 0.001^{a}$
21 July	11.50	0.002^{a}
23 Oct.	b	
24 Oct.	11.04	0.002^{a}
	22 May 30 May 21 July 21 July 23 Oct.	22 May 0.41 30 May 0.12 21 July 72.20 21 July 11.50 23 Oct. b

^a Effect is significant at $\alpha = 0.05$; ^b Analysis not performed (all data = 0)

Table B-4. Mean (\pm Standard error [SE]) stand in number of plants per 17.5 ft. of row, node-injury rating (0-3 scale) of corn rootworm larval feeding injury, percent consistency (percentage of roots with a node-injury rating of less than 0.25), percent "gooseneck" (root) lodging, and yield in bushels per acre corrected to 15.5% moisture.

						Percent	
				Node-injury	Percent	gooseneck	
		Stand (V2)	Stand (V3)	rating (R1)	consistency (R1)	lodging (R6)	Yield
Trt	Treatment	22 May 2023	30 May 2023	21 July 2023	21 July 2023	23 Oct. 2023	24 Oct. 2023
1	None	$38.6\pm1.2~a^a$	$37.4\pm0.9\;a$	2.24 ± 0.11 a	0 ± 0 c	0 ± 0 a	52 ± 15 b
2	Ethos XB (10 fl oz/a)	$37.4 \pm 1.1 \text{ a}$	$37.5 \pm 1.1 \text{ a}$	$1.18\pm0.14\ b$	10 ± 6 bc	0 ± 0 a	$86 \pm 9 a$
3	Force Evo (8 fl oz/a)	$37.1\pm0.8\;a$	38.1 ± 1.2 a	$0.50\pm0.06\;c$	$25\pm10\ b$	0 ± 0 a	103 ± 10 a
4	Aztec HC (1.5 oz						
	wt/1000 row-ft)	$38.0 \pm 1.0 \text{ a}$	$37.6 \pm 1.0 \text{ a}$	$0.40\pm0.08\ c$	45 ± 10 a	0 ± 0 a	94 ± 12 a
	wt/100010w-1t)				$+3 \pm 10 a$		J = 12 a

^a Means followed by the same letter within a column are not different based on the Fisher method of least significant difference ($\alpha = 0.05$)

C. Evaluation of corn rootworm trait packages including VT4 PRO, 2023

Location: University of Illinois Agricultural and Biological Engineering Farm, Urbana, IL (40.068879, -88.210288)

Objective: To assess the performance of four biotech trait packages for control of corn rootworm (particularly western corn rootworm, *Diabrotica virgifera virgifera*) larval damage.

Summary: Both hybrids of SmartStax PRO and VT4PRO resulted in reduced node-injury ratings compared with both non-CRW Bt VT Double Pro hybrids. The two SmartStax hybrids had reduced node-injury ratings compared with one of the two VT Double Pro hybrids. Stand varied by treatment, though it was not consistent by trait package and might have been an agronomic effect of the hybrids or due to differences in seed weight during planting. Yields were generally reduced in the VT Double Pro hybrids compared with the other trait packages, though variability was high, and yields were poor overall due to drought stress at the site of the experiment.

Funding: Project funding, seed, and pesticide materials for this trial were provided by Bayer CropScience.

Seed coatings	Unknown (supplied by Bayer)		
Previous crop	Trap crop: late-planted, non-Bt field corn inter-seeded with		
	pumpkins		
Soil type	Drummer silty clay loam/Elburn silt loam		
Tillage	Conventional		
Row spacing	30 inches		
Seeding Rate	35,000 seeds per acre		
Planting date	May 4 2023		
Emergence date	May 11 2023		
Herbicide	Pre-emerge: 32% UAN (0.28 T/ac), Harness Xtra ^a (0.5 gal/ac)		
	Post-emerge: Roundup PowerMAX ^a (32 oz/ac), Warrant ^a (2 qt/ac)		
Plot size	4 rows (10 ft) wide by 30 ft long, 5 ft unplanted alleys		

Table C-1. Plot information

^a Bayer CropScience, St. Louis, MO

Table C-2	Corn	rootworm	treatments
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Treatment	CRW Traits
VT Double Pro Hybrid 1	None
SmartStax Hybrid 1	Cry3Bb1 + Cry34/35Ab1
SmartStax PRO Hybrid 1	Cry3Bb1 + Cry34/35Ab1 + DvSnf7 dsRNA
VT4PRO Hybrid 1	
VT Double Pro Hybrid 2	None
SmartStax Hybrid 2	Cry3Bb1 + Cry34/35Ab1
SmartStax PRO Hybrid 2	Cry3Bb1 + Cry34/35Ab1 + DvSnf7 dsRNA
VT4PRO Hybrid 2	
	VT Double Pro Hybrid 1 SmartStax Hybrid 1 SmartStax PRO Hybrid 1 VT4PRO Hybrid 1 VT Double Pro Hybrid 2 SmartStax Hybrid 2 SmartStax PRO Hybrid 2

^a Seed provided by Bayer CropScience, St. Louis, MO

Table C- 3. Generalized linear mixed model statistics. Each analysis had 28 total degrees of freedom (Treatment = 7 df, Error = 21 df). Probability distribution is indicated in parentheses.

Dependent Variable	Date	F	Р
Plant stand (lognormal)	17 May	10.06	$< 0.001^{a}$
	22 May	10.66	$< 0.001^{a}$
	30 May	10.91	$< 0.001^{a}$
Root injury rating (gamma)	13 July	3.51	0.012 ^a
Proportion consistency (normal)	13 July	1.73	0.156
Proportion lodging (normal)	20 Oct.	1.57	0.198
Yield (lognormal)	23 Oct.	5.31	0.001^{a}

^a Effect is significant at $\alpha = 0.05$

Table C- 4. Mean (\pm Standard error [SE]) stand in number of plants per 17.5 ft. of row, node-injury rating (0-3 scale) of corn rootworm larval feeding injury, percent consistency (percentage of roots with a node-injury rating of less than 0.25), percent "gooseneck" (root) lodging, and yield in bushels per acre corrected to 15.5% moisture.

					Node-injury	Percent consistency	Percent	
Trt	Treatment	Stand (V2) 17 May 2023	Stand (V3) 22 May 2023	Stand (V5) 30 May 2023	rating (R1) 13 July 2023	(R1) 13 July 2023	lodging (R6) 20 Oct. 2023	Yield 23 Oct. 2023
1	VT Double							
	Pro Hybrid 1	$33.3\pm0.4~b$	33.6 ± 0.3 b	34.0 ± 0.5 c	$1.13 \pm 0.08 \text{ ab}$	5 ± 3 a	3 ± 1 a	88 ± 11 b
2	SmartStax							
	Hybrid 1	$34.9 \pm 0.4 \text{ ab}$	35.3 ± 0.4 ab	36.0 ± 0.5 a	$0.64\pm0.08~\mathrm{bc}$	28 ± 9 a	1 ± 1 a	123 ± 10 a
3	SmartStax							
	PRO Hybrid 1	35.8 ± 0.3 a	35.0 ± 0.3 ab	36.4 ± 0.3 a	$0.42\pm0.06~\mathrm{c}$	40 ± 16 a	3 ± 2 a	123 ± 10 a
4	VT4PRO							
	Hybrid 1	30.4 ± 0.5 c	30.3 ± 0.8 c	$30.6 \pm 0.7 \text{ d}$	$0.52\pm0.06~\mathrm{c}$	30 ± 4 a	2 ± 1 a	$112 \pm 10 \text{ ab}$
5	VT Double							
	Pro Hybrid 2	36.0 ± 0.6 a	35.9 ± 0.4 a	$35.9 \pm 0.4 \text{ ab}$	1.37 ± 0.11 a	3 ± 3 a	3 ± 1 a	67 ± 19 c
6	SmartStax							
	Hybrid 2	35.8 ± 1.0 a	35.1 ± 0.7 ab	$35.4 \pm 0.7 \text{ abc}$	$0.58\pm0.08~\mathrm{bc}$	35 ± 13 a	5 ± 3 a	$100 \pm 9 \text{ ab}$
7	SmartStax							
	PRO Hybrid 2	$34.5 \pm 0.6 \text{ ab}$	$35.0 \pm 0.5 \text{ ab}$	$35.1 \pm 0.5 \text{ abc}$	$0.49 \pm 0.06 \text{ c}$	33 ± 17 a	9 ± 4 a	$117 \pm 6 \text{ ab}$
8	VT4PRO							
	Hybrid 2	$33.9\pm0.4~b$	34.0 ± 0.5 b	$34.3 \pm 0.5 \text{ bc}$	0.47 ± 0.07 c	45 ± 18 a	2 ± 1 a	$111 \pm 5 \text{ ab}$
a N	Aeans followed by	z the same letter v	vithin a column ar	e not different ba	sed on the Fisher	method of least s	significant differe	nce ($\alpha =$

^a Means followed by the same letter within a column are not different based on the Fisher method of least significant difference ($\alpha = 0.05$)

D. Evaluation of Nurizma and other soil insecticides for control of corn rootworm on a non-CRW Bt hybrid

Location: University of Illinois Agricultural and Biological Engineering Farm, Urbana, IL (40.067902, -88.210168)

Objective: To compare the performance of soil insecticides for control of corn rootworm (particularly western corn rootworm, *Diabrotica virgifera virgifera*) larval damage when applied to a non-CRW Bt hybrid.

Summary: Capture LFR, Force Evo, and Aztec HC resulted in reduced node-injury ratings compared with the untreated plots; Force Evo and Aztec HC resulted in additional reductions compared with the other materials we tested and had the highest consistency among the materials we tested. Yields were poor due to the combination of drought stress, rootworm injury, and drought cracks that formed along seed furrows.

Funding: Project funding and pesticide materials for this trial were provided by BASF; FMC, AMVAC and Syngenta Crop Protection provided additional pesticide materials for testing. Seed and maintenance herbicides were provided by Bayer CropScience.

Variety	KSC 6810 ^a VT Double Pro
Seed coatings	Clothianidin (0.25 mg/seed) (Poncho 600)
-	Fungicide base: Allegiance FL ^b (2 g AI/100 kg seed) + Redigo 480 ^b
	(7.5 g AI/100 kg seed) + fluoxastrobin (7.5 g AI/100 kg seed)
Previous crop	Trap crop: late-planted, non-Bt field corn inter-seeded with
-	pumpkins
Soil type	Drummer silty clay loam loam
Tillage	Conventional
Row spacing	30 inches
Seeding Rate	35,000 seeds per acre
Soil insecticide	Trts 2-6, 8 Liquid in-furrow, 5 gal/acre application volume, water is
application	carrier, size 28 orifice plate (CP4916-28)
	Trt 7 Granular in-furrow, SmartBox ^a research-scale granular
	applicator
Planting date	May 5 2023
Emergence date	May 12 2023
Herbicide	Pre-emerge: 32% UAN (0.28 T/ac), Harness Xtra ^b (0.5 gal/ac)
	Post-emerge: Roundup PowerMAX ^b (32 oz/ac), Warrant ^b (2 qt/ac)
Plot size	4 rows (10 ft) wide by 30 ft long, 5 ft unplanted alleys

Table D-1. Plot information

^a AMVAC Chemical Corporation, Los Angeles, CA; ^bBayer CropScience, St. Louis, MO

Table D-2. Corn rootworm treatments

Trt	Soil Insecticide	Active Ingredient
1	Untreated	
2	Nurizma ^a (1 fl oz/a)	Broflanilide (2.5 lb active ingredient [a.i.] per gallon), suspension concentrate (SC)
3	Nurizma ^a (1.2 fl oz/a)	Broflanilide (2.5 lb a.i. per gallon), SC
4	BAS 450 LFC ^a (1 fl oz/a)	Broflanilide, pre-commercial formulation
5	Capture LFR ^b (8.5 fl oz/a)	Bifenthrin (1.5 lb a.i. per gallon), capsule suspension (CS)
6	Force Evo ^c (8 fl oz/a)	Tefluthrin (2.1 lb a.i. per gallon), emulsifiable concentrate
7	Aztec HC^d (1.63 lb/a)	Tebupirimphos (8.9%) + Cyfluthrin (0.44%), granule
8	Nurizma ^a (1 fl oz/a)	Broflanilide (2.5 lb a.i. per gallon), SC
	+ TWO.O ^a (1.31 fl oz/a)	Bacillus thuringiensis strain EX297512, 5×10 ⁴
		colony-forming units per ml

^a BASF Corporation, Research Triangle Park, NC; ^b FMC Corporation, Philadelphia, PA; ^c Syngenta Crop Protection, Greensboro, NC; ^d AMVAC, Chemical Corporation, Newport Beach, CA

Table D-3. Generalized linear mixed model statistics. Each analysis had 28 total degrees of freedom (Treatment = 7 df, Error = 21 df). Probability distribution is indicated in parentheses.

Dependent Variable	Date	F	Р
Plant stand (lognormal)	17 May	0.68	0.689
	22 May	0.74	0.644
	30 May	0.49	0.833
Root injury rating (gamma)	19 July	5.83	0.001 ^a
Proportion consistency (normal)	19 July	7.44	$< 0.001^{a}$
Proportion gooseneck lodging (normal)	23 Oct.	b	
Yield (lognormal)	24 Oct.	6.22	0.001 ^a
^a Effect is significant at $n = 0.05$			

^a Effect is significant at $\alpha = 0.05$

					Node-injury	Percent consistency	Percent lodging	
Trt	Treatment	Stand (V2) 17 May 2023	Stand (V3) 22 May 2023	Stand (V5) 30 May 2023	rating (R1) 13 July 2023	(R1) 13 July 2023	(R6) 23 Oct. 2023	Yield 24 Oct. 2023
1	Untreated	$36.6\pm0.6\ a$	$37.5 \pm 0.7 \text{ a}$	37.4 ± 0.8 a	1.09 ± 0.14 a	$10 \pm 6 b$	0 ± 0 a	$56.3 \pm 8.4 \text{ bc}$
2	Nurizma (1 fl oz/a)	38.1 ± 1.0 a	39.6 ± 1.4 a	38.5 ± 1.2 a	$0.78\pm0.12~ab$	$10 \pm 6 b$	0 ± 0 a	$52.1\pm9.9~c$
3	Nurizma (1.2 fl oz/a)	37.3 ± 0.7 a	$37.9\pm0.9\ a$	$37.8\pm0.7~a$	$0.88\pm0.15~ab$	$10 \pm 6 b$	0 ± 0 a	75.1 ± 4.7 a
4	BAS 450 LFC (1 fl oz/a)	$38.0\pm0.5~a$	$38.0\pm0.8~\text{a}$	$37.0\pm0.7~a$	$0.82\pm0.14~ab$	$15 \pm 10 \text{ b}$	0 ± 0 a	$46.2\pm4.9~c$
5	Capture LFR (8.5 fl oz/a)	$37.8\pm0.9~a$	38.3 ± 1.1 a	$37.8\pm0.8\ a$	$0.60\pm0.09~bc$	$15 \pm 10 \text{ b}$	0 ± 0 a	74.4 ± 6.1 a
6	Force Evo (8 fl oz/a)	$37.4 \pm 1.0 \text{ a}$	$37.8\pm0.9~a$	37.3 ± 1.0 a	$0.31 \pm 0.06 \text{ d}$	50 ± 13 a	0 ± 0 a	71.8 ± 7.1 a
7	Aztec HC (1.63 lb/a)	36.8 ± 1.1 a	37.9 ± 1.1 a	36.8 ± 1.1 a	$0.43\pm0.09~cd$	50 ± 10 a	0 ± 0 a	80.6 ± 5.0 a
8	Nurizma (1 fl oz/a) + TWO.O (1.31 fl oz/a)	37.9 ± 1.2 a	39.1 ± 0.9 a	38.1 ± 0.8 a	$0.81 \pm 0.10 \text{ ab}$	15 ± 15 b	0 ± 0 a	68.3 ± 11.4 ab

Table D- 4. Mean (\pm Standard error [SE]) stand in number of plants per 17.5 ft. of row, node-injury rating (0-3 scale) of corn rootworm larval feeding injury, percent consistency (percentage of roots with a node-injury rating of less than 0.25), percent "gooseneck" (root) lodging, and yield in bushels per acre corrected to 15.5% moisture.

^a Means followed by the same letter within a column are not different based on the Fisher method of least significant difference ($\alpha = 0.05$)

E. Evaluation of Nurizma in Combination with a Pyramided CRW Trait Hybrid for Corn Rootworm Control

Location: University of Illinois Agricultural and Biological Engineering Farm, Urbana, IL (40.067901, -88.210312)

Objective: To compare the performance of Nurizma when applied to a pyramided Bt trait package for control of corn rootworm (particularly western corn rootworm, *Diabrotica virgifera virgifera*) larval damage.

Summary: While corn rootworm injury exceeded the unexpected injury threshold of 0.500 for a pyramided corn rootworm trait package (in this case SmartStax), injury was not sufficient to separate the insecticide treatments from the untreated control. No significant differences were observed in stand, node-injury rating, percent consistency, lodging, or yield. Yields were poor due to drought stress.

Funding: Project funding and pesticide materials for this trial were provided by BASF. Seed and maintenance herbicides were provided by Bayer CropScience.

Variety	KSC 6812 ^a SmartStax
Seed coatings	Clothianidin (0.25 mg/seed) (Poncho 600)
-	Fungicide base: Allegiance FL ^b (2 g AI/100 kg seed) + Redigo 480 ^b (7.5
	g AI/100 kg seed) + fluoxastrobin (7.5 g AI/100 kg seed)
Previous crop	Trap crop: late-planted, non-Bt field corn inter-seeded with pumpkins
Soil type	Drummer silty clay loam
Tillage	Conventional
Row spacing	30 inches
Seeding Rate	35,000 seeds per acre
Soil insecticide	Trts 2-4 8 Liquid in-furrow, 5 gal/acre application volume, water is
application	carrier, size 28 orifice plate (CP4916-28)
Planting date	May 5, 2023
Emergence date	May 12, 2023
Herbicide	Pre-emerge: 32% UAN (0.28 T/ac), Harness Xtra ^b (0.5 gal/ac)
	Post-emerge: Roundup PowerMAX ^b (32 oz/ac), Warrant ^b (2 qt/ac)
Plot size	4 rows (10 ft) wide by 30 ft long, 5 ft unplanted alleys

Table E-1. Plot information

^a Kitchen Seed Company, Arthur, IL; ^b Bayer CropScience, St. Louis, MO

 Table E-2. Corn rootworm treatments

Trt	Soil Insecticide	Active Ingredient				
1	Untreated	N/A				
2	Nurizma ^a (1 fl oz/a)	Broflanilide (2.5 lb active ingredient [a.i.] per gallon), suspension concentrate (SC)				
3	Nurizma (1.2 fl oz/a)					
4	BAS 450 LFC (1 fl oz/a)	Broflanilide, pre-commercial formulation				
^a BAS	^a BASE Corporation Research Triangle Park NC					

^a BASF Corporation, Research Triangle Park, NC

Table E-3. Generalized linear mixed model statistics. Each analysis had 12 total degrees of freedom (Treatment = 3 df, Error = 9 df). Probability distribution is indicated in parentheses.

Dependent Variable	Date	F	P
Plant stand (lognormal)	17 May	0.41	0.750
	22 May	0.36	0.786
	30 May	1.25	0.349
Root injury rating (gamma)	19 July	0.86	0.495
Proportion consistency (normal)	19 July	0.05	0.984
Proportion gooseneck lodging (normal)	23 Oct.	0.42	0.743
Yield (lognormal)	24 Oct.	0.65	0.600
^a Effect is significant at $\alpha = 0.05$			

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Table E-4. Mean (\pm Standard error [SE]) stand in number of plants per 17.5 ft. of row, node-injury rating (0-3 scale) of corn rootworm larval feeding injury, percent consistency (percentage of roots with a node-injury rating of less than 0.25), percent "gooseneck" (root) lodging, and yield in bushels per acre corrected to 15.5% moisture.

Trt	Treatment	Stand (V2) 17 May 2023	Stand (V3) 22 May 2023	Stand (V5) 30 May 2023	Node-injury rating (R1) 19 July 2023	Percent consistency (R1) 19 July 2023	Percent lodging (R6) 23 Oct. 2023	Yield 24 Oct. 2023
1	Untreated	$36.5\pm0.5~a^{\rm a}$	36.8 ± 1.0 a	37.0 ± 0.4 a	0.76 ± 0.13 a	25 ± 19 a	3 ± 3 a	108 ± 11 a
2	Nurizma (1 fl							
	oz/a)	37.0 ± 0.4 a	$36.8\pm0.8\;a$	$36.5 \pm 0.6 a$	0.50 ± 0.08 a	25 ± 5 a	9 ± 6 a	117 ± 11 a
3	Nurizma (1.2							
	fl oz/a)	35.5 ± 0.6 a	36.0 ± 0.7 a	$36.5 \pm 0.3 \text{ a}$	0.46 ± 0.08 a	$25\pm10~a$	10 ± 9 a	115 ± 11 a
4	BAS 450 LFC							
	(1 fl oz/a)	37.3 ± 1.9 a	37.3 ± 1.9 a	38.5 ± 1.5 a	0.57 ± 0.11 a	30 ± 13 a	5 ± 3 a	120 ± 6 a

^a Means followed by the same letter within a column are not different based on the Fisher method of least significant difference ($\alpha = 0.05$)

<u>F. Evaluation of Plinazolin and other liquid in-furrow insecticides in combination with Bt</u> traits for corn rootworm control, 2023

Location: University of Illinois Agricultural and Biological Engineering Farm, Urbana, IL (40.06796, -88.210819)

Objective: To evaluate the performance of liquid in-furrow soil-applied insecticides in combination with pyramided Bt traits for control of corn rootworm (particularly western corn rootworm, *Diabrotica virgifera virgifera*) larval damage on a non-CRW Bt hybrid.

Summary: While rootworm pressure was low in this trial, applying one of three soil insecticides to SmartStax resulted in reduced node-injury ratings compared with corn that lacked a rootworm-targeting Bt trait. Yields were compromised due to drought stress; while there were differences among treatments, they did not follow a clear pattern related to corn rootworm injury, though SmartStax yields were generally higher than those for VT Double Pro.

Funding: Project funding was provided by Syngenta; insecticide materials for testing were provided by Syngenta and FMC. Seed was provided by Bayer CropScience.

	-
Seed coatings	DKC 61-41 ^a Clothianidin (0.50mg ai/seed) [Acceleron FALEH2Q]
	DKC 61-40 ^a Clothianidin (0.50mg ai/seed) [Acceleron FALEH2Q]
Previous crop	Trap crop: late-planted, non-Bt field corn inter-seeded with
	pumpkins
Soil type	Drummer silty clay loam
Tillage	Conventional
Row spacing	30 inches
Seeding Rate	35,000 seeds per acre
Soil insecticide	Trts 2,3,4,6,7,8: Liquid in-furrow, 5 gal/acre application volume,
application	carrier was liquid starter fertilizer (6-24-6), nozzle was an orifice
	plate (CP4916-28) ^b
Planting date	May 11 2023
Emergence date	May 17 2023
Herbicide	Pre-emerge: 32% UAN (0.28 T/ac), Harness Xtra ^a (0.5 gal/ac)
	Post-emerge: Roundup PowerMAX ^a (32 oz/ac), Warrant ^a (2 qt/ac)
Plot size	4 rows (10 ft) wide by 30 ft long, 5 ft unplanted alleys

Table F-1. Plot information

^a Bayer CropScience, St. Louis, MO; ^b TeeJet, Spraying Systems Company, Wheaton, IL

 Table F-2. Corn rootworm treatments

Treatment	Seed Variety	CRW Trait	Insecticide
VT Double Pro	DKC 61-41 ^a	None	None
VT Double Pro	DKC 61-41	None	Tefluthrin (2.1 lb per gallon), emulsifiable
+ Force Evo ^b (8 fl oz/a)			concentrate
VT Double Pro	DKC 61-41	None	Plinazolin [®] Technology, pre-commercial
+ A22466G ^b (5.25 fl oz/a)			
VT Double Pro	DKC 61-41	None	Bifenthrin (1.5 lb per gallon), suspension concentrate
+ Capture LFR ^c (8.5 fl oz/a)			
SmartStax	DKC 61-40 ^a	Cry3Bb1 + Cry34/35Ab1	None
SmartStax	DKC 61-40	Cry3Bb1 + Cry34/35Ab1	Tefluthrin (2.1 lb per gallon), emulsifiable
+ Force Evo (8 fl oz/a)			concentrate
SmartStax	DKC 61-40	Cry3Bb1 + Cry34/35Ab1	Plinazolin [®] Technology, pre-commercial
+ A22466G (5.25 fl oz/a)			
SmartStax	DKC 61-40	Cry3Bb1 + Cry34/35Ab1	Bifenthrin (1.5 lb per gallon), suspension concentrate
+ Capture LFR (8.5 fl oz/a)			
	VT Double Pro VT Double Pro + Force Evo ^b (8 fl oz/a) VT Double Pro + A22466G ^b (5.25 fl oz/a) VT Double Pro + Capture LFR ^c (8.5 fl oz/a) SmartStax + Force Evo (8 fl oz/a) SmartStax + A22466G (5.25 fl oz/a) SmartStax + Capture LFR (8.5 fl oz/a)	VT Double ProDKC $61-41^{a}$ VT Double ProDKC $61-41^{a}$ + Force Evo ^b (8 fl oz/a)DKC $61-41^{a}$ + A22466G ^b (5.25 fl oz/a)DKC $61-41^{a}$ + A22466G ^b (5.25 fl oz/a)DKC $61-41^{a}$ + Capture LFR ^c (8.5 fl oz/a)DKC $61-40^{a}$ SmartStaxDKC $61-40^{a}$ + Force Evo (8 fl oz/a)DKC $61-40^{a}$ SmartStaxDKC $61-40^{a}$ + Force Evo (8 fl oz/a)DKC $61-40^{a}$ SmartStaxDKC $61-40^{a}$ + A22466G (5.25 fl oz/a)DKC $61-40^{a}$ SmartStaxDKC $61-40^{a}$ + Capture LFR (8.5 fl oz/a)DKC $61-40^{a}$	VT Double ProDKC $61-41^{a}$ NoneVT Double ProDKC $61-41$ None+ Force Evo b (8 fl oz/a)DKC $61-41$ None+ A22466G b (5.25 fl oz/a)DKC $61-41$ None+ A22466G b (5.25 fl oz/a)DKC $61-41$ None+ Capture LFR c (8.5 fl oz/a)DKC $61-40^{a}$ Cry3Bb1 + Cry34/35Ab1SmartStaxDKC $61-40$ Cry3Bb1 + Cry34/35Ab1+ Force Evo (8 fl oz/a)DKC $61-40$ Cry3Bb1 + Cry34/35Ab1+ A22466G (5.25 fl oz/a)DKC $61-40$ Cry3Bb1 + Cry34/35Ab1SmartStaxDKC $61-40$ Cry3Bb1 + Cry34/35Ab1+ A22466G (5.25 fl oz/a)DKC $61-40$ Cry3Bb1 + Cry34/35Ab1

^a Bayer CropScience, St. Louis, MO; ^b Syngenta Crop Protection, Greensboro, NC; ^c FMC Corporation, Philadelphia, PA

Dependent Variable	Date	F	Р
Plant stand	22 May	0.45	0.856
	30 May	1.18	0.357
Root injury rating	26 July	4.07	0.006^{a}
Proportion consistency	26 July	4.07	0.006^{a}
Proportion gooseneck lodging	23 Oct.	1.00	0.459
Proportion stalk lodging	23 Oct.	0.88	0.536
Yield	23 Oct.	5.08	0.002^{a}

Table F-3. Generalized linear mixed model statistics. Each analysis had 28 total degrees of freedom (Treatment = 7 df, Error = 21 df).

^a Effect is significant at $\alpha = 0.05$

Table F-4. Mean (\pm Standard error [SE]) stand in number of plants per 17.5 ft. of row, node-injury rating (0-3 scale) of corn rootworm larval feeding injury, percent consistency (percentage of roots with a node-injury rating of less than 0.25), percent "gooseneck" (root) lodging, and yield in bushels per acre corrected to 15.5% moisture.

Trt	Treatment	Stand (V1) 22 May 2023	Stand (V3) 30 May 2023	Node-injury rating (R1) 13 July 2023	Percent consistency (R1) 13 July 2023	Percent lodging (R6) 20 Oct. 2023	Yield 23 Oct. 2023
<u>1rt</u>		U	U	U	e e		
1	VT Double Pro	$40.3 \pm 1.6 a^{a}$	39.3 ± 1.0 a	0.58 ± 0.07 a	$25 \pm 5 c^a$	$0.0\pm0.0~a^a$	$105.2 \pm 14.1 \ b^{a}$
2	VT Double Pro	38.5 ± 1.0 a	39.5 ± 1.2 a	$0.40\pm0.08~abc$	40 ± 14 bc	0.0 ± 0.0 a	86.9 ± 9.0 c
	+ Force Evo ^b (8 fl oz/a)						
3	VT Double Pro	39.3 ± 1.9 a	38.5 ± 2.1 a	0.63 ± 0.11 a	25 ± 13 c	0.0 ± 0.0 a	$88.9 \pm 25.1 \text{ c}$
	+ A22466G ^b (5.25 fl oz/a)						
4	VT Double Pro	35.8 ± 1.4 a	36.5 ± 1.5 a	0.53 ± 0.11 ab	$40 \pm 8 \text{ bc}$	0.0 ± 0.0 a	$92.6 \pm 10.4 \text{ c}$
	+ Capture LFR ^c (8.5 fl oz/a)						
5	SmartStax	37.5 ± 1.0 a	$37.8 \pm 1.1 \text{ a}$	$0.35\pm0.06~abc$	$45 \pm 10 \text{ bc}$	0.0 ± 0.0 a	140.1 ± 13.7 a
6	SmartStax	$38.0 \pm 1.8 \text{ a}$	37.8 ± 1.9 a	$0.23\pm0.09~\mathrm{c}$	$85 \pm 10 a$	0.0 ± 0.0 a	132.7 ± 12.8 ab
	+ Force Evo (8 fl oz/a)						
7	SmartStax	$38.0 \pm 1.7 \text{ a}$	38.8 ± 1.0 a	$0.22\pm0.05~\mathrm{c}$	$65 \pm 10 \text{ ab}$	0.3 ± 0.3 a	$130.5 \pm 9.2 \text{ ab}$
	+ A22466G (5.25 fl oz/a)						
8	SmartStax	37.0 ± 1.9 a	38.8 ± 1.8 a	$0.30\pm0.05~bc$	$40 \pm 14 \text{ bc}$	0.0 ± 0.0 a	$133.9\pm10.0 \text{ ab}$
	+ Capture LFR (8.5 fl oz/a)						

^a Means followed by the same letter within a column are not different based on the Fisher method of least significant difference ($\alpha = 0.05$)

G. Evaluation of liquid in-furrow insecticides for corn rootworm control, 2023

Location: University of Illinois Agricultural and Biological Engineering Farm, Urbana, IL (40.067922, -88.210366)

Objective: To compare the performance of liquid insecticides applied in-furrow at planting for control of corn rootworm (particularly western corn rootworm, *Diabrotica virgifera virgifera*) larval damage.

Summary: Corn rootworm pressure was not sufficient to assess the effectiveness of these materials, as there were no differences in any of the response variables among treatments. Yields were low due to drought stress, including cracks that formed along seed furrows.

Funding: Project funding and pesticide materials for this trial were provided by FMC Corporation and ProFarm Group. Seed was provided by Bayer Crop Science.

Variety	DKC 111-35 ^a VT Double Pro		
5			
Seed coatings	Clothianidin (0.50mg ai/seed) [Acceleron FALEH2Q ^a]		
Previous crop	Trap crop: late-planted, non-Bt field corn inter-seeded with		
	pumpkins		
Soil type	Drummer silty clay loam		
Tillage	Conventional		
Row spacing	30 inches		
Seeding Rate	35,000 seeds per acre		
Soil insecticide application	Liquid in-furrow, 5 gal/acre application volume, carrier was water,		
	nozzle was an orifice plate (CP4916-28) ^b		
Planting date	May 11 2023		
Emergence date	May 17 2023		
Herbicide	Pre-emerge: 32% UAN (0.28 T/ac), Harness Xtra ^a (0.5 gal/ac)		
	Post-emerge: Roundup PowerMAX ^a (32 oz/ac), Warrant ^a (2 qt/ac)		
Plot size	4 rows (10 ft) wide by 30 ft long, 5 ft unplanted alleys		

Table G-1. Plot information

^a Bayer CropScience, St. Louis, MO; ^b TeeJet, Spraying Systems Company, Wheaton, IL

 Table G-2. Corn rootworm treatments

Trt	Soil Insecticide	Active Ingredient					
1	Untreated						
2	Capture LFR ^a (17 fl	Bifenthrin, 1.5 lb AI per gallon, suspension concentrate (SC)					
	oz/a)						
3	MBI-306 ^b (20 fl oz/a)	Pre-commercial, SC					
4	Ethos XB ^a (10 fl oz/a)	Bifenthrin, 1.5 lb AI per gallon + Bacillus amyloliquefaciens					
		strain D747 1×10 ¹⁰ colony-forming units per ml, SC					
5	Capture LFR (10 fl oz/a)						
6	Force Evo ^c (8 fl oz/a)	Tefluthrin, 2.1 lb AI per gallon, emulsifiable concentrate					
^a FM0	^a FMC Corporation, Philadelphia, PA; ^b ProFarm Group, Belding, MI; ^c Syngenta Crop						
Ducto	Protection Crosseland NC						

Protection, Greensboro, NC

Table G-3. Generalized linear mixed model statistics. Each analysis had 20 total degrees of freedom (Treatment = 5 df, Error = 15 df). Probability distribution is indicated in parentheses.

Dependent Variable	Date	F	Р
Plant stand (lognormal)	22 May	0.71	0.626
	30 May	1.64	0.211
Root injury rating (gamma)	21 July	1.40	0.280
Percent consistency (normal)	21 July	1.01	0.447
Percent lodging (normal)	23 Oct.	b	
Yield (lognormal)	23 Oct.	0.93	0.487

^a Effect is significant at $\alpha = 0.05$; ^b Analysis not performed, all data = 0

Table G-4. Mean (\pm Standard error [SE]) stand in number of plants per 17.5 ft. of row, node-injury rating (0-3 scale) of corn rootworm larval feeding injury, percent consistency (percentage of roots with a node-injury rating of less than 0.25), percent "gooseneck" (root) lodging, and yield in bushels per acre corrected to 15.5% moisture.

					Percent		
Trt	Treatment	Stand (V2) 22 May 2023	Stand (V3) 30 May 2023	Node-injury rating (R1) 13 July 2023	consistency (R1) 13 July 2023	Percent lodging (R6) 23 Oct. 2023	Yield 23 Oct. 2023
1	Untreated	$37.0 \pm 1.3 \text{ a}$	$37.4 \pm 1.1 \text{ a}$	$0.57 \pm 0.11~a$	40 ± 25 a	0 ± 0 a	123 ± 23 a
2	Capture LFR (17 fl oz/a)	$36.1\pm0.8~a$	$36.3\pm0.6\;a$	$0.59\pm0.11~\mathrm{a}$	25 ± 13 a	0 ± 0 a	138 ± 10 a
3	MBI-306 (20 fl oz/a)	$37.8\pm0.5~a$	$37.3\pm0.4\;a$	$0.41\pm0.07~a$	35 ± 22 a	0 ± 0 a	125 ± 17 a
4	Ethos XB (10 fl oz/a)	$36.4\pm0.6\ a$	36.1 ± 0.6 a	$0.34\pm0.08\;a$	60 ± 16 a	0 ± 0 a	136 ± 13 a
5	Capture LFR (10 fl oz/a)	$37.0\pm0.8~a$	$37.5\pm0.8\ a$	$0.41\pm0.08~a$	40 ± 14 a	0 ± 0 a	128 ± 15 a
6	Force Evo (8 fl oz/a)	$37.0 \pm 0.5 \text{ a}$	$36.3 \pm 0.8 \text{ a}$	$0.21\pm0.03~a$	70 ± 13 a	0 ± 0 a	$142 \pm 16 a$

^a Means followed by the same letter within a column are not different based on the Fisher method of least significant difference ($\alpha = 0.05$)

H. Evaluation of a biological seed-applied insecticide on VT Double Pro corn, 2023

Location: University of Illinois Agricultural and Biological Engineering Farm, Urbana, IL (40.068844, -88.210856)

Objective: To evaluate the performance of a biological seed-applied insecticide in combination with in-furrow soil-applied materials for control of corn rootworm (particularly western corn rootworm, *Diabrotica virgifera virgifera*) larval damage on a non-CRW Bt hybrid.

Summary: Overall rootworm pressure was low in this trial; Aztec HC resulted in reduced nodeinjury ratings compared with the untreated plots when applied alone, but no other treatments were different from the untreated plots. Yields were compromised by drought stress and were not affected by treatment.

Funding: Project funding and pesticide materials for this trial were provided by AMVAC Chemical Corporation; seed was provided by Bayer CropScience.

X 7 • .	
Variety	DKC61-41 ^a : VT Double Pro
Seed coatings	Clothianidin (0.50mg ai/seed) [Acceleron FALEH2Q]
Previous crop	Trap crop: late-planted, non-Bt field corn inter-seeded with
	pumpkins
Soil type	Elburn silt loam
Tillage	Conventional
Row spacing	30 inches
Seeding Rate	35,000 seeds per acre
Soil insecticide	Trt 2 and 5 Granular in-furrow, SmartBox ^b research-scale
application	granular applicator
	Trt 3 and 6 Liquid in-furrow, 5 gal/acre application volume,
	carrier was water, nozzle was an orifice plate (CP4916-28) ^c
Planting date	May 4 2023
Emergence date	May 12 2023
Herbicide	Pre-emerge: 32% UAN (0.28 T/ac), Harness Xtra ^a (0.5 gal/ac)
	Post-emerge: Roundup PowerMAX ^a (32 oz/ac), Warrant ^a (2
	qt/ac)
Plot size	4 rows (10 ft) wide by 30 ft long, 5 ft unplanted alleys

Table H-1. Plot information

^a Bayer CropScience, St. Louis, MO; ^b AMVAC Chemical Corporation, Los Angeles, CA; ^c TeeJet, Spraying Systems Company, Wheaton, IL

Table H- 2. Corn rootworm treatments

Trt	Soil Insecticide	Active Ingredient				
1	None					
2	Aztec HC ^a (1.63 lb per acre)	8.9% tebupirimphos + 0.44% cyfluthrin, high concentration granules				
3	Xpedient Plus ^a (12.8 oz per acre)	Bifenthrin, 2 lb AI per gallon, emulsifiable concentrate				
4	AMV1080 ^a (32 g per 80,000 seed)	Pre-commercial biological seed treatment				
5	AMV 1080 (32 g per 80,000 seed)	-				
	+ Aztec HC (1.63 lb per acre)					
6	AMV 1080 (32 g per 80,000 seed)					
	+ Xpedient Plus (12.8 oz per acre)					
^a ΔM	^a AMVAC Chemical Corporation Los Angeles					

^a AMVAC Chemical Corporation, Los Angeles

Table H- 3. Generalized linear mixed model statistics. Each analysis had 20 total degrees of freedom (Treatment = 5 df, Error = 15 df). Probability distribution is indicated in parentheses.

Date	DF	F	Р
17 May	5, 15	1.59	0.224
22 May	5, 15	0.85	0.536
30 May	5, 15	1.42	0.272
13 July	5, 15	4.34	0.012 ^a
13 July	5, 15	1.68	0.201
23 Oct.	b		
23 Oct.	5, 15	1.63	0.213
	17 May 22 May 30 May 13 July 13 July 23 Oct.	17 May 5, 15 22 May 5, 15 30 May 5, 15 13 July 5, 15 13 July 5, 15 23 Oct. b	17 May 5, 15 1.59 22 May 5, 15 0.85 30 May 5, 15 1.42 13 July 5, 15 4.34 13 July 5, 15 1.68 23 Oct. b b

^a Effect is significant at $\alpha = 0.05$; ^b All data=0, therefore model did not converge

Table H- 4. Mean (\pm Standard error [SE]) stand in number of plants per 17.5 ft. of row, node-injury rating (0-3 scale) of corn rootworm larval feeding injury, percent consistency (percentage of roots with a node-injury rating of less than 0.25), percent "gooseneck" (root) lodging, and yield in bushels per acre corrected to 15.5% moisture.

T d	T é é	Stand (V2)	Stand (V3)	Stand (V5)	Node-injury rating (R1)	Percent consistency (R1)	Percent lodging (R6) 23 Oct.	Yield
Trt	Treatment	17 May 2023	22 May 2023	30 May 2023	13 July 2023	13 July 2023	2023	23 Oct. 2023
1	None	$38.0 \pm 1.0 \text{ a}$	$38.5 \pm 0.7 \text{ a}$	$37.8 \pm 1.0 \text{ a}$	0.23 ± 0.05 ab	65 ± 15 a	0 ± 0 a	$109 \pm 16 a$
2	Aztec HC	38.0 ± 1.0 a	$39.8 \pm 1.0 \text{ a}$	39.3 ± 1.1 a	$0.12\pm0.03~\text{c}$	90 ± 6 a	0 ± 0 a	$132 \pm 14 a$
3	Xpedient Plus	$37.0 \pm 1.0 \text{ a}$	37.0 ± 1.6 a	37.1 ± 1.0 a	0.25 ± 0.05 ab	60 ± 18 a	0 ± 0 a	119 ± 17 a
4	AMV1080	37.0 ± 1.0 a	39.4 ± 1.3 a	39.3 ± 1.0 a	0.38 ± 0.11 ab	60 ± 23 a	0 ± 0 a	116 ± 12 a
5	AMV 1080 +							
	Aztec HC	37.0 ± 1.0 a	37.6 ± 1.4 a	37.8 ± 1.0 a	$0.22\pm0.06~bc$	70 ± 17 a	0 ± 0 a	$132 \pm 11 \text{ a}$
6	AMV 1080 +							
	Xpedient Plus	38.0 ± 1.0 a	38.1 ± 1.1 a	37.1 ± 1.1 a	$0.34\pm0.09~a$	65 ± 17 a	0 ± 0 a	117 ± 10 a
a	Means followed b	with a same latter w	vithin a column or	a not different be	and on the Fisher	mathed of least a	anificant diff	$\sigma ron oo (\alpha =$

^a Means followed by the same letter within a column are not different based on the Fisher method of least significant difference ($\alpha = 0.05$)

I. Evaluation of a biological seed-applied insecticide on SmartStax corn, 2023

Location: University of Illinois Agricultural and Biological Engineering Farm, Urbana, IL (40.068855, -88.211002)

Objective: To evaluate the performance of a biological seed-applied insecticide in combination with in-furrow soil-applied materials for control of corn rootworm (particularly western corn rootworm, *Diabrotica virgifera virgifera*) larval damage on a pyramided CRW Bt hybrid.

Summary: Plots treated with Aztec HC (with or without AMV1080) and plots treated with Xpedient Plus + AMV1080 resulted in lower node-injury ratings and greater consistency of control than the untreated plots. However, overall corn rootworm pressure was low, and yield was not affected by treatment.

Funding: Project funding and pesticide materials for this trial were provided by AMVAC Chemical Corporation; seed was provided by Bayer CropScience.

Variety	DKC61-40 ^a : SmartStax
Seed coatings	Clothianidin (0.50mg ai/seed) [Acceleron FALH2VQ ^b]
Previous crop	Trap crop: late-planted, non-Bt field corn inter-seeded with pumpkins
Soil type	Elburn silt loam
Tillage	Conventional
Row spacing	30 inches
Seeding Rate	35,000 seeds per acre
Soil insecticide application	Trt 2 and 5 Granular in-furrow, SmartBox ^b research-scale granular applicator
	Trt 3 and 6 Liquid in-furrow, 5 gal/acre application volume, carrier was water, nozzle was an orifice plate (CP4916-28) ^c
Planting date	May 4 2023
Emergence date	May 11 2023
Herbicide	Pre-emerge: 32% UAN (0.28 T/ac), Harness Xtra ^a (0.5 gal/ac)
	Post-emerge: Roundup PowerMAX ^a (32 oz/ac), Warrant ^a (2 qt/ac)
Plot size	4 rows (10 ft) wide by 30 ft long, 5 ft unplanted alleys

Table I-1. Plot information

^a Bayer CropScience, St. Louis, MO; ^b AMVAC Chemical Corporation, Los Angeles, CA; ^c TeeJet, Spraying Systems Company, Wheaton, IL

Table I-2.	Corn	rootworm	treatments
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Trt	Soil Insecticide	Active Ingredient [AI]
1	None	
2	Aztec HC ^a (1.63 lb per acre)	8.9% tebupirimphos + 0.44% cyfluthrin, high concentration granules
3	Xpedient Plus ^a (12.8 oz per acre)	Bifenthrin, 2 lb AI per gallon, emulsifiable concentrate
4	AMV1080 ^a (32 g per 80,000 seed)	Pre-commercial biological seed treatment
5	AMV 1080 (32 g per 80,000 seed)	
	+ Aztec HC (1.63 lb per acre)	
6	AMV 1080 (32 g per 80,000 seed)	
	+ Xpedient Plus (12.8 oz per acre)	
a AM	VAC Chemical Corporation I of Ange	

^a AMVAC Chemical Corporation, Los Angeles, CA

Table I-3. Generalized linear mixed model statistics. Each analysis had 20 total degrees of freedom (Treatment = 5 df, Error = 15 df). Probability distribution is indicated in parentheses.

Dependent Variable	Date	F	Р
Plant stand (lognormal)	17 May	3.44	0.029 ^a
	22 May	0.88	0.516
	30 May	0.32	0.890
Root injury rating (beta)	17 July	4.92	0.007^{a}
Proportion consistency (normal)	17 July	3.00	0.045 ^a
Proportion gooseneck lodging (normal)	23 Oct.	b	
Yield (lognormal)	23 Oct.	0.41	0.838
^a Effect is significant at $\alpha = 0.05$: ^b All data	-0 model	did not a	onvorgo

^a Effect is significant at $\alpha = 0.05$; ^bAll data = 0, model did not converge

Table I-4. Mean (\pm Standard error [SE]) stand in number of plants per 17.5 ft. of row, node-injury rating (0-3 scale) of corn rootworm larval feeding injury, percent consistency (percentage of roots with a node-injury rating of less than 0.25), percent "gooseneck" (root) lodging, and yield in bushels per acre corrected to 15.5% moisture.

Trt	Treatment	Stand (V2) 17 May 2023	Stand (V3) 22 May 2023	Stand (V5) 30 May 2023	Node-injury rating (R1) 17 July 2023	Percent consistency (R1) 17 July 2023	lodging (R6) 23 Oct. 2023	Yield 23 Oct. 2023
1	None	$35 \pm 1 b$	35 ± 1 a	34 ± 1 a	0.20 ± 0.06 a	70 ± 13 b	0 ± 0 a	165 ± 15 a
2	Aztec HC	$35 \pm 1 b$	35 ± 1 a	35 ± 1 a	0.06 ± 0.03 bc	$95\pm5~a$	0 ± 0 a	178 ± 16 a
3	Xpedient Plus	37 ± 1 a	35 ± 2 a	35 ± 2 a	0.11 ± 0.04 abc	85 ± 15 ab	0 ± 0 a	165 ± 16 a
4	AMV1080	36 ± 1 ab	36 ± 1 a	$36 \pm 1 a$	$0.15 \pm 0.04 \text{ ab}$	$80 \pm 8 ab$	0 ± 0 a	167 ± 12 a
5	AMV 1080 +							
	Aztec HC	36 ± 1 a	36 ± 1 a	35 ± 1 a	$0.04\pm0.01~c$	100 ± 0 a	0 ± 0 a	$166 \pm 8 a$
6	AMV 1080 +							
	Xpedient Plus	34 ± 1 b	35 ± 1 a	35 ± 1 a	$0.05\pm0.01~\text{c}$	100 ± 0 a	0 ± 0 a	162 ± 10 a

^a Means followed by the same letter within a column are not different based on the Fisher method of least significant difference ($\alpha = 0.05$

Evaluation of SmartStax Pro for corn rootworm control.

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Location: University of Illinois Agricultural and Biological Engineering Farm, Urbana, IL (40.06872, -88.20961)

Objective: Compare the performance of SmartStax Pro and SmartStax for control of corn rootworm (particularly western corn rootworm (WCR), *Diabrotica virgifera virgifera*) larval damage.

Summary: A SmartStax PRO Bt + RNAi pyramided hybrid expressing the Cry3Bb1 + Cry 34/35Ab1 Bt toxins and the RNAi (*DvSnf7*) gene had reduced corn rootworm injury relative to the SmartStax pyramid expressing the Cry3Bb1 + Cry 34/35Ab1 Bt toxins and the VT Double PRO hybrid that lacked any Bt rootworm protection traits (**Table _-2**). Significantly greater protection from rootworm injury in SmartStax relative to VT Double PRO indicates that the pyramid of Cry3Bb1 + Cry34/35Ab1 is capable of providing some limited efficacy against corn rootworm. However at a NIS of 0.54 ± 0.04 , economic injury and significant yield loss could be expected. Laboratory bioassays and recent field performance evaluations of single trait Bt hybrids expressing the Cry3Bb1 and Cry34/35Ab1 Bt toxins indicate the presence of a high level of resistance to these Bt toxins and little evidence of field efficacy against WCR larvae unless they are expressed in a pyramided Bt hybrid. And even then, SmartStax efficacy at this location has been variable. NIS Consistency was significantly greater for SmartStax PRO relative to VT Double PRO, but not significantly greater than that of SmartStax (**Table _-3**).

Funding: Project funding was supported by an USDA HATCH Award to J.L. Spencer [ILLU-875-969]. Project seed provided by Bayer CropScience and Pioneer HiBred.

Seed coatings	Included ≤ 0.50 mg clothianidin per seed, plus standard fungicide package
Previous crop	Trap crop: late-planted, non-Bt field corn inter-seeded with pumpkins
Soil type	Drummer silty clay loam
Tillage	Conventional
Row spacing	30 inches
Seeding Rate	35,500 seeds per acre
Planting date	May 4, 2023
Emergence date	May 12, 2023
Herbicide	Pre-emerge: 32% UAN (0.28 T/ac), Harness Xtra ^a (0.5 gal/ac)
	Post-emerge: Roundup PowerMAX ^a (32 oz/ac), Warrant ^a (2 qt/ac)
Plot size	8 rows (20 ft) wide by 30 ft long, 5 ft unplanted alleys

 Table 1. Plot information.

^a Bayer CropScience, St. Louis, MO

 Table 2. Corn rootworm treatments.

Trait package	Corn hybrid	CRW Traits	Seed source
VT Double Pro	DKC 65-95	None	Bayer
SmartStax	DKC 65-94	Cry3Bb1 + Cry34Ab1/35Ab1 ^a	Bayer
SmartStax PRO	DKC 111-33	Cry3Bb1 + Cry34Ab1/35Ab1 + RNAi ^b	Bayer

^aThe Bt trait previously known as Cry34Ab1/Cry35Ab, the toxin has been renamed Gpp34Ab1/Tpp35Ab1. ^bRNA interference (RNAi) trait is derived from *DvSnf7* gene.

Table 3. Node-injury score (NIS, 0-3 scale) of corn rootworm larval feeding injury and percent consistency (percentage of roots with NIS <0.25) for corn rootworm treatments. Planted 16 May 2023 at 35,500 seeds/acre. N=3 replications per trait package. NIS evaluation was on 19 July 2023.

Trait package	Mean Node-injury score (±SEM) 19 July 2023	Percentage consistency (±SEM) 19 July 2023	Seed source
VT Double PRO	$1.09 \pm 0.10 \ a^{a}$	$0.07\pm0.07~b$	Bayer
SmartStax	$0.54\pm0.04~b$	$0.33\pm0.07~ab$	Pioneer
SmartStax PRO	0.17 ± 0.03 c	0.73 ± 0.13 a	Bayer

Bt resistance in Illinois populations of western and northern corn rootworms

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Introduction. Resistance to Bt traits in the western corn rootworm (WCR) (Diabrotica v. virgifera LeConte) and northern corn rootworm (NCR) (Diabrotica barberi (Smith and Lawrence)) is a growing problem in Illinois and across the Corn Belt (Gassmann 2021). Fieldevolved Bt resistance in WCR has been documented for every commercial Bt toxin (i.e., Cry3Bb1, mCry3A, eCry3.1Ab and Cry34/35Ab1). Patterns of WCR and NCR resistance to Bt toxins are similar; however, it took almost twice as long for practical NCR Bt resistance to arise in the field (Tabashnik et al., 2023). Slower NCR resistance evolution may be due to prolonged egg diapause in NCR which allows a portion of the NCR egg population to delay hatch for a year or more. This phenomenon results in a significant portion of the NCR population having what is essentially a 2-year lifecycle and being exposed to Bt only every other year. Longer generation times in the NCR means that it has taken longer for NCR to experience the same level of resistance selection as in the WCR where prolonged diapause is rare. While resistance (and cross-resistance) to the structurally similar Cry3 toxins (i.e., Cry3Bb1, mCry3A, and eCry3.1Ab) is widespread, there are regions (including in Illinois) where the Cry34/35Ab1 Bt toxin (recently renamed Gpp34Ab1/Tpp35Ab1) still provides some efficacy against corn rootworm larvae. For this reason, rootworm susceptibility to the Cry34/35Ab1 Bt toxin has been crucial to the efficacy of pyramided Bt corn hybrids, most of which combine expression of the Cry34/35Ab1 toxin with one of the Cry3 toxins.

A new trait package with activity against corn rootworms was commercialized on limited acres in 2022 and fully launched in 2023. That trait package, SmartStax® PRO (SSX PRO), is a pyramid of the familiar Cry3Bb1 + Cry34/35Ab1 Bt toxins with a novel mode of action that uses double-stranded RNA to interfere with cell function, eventually killing rootworm larvae (i.e., RNA interference or "RNAi") (USEPA. 2017, Khajuria et al. 2018). The rootworm-active RNAi trait is the first new mode of action for rootworms in almost a decade. RNAi works by introducing double-stranded RNA from the *DvSnf7* gene of WCR into cells the RNA will interfere with the production of essential products of that gene. Unlike Bt toxins which quickly kill larvae by making their digestive systems leaky, RNAi kills more slowly by disrupting a critical supply chain in cells. Since the RNAi mode of action using the *DvSnf7* gene is novel, SSX PRO corn hybrids are expected to protect corn roots from rootworm populations that have or are developing resistance to pyramided Bt hybrids.

Annually, populations of adult WCR and NCR are collected from a variety of field locations. Eggs collected from these populations are the source of larvae used in annual Bt resistance bioassays to measure corn rootworm larval susceptibility during the following summer. The 2023 bioassays described here, used the offspring of WCR and NCR populations collected during 2022. Availability of Illinois rootworm populations collected during a year when SSX PRO was grown on limited acreage presented an opportunity to assess the susceptibility of Illinois WCR and NCR populations to the new SSX PRO pyramid of Bt + RNAi when their potential exposure to the new RNAi mode of action has been very limited.

<u>Summary</u>. Bioassays of Illinois WCR populations from Champaign Co. along with WCR and NCR populations from Kane Co. confirm that Cry3Bb1 resistance was present in both species. Significantly reduced susceptibility to the Cry34/35Ab1 toxin was also detected. Unlike highly

Cry3Bb1 resistant WCR and NCR larvae that develop normally on Cry3Bb1 hybrids, many larvae surviving on Cry34/35Ab1 hybrids experienced significant developmental delays compared to those on non-Bt hybrids. Developmental sensitivity to a particular Bt toxin in the diet indicates that a population is not fully adapted to that toxin. Illinois WCR and NCR populations exhibit significantly reduced susceptibility to the SSX Bt pyramid of Cry3B1 and Cry34/35Ab1 toxins, but with significant developmental delays among most survivors. Susceptibility to SSX hybrids is attributable to susceptibility to the Cry34/35Ab1 trait. WCR populations were largely susceptible to the SSX PRO Bt + RNAi pyramid. However, the proportion of larval survival for Champaign Co. and the Kane Co. WCR populations on SSX PRO (0.039 ± 0.012 and 0.092 ± 0.026 , mean \pm SEM, respectively) was significantly greater than the susceptible control populations. Kane Co. NCR populations were susceptible to SSX PRO; no larvae survived in the bioassay. The few surviving WCR larvae from SSX PRO bioassays generally experienced significant developmental delays. The presence of reduced susceptibility to SSX PRO in populations without extensive prior exposure to its novel RNAi mode-of-action underscores the importance of following best management practices and only planting SSX PRO where it is needed. Using SSX PRO as an "insurance pest management" tactic exposes it to unnecessary selection for resistance.

<u>Materials and Methods</u>. During summer 2022, several WCR adult populations were collected from cornfields at the Agricultural and Biological Engineering Farm, Research and Training Center on the University of Illinois' Urbana-Champaign campus in Urbana, IL (40.070510, - 80.214430). An additional mixed population of adult WCR and NCR beetles were collected from corn plants along the edge of a private cornfield in far western Kane Co., IL on 15 August 2022. Following almost two decades of exposure to Bt, all field-collected WCR and NCR populations are suspected to carry some level of Bt resistance to Cry3Bb1 (and the other structurally similar Cry3 toxins mCry3A and eCry.1Ab) and Cry34/35Ab1 Bt toxins. We refer them as "suspected resistant populations". The Kane Co. beetles were separated by species and maintained in the laboratory on corn silks and developing ears. Eggs were regularly collected from each population and stored at 6°C for ≥5 mon. until needed to provide larvae for bioassays.

Single-plant Bt resistance bioassays were conducted following the method of Gassmann et al. (2011). In each bioassay, the proportion of larvae surviving a bioassay treatment and the proportions of mature (3rd instar) larvae among any survivors were measured for each population following exposure to Bt and non-Bt corn hybrids. Suspected-Bt resistant Illinois field populations were tested with a Bt-susceptible laboratory population obtained from the USDA-ARS, North Central Agricultural Research Laboratory in Brookings, SD.

Bayer CropScience, provided seed for three corn hybrids from the SSX PRO "family" in a similar genetic background: SSX PRO (a pyramided hybrid expressing the Cry3Bb1 + Cry34/35Ab1 Bt toxins and RNAi), SmartStax® (SSX) (a pyramided hybrid expressing the Cry3Bb1 + Cry34/35Ab1 Bt toxins), and VT Double PRO (VT2P) (a "non-Bt" near isoline of SSX PRO and SSX that expresses no rootworm active Bt toxins). We also bioassayed the WCR populations on single trait Cry3Bb1 and Cry34/35Ab1 hybrids and associated non-Bt hybrids or isolines (**Table 1**).

WCR larvae were evaluated for resistance to Cry3Bb1 and Cry34/35Ab1 Bt toxins expressed in single-trait commercial corn hybrids (and their respective non-Bt isoline/near isoline; a hybrid, nearly identical to the Bt hybrid, that lacks expression of the Bt toxin). Due to limited availability of larvae, NCR could not be bioassayed on the single-trait commercial hybrids. However, all WCR and NCR populations were evaluated for resistance to: SmartStax® PRO (SSX PRO), SmartStax® (SSX), and VT Double PRO (VT2P) (**Table 1**). Greenhouse-grown cups (946 L capacity) of bioassay plants were inoculated with 10 newly-emerged rootworm larvae per cup at the V5-V6 stage (*ca.* 1 month after planting). Each field population was bioassayed along with a Bt-susceptible USDA laboratory population. There were 12 replicates per population \times Bt hybrid combination. Seventeen days after inoculation, surviving larvae were extracted from bioassay cups using Berlese funnels (devices that use a lightbulb to provide heat and light that drive surviving larvae out of bioassay cup soil). Surviving larvae were counted and their head capsule widths (a correlate of larval developmental stage) were measured.

<u>Analysis.</u> Data for proportion larval survival and proportion 3rd instar larvae among surviving larvae were non-normal. Comparisons among corn hybrids within each Bt trait family (Cry3Bb1, Cry34/35Ab1, and SSX PRO families of hybrids) for the WCR and NCR field and laboratory populations were analyzed with the non-parametric Kruskal-Wallis test. Following a significant result, the Steel-Dwass method (a non-parametric version of Tukey's method that protects the experimentwise error rate) was used to conduct multiple comparisons. Data for all USDA Bt susceptible WCR or NCR replicates were pooled for use in analyses of individual field-collected WCR or NCR populations, respectively.

<u>Results.</u> Bt resistance in Champaign Co. WCR. The Champaign Co. WCR populations had equivalent survival on both the Cry3Bb1 and Cry34/35Ab1 Bt hybrids that was significantly greater than that of the susceptible populations on the same hybrids (**Table 2**). Due to existing cross-resistance among Cry3 Bt toxins in WCR, these populations would be expected to also survive well on hybrids expressing Cry3 toxins other than Cry3Bb1 (i.e., mCry3A and eCry3.1Ab toxins). <u>Champaign Co. WCR</u> survival on the Cry3Bb1 hybrid was significantly greater than their survival on the non-Bt isoline, while survival on the Cry 34/35Ab1 hybrid was significantly less than survival on the non-Bt hybrid in that Bt toxin family.

Among the Champaign Co. WCR larvae surviving on the Cry3Bb1 hybrid, a high proportion were fully developed 3rd instars, as were nearly all larvae developing on the non-Bt hybrid's roots. The presence of 3rd instars at the conclusion of the 17-day bioassay period indicates that the surviving larvae were developing at a normal rate and were likely unaffected by the Bt toxin. In contrast, most of the Bt-susceptible population's survivors from Cry3Bb1 plants exhibited delayed development and had not reached the 3rd instar at the end of the bioass—a result consistent with a highly Bt susceptible control population.

Among the Champaign Co. WCR larvae tested on the Cry34/35Ab1 hybrid, there were only modest numbers of survivors that reached the 3rd instar. The presence of about half of the survivors (0.462) with developmental delays suggests that the population is still negatively affected by the Cry34/35Ab1 Bt toxin in their diet. Delayed larval development may disadvantage these survivors and help keep potentially resistant populations in check (Reinders et al. 2022). Slower developing larvae are exposed to soil predators and disease longer. If they emerge late as adults, they may have fewer opportunities to exploit high quality foods (e.g., corn pollen, fresh corn silks). That disadvantage may translate into fewer opportunities to mate and compromise their ability to maximize their lifetime production of eggs. The offspring of beetles with genes that better protected them from larval developmental delays due to Bt exposure may outcompete less resistant surviving beetles. A WCR population with robust resistance to Cry34/35Ab1 would have larvae that survive in high proportions and develop at a normal rate in the presence of Cry34/35Ab1. Bioassay results for Champaign County WCR populations (**Table** 2) indicated that the Champaign Co. WCR populations were resistant to the Cry3Bb1 toxin and possess significantly reduced susceptibility to the Cry34/35Ab1 toxins that is short of full resistance.

Bioassay results for WCR populations evaluated on hybrids from the SSX PRO family were consistent with survival data from the individual single-trait hybrids. The Champaign Co. WCR population exhibited survival on the SSX pyramid that was statistically equivalent to their survival on the non-Bt isoline—a compelling indication of developing resistance to the pyramid and a predictable outcome based on single Bt toxin survival patterns for the component toxins expressed in SSX (**Table 2**). In contrast, the USDA Bt susceptible populations had low survival on SSX indicating that they remain highly susceptible. Modest proportions of 3rd instars among the Champaign Co. WCR that survived on SSX indicate that the trait combination expressed in this pyramided hybrid slows larval development for about half of survivors. Knowing that Champaign Co. WCR are resistant to Cry3Bb1 toxin, we can conclude that the efficacy provided by SSX must depend on the presence of the Cry34/35Ab1 toxin. Full resistance to the Cry34/35Ab1 toxin would render the SSX pyramid ineffective against the Champaign Co. WCR

The RNAi mode of action expressed in the SSX PRO hybrid is a novel mechanism for WCR management to which the local 2022 populations of WCR had not previously been exposed. Thus, survival patterns for Champaign Co. WCR on SSX PRO hybrids reflect their natural "background" susceptibility to RNAi. Proportion larval survival for the Champaign Co. WCR population on SSX PRO was significantly greater than that of susceptible control populations, but it was still significantly less than the survival of either population on the non-Bt control, respectively (**Table 2**). Evidence of elevated survival on SSX PRO among Champaign Co. WCR must be tempered by the observation that this level of survival was not statistically different from larval survival of the Champaign populations on SSX hybrids. Considering the response across the SSX PRO family of hybrids, naïve Champaign Co. WCR populations exhibit larval survival patterns on SSX PRO that suggest they naturally possess some significantly reduced susceptibility to the RNAi mode of action. A very similar pattern was observed in the 2021 Champaign Co. populations.

Despite significantly elevated larval survival on SSX PRO (vs. the susceptible control), the surviving larvae still experienced significant developmental delays. The proportions of 3rd instars among surviving larvae were low (**Table 2**). The presence of developmental delays among the survivors of SSX PRO is an encouraging outcome with respect to the durability of SSX PRO—survivors from this hybrid perform poorly. However, reduced susceptibility to a mode-of-action that is new to the market is concerning. Even a low level of reduced innate susceptibility to RNAi may provide Champaign Co. WCR with a "head start" on the path toward resistance to the only mode of action that WCR have not already overcome.

<u>Results.</u> Status of Bt resistance in Kane Co., IL WCR. Larval survival on either of the single trait Bt hybrids expressing Cry3Bb1 and Cry34/35Ab1 (i.e. DKC 61-88 and P1417) was equivalent to survival on the associated non-Bt hybrids (**Table 3**). These data indicate that the Kane Co., IL WCR likely have a high level of resistance to both Cry3Bb1 (and other Cry3-toxins: mCry3A and eCry3.1Ab, due to cross resistance among the structurally-similar "Cry3" Bt toxins) and the Cry34Ab1/Cry35Ab1 toxin The proportion of 3rd instar larvae among the survivors on these hybrids was high (**Table 3**). This is a clear indication that most larvae were developing at a near normal rate in the assays. Lower percentages of 3rd instars among survivors (or the presence of earlier 2nd and occasionally 1st instar larvae) on some Bts can indicate that, although larvae survive, their development has been significantly slowed by Bt. A bioassay-based determination of resistance to a toxin is troublesome when individuals from a population survive on a Bt hybrid

at a high proportion *and* the survivors also develop at a near normal rate. It is important to remember that unless a population (Bt resistant or not) exceeds the economic threshold, their feeding activity will not likely lead to economic injury. Treating such a subeconomic population is counter-productive. The yield benefit of planting a pyramided Bt hybrid will not exceed the management cost and unnecessary exposure to the traits in the pyramid can select for an ever-greater level of resistance. if bioassay-based indicators of resistance are already associated with unexpected injury to Bt hybrids (lodging, reduced yield, along with abundant beetles) the presence of practical resistance in the field is a reasonable conclusion and that trait (or those traits) should be avoided.

Significant larval survival on hybrids expressing the single trait Bt hybrids expressing Cry3Bb1 and Cry34/35Ab1, make it unsurprising (even predictable) that this population would also survive well on the SSX hybrid (DKC 58-34) which expresses both of those toxins as pyramid (**Table 3**). WCR survival on the SSX pyramid was equivalent to survival on the non-Bt isoline hybrid (VT2P = DKC 58-35), though the absolute proportions were a bit lower (but not statistically so). Only modest proportions of 3^{rd} instar larvae among the survivors from the Kane Co., WCR population (p=0.627 ± 0.081), suggests that a portion of this population suffers delayed development when exposed to the two Bt traits expressed in a pyramid. While delayed emergence of resistant adults may slow resistance evolution over time, the immediate impact of inferior root protection on yield mitigates against continued use of poor performing hybrids.

The year 2023 was the first year of full commercial availability of SSX PRO (there was limited availability in 2022). Tested on SSX PRO, the Kane Co. WCR population survived significantly better than a susceptible population (9.2% survival vs. 0.4% survival). This is the key comparison. While $9.2 \pm 0.03\%$ survival was also not statistically different from survival on SSX (DKC 58-34 = 30.8% survival) or the non-Bt isoline of SSX (DKC 58-35 = 19.2% survival), it would be irresponsible to suggest that WCR in Kane Co. are resistant to SSX PRO upon their first exposure. We found a similar level of survival $(6.0 \pm 0.01\%)$ on SSX PRO in two Champaign Co., IL populations tested in 2022 and survival at 0.040 ± 0.003 among the Champaign Co. WCR tested this year. Practically speaking, results from the Kane Co. WCR bioassay (and the 2022 Champaign Co. WCR) indicate reduced baseline susceptibility to SSX PRO in a bioassay compared to a susceptible population. In the NE Illinois corn growing region, corn rootworms have been targeted by management tactics for decades-but not yet by SSX PRO. They have undoubtedly accumulated a variety of adaptations over the years, some of that variation has endowed them with an elevated tolerance of SSX PRO compared to laboratory susceptible populations. These findings suggest that it will be important to closely monitor WCR field performance on SSX PRO - especially if there is any local field evidence of lodging or other reduced susceptibility. Industry research aimed at selecting for resistance to SSX PRO (to the RNAi mode-of-action) in the laboratory generated a RNAi-resistant population in three generations. Beginning with a naïve field population, heavy selection lead to an RNAi resistance that was not applicable to just the DvSnf7 gene exploited by SSX PRO, but was generalized to the RNAi mechanism itself. This raises the possibility that future field-evolved resistance might broadly compromise the efficacy of any RNAi mode of action. This potential, combined with a small, but significant, baseline reduction in SSX PRO susceptibility underscores the importance of careful stewardship of the only currently available novel rootworm mode-of-action

<u>Status of Bt resistance in Kane Co., IL NCR:</u> Due to lower availability of larvae, Kane Co. NCR larval survival was tested on just the SSX PRO family of traits. The results were clear (**Table 4**). Kane Co. NCR have little susceptibility to the SSX pyramid (of Cry3Bb1 and Cry34/35Ab1 toxins) in a bioassay. NCR survived on SSX as well as they did on a VT2P

hybrid that did not express any rootworm protection. This implies that, like the local WCR population, they are highly resistant to both the Cry3Bb1 and Cry34/35Ab1 toxins. In contrast to the reduced baseline SSX PRO susceptibility in Kane Co. WCR, the Kane Co. NCR population was completely susceptible to the SSX PRO hybrid - there were zero NCR larval survivors on the pyramid of Bt traits and RNAi. Given that they are likely resistant to the two Bt MOAs (based on their survival on the SSX Bt pyramid of Cry3BB1 and Cry34/35Ab1), the efficacy on display in this bioassay can be attributed solely to the activity of RNAi. The proportion of 3rd instar larvae among the NCR survivors was uninformative statistically due to variability among the treatments. A numerically lower proportion of 3rd instars on the SSX hybrid than on the VT2P suggest that any NCR that survive on SSX are experiencing development delays. If that is truly the case, NCR resistance to SSX may still be developing. Because of NCR prolonged diapause, in any given area, there are local subpopulations with 2-year (and longer) generation times that have been exposed to Bt MOAs at lower frequency than the rest of the population over the decade. With fewer opportunities for selection compared to populations that are all annually exposed to Bt (i.e. the WCR populations in the same fields), the level of resistance in NCR will be less.

<u>WCR corrected survival on Bt hybrids.</u> To gain additional perspective on the impact of resistance on local populations, it is informative to "correct" proportion larval survival on a Bt hybrid for their background level of larval survival on the non-Bt isoline hybrid. This is done by dividing proportion larval survival on the Bt hybrid by larval survival on the non-Bt hybrid. A population that survives equally well on the Bt and non-Bt hybrids will have corrected larval survival ("CS") of 1.0. This is useful for comparing data between bioassays where the survival proportions differ greatly. Populations with poor survival on Bt hybrids, relative to non-Bt hybrids, will have low CS; completely susceptible populations will have corrected survival of 0.0 on Bt hybrids.

Bt resistance bioassays have been used to evaluate the Bt susceptibility of WCR collected in Champaign Co. since 2013. From 2013 to 2022, there has been a significant upward linear trend in CS for WCR bioassayed on corn hybrids expressing single Bt traits (e.g., Cry3Bb1, mCry3A, & Cry3435Ab1) (Figure 1). The upward trend indicates that CS of Champaign Co. WCR populations on the toxins expressed in single-trait hybrids has increased at *ca*. 9.7% per year (0.097 is the slope of the relationship). It is notable that the rise in CS (indicative of declining susceptibility) occurred during a period (2015-present) when local WCR abundance was far below levels where WCR larval pressure may have inflicted economic injury to unprotected corn. Planting Bt corn hybrids when there is no risk of economic injury imposes unnecessary selection for resistance on rootworm populations and could have contributed to the upward trend in survival. With the era of Bt efficacy arguably drawing to a close, it is imperative that the use of new hybrids expressing the RNAi mode of action is justified by pest monitoring data. Loss of RNAi efficacy at a rate similar to the loss of efficacy among single-trait Bt toxins, especially among populations like WCR from Champaign Co. and Kane Co. with some naturally-reduced susceptibility to the new RNAi mode of action, could leave growers vulnerable to unexpected damage if/when WCR population abundance rebounds.

Discussion. Among the take-home messages from these results is that WCR and NCR field populations have resistance or significantly reduced susceptibility to the Bt toxins that are expressed in pyramided Bt corn hybrids. Susceptibility to the SSX pyramided hybrid is attributable to the presence of the Cry34/35Ab1 toxin. Susceptibility to the Cry34/35Ab1 (and other Bt toxins) is in steady decline. Over the last decade of bioassays, the survival (i.e. "corrected survival" which corrects for non-Bt caused mortality in bioassays) of Champaign Co.

WCR inoculated onto single trait Bt hybrids as increased at *ca*. 10% per year (**Figure 1**). WCR larvae can now survive on a Bt hybrid. Bioassay data indicate that NCR are following a similar trajectory toward resistance.

Growing resistance to Bt traits not only jeopardizes the efficacy of Bt pyramids, but threatens the role of the Bt traits as additional modes of action in Bt + RNAi pyramids. Documentation of low (but significantly elevated) larval survival on the SSX PRO Bt +RNAi pyramid indicates that some WCR populations possess natural variation that could be the basis for future resistance. Without a significant contribution to rootworm mortality from the Bt toxins they express, Bt + RNAi pyramids functionally become single mode-of-action hybrids which put the RNAi trait under heavier selection for resistance. With this in mind, we suggest that SSX PRO should be reserved for fields where there is a documented rootworm problem and risk of economic injury. Using SSX PRO broadly as "insurance" on subeconomic populations or fields that could be rotated to soybean will hasten the loss of its efficacy.

It has been many years since most Illinois' growers experienced rootworm pressure capable of causing economic injury. The recommended, but unpopular, practice of monitoring rootworm beetle abundance can help growers avoid unnecessary use of Bt hybrids on subeconomic rootworm populations. Staying informed about your rootworm risk is critical to making management decisions that maximize profits and prolong the durability of pest protection tactics. When injurious rootworm populations are expected, reliance on pyramided Bt hybrids like SSX in fields with a history of poor/declining Bt/pyramid performance is not advised. Rotating to soybean is the first choice "Best Management Practice" where Bt efficacy is in question, high populations are expected, and rotation is an option. If corn must be planted following corn and significant rootworm pressure is expected, a pyramided Bt + RNAi hybrid like SSX PRO is justified. When possible, it would be informative to also plant a small amount of a refuge, or other non-Bt, corn hybrid in an accessible area in the field. Availability of a non-Bt check in a field with an insect-protected corn hybrid provides an opportunity to compare that hybrid's performance (standability, root injury and yield) to a non-Bt check and potentially document unexpected injury/resistance should it occur. Resistance is an inevitable consequence of using practices or products that kill pests. The rise of rootworm Bt resistance is well documented as are circumstances that are hastening the loss of Bt efficacy. As the rootworm management value of Bt traits declines, leaving RNAi traits as the only effective mode-of-action against rootworms, the urgency of limiting the use Bt + RNAi pyramided hybrids to acres facing significant rootworm threats cannot be emphasized enough.

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Table 7. Bt corn hybrid information for seed used in 2023 single-plant, Bt-resistance bioassaysof 2022 Illinois field-collected populations of the western corn rootworm (WCR) (Diabroticav. virgifera LeConte) and northern corn rootworm (NCR) (Diabrotica barberi (Smith and
Lawrence)).

Bt toxin family	Corn hybrid	Hybrid type	Bt expression	Seed source
Cry3Bb1	DKC 61-88 ¹	Single trait Bt	(+) Bt	Bayer
	DKC 61-86 ²	non-Bt isoline	non-Bt isoline	Bayer
Cry34Ab1/Cry35Ab1*	P1417 ³	Single trait Bt	(+) Bt	Pioneer
	2H723 ⁴	non-Bt	non-Bt ⁷	Mycogen
Cry3Bb1+Cry34/35Ab1+DvSnf7	DKC 107-33 ⁵	Pyramided Bt + RNAi	(+) Bt (+) RNAi	Bayer
	DKC 58-34 ⁶	Pyramided Bt	(+) Bt	Bayer
	DKC 58-35 ²	non-Bt isoline	non-Bt isoline	Bayer

¹YieldGard RW ²VT Double Pro ³AcreMax Xtra ⁴AcreMax ⁵SmartStax PRO ⁶SmartStax ⁷Due to poor germination of the planned AcreMax Xtra (AMX) hybrid, 2H695, associated with the AcreMax 2H723 isoline, we were forced to substitute a different AMX hybrid, P1417; it was not isogenic with 2H723. *Previously known as Cry34Ab1/Cry35Ab, the Bt toxin has been renamed Gpp34Ab1/Tpp35Ab1. Shading indicates cells containing information about corn hybrids that express Bt toxins.

Table 8. Proportion western corn rootworm (WCR) (*Diabrotica v. virgifera* LeConte) larval survival and proportion 3rd instar larvae from single-plant, Bt-resistance bioassays on a Kane Co., IL population collected in 2022 from a cornfield.

Bt trait family	Bt expressed in corn hybrid	WCR test population	n	Proportion larval survival (mean ± SEM) ^a	n	Proportion 3 rd instar larvae (mean ± SEM)
Cry3Bb1	Cry3Bb1	Kane Co. field pop.	12	0.258 ± 0.050 a	11	$0.739 \pm 0.096 \text{ ab}$
		USDA Bt susceptible pop.	48	$0.075 \pm 0.013 \ b$	24	$0.431 \pm 0.092 \ b$
	Non-Bt isoline	Kane Co. field pop.	12	$0.383 \pm 0.051 \text{ a}$	12	0.905 ± 0.083 a
		USDA Bt susceptible pop.	47	0.238 ± 0.024 a	39	$0.639 \pm 0.065 \text{ ab}$
Cry34/35Ab1*	Cry34/35Ab1	Kane Co. field pop.	12	0.342 ± 0.034 a	12	0.833 ± 0.068 a
		USDA Bt susceptible pop.	42	$0.050 \pm 0.016 \ b$	13	$0.000\pm0.000\ b$
	Non-Bt isoline	Kane Co. field pop.	12	$0.392 \pm 0.058 \text{ a}$	12	0.938 ± 0.033 a
		USDA Bt susceptible pop.	48	$0.373 \pm 0.027 \ a$	45	$0.737 \pm 0.048 \ a$
Cry34/35Ab1 +	Cry34/35Ab1 + Cry3Bb1	Kane Co. field pop.	12	0.092 ± 0.026 a	7	0.714 ± 0.149 ab
Cry3Bb1 + RNAi	+RNAi	USDA Bt susceptible pop.	48	$0.004 \pm 0.003 \text{ b}$	2	$0.500 \pm 0.500 \text{ ab}$
	Cry34/35Ab1 + Cry3Bb1	Kane Co. field pop.	12	0.308 ± 0.057 a	11	$0.627 \pm 0.081 \text{ ab}$
		USDA Bt susceptible pop.	48	$0.019 \pm 0.006 \ b$	9	$0.111 \pm 0.111 \text{ b}$
	Non-Bt isoline	Kane Co. field pop.	12	$0.192 \pm 0.040 \text{ a}$	11	$0.400\pm0.131~ab$
		USDA Bt susceptible pop.	48	0.144 ± 0.023 a	29	$0.799 \pm 0.065 \text{ a}$

^a Proportion WCR larval survival and proportion 3^{rd} instar larvae data were non-normal and were analyzed using the non-parametric Kruskal-Wallis test, with multiple comparisons performed for all data pairs within a Bt trait family using the Steel-Dwass method (a non-parametric version of Tukey's method that protects the overall α =0.05 error rate) (JMP Pro 16 (2021 SAS Institute)). Mean proportions sharing the same letter within a trait family are not significantly different. *Previously known as Cry34Ab1/Cry35Ab, the Bt toxin has been renamed Gpp34Ab1/Tpp35Ab1. **Table 9.** Proportion northern corn rootworm (NCR) (Diabrotica barberi (Smith and Lawrence))larval survival and proportion 3rd instar larvae from single-plant, Bt-resistance bioassays on aKane Co., IL population collected in 2022 from a cornfield.

Bt trait family	Bt expressed in corn hybrid	NCR test population	n	Proportion larval survival (mean ± SEM) ^a	n	Proportion 3 rd instar larvae (mean ± SEM) ^a
Cry34/35Ab1* +	Cry34/35Ab1 + Cry3Bb1	Kane Co. field pop.	12	$0.000\pm0.000~b$	0	
Cry3Bb1 + RNAi	+RNAi	USDA Bt susceptible pop.	12	$0.000\pm0.000\ b$	0	
	Cry34/35Ab1 + Cry3Bb1	Kane Co. field pop.	12	0.458 ± 0.067 a	12	0.364 ± 0.109 a
		USDA Bt susceptible pop.	12	$0.025 \pm 0.013 \; b$	3	0.000 ± 0.000 a
	Non-Bt isoline	Kane Co. field pop.	12	0.600 ± 0.070 a	12	0.730 ± 0.092 a
		USDA Bt susceptible pop.	12	$0.492 \pm 0.073 \; a$	12	0.471 ± 0.102 a

^a Proportion NCR larval survival and proportion 3^{rd} instar larvae data were non-normal and were analyzed using the non-parametric Kruskal-Wallis test, with multiple comparisons performed for all data pairs within a Bt trait family using the Steel-Dwass method (a non-parametric version of Tukey's method that protects the overall α =0.05 error rate) (JMP Pro 16 (2021 SAS Institute)). Mean proportions sharing the same letter within a trait family are not significantly different. *Previously known as Cry34Ab1/Cry35Ab, the Bt toxin has been renamed Gpp34Ab1/Tpp35Ab1.

Table 10. Proportion western corn rootworm (WCR) (*Diabrotica v. virgifera* LeConte) larval survival and proportion 3rd instar larvae from single-plant, Bt-resistance bioassays on three Champaign Co., IL population collected in 2022 from UIUC campus farm locations.

Bt trait family	Bt expressed in corn hybrid	WCR test population	n	Proportion larval survival (mean ± SEM) ^a	n	Proportion 3 rd instar larvae (mean ± SEM)
Cry3Bb1	Cry3Bb1	Champaign Co. field pops.	36	0.283 ± 0.033 a	29	0.569 ± 0.054 a
		USDA Bt susceptible pop.	48	$0.075 \pm 0.013 \text{ c}$	24	0.431 ± 0.092 a
	Non-Bt isoline	Champaign Co. field pops.	36	$0.161 \pm 0.022 \ b$	28	0.726 ± 0.070 a
		USDA Bt susceptible pop.	47	$0.238\pm0.024\ ab$	39	0.639 ± 0.065 a
Cry34/35Ab1*	Cry34/35Ab1	Champaign Co. field pops.	32	$0.159\pm0.032~b$	22	$0.462 \pm 0.096 \text{ b}$
		USDA Bt susceptible pop.	42	$0.052 \pm 0.016 \text{ c}$	13	$0.000\pm0.000~\text{c}$
	Non-Bt isoline	Champaign Co. field pops.	36	0.336 ± 0.031 a	35	0.708 ± 0.049 a
		USDA Bt susceptible pop.	48	$0.373 \pm 0.027 \; a$	45	$0.737 \pm 0.048 \; a$
Cry34/35Ab1 +	Cry34/35Ab1 + Cry3Bb1	Champaign Co. field pops.	36	$0.039 \pm 0.012 \text{ bc}$	10	$0.383 \pm 0.145 \text{ ab}$
Cry3Bb1 + RNAi	+RNAi	USDA Bt susceptible pop.	48	$0.004 \pm 0.003 \text{ d}$	2	$0.500 \pm 0.500 \text{ ab}$
	Cry34/35Ab1 + Cry3Bb1	Champaign Co. field pops.	36	$0.086 \pm 0.017 \text{ ab}$	20	$0.563 \pm 0.109 \text{ ab}$
		USDA Bt susceptible pop.	48	$0.019\pm0.006~cd$	9	$0.111 \pm 0.111 \text{ b}$
	Non-Bt isoline	Champaign Co. field pops.	36	$0.108 \pm 0.017 \text{ a}$	24	$0.785 \pm 0.078 \; a$
		USDA Bt susceptible pop.	48	$0.144 \pm 0.023 \text{ a}$	29	$0.799 \pm 0.065 \ a$

^a Proportion WCR larval survival and proportion 3^{rd} instar larvae data were non-normal and were analyzed using the non-parametric Kruskal-Wallis test, with multiple comparisons performed for all data pairs within a Bt trait family using the Steel-Dwass method (a non-parametric version of Tukey's method that protects the overall α =0.05 error rate) (JMP Pro 16 (2021 SAS Institute)). Mean proportions sharing the same letter within a trait family are not significantly different. *Previously known as Cry34Ab1/Cry35Ab, the Bt toxin has been renamed Gpp34Ab1/Tpp35Ab1.

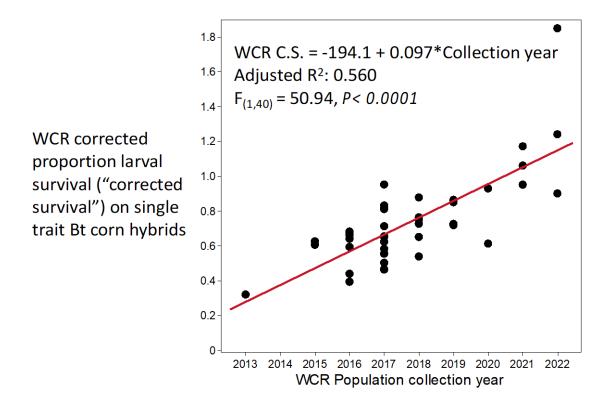


Figure 10. Linear regression of WCR corrected proportion larval survival (corrected survival, "C.S") on single-trait Bt corn hybrids for (n=41) Champaign Co. WCR populations from 2013-2022. C.S. data for single trait hybrids expressing the Cry3Bb1 and Cry34/35Ab1 toxins were pooled for this analysis. C.S. is the quotient of proportion larval survival on a Bt maize hybrid divided by proportion larval survival on the corresponding non-Bt hybrid. A C.S. of 1.0 indicates equal proportions of larval survival on Bt and non-Bt corn hybrids; a value of 0.5 indicates that half as many larvae survived on Bt corn compared to non-Bt corn. Lower values indicate greater trait efficacy.

Sticky Trap Orientation Affects Western Corn Rootworm Capture

Sagnika Das¹ and J.L. Spencer²

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Objective: Determine the effect of sticky trap angle on western corn rootworm (WCR) capture in soybean fields.

Locations:

Study plots were located on University of Illinois farmland: 1. SoyFACE Farm, Urbana, IL (40.043271, -88.2225202), 2. Main Farm, Champaign, IL (40.087175, -88.231809)

Introduction:

Bt corn hybrids are the primary tactic adopted to manage western corn rootworm (*Diabrotica virgifera virgifera* LeConte) (WCR) populations across the U.S. Corn Belt. However, not every cornfield will host a damaging population of WCR larvae requiring use of Bt corn or other tactics to prevent economic injury. Monitoring beetle abundance using Pherocon® AM sticky traps yields data useful for making pest management decisions which can reduce the unnecessary application of insecticides or use of Bt hybrids. In the eastern Corn Belt, where most corn is grown in rotation with soybeans and where crop rotation-resistant WCR beetles may lay many eggs in soybean fields, WCR abundance monitoring is needed to forecast the risk of larval injury in subsequent first-year corn.

As part of a project to evaluate innovative approaches to WCR management and monitoring, we are testing the feasibility of unmanned aerial vehicles (UAVs or drones) as tools to remotely visit, photograph, and count WCR beetles captured on Pherocon® AM sticky traps in soybean fields. The challenge of making weekly trips far out into soybean fields to check sticky traps is often cited as a reason why monitoring WCR abundance is unpopular. If an aerial drone could fly out into a field and return with high resolution photographs of each sticky trap, we could eliminate the need to repeatedly enter fields to collect WCR abundance data. Increasing use of versatile drones by commercial crop consultants for a variety of other tasks suggests that some form of drone-based pest monitoring is possible in the future. A number of challenges must be overcome to make drone-based WCR abundance monitoring feasible.

In a preliminary study, we identified and counted WCR beetles from drone-acquired images of sticky traps in the field; however, we found that standard vertically oriented sticky traps were difficult to approach with a drone because the trap faces are often at canopy level. Flying just above the plant canopy to take a photograph puts a drone at risk of entanglement and a costly crash. We hypothesized that tilting the traps upward would allow traps to be approached from above with less crash-risk and make it easier to align the camera with the face of the trap. Field tests confirmed the ease of approaching and photographing sticky traps with a drone from above. However, tilting the trap orientation away from vertical reduced the number of WCR beetles caught on a trap compared to a standard vertical sticky trap. Also, tilting traps limited the drone to only photographing the WCR on the upper "top" side of each trap.

In 2022, the effect of sticky trap orientation angles (i.e., vertical - 0°, 45°, 67°, & horizontal - 90°) on WCR captured per trap were investigated and shared in the 2022 Applied Research Results publication. A significant reduction in the number of WCR captured on a trap as the angle increased from vertical to horizontal was reported. In addition, WCR abundance measured on the visible (top) sides of angled sticky traps was discovered to be reliably related to the total WCR abundance (on both sides) of a standard vertical trap. The strongest relationship between abundance on a standard vertical trap and an angled trap was for traps oriented at 45°. These results demonstrated that drone-based monitoring was feasible. A group of engineering collaborators also used sticky trap photographs of traps in the field to test and prototype a program that could automatically detect and count WCR beetles on photographs of sticky traps.

In 2023, the investigation of trap angles was repeated and two additional treatments were added to test a hypothesis about WCR perception of sticky traps. We hypothesized that angled traps caught fewer WCR because, when viewed from the perspective of a beetle approaching a trap, the apparent area of an angled trap is smaller than the same sized trap oriented vertically. This hypothesis assumes that most WCR orientation to sticky traps occurs at or just above the plant canopy. We found that when an angled trap is viewed face-on, the apparent area of an angled sticky trap is reduced (relative to a vertically oriented trap) by the cosine of the trap angle. Thus traps mounted at 45° or 67° angles, when viewed face on, have apparent areas that are just 0.71 and 0.39 (i.e. cosines of 45° and 67° are ca. 0.71 and ca. 0.39, respectively) of the area of a full size, vertically oriented trap (**Figures 2 & 3**). If WCR attraction to, and abundance on, sticky traps is a function of their area and/or apparent area, sticky traps mounted at 45° and 67° angles, should catch fewer adults in proportion to the cosine of the mounting angle. Furthermore, WCR abundance as measured on angled traps should be the same as WCR abundance measured on corresponding vertical traps whose area has been reduced to coincide with the apparent area of the angled trap.

Materials & Methods:

Field experiments were established at two University of Illinois, Urbana-Champaign soybean field locations (0.76 m row spacing). Sticky trap treatments were distributed in groups (blocks) of six treatments using a randomized complete block design with a total of 25 replicates distributed across the two locations. Pherocon® AM unbaited yellow sticky traps (Great Lakes IPM, Vestaburg, MI 48891) were mounted on 2.54 cm dia. 1.5 m tall PVC poles spaced ca. 11.5 m apart and installed in the soybean row. Among the six treatments were full-size sticky traps mounted at four different angles: 0° , 45° , 67° , & 90° . The last two treatments were vertically mounted (0°) traps with reduced trap areas. The 0.71 area trap was sized to represent the apparent area of a full size trap mounted at 45°, and the 0.39 area trap was sized to represent the apparent area of a full size trap mounted at 67. The 0° sticky trap is the conventional vertically oriented trap used to monitor WCR beetle abundance in soybean fields. At the other extreme, a 90° trap angle was a full-size trap oriented horizontally. Angled traps were attached to PVC poles using mounts constructed from PVC couplers, garden stakes, wire locks, binder clips, & twist ties. Before traps were placed in the field, the intended top side of each was marked with a "T" in the lower right corner; the unmarked side was the bottom (Figure 4). To distinguish between the sides of vertical traps, one side was designated as the top and marked with a "T" like the other angle treatments. At the time of trap visitation, WCR beetle counts from the top and bottom sides of each trap were recorded separately on datasheets while in the field. Trap arrays were sampled for up to 6 weeks (July-August 2023). The length of the sampling interval sometimes varied

among the sites due to weather limitations, thus for analyses, WCR counts were converted to WCR/trap/day during the trapping period at each site. Beetle capture data were non-normal and were analyzed using non-parametric methods. WCR/trap/day data for each angle treatment were analyzed within a sample location using the non-parametric Kruskal-Wallis test; if significant, the non-parametric Steel-Dwass method (q=2.569, $\alpha = 0.05$) was used to perform multiple comparisons among trap angles. Comparisons of actual and predicted WCR abundance for each angled trap treatment was performed using paired t-tests. All data analyses were performed using JMP Pro software 16.2.0 (2021 SAS Institute).

Results:

<u>Sticky trap angle.</u> Total WCR abundance (combined top and bottom side counts) was significantly greater on 0° (vertical) sticky traps than on all other angled trap treatments at the SoyFACE location (**Figure 5**). Among the other angled treatments, total WCR abundance on 45° sticky traps was significantly greater than captures on the 67° and 90° (horizontal) sticky traps. There were no significant differences in WCR abundance among treatments at the Main Farm location. At the SoyFACE location, where WCR were more abundant, the pattern of captures on sticky traps suggests that WCR captures significantly decrease as the trap angle deviated from vertical. This pattern of declining abundance on angled sticky traps is nearly identical to what was found in 2022.

<u>Sticky trap angles and areas.</u> At the SoyFACE Farm location, reducing sticky trap area significantly reduced the abundance of WCR adults captured on traps in proportion with the reduction in area (**Figure 6**). The pattern was not significant among traps at the Main Farm location where WCR populations were much lower. There was a significant parallel reduction in WCR abundance on 67° traps compared to the abundance on vertical 0° traps. Among traps with similar apparent vs. actual areas (i.e. 45° full traps vs. 0.71 reduced traps and 67° full traps vs. 0.39 reduced traps [labeled with a "y's" and "x's", respectively in **Figure 6**]), WCR did not always accumulate on the traps in proportion to their actual or apparent trap areas. Compared to WCR abundance on full size vertical sticky traps, vertical traps with reduced areas accumulated WCR beetles in significant proportion with their areas (**Table 1**). However, the abundance of WCR on the angled 45° and 67° traps was significantly lower than the expected WCR/trap/day if abundance was simply a function of the apparent area.

Discussion:

Measuring WCR abundance using Pherocon® AM unbaited yellow sticky traps is an activity familiar to field crop entomologists, crop consultants and growers. Documenting the impact of sticky trap orientation on WCR abundance provides a basis for interpreting beetle catch if angled traps are deployed to facilitate monitoring with an aerial drone.

Curiosity about the basis for reduced beetle catch on angle traps lead to testing the hypothesis that reduced catch was related to the apparent area of angled traps. Documenting a relationship between vertical trap area and measurement of WCR abundance provides some a new insight into WCR perception and orientation to yellow sticky traps and visual stimuli in general. Direct observation of WCR orientation to sticky traps is planned, along with repeating this study in 2024. It is unclear why the numbers of WCR captured on 45° and 67° angled sticky traps were not identical to captures on the corresponding traps with areas equal to 0.71 and 0.39 of a full

trap's area. Our assumption was that WCR beetles would perceive these as pairs of traps with identical area, but this was incorrect.

It is evident when traps are vertically oriented, that trap area affects WCR captures. It seems likely that most of the WCR that become stuck on vertical traps must orient toward the trap faces (i.e. they can see them best) from zones on either side. When a trap is oriented at an angle, it becomes possible to also see it from above as well as from the side (albeit, the bottom side is shaded). Presumably, some flying WCR approach traps from above. That there are any WCR captured on the top surfaces of 90° (horizontal) sticky traps provides some support for potential WCR orientation to trap stimuli visible from above (data from direct observation is needed to understand from where these beetles arrived). Significantly reduced WCR captures on sticky traps oriented at less extreme angles may indicate that the slanted surfaces are not as stimulatory as vertical surfaces (or less capable of retaining a beetle that contacts the surface). Perhaps the build-up of debris/dust/other insects and fading of the color on the exposed upper surface diminishes its attractiveness? Constant upper surface exposure to the elements (e.g. heat, rain, etc.) may make the top side less sticky leading to significant reduction in WCR captures when a beetle contacts the surface. Understanding why some traps are less successful at catching WCR will improve our ability to gather robust monitoring data. More importantly, learning how WCR beetles respond to various stimuli in their environment may reveal general principles of WCR perception that can be exploited more broadly.

The ability to use angled sticky traps for monitoring would enable an aerial drone to approach & photograph a trap with less risk of crashing into the soybean foliage. Future availability of this innovative approach or other time-saving uses of technology may facilitate greater adoption of sticky trap monitoring leading to more judicious use of management tactics (including new Bt corn hybrids).

WCR abundance monitoring is sensitive to the orientation of Pherocon® AM sticky traps. Leaning traps could interfere with IPM-based WCR abundance monitoring. Sticky traps that lean at 45° or more will capture significantly fewer (i.e., <50%) adults than vertical traps at the same location and could result in a WCR abundance undercount.

This study will be repeated in 2024.

Summary:

We conclude that mounting sticky traps at angles that deviate from the conventional (0°) vertical orientation significantly decreased WCR beetle captures. The reduction in WCR beetle captures may be related to how WCR perceive an angled sticky trap.

Funding:

A "Futuristic Methods to Sustain Management of Corn Rootworm Populations" grant from Corteva Agriscience™ (Indianapolis, IN) funds Sagnika Das' graduate research; additional project support was provided by a USDA HATCH Award to J.L. Spencer [ILLU-875-969].

Acknowledgments:

We thank the Department of Crop Sciences farm staff for planting, plot maintenance, and harvest assistance. We also thank undergraduate student assistants, Max Garmon, Eloise O'Leary, and Evan Lemberger for their help establishing the trapping arrays and data collection.



Figure 11. Angled traps array in the Main Farm soybean field. Pherocon® AM unbaited yellow sticky traps were mounted on 2.54 cm dia. 1.5 m PVC poles at four different angles; two additional sticky trap treatments involving reduced trap areas are depicted in the next figures.

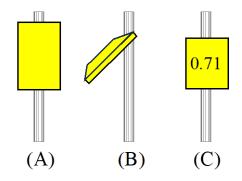


Figure 12. Trap A is a standard-size vertically mounted sticky trap. Trap B is a side view of a standard-size sticky trap mounted at 45°. Trap C is a sticky trap with area reduced to match the apparent area of a standard-size sticky trap mounted at 45° and viewed face on. If WCR beetles simply perceive angled traps as smaller traps, we should find similar numbers of beetles on angled traps with those sized to match their apparent areas.



Figure 13. Views of 0° (vertical), 45°, and 67° angled sticky traps and traps with reduced areas matching the apparent area of the corresponding angled traps. A. Full size vertical sticky trap. B. Face on view of a 45° angled sticky trap. C. Sticky trap with reduced area (0.71 of full trap) to match the apparent area of a 45° trap. D. Side view of 67° angled sticky trap. E. Face on view of a 67° angled sticky trap. F. Sticky trap with reduced area (0.39 of full trap) to match the apparent area of a 67° trap.



Figure 14. Top vs. Bottom side of a 0° (vertically-oriented) sticky trap. The top sides of 0° traps were indicated with a "T" (lower right); the unmarked side was designated as the bottom.

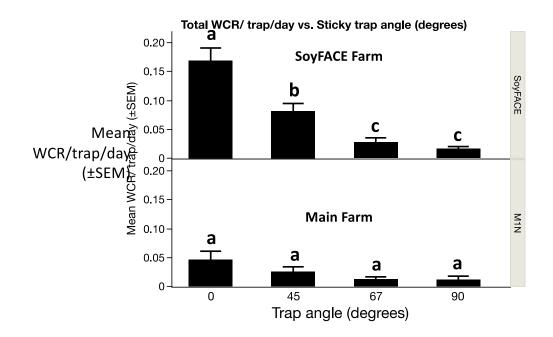


Figure 15. Mean WCR/trap/day (±SEM) vs. Trap angle for sticky traps placed in soybean at two University of Illinois farm locations from July-August, 2023. Data were non-normal and were analyzed using the non-parametric Kruskal-Wallis test, followed by the non-parametric Kruskal-Wallis test, followed by the non-parametric Steel-Dwass method (q=2.569, $\alpha = 0.05$) to perform multiple comparisons within location. Bars bearing the same letter within location are not significantly different at $\alpha = 0.05$.

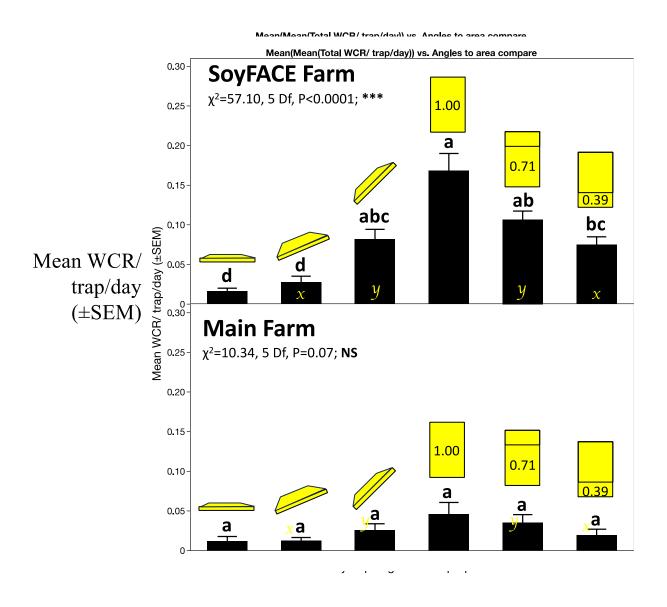


Figure 16. Mean WCR/trap/day (±SEM) vs. sticky trap angles and trap sizes treatments placed in soybean at two University of Illinois farm locations from July-August, 2023. Pairs of bars labeled with the same letter within the bar ("x" or "y") indicate sticky trap treatments that would present the same apparent size when viewed from a horizontal perspective. Traps mounted at 45° and 67° have apparent areas of 0.71 and 0.39, respectively, when compared to a full sticky trap viewed horizontally. Data were non-normal and were analyzed using the non-parametric Kruskal-Wallis test, followed by the non-parametric Kruskal-Wallis test, followed by the nonparametric Steel-Dwass method (q=2.569, $\alpha = 0.05$) to perform multiple comparisons within location. Treatment bars bearing the same letter within location are not significantly different at $\alpha = 0.05$.

Table 11. Comparison of actual WCR abundance measured on angled sticky traps and trap areabased predictions of WCR abundance based on trap area or apparent trap area relative to a full size vertical trap.

Sticky trap angle treatment	Mean WCR abundance (WCR/Trap/d ±SEM) ^a	Area-based abundance prediction (WCR/trap/d ±SEM) ^b	Proportion of full sized WCR trap abundance captured on treatment traps	Does treatment trap abundance match trap area-based prediction? °
Full sized trap at 90° (horiz.)	0.015 ± 0.003	0.000	0.152	No (P=0.0001)
Full sized trap at 67°	0.022 ± 0.005	0.049	0.199	No (P=0.0001)
Full sized trap at 45°	0.061 ± 0.010	0.088	0.510	No (P=0.0067)
Full sized trap at 0° (vertical)	0.124 ± 0.019	0.124	1.000	Yes (P=0.9955)
0.71 of a trap at 0° (vertical)	0.081 ± 0.010	0.088	0.678	Yes (P=0.3574)
0.39 of a trap at 0° (vertical)	0.055 ± 0.009	0.049	0.437	Yes (P=0.3628)

^aMean WCR abundance on sticky trap angle treatments was pooled across Main Farm and SoyFACE Farm locations before analysis. ^bArea-based abundance prediction is based on abundance on full size trap at 0° adjusted by the proportion of trap area or apparent trap area for angled traps. ^cMean WCR abundance on trap treatments was compared to predicted WCR abundance based on trap area or apparent trap area (based on cosine of trap mounting angle) using paired t-tests, 25 DF, α =0.05 [JMP Pro 16, (2021 SAS Institute)].

Evaluation of foliar-applied insecticides for control of soybean insect pests, 2023

Location: University of Illinois Agricultural and Biological Engineering Farm, Urbana, IL (40.070930, -88.213900)

Objective: To evaluate the performance of common foliar-applied, broadcast insecticides for control of bean leaf beetle, green cloverworm, and stink bugs during pod fill.

Materials and Methods: A field experiment was established in a randomized complete block design with 4 replicate blocks and 7 treatments. The experimental units were plots of soybean (Table 1) that were 10 feet wide and 40 feet long; 5 feet of unsprayed border separated plots within a replicate block. The 7 treatments (Table 2) were different rate combinations of conventional and pre-commercial insecticides applied on 29 August 2023 using a CO2-powered backpack sprayer with a 10-foot spray boom (Table 1). Population densities of all insect pests were assessed on 1 September (3 days post-application), 5 September (7 days post-application), 8 September (10 days post-application), and 12 September (14 days post-application) by taking 25 sweeps per plot using a standard 15 inch-diameter polyester sweep net swung perpendicular to the rows through the soybean canopy. Yields were assessed for each plot on 3 October 2023 by harvesting rows 2 and 3 using a small-plot combine (Massey Ferguson 8XP, Kincaid Equipment, Haven, KS) with a built-in weight and moisture monitor (HarvestMaster, Logan, UT).

<u>Data analysis</u>. Insect counts per 25 sweeps (including bean leaf beetle [adults, *Cerotoma trifurcata*], stink bugs [adults and nymphs; green stink bug, *Chinavia hilaris*, brown stink bug, *Euschistus servus*, one-spot stink bug, *Euschistus variolarius*, brown marmorated stink bug, *Halyomorpha halys*], green cloverworm [larvae, *Hypena scabra*]; other pest species were identified and counted, but were not present in sufficient numbers to assess insecticide efficacy) and soybean yield at 13% moisture were analyzed using a generalized linear mixed model where treatment was a fixed effect and replicate block was a random effect. Analyses were performed using SAS (version 9.4, SAS Institute, Cary, NC).

Summary: All insecticides tested reduced densities of bean leaf beetle compared with the untreated control plots at 3-, 7-, 10- and 14-days following application. All materials tested except for Warrior II reduced densities of green cloverworm at 3 days following application. Densities in the untreated plots declined at 7-, 10-, and 14-days following application, though the two rates of A21550[L] and Brigade 2EC maintained green cloverworm populations at densities lower than the untreated plots throughout the experiment. Stink bug densities were relatively low, though all materials except for the low rate of Asana XL reduced stink bugs compared with the untreated plots at 3 days following application; the two rates of A21550[L] resulted in reduced densities compared with the untreated plots and Asana at 10 days following application. None of the materials (and, by extension, none of the insect pests they controlled) affected soybean yield in this experiment.

Funding: Project funding and insecticide materials were provided by Syngenta and Valent.

Acknowledgements: We thank Tim Lecher (Farm Manager) for assisting with planting and plot maintenance, graduate students Yony Callohuari Quispe, and undergraduate students Grayce Montano, Fay Siringoringo, China Carr, Solomon Davenport, and Will Foulke for assisting with plot maintenance and data collection.

Soybean variety	AG31XF2 ^a
Previous crop	Corn
Soil type	Drummer silty clay loam
Tillage	Conventional
Row spacing	30-inch
Seeding rate	140,000 seeds per acre
Planting date	22 May 2023
Herbicide	Pre-emerge: Boundary 6.5 EC ^b (32 oz/a)
	Post-emerge: Liberty ^c (44 oz/a)
Plot size	10 feet (4 rows) wide by 40 feet long; 5 feet (2 rows) of unsprayed
	soybean separated plots within a block
Insecticide treatment	10 gallons of water per acre applied using a CO ₂ -powered backpack
application	sprayer on 29 Aug. 2023 (R5); 20-inch nozzle spacing, 30 psi, 2.5 mph
	ground speed, TeeJet TT11001-VP ^d wide-angle flat spray nozzle tips

 Table 12. Plot information

^a Asgrow, Bayer Crop Science, St Louis, MO; ^b Syngenta Crop Protection, Greensboro, NC; ^c BASF Corporation, Research Triangle Park, NC; ^d Spraying Systems Co., Glendale Heights, IL

Table 13. Insecticide treatments

Trt	Material and rate	Active ingredient and formulation
1	Untreated	n/a
2	A21550[L] ^a (1.03 fl oz/ac)	Plinazolin [®] technology, pre-commercial formulation
3	A21550[L] (1.54 fl oz/ac)	
4	Asana XL ^b (6.4 fl oz/ac)	Esfenvalerate, 0.66 lbs active ingredient per gallon, emulsifiable concentrate (EC)
5	Asana XL (9.6 fl oz/ac)	
6	Brigade 2EC ° (6.4 fl oz/a)	Bifenthrin, 2 lb active ingredient per gallon, EC
7	Warrior II ^a (1.6 fl oz/a)	Lambda-cyhalothrin, 2.08 lb active ingredient per
		gallon, capsule suspension (CS)

^a Syngenta Crop Protection, Greensboro, NC; ^b Valent USA Corporation, Walnut Creek, CA; ^c FMC Corporation, Philadelphia, PA

Table 14. Generalized linear mixed model statistics. Insecticide treatment was the lone fixed effect. The probability distribution used in the analysis is listed in parentheses for each dependent variable.

	DF (numerator,			
Dependent variable	denominator)	Date	F	Р
Bean leaf beetle (normal distribution) ^a	6, 18	1 Sept.	9.83	< 0.001 ^b
	6, 18	5 Sept.	9.01	$< 0.001^{b}$
	6, 18	8 Sept.	10.51	$< 0.001^{b}$
	6, 18	12 Sept.	27.74	$< 0.001^{b}$
Green cloverworm (normal distribution) ^a	6, 18	1 Sept.	7.57	< 0.001 ^b
	6, 18	5 Sept.	9.18	$< 0.001^{b}$
	6, 18	8 Sept.	9.92	$< 0.001^{b}$
	6, 18	12 Sept.	4.63	0.005^{b}
Stink bugs (all spp., stages; normal distribution) ^a	6, 18	1 Sept.	5.68	0.002 ^b
	6, 18	5 Sept.	0.87	0.534
	6, 18	8 Sept.	5.22	0.003 ^b
	6, 18	12 Sept.	2.18	0.094
Yield at 13% moisture (lognormal)	6,18	3 Oct.	2.40	0.070

^a Insect count per 25 sweeps using a sweep net; ^b Effect is significant at $\alpha = 0.05$; ^c No analysis, count = 0 for all plots

Table 15. Mean (± standard error [SE]) bean leaf beetle (BLB, *Certotoma trifurcata*, Coleoptera: Chrysomelidae) adults per 25 sweeps.

Trt.	Treatment	1 Sept. 3 DAAª	5 Sept. 7 DAA	8 Sept. 10 DAA	12 Sept. 14 DAA
1	Untreated	$45.3\pm13.9~a^{b}$	67.5 ± 21.5 a	57.5 ± 17.1 a	36.0 ± 6.1 a
2	A21550[L] (1.03 fl oz/ac)	$2.0\pm0.9\ b$	$1.3\pm0.8\;b$	$2.8\pm0.9\;b$	$1.3\pm0.3\ b$
3	A21550[L] (1.54 fl oz/ac)	$0.0\pm0.0\;b$	$0.8\pm0.5\;b$	$0.8\pm0.3\;b$	$0.8\pm0.3\;b$
4	Asana XL (6.4 fl oz/ac)	$2.0\pm0.4\;b$	8.8 ± 1.7 b	$5.3\pm0.9\ b$	$3.5\pm0.3\ b$
5	Asana XL (9.6 fl oz/ac)	$1.8\pm0.5\;b$	$6.3 \pm 1.3 \text{ b}$	$1.0\pm0.6\;b$	$4.5\pm1.9~b$
6	Brigade 2EC (6.4 fl oz/a)	$0.3\pm0.3\;b$	$1.5\pm0.6\;b$	$0.0\pm0.0\;b$	$0.3\pm0.3\;b$
7	Warrior II (1.6 fl oz/a)	$2.0 \pm 1.7 \text{ b}$	$4.3\pm1.3~b$	$1.5 \pm 1.0 \text{ b}$	1.8 ± 1.0 b

^a Days after application; ^b Means followed by the same letter within a column are not different based on the Fisher method of least significant difference ($\alpha = 0.05$)

Trt.	Treatment	1 Sept. 3 DAAª	5 Sept. 7 DAA	8 Sept. 10 DAA	12 Sept. 14 DAA
1	Untreated	$23.5\pm4.6\;a^{b}$	$6.3 \pm 2.0 \text{ ab}$	5.0 ± 1.6 a	1.8 ± 0.3 a
2	A21550[L] (1.03 fl oz/ac)	$4.8\pm2.9~b$	$0.0\pm0.0\ c$	$0.0\pm0.0\;b$	$0.0\pm0.0\;b$
3	A21550[L] (1.54 fl oz/ac)	$0.8\pm0.3\;b$	$0.0\pm0.0\ c$	$0.0\pm0.0\;b$	$0.0\pm0.0\;b$
4	Asana XL (6.4 fl oz/ac)	$3.5\pm0.6\ b$	3.5 ± 1.5 b	$4.0 \pm 1.1 \text{ a}$	1.0 ± 0.6 ab
5	Asana XL (9.6 fl oz/ac)	$4.3\pm1.7\ b$	$3.8\pm0.6\ b$	1.5 ± 0.5 b	$1.3 \pm 0.5 \ a$
6	Brigade 2EC (6.4 fl oz/a)	$0.3\pm0.3\;b$	$0.5\pm0.5~\text{c}$	$0.0\pm0.0\;b$	$0.0\pm0.0\;b$
7	Warrior II (1.6 fl oz/a)	16.0 ± 6.7 a	$7.3 \pm 1.1 \text{ a}$	5.3 ± 0.8 a	$1.3 \pm 0.5 a$

Table 16. Mean (\pm SE) total green cloverworm (*Hypena scabra*, Noctuidae: Erebidae) larvae per 25 sweeps.

^a Days after application; ^b Means followed by the same letter within a column are not different based on the Fisher method of least significant difference ($\alpha = 0.05$)

Table 17. Mean (\pm SE) total pest stink bug (Hemiptera: Pentatomidae) adults and nymphs per 25 sweeps. Includes green stink bug (*Chinavia hilaris*), brown stink bug (*Euschistus servus*), and one-spotted stink bug (*Euschistus variolarius*)

Trt.	Treatment	1 Sept. 3 DAA ^a	5 Sept. 7 DAA	8 Sept. 10 DAA	12 Sept. 14 DAA
1	Untreated	$2.5\pm0.6\;a^{\text{b}}$	1.3 ± 0.9 a	2.8 ± 0.9 a	2.8 ± 0.6 a
2	A21550[L] (1.03 fl oz/ac)	$0.8\pm0.3\;b$	0.0 ± 0.0 a	0.3 ± 0.3 c	0.0 ± 0.0 a
3	A21550[L] (1.54 fl oz/ac)	$0.8\pm0.5\;b$	0.0 ± 0.0 a	$0.5\pm0.3~\text{c}$	$0.5\pm0.5~\mathrm{a}$
4	Asana XL (6.4 fl oz/ac)	2.8 ± 0.4 a	$1.5 \pm 1.2 \text{ a}$	$3.3 \pm 0.6 a$	2.5 ± 1.7 a
5	Asana XL (9.6 fl oz/ac)	$0.8\pm0.3\;b$	1.3 ± 0.6 a	$2.0\pm0.4~ab$	1.5 ± 0.6 a
6	Brigade 2EC (6.4 fl oz/a)	$0.5\pm0.3\;b$	$1.0\pm0.7~\mathrm{a}$	$1.0 \pm 0.4 \ bc$	0.0 ± 0.0 a
7	Warrior II (1.6 fl oz/a)	$0.5\pm0.3\;b$	$1.8 \pm 0.9 \; a$	1.0 ± 0.4 bc	$1.3 \pm 0.5 \ a$

^a Days after application; ^b Means followed by the same letter within a column are not different based on the Fisher method of least significant difference ($\alpha = 0.05$)

Table 18. Mean (± SE) soybean yield in bushels per acre, corrected to 13% moisture

Trt.	Treatment	3 Oct. 2023
1	Untreated	$76.0 \pm 1.8 \ a^{a}$
2	A21550[L] (1.03 fl oz/ac)	75.4 ± 1.0 a
3	A21550[L] (1.54 fl oz/ac)	72.1 ± 1.6 a
4	Asana XL (6.4 fl oz/ac)	74.8 ± 1.2 a
5	Asana XL (9.6 fl oz/ac)	72.6 ± 2.2 a
6	Brigade 2EC (6.4 fl oz/a)	70.5 ± 1.5 a
7	Warrior II (1.6 fl oz/a)	69.3 ± 1.9 a

^a Means followed by the same letter within a column are not different based on the Fisher method of least significant difference ($\alpha = 0.05$)

Evaluation of Aviator SC alone and in combination with Steward for control of soybean <u>caterpillar pests</u>, 2023

Location: University of Illinois Agricultural and Biological Engineering Farm, Urbana, IL (40.070930, -88.213900)

Objective: To evaluate the performance of foliar insecticide combinations for control of caterpillar pests, particularly green cloverworm (*Hypena scabra* Lepidoptera: Erebidae)

Materials and Methods: A field experiment was established in a randomized complete block design with 4 replicate blocks and 4 treatments. The experimental units were plots of soybean (Table 1) that were 10 feet wide and 40 feet long; 5 feet of unsprayed border separated plots within a replicate block. The 4 treatments (Table 2) were different rate combinations of insecticides applied on 11 August 2023 using a CO2-powered backpack sprayer with a 10-foot spray boom (Table 1). Population densities of all insect pests were assessed on 15 August (4 days post-application), 18 August (7 days post-application), 21 August (10 days post-application), August 25 (14 days post-application), September 1 (21 days post-application), and September 8 (28 days post-application) by taking 25 sweeps per plot using a standard 15 inch-diameter polyester sweep net swung perpendicular to the rows through the soybean canopy. Yields were assessed for each plot on 3 October 2023 by harvesting rows 2 and 3 using a small-plot combine (Massey Ferguson 8XP, Kincaid Equipment, Haven, KS) with a built-in weight and moisture monitor (HarvestMaster, Logan, UT).

Data analysis. Insect counts per 25 sweeps (including green cloverworm [larvae, *Hypena scabra*], bean leaf beetle [adults, *Cerotoma trifurcata*], stink bugs [adults and nymphs; green stink bug, *Chinavia hilaris*, brown stink bug, *Euschistus servus*, one-spot stink bug, *Euschistus variolarius*, brown marmorated stink bug, *Halyomorpha halys*]; other pests were also identified, but did not occur at sufficient densities to evaluate insecticide performance) and soybean yield were analyzed using a generalized linear mixed model, where treatment was a fixed effect and replicate block was a random effect. Analyses were performed using SAS (version 9.4, SAS Institute, Cary, NC). A normal distribution was used for insect count data in those cases where a model using a negative binomial distribution did not converge due to the large number of "0"-values.

Summary: All insecticides tested reduced densities of green cloverworm compared with the untreated control plots throughout the course of the evaluation. Other insect population densities were generally low; only bean leaf beetle at 14 days following application was impacted by the insecticide treatment, and the impact did not reflect effective control. (Note that these materials were not expected to impact this pest). Yield was not affected by insecticide treatment, indicating the densities of green cloverworm we observed were not sufficient to reduce soybean yields.

Funding: Project funding and insecticide materials were provided by Albaugh, LLC via SynTech Research (Stilwell, KS).

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Soybean variety	Asgrow AG31XF2 ^a
Previous crop	Corn
Soil type	Drummer silty clay loam
Tillage	Conventional tillage
Row spacing	30-inch
Seeding rate	140,000 seeds per acre
Planting date	22 May 2023
Herbicide	Pre-emerge: Boundary 6.5 EC ^b (32 oz/a)
	Post-emerge: Liberty ^c (44 oz/a)
Plot size	10 feet (4 rows) wide by 40 feet long; 5 feet (2 rows) of unsprayed
	soybean separated plots within a block
Insecticide treatment	10 gallons of water per acre applied using a CO ₂ -powered backpack
application	sprayer on 11 Aug. 2023 (R5); 20-inch nozzle spacing, 30 psi, 2.5 mph
	ground speed, TeeJetXR8001VS ^d extended range flat fan nozzle tips

 Table 19. Plot information

^a Bayer Crop Science, St. Louis, MO; ^b Syngenta Crop Protection, Greensboro, NC; ^c BASF Corporation, Research Triangle Park, NC; ^d Spraying Systems Co., Glendale Heights, IL

Table 20. Insecticide treatments

Trt	Material and rate	Active ingredient and formulation
1	Untreated	n/a
2	Intrepid 2F ^a (6 oz/a)	Methoxyfenozide, 2 lb. active ingredient [AI] per gallon, flowable
	+ Steward EC b (7 oz/a)	+ Indoxacarb, 1.25 lb. AI per gallon, emulsifiable concentrate
3	Aviator 2SC ° (6 oz/a)	Methoxyfenozide, 2 lb. AI per gallon, suspension concentrate
	+ Steward EC (7 oz/a)	
4	Aviator 2SC (6 oz/a)	

^a Corteva Agriscience, Indianapolis, IN; ^b FMC Corporation, Philadelphia, PA; ^c Albaugh LLC, Ankeny, IA

	DF			
Dependent variable	(numerator, denominator)	Date	F	Р
Green cloverworm (normal distribution) ^a	3,9	15 Aug.	13.59	0.001 ^b
, , , , , , , , , , , , , , , , , , ,	3, 9	18 Aug.	27.83	$< 0.001^{b}$
	3, 9	21 Aug.	31.88	$< 0.001^{b}$
	3, 9	25 Aug.	99.53	$< 0.001^{b}$
	3, 9	1 Sept.	123.87	$< 0.001^{b}$
	3, 9	8 Sept	4.49	0.035 ^b
Bean leaf beetle (negative binomial distribution) ^a	3, 9	15 Aug.	1.96	0.191
,	3, 9	18 Aug.	1.56	0.267
	3, 9	21 Aug.	1.40	0.305
	3, 9	25 Aug.	4.35	0.037^{b}
	3, 9	1 Sept.	2.75	0.105
	3, 9	8 Sept	2.95	0.091
Stink bugs (all spp., stages; normal distribution) ^a	3, 9	15 Aug.	0.36	0.783
<i>,</i>	3, 9	18 Aug.	0.33	0.802
	3, 9	21 Aug.	1.94	0.194
	3, 9	25 Aug.	0.91	0.474
	3, 9	1 Sept.	0.69	0.583
	3, 9	8 Sept	0.24	0.866
Yield at 13% moisture (lognormal)	3, 9	3 Oct.	0.92	0.471

Table 21. Generalized linear mixed model statistics. Insecticide treatment was the lone fixed effect. The probability distribution used in the analysis is listed in parentheses for each dependent variable.

^a Insect count per 25 sweeps using a sweep net; ^b Effect is significant at $\alpha = 0.05$

		15 Aug.	18 Aug.	21 Aug.	25 Aug.	1 Sept.	8 Sept.
Trt.	Treatment	4 DAA ^a	7 DAA	10 DAA	14 DAA	21 DAA	28 DAA
1	Untreated	$10.0 \pm 2.4 \ a^{b}$	$34.5 \pm 6.5 \text{ a}$	$36.3 \pm 6.2 \text{ a}$	$52.8 \pm 5.1 \text{ a}$	31.5 ± 2.5 a	6.0 ± 1.5 a
2	Intrepid 2F ^a (6 oz/a) + Steward EC ^b (7 oz/a)	$0.8\pm0.5\;b$	$0.0\pm0.0\;b$	$0.3\pm0.3~b$	$1.0\pm1.0\;b$	$0.8\pm0.5\;b$	$1.8 \pm 1.1 \text{ b}$
3	Aviator 2SC ^c (6 oz/a) + Steward EC (7 oz/a)	$0.0\pm0.0\;b$	$0.0\pm0.0\ b$	$0.0\pm0.0\;b$	$0.5\pm0.5\;b$	$0.3\pm0.3~\text{b}$	$0.8\pm0.3\;b$
4	Aviator 2SC (6 oz/a)	$2.5\pm0.9\ b$	$1.5\pm0.3\;b$	$4.8\pm1.6\ b$	$5.3\pm0.6\ b$	$2.5\pm1.0\;b$	$2.3\pm1.1\;b$

 Table 22. Mean (± standard error [SE]) total green cloverworm (Hypena scabra, Noctuidae: Erebidae) larvae per 25 sweeps.

^a Days after application; ^b Means followed by the same letter within a column are not different based on the Fisher method of least significant difference ($\alpha = 0.05$)

Table 23. Mean (± SE) bean leaf beetle (BLB, *Certotoma trifurcata*, Coleoptera: Chrysomelidae) adults per 25 sweeps.

		15 Aug.	18 Aug.	21 Aug.	25 Aug.	1 Sept.	8 Sept.
Trt.	Treatment	4 DAA ^a	7 DAA	10 DAA	14 DAA	21 DAA	28 DAA
1	Untreated	$7.0 \pm 1.8 \ a^{b}$	20.0 ± 2.7 a	6.3 ± 0.8 a	$14.3\pm1.8~b$	26.0 ± 6.5 a	26.0 ± 5.1 a
2	Intrepid 2F ^a (6 oz/a) + Steward EC ^b (7 oz/a)	$3.8\pm0.5~a$	27.3 ± 3.4 a	7.3 ± 1.7 a	26.0 ± 0.9 a	48.8 ± 8.4 a	$47.0 \pm 4.5 \text{ a}$
3	Aviator $2SC^{\circ}$ (6 oz/a) + Steward EC (7 oz/a)	5.8 ± 1.0 a	27.3 ± 1.8 a	$10.5\pm1.9~a$	$28.0\pm2.5~a$	$45.3\pm4.6\ a$	38.0 ± 6.1 a
4	Aviator 2SC (6 oz/a)	$7.8 \pm 1.1 \text{ a}$	24.8 ± 2.9 a	7.8 ± 2.1 a	26.3 ± 5.7 a	$35.0\pm4.7~a$	40.8 ± 4.7 a

^a Days after application; ^b Means followed by the same letter within a column are not different based on the Fisher method of least significant difference ($\alpha = 0.05$)

Table 24. Mean (\pm SE) total stink bug (Hemiptera: Pentatomidae) adults and nymphs per 25 sweeps. Includes green stink bug (*Chinavia hilaris*), brown stink bug (*Euschistus servus*), one-spotted stink bug (*Euschistus variolarius*), and brown marmorated stink bug (*Halyomorpha halys*).

		15 Aug.	18 Aug.	21 Aug.	25 Aug.	1 Sept.	8 Sept.
Trt.	Treatment	4 DAA ^a	7 DAA	10 DAA	14 DAA	21 DAA	28 DAA
1	Untreated	$0.0\pm0.0~a^{b}$	0.5 ± 0.5 a	0.0 ± 0.0 a	0.3 ± 0.3 a	$1.25 \pm 0.5 \ a$	1.3 ± 0.8 a
2	Intrepid 2F ^a (6 oz/a) + Steward EC ^b (7 oz/a)	0.3 ± 0.3 a	0.0 ± 0.0 a	0.5 ± 0.3 a	1.0 ± 0.4 a	1.5 ± 0.9 a	1.8 ± 1.4 a
3	Aviator 2SC ^c (6 oz/a) + Steward EC (7 oz/a)	0.3 ± 0.3 a	$0.5\pm0.5\;a$	0.0 ± 0.0 a	0.5 ± 0.5 a	$0.5\pm0.3\ a$	$2.8\pm0.9\;a$
4	Aviator 2SC (6 oz/a)	0.3 ± 0.3 a	$0.5\pm0.5\;a$	0.3 ± 0.3 a	1.0 ± 0.4 a	1.0 ± 0.4 a	2.3 ± 1.9 a

^a Days after application; ^b Means followed by the same letter within a column are not different based on the Fisher method of least significant difference ($\alpha = 0.05$)

Table 25. Mean (\pm SE) soybean yield in bushels per acre, corrected to 13% moisture.

Trt.	Treatment	3 Oct. 2023
1	Untreated	$54.3 \pm 7.3 \ a^a$
2	Intrepid 2F ^a (6 oz/a)	62.7 ± 1.9 a
	+ Steward EC ^b (7 oz/a)	
3	Aviator 2SC ^c (6 oz/a)	63.9 ± 5.6 a
	+ Steward EC (7 oz/a)	
4	Aviator 2SC (6 oz/a)	62.1 ± 2.4 a

^a Means followed by the same letter within a column are not different based on the Fisher method of least significant difference ($\alpha = 0.05$)



2023 Field Crop Entomology summer crew, from left: Nick Seiter, Will Foulke, Grayce Montano, China Carr, Fay Siringoringo, Solomon Davenport, Ashley Decker