

2022 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



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Table of Contents

| Item | Page |
|---|------|
| Growing Season Weather and Climate Summary | 1 |
| Production Overview | 9 |
| Illinois Statewide Insect Survey Results | 10 |
| Soybean Gall Midge Survey – Illinois 2022 | 16 |
| Dectes stem borer survey – larvae and stem tunneling | 18 |
| Regional corn rootworm adult sticky-trap survey | 20 |
| Bt resistance in Illinois populations of western and northern corn rootworm | 21 |
| Evaluations of insecticides and Bt hybrids for control of corn rootworm in Illinois | 36 |
| A. Evaluation of Aztec HC on non-CRW Bt and pyramided CRW trait hybrids | 37 |
| B. Evaluation of Nurizma and Force Evo for corn rootworm control | 40 |
| C. Evaluation of SmartStax Pro for corn rootworm control | 43 |
| D. Evaluation of commercial and pre-commercial soil-applied pesticides for corn rootworm control | 46 |
| E. Evaluation of 3RIVE insecticide formulations for control of corn rootworm larvae, 2022 | 49 |
| F. Evaluation of MBI-306 and commercial insecticides for corn rootworm control | 52 |
| G. Evaluation of liquid soil insecticides in combination with Bt trait packages | 55 |
| H. Large-plot evaluation of in-furrow soil insecticides for rootworm control | 58 |
| I. Evaluation of Ampex EZ for control of corn rootworm larval damage | 60 |
| J. Evaluation of pyramided Bt hybrids and Force Evo for control of corn rootworm – Monmouth 2022 | 63 |
| K. Corn rootworm trait demonstration – Freeport, 2022 | 66 |
| L. Corn rootworm trait demonstration – Oglesby, 2022 | 68 |

Table of Contents (continued)

| Item | Page |
|---|------|
| Biocontrol of rootworms using nematodes – Year 2 | 70 |
| Sticky trap orientation affects western corn rootworm capture | 71 |
| Evaluation of insecticide seed treatments for corn insect control | 77 |
| Evaluation of insecticide seed treatments for control of early season soybean insects | 80 |
| Evaluation of foliar-applied insecticides for control of soybean insect pests, 2022 | 83 |
| University of Illinois Plant Clinic – Agronomic Crops Report, 2022 | 87 |

2022 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, 2022 brought its own interesting characteristics and events. From drought to extreme rainfall and early season heat waves to a very pleasant fall, in this article I will review the 2022 growing season from a climatological perspective.

Rainy, Gloomy April and an Early Start to Summer

For the second straight year, both January and February temperatures were 3 to 4 degrees below normal across the state. Despite the 2nd warmest December on record statewide in 2021, the colder months of January and February brought soil temperatures much closer to normal across the state as we headed into spring.

Spring 2022 came with typically variable temperatures. Much of central and northern Illinois swung from temperatures that were 20 to 25 degrees below normal to temperatures that were 15 to 20 degrees above normal in a matter of days. By comparison, April temperatures were much less variable, with most places having 20 to 25 days in April with below normal temperatures. A persistent Pacific pattern continually brought cool, cloudy weather across the Midwest in April. In fact, the persistently cloudy weather resulted in April having the 5th lowest average daily solar radiation (i.e., sunlight reaching the ground) on record in Champaign (Figure 1). The cooler April weather also resulted in near normal last spring freeze dates across the state. Most of southern Illinois got their last spring freeze in the first week of April, whereas places north of Interstate 64 observed their last spring freeze in the third and fourth weeks of the month, anywhere between 1 and 5 days later than normal.



Figure 1. Plot shows daily average solar radiation measured at the Champaign Illinois Climate Network site.

The summer weather we were all hoping for in April came to us with a vengeance in May. The week of May 9th to 15th was one of the warmest May weeks on record statewide, with high temperatures in the mid- to upper-90s, 20 to 25 degrees above normal. Rockford broke daily high temperature records in four consecutive days that week, and both Rockford and Chicago recorded their earliest 70-degree nighttime low temperature on record. I heard many reports of

May-planted corn "popping out of the ground" in response to the rapidly accumulating growing degree days in May.

Overall, March and May were 1 to 6 degrees warmer than normal across Illinois last year, sandwiching an April that was 2 to 6 degrees colder than normal statewide (Figure 2).



Monthly Average Temperature Departure (°F)

Figure 2. Maps show average temperature departures from 1991-2020 normal in March, April, and May 2022.

Just Enough Spring Rain to Delay Planting

Both February and March were wetter than normal statewide, keeping topsoils saturated through the first half of April. While April was not exceedingly wet, frequent small rain and persistent cloudy, cool weather kept the moisture in the ground. For example, Macomb had 25 out of 30 April days with measurable rain, but still ended the month 0.5 inch drier than normal. The rainy, cloudy, and cooler April weather did very little to make workable field conditions, resulting in widespread planting delays and poor or uneven emergence for those who were able to get into the field prior to late April. The less-than-ideal April weather also complicated cover crop termination, pre-emergence herbicide application, and several other important spring field activities. May gave us a break from the clouds and rain folks were able to make great (re) plant progress in the first couple weeks of the month (Figure 3).



Figure 3. Maps show total precipitation departures from 1991-2020 normal in March, April, and May 2022.

Mild(er) Summer

June began much as May ended, with well above average temperatures across the state. In particular, the week of June 13-18 was extremely warm across the state, with high temperatures in the upper 90s on multiple days, and even into the 100s in a few locations. Combined with high humidity, heat index values approached 120 degrees in southern Illinois on June 13th and 14th. The humidity also made for a few very warm nights, including a 78-degree low temperature in Peoria and an 83-degree low at Chicago Midway, the latter of which broke Midway's previous June low temperature record by 4 degrees. High nighttime temperatures can be detrimental to crop yield if timed during critical reproductive stages. The heat finally broke in late June, and July and August were relatively mild, ending 0.1 and 0.2 degrees warmer than normal statewide, respectively (Figure 4).



Monthly Average Temperature Departure (°F)

Figure 4. Maps show monthly average temperature departures from normal in (left) June, (middle) July, and (right) August 2022.

Lower humidity allowed nighttime temperatures to dip into the low 60s and even upper 50s in July and August. As Figure 5 shows, the summer average dewpoint temperature – an indicator of humidity – was 2 degrees lower than in 2021 in Springfield. Overall lower dewpoint temperatures last decreased nighttime dew formation and daytime leaf wetness, which reduced fungal disease pressure for corn and soybeans. The persistently high humidity in summer 2021 was a major contributor to exceedingly high disease pressure, including widespread tar spot issues. This past summer, the lower humidity levels both reduced disease pressure and made for a more pleasant summer to be outside.



Figure 5. Plot shows summer average dewpoint temperatures in Springfield between 1948 and 2022.

Can't We All Just Share the Rain?

Illinois spent much of summer 2022 under the influence of a persistent atmospheric ridge pattern to our west and northwest, which brought cooler, drier air out of central Canada and was responsible for our milder summer weather. However, this pattern also brought a lack of consistent summer rainfall, which caused pockets of drought to pop up in virtually all corners of the state during the growing season. While June was the 25th driest on record statewide, it was a top 10 driest June on record in Champaign-Urbana (0.81" total), Danville (1.17" total), Belleville (1.20" total), and Carbondale (0.68" total). The result of hot and dry June weather was a rapid drop in soil moisture conditions, and a flash drought that affected parts of east-central Illinois from Bloomington-Normal to Danville.

July brought relief (in some cases too much relief) to south-central Illinois but kept most of central Illinois somewhat drier than normal. A combined June and July precipitation of over 7 inches in Champaign and Vermilion Counties severely stressed crops and gardens. The only silver lining was that I did not have to mow my grass once between June 20th and August 20th, which was nice given the price of gas. Thankfully, August rains provided much needed relief to drought areas in central Illinois and turned what looked like a bad crop year into a decent one.

While most of central Illinois was dealing with drought, parts of southwest and south-central Illinois were more than willing to share their precipitation. July and August brought a series of very intense rainfall events from the St. Louis Metro East to the Effingham-Olney area. A series of storms in the early morning of July 26th produced 4 to 8 inches of rain in less than eight hours across the Metro East, causing widespread flooding in Cahokia Heights, Belleville, and surrounding communities (Figure 6).



Figure 6. Photo of flooding in Belleville, Illinois. Source: St. Clair County Sheriff.

Just two weeks later, a swath of Effingham, Jasper, and Richland Counties picked up 7 to 10 inches of rain in less than 24 hours, causing widespread flooding in nearly mature corn and soybean fields. Farms and fields were also flooded downstream along the Little Wabash and Embarras Rivers, with significant crop damage in a large part of east-southeast Illinois. Days later, a series of storms produced up to 11 inches of rain in less than 48 hours in parts of Jo Daviess and Stephenson Counties in northwest Illinois. The rain inundated roads, flooded homes in and around Freeport, and flooded farms along the Pecatonica River.

Pleasant and Dry Fall

For my money, fall is the best season in Illinois. The cooler and drier weather encourages us to enjoy fall festivals, celebrate harvest, and enjoy the wonderful fall color. For all these reasons, we couldn't have asked for a nicer fall season than the one we got in 2022. All three months of climatological fall – September, October, and November – were within 1 degree of normal. Following one of the warmest and wettest Octobers on record statewide in 2021, this past October was much drier and milder, both facilitating outdoor activities and a timely harvest. The lack of humidity allowed nighttime temperatures in October to dip into the mid to upper 30s, resulting in first fall freeze events in the first three weeks of October across the state, within about 1 week of normal.

While the dry weather was great for harvest activities, it did not help our ongoing drought situation. As Figure 7 shows, all three fall months were drier than normal statewide, with season-total deficits ranging from less than one inch in northwest Illinois to over 7 inches in far southern Illinois.



Figure 7. Maps show total monthly precipitation departures from normal in (left) September, (middle) October, and (right)

November 2022.

The dryness in fall delayed winter wheat emergence, but otherwise did not have significant direct impacts on agriculture. However, the extreme fall dryness in southern Illinois was a part of a larger regional drought pattern throughout the Ohio River Valley. In fact, the lower Ohio basin, from Louisville, KY to Cairo, IL, had less than 50% of normal fall precipitation in 2022. Because the Ohio contributes over 60% of flow to the lower Mississippi River (south of Cairo), the Ohio Valley drought contributed mightily to near-record low flows on the Mississippi. River levels from St. Louis all the way to the Gulf were somewhat to greatly below normal, restricting barge traffic moving grain out of the Midwest. The farmdoc Daily article from Arita *et al.* summarizes the low-flow issues along the Mississippi River and the impacts to agriculture economics (https://farmdocdaily.illinois.edu/2022/11/low-mississippi-river-barge-disruptions-effects-on-grain-barge-movement-basis-and-fertilizer-prices.html).

As Figure 8 shows, Mississippi River streamflow has improved since the fall, but is still well below the long-term average. The Ohio River basin has improved its drought condition, but large rivers tend to be a lagging indicator, meaning streamflow may not recover entirely for months.



Figure 8. Streamflow along the Mississippi River at Memphis. The orange line shows current streamflow while the black line shows the long-term average.

Conclusion

As with every year, the 2022 growing season was a different experience for different folks around the state. Following a cold and gloomy April and a hot May and June, temperatures between July and November were mild and pleasant. Humidity levels were much lower than in past years, helping reduce stress from extreme heat and disease. Mild and dry fall weather facilitated timely harvest, which was greatly beneficial given planting delays from less-than-ideal April weather.

Throughout the growing season, most areas between Interstates 70 and 80 dealt with persistently dry conditions that evolved into drought for some spots in June and July. While crop impacts from drought were less intense than in past drought years, yield impacts were reported from Monmouth to Champaign, as much of central Illinois received between 30 and 60% of normal growing season precipitation. Meanwhile, areas between St. Louis and Effingham were dealing with extremely wet conditions from a handful of intense rainfall events in July and August. Field flooding around and along the Little Wabash and Embarras River caused some isolated impacts to crops in east-southeast Illinois.

Great harvest weather in October and November also helped persist drought throughout southern Illinois and the lower Ohio River basin. These drought conditions contributed to severely low flow and reduced barge traffic on the lower Mississippi River through the fall and early winter.

Much like the previous year, 2022 brought its own set of diverse challenges and benefits to agriculture. Another typically atypical weather year in Illinois.

2022 Production Overview

Giovani Preza Fontes, Assistant Professor, Field Crop Agronomy University of Illinois Department of Crop Sciences

Every crop year brings its own set of challenges during the growing season. The big story of the 2022 growing season in Illinois has been dry weather and related crop stress symptoms at times in some parts of the state. Despite a slow start to the planting season, followed by a hot and dry summer, the USDA-NASS projections showed that crop yields were better than most expected. A summary of the Illinois soybean, corn, and winter wheat production from 2018 to 2022 is shown in Table 1.

Corn was planted about two weeks later than normal, on approximately 10.8 million acres in 2022, down 2% from 2021. Yet, it is estimated that Illinois corn farmers raised 2.27 billion bushels, up 3% from last year. The average corn yield is estimated at a record of 214 bushels per acre, up 12 bushels from 2021. The previous yield record was set in 2018 at 210 bushels per acre.

Soybean planted and harvested acres in 2022 were up 2% from the previous year. It is estimated that Illinois soybean farmers harvested 677.3 million bushels on 10.75 million acres, averaging 63 bushels per acre.

Winter wheat harvested area in 2022 is estimated at 560,000 acres, down 8% from the previous year. Similar to 2021, the average yield is estimated at 79 bushels per acre. Production in 2022 was 44.2 million bushels compared to 48.2 million bushels in 2021.

| | 2022 Producti | on Overview | rom 2018 to 2 | 2022 | |
|-----------------------------|----------------------|-------------|---------------|------------|------------|
| Soybean | 2022 ^a | 2021 | 2020 | 2019 | 2018 |
| Acres planted | 10,800,000 | 10,600,000 | 10,300,000 | 9,950,000 | 10,800,000 |
| Acres harvested | 10,750,000 | 10,550,000 | 10,250,000 | 9,860,000 | 10,500,000 |
| Yield (bushels per acre) | 63 | 64 | 60 | 54 | 63.5 |
| Price received (per | \$14.00 ^a | \$13.50 | \$10.90 | \$8.84 | \$8.74 |
| bushel) | | | | | |
| Corn | 2022 ^a | 2021 | 2020 | 2019 | 2018 |
| Acres planted | 10,800,000 | 11,000,000 | 11,300,000 | 10,500,000 | 11,000,000 |
| Acres harvested (grain) | 10,600,000 | 10,800,000 | 11,100,000 | 10,200,000 | 10,800,000 |
| Yield (bushels per acre) | 214 | 207 | 191 | 181 | 210 |
| Price received (per | \$6.70ª | \$5.96 | \$4.46 | \$3.55 | \$3.62 |
| bushel) | | | | | |
| Wheat | 2022 ^a | 2021 | 2020 | 2019 | 2018 |
| Acres planted | 650,000 | 670,000 | 570,000 | 650,000 | 600,000 |
| Acres harvested | 560,000 | 610,000 | 520,000 | 550,000 | 560,000 |
| Yield (bushels per acre) | 79 | 79 | 68 | 67 | 66 |
| Price received (per bushel) | \$9.10 ^a | \$6.43 | \$5.39 | \$5.06 | \$4.77 |

^a 2022 prices are projections from the December 2022 USDA World Agricultural Supply and Demand Estimates for the marketing year beginning September 2021; prices from 2018-2021 are the historical marketing year averages for price received. Data obtained from the USDA-NASS Quick Stats database (https://quickstats.nass.usda.gov); accessed 6 January 2022.

2022 Illinois Statewide Insect Survey Results

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 eleven of the last twelve years (2011, 2013-2022). Methods of the survey have remained the same throughout the years, with the goal of survey to estimate 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 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 | | | | | | N | r | 7 | | _ |
|-------------------|---------------------|-------------------|--------------------|-----------------|-----------------|-------------|-------------|------------------------|------------|----------------------|
| | Leaf tle | pe spis | nese tle | nern W | nern W | CR | oppe | vorn Jers | Bugs | Sten er |
| | Bean Leaf Beetle | Grape Colaspis | Japanese Beetle | Northern CRW | Southern CRW | Western CRW | Grasshopper | Cloverworm/ Loopers | Stink Bugs | Dectes Stem Borer |
| | | | | | | M | Ð | С | •1 | Γ |
| Northwest | 0.10 | 0.80 | 48.40 | 7.80 | 0.90 | 0.50 | 4.90 | 0.10 | 1.60 | 0.00 |
| Northeast | 1.10 | 0.20 | 39.30 | 18.00 | 1.70 | 1.00 | 6.80 | 0.00 | 2.90 | 0.30 |
| West | 2.30 | 0.50 | 107.60 | 9.10 | 0.90 | 0.00 | 9.50 | 3.70 | 2.40 | 0.00 |
| Central | 1.00 | 0.5 | 7.50 | 0.10 | 2.30 | 0.00 | 2.80 | 2.10 | 0.90 | 0.00 |
| East | 2.90 | 1.40 | 10.50 | 0.20 | 0.80 | 0.20 | 6.40 | 0.90 | 0.10 | 0.00 |
| West Southwest | 1.44 | 2.80 | 35.20 | 1.36 | 1.28 | 0.00 | 8.64 | 2.32 | 2.56 | 0.00 |
| East | 1.77 | 2.00 | 33.20 | 1.50 | 1.20 | 0.00 | 0.04 | 2.52 | 2.50 | 0.00 |
| Southeast | 1.36 | 1.52 | 9.76 | 0.40 | 1.28 | 0.56 | 4.00 | 0.32 | 1.36 | 0.08 |
| Southwest | 0.00 | 5.07 | 2.13 | 0.00 | 2.53 | 0.00 | 2.80 | 4.13 | 0.53 | 6.40 |
| Southeast | 0.50 | 4.90 | 4.60 | 0.00 | 1.50 | 0.00 | 3.80 | 2.5 | 1.00 | 2.30 |
| STATE | | | | | | | | | | |
| AVERAGE | 1.19 | 1.97 | 29.44 | 4.11 | 1.47 | 0.25 | 5.52 | 1.79 | 1.48 | 1.01 |

Table 1. Average number of insects per 100 sweeps on the edge of the field (2022).

| District | f | | | _ | _ | | er | m | S | m |
|-------------------|---------------------|-------------------|--------------------|-----------------|-----------------|----------------|-------------|------------------------|------------|----------------------|
| | Bean Leaf Beetle | Grape Colaspis | Japanese Beetle | Northern CRW | Southern CRW | Western CRW | Grasshopper | Cloverworm / Looper | Stink Bugs | Dectes Stem Borer |
| | Bea | C C | Ja I |) N | So So | M | Gra | Clov /I | Stiı | Dec |
| Northwest | 0.30 | 0.00 | 45.00 | 4.40 | 1.40 | 0.30 | 2.50 | 0.60 | 2.13 | 0.00 |
| Northeast | 1.20 | 0.10 | 26.80 | 11.90 | 2.40 | 1.20 | 2.80 | 0.30 | 2.10 | 0.00 |
| West | 2.90 | 5.70 | 80.80 | 2.50 | 1.50 | 0.10 | 8.40 | 4.30 | 2.20 | 0.00 |
| Central | 0.70 | 0.80 | 6.50 | 0.70 | 14.80 | 0.70 | 2.80 | 1.90 | 2.20 | 0.00 |
| East | 6.00 | 0.50 | 7.90 | 0.40 | 1.00 | 0.30 | 3.80 | 1.40 | 0.70 | 0.00 |
| West Southwest | 1.60 | 2.08 | 20.88 | 0.40 | 0.64 | 0.00 | 3.12 | 1.52 | 1.60 | 0.00 |
| East Southeast | 0.72 | 2.08 | 4.88 | 0.64 | 1.36 | 0.16 | 2.88 | 0.48 | 1.04 | 0.16 |
| Southwest | 0.27 | 7.33 | 1.07 | 0.00 | 2.80 | 0.00 | 4.27 | 4.53 | 0.80 | 3.33 |
| Southeast | 0.40 | 4.30 | 6.30 | 0.00 | 1.10 | 0.20 | 2.20 | 1.50 | 0.70 | 1.33 |
| STATE AVERAGE | 1.57 | 2.54 | 22.24 | 2.33 | 3.00 | 0.33 | 3.64 | 1.84 | 1.50 | 0.54 |

Table 2. Average number of insects per 100 sweeps in the interior of the field (2022).

Pest populations once again remained relatively low during the 2022 growing season. Reports of pest issues were few throughout the growing season. Results from the survey did illustrate several areas of the state where pest pressure was higher.

Japanese beetles (Figure 1, Table 3) continue to garner attention each summer, particularly following large numbers of Japanese beetles in 2017 and 2018. While we didn't observe those kinds of populations in 2022, western and northwestern Illinois once again had higher numbers of Japanese beetles in sweep samples, particularly Adams (averaging 291 beetles/100 sweeps) and Lee county (120 beetles/100 sweeps). While the northeastern crop reporting district average was lower than the previously two mentioned, it is worth noting that DeKalb county recorded high Japanese beetle counts as well (average of 106 beetles/100 sweeps).



Figure 9. Average number of Japanese Beetles in soybeans per 100 sweeps (2019-2022).

Table 3. Average number of Japanese Beetles in soybeans per 100 sweeps (2019-2022; duplicates Figure 1).

| District | 2019 | 2020 | 2021 | 2022 |
|----------------|------|------|-------|-------|
| Northwest | 52.6 | 67.1 | 119.8 | 48.4 |
| Northeast | 23.3 | 7.3 | 20.2 | 39.3 |
| West | 26.3 | 21.9 | 37.4 | 107.6 |
| Central | 17.5 | 15.9 | 6.0 | 7.5 |
| East | 51.3 | 9.4 | 7.2 | 10.5 |
| West Southwest | 20.2 | 11.9 | 12.6 | 35.2 |
| East Southeast | 10.6 | 15.7 | 4.8 | 9.8 |
| Southwest | 3.9 | 2.7 | 3.4 | 2.1 |
| Southeast | 3.3 | 13.7 | 3.3 | 4.6 |
| STATE | 19.6 | 18.4 | 23.9 | 29.4 |
| AVERAGE | | | | |

2021 survey results yielded several questions regarding Northern Corn Rootworm (Figure 2, Table 4) in Illinois with extremely high numbers found in northeastern Illinois. Curiosity on if those numbers would remain high in 2022 were at the top of the list. Noticeable populations of northern corn rootworms were observed in several counties, even if the crop reporting district averages do not illustrate it. These counties were spread through the northern and northwestern

part of the state with average per 100 sweeps much higher than district or state averages – DeKalb (69 beetles/100 sweeps), Warren (35 beetles/100 sweeps), Carroll (17 beetles/100 sweeps), and Lee (14 beetles/100 sweeps).



Figure 10. Average number of Northern Corn Rootworm Beetles in soybeans per 100 sweeps (2019-2022).

| Table 4. Average number of Northern Corn Rootworm Beetles in soybeans per 100 sweeps | |
|--|--|
| (2019-2022; duplicates Figure 2). | |

| District | 2019 | 2020 | 2021 | 2022 |
|----------------|------|------|------|------|
| Northwest | 0.2 | 21.4 | 88.9 | 7.8 |
| Northeast | 0.3 | 3.7 | 5.0 | 18.0 |
| West | 0.0 | 2.1 | 0.4 | 9.1 |
| Central | 0.0 | 2.6 | 0.1 | 0.1 |
| East | 3.6 | 0.1 | 0.0 | 0.2 |
| West Southwest | 0.0 | 0.2 | 0.0 | 1.36 |
| East Southeast | 0.0 | 0.0 | 0.0 | 0.4 |
| Southwest | 0.5 | 0.0 | 0.0 | 0.0 |
| Southeast | 0.1 | 0.0 | 0.0 | 0.0 |
| STATE | 0.6 | 3.4 | 10.5 | 4.1 |
| AVERAGE | | | | |

Dectes Stem Borer (Figure 3, Table 5) has been making itself known in the southern third of the state in recent years. Washington, Perry, Saline and Hamilton all had significantly higher numbers of Dectes stem borer in sweeps compared to surrounding counties. Results varied from field to field and county to county, but it is evident that Dectes stem borer is well established in southern Illinois.



Figure 11. Average number of Dectes Stem Borer in soybeans per 100 sweeps (2019-2022).

| District | 2019 | 2020 | 2021 | 2022 |
|----------------|------|------|------|------|
| Northwest | 0.0 | 0.0 | 0.0 | 0.0 |
| Northeast | 0.0 | 0.0 | 0.0 | 0.3 |
| West | 0.0 | 0.7 | 0.0 | 0.0 |
| Central | 0.0 | 0.0 | 0.2 | 0.0 |
| East | 0.0 | 0.0 | 0.0 | 0.03 |
| West Southwest | 0.2 | 0.2 | 0.2 | 0.0 |
| East Southeast | 0.1 | 0.0 | 0.4 | 0.08 |
| Southwest | 1.6 | 0.4 | 3.5 | 6.4 |
| Southeast | 2.5 | 0.4 | 2.5 | 2.3 |
| STATE | 0.6 | 0.2 | 0.8 | 1.0 |
| AVERAGE | | | | |

| Table 5. Average number of Dectes Stem Borer in soybeans per 100 sweeps (2019-2022; |
|---|
| duplicates Figure 3). |

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. Much like 2021, western corn rootworm beetle populations remained low in several areas of the state, but higher numbers were observed in northwest Illinois (Table 6). Both Carroll and Lee counties reported significantly higher numbers of western corn rootworm beetles in per plant counts.

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

 Table 6. Mean number of western corn rootworm beetles per plant in corn by crop reporting district and year.

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 2022

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 338 soybean fields in 53 counties and found no evidence of soybean gall midge in Illinois.

Survey methods: Our survey efforts were conducted in two phases. The majority (302) of fields we examined for soybean gall midge were sampled as part of the Illinois Statewide Insect Survey (additional results of this survey are available on page 10 of this document); 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. 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). 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. Soybean gall midge surveys will be repeated during Summer 2023.

Funding: Illinois Soybean Association and the North Central Soybean Research Program funded this work.

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

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>

2022 Soybean Gall Midge Field Survey





2022 Dectes stem borer survey – larvae and stem tunneling

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Objective: Determine the distribution and severity of dectes stem borer larvae in Illinois.

Materials and Methods: Soybean fields (n = 18) in southern IL were sampled in September-October 2022 (growth stages R6-R8). The main stems of 25 soybean plants per field were split open, and the presence or absence of dectes stem borer larvae and/or their tunnels was recorded. In addition, eight no-till fields in Warren and Henderson Counties in western Illinois were sampled post-harvest by examining soybean residue for dectes tunnels and larvae at the basal portion of the plant remaining after harvest (i.e. the portion of the plant where dectes stem borer larvae overwinter. These values were then used to determine the percent of plants infested for each field.

Summary: The level of infestation ranged from 0-92% of plants infested with either tunnels or larvae in previously (2021) surveyed areas in south-central Illinois (see map on following page; last year's survey results can be found at <u>https://go.illinois.edu/2021PestPathogenARB</u>). No dectes stem borer larvae were found in Warren or Henderson Counties. This is the second year of a planned multi-year survey to observe the distribution and spread of this insect. If you are interested in participating in future surveys, please email <u>nseiter@illinois.edu</u> with the subject line "Illinois dectes survey."

Funding: The Illinois Soybean Association provided funding for this effort.

Acknowledgements: We thank Andrea Kohring (Precision Conservation Management), Phil Krieg (Syngenta), Randy McElroy (Bayer CropScience), Talon Becker (University of Illinois Extension), and Chelsea Harbach (University of Illinois Extension) for their help identifying and/or surveying fields. In addition, we thank Dennis Bowman (University of Illinois Extension) for preparing Fig. 2).



Figure 12. Dectes stem borer larva and tunnel in a soybean stem



Figure 13. Map showing percent infestation of fields sampled for dectes stem borer larvae and tunneling in Illinois

Regional corn rootworm adult sticky-trap survey - 2022

N. J. Seiter, K. A. Estes, J. L. Spencer

Objective: Track western and northern corn rootworm population trends in Illinois (and throughout corn-producing regions in the U.S. and Canada) as part of a regional monitoring network.

Summary: 2022 was the second year of a regional survey for corn rootworm adults using yellow sticky card traps. Along with colleagues in 12 U.S. states and 5 Canadian provinces, we distributed corn rootworm sticky card traps to farmer-cooperators in Illinois. **Annual reports of the regional results are available at <u>www.rootwormipm.org</u>. (Click on "Adult Trapping Network", scroll down to "Reports" in the middle of the page; reports for 2022 and 2021 are available for download) In addition, a real-time map of results is available through this site (click on "Adult Trapping Network" at the link above to access both the annual reports and the live map).**

Acknowledgments: Erin Hodgson and Ashley Dean (Iowa State University) coordinated the regional monitoring network and protocol development. Tracey Baute and Dan Bihari (Ontario Ministry of Agriculture, Food and Rural Affairs) developed a data sharing and mapping platform to display the regional data. We thank over 20 farmers, consultants, extension, and industry personnel for setting up and monitoring traps. Funding for this effort was provided by USDA Hatch funds (Hatch project number ILLU-802-979).

To access reports:

- Go to <u>www.rootwormipm.org</u>
- Click on "Adult Trapping Network" at the menu bar across the top of the screen
- To access annual reports: scroll down to the "Reports" heading in the middle of the page
- To access the live map: click on the image at the top of the screen labeled "Corn Rootworm Monitoring Data Entry and Maps

To participate in the network:

• Send an email to <u>nseiter@illinois.edu</u> with "Adult rootworm trapping network" as the subject heading

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). Field-evolved Bt resistance in WCR has been documented for every commercial Bt toxin (i.e., Cry3Bb1, mCry3A, eCry3.1Ab and Cry34/35Ab1). Furthermore, patterns of WCR and NCR resistance to Bt toxins are similar. 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 provides some efficacy against corn rootworm larvae. For this reason, rootworm susceptibility to the Cry34/35Ab1 Bt toxin is crucial to the efficacy of pyramided Bt corn hybrids, which all combine expression of the Cry34/35Ab1 toxin with one of the Cry3 toxins.

A new trait package with activity against corn rootworms was first commercialized in 2022. 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 (i.e., RNA interference or "RNAi") (USEPA. 2017, Khajuria et al. 2018). The rootworm-active RNAi trait is the first truly new mode of action for rootworms in almost a decade. RNAi works by introducing double-stranded RNA from the DvSnf7 gene of the WCR into cells where it will interfere with the 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 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.

Each summer we collect adult WCR and NCR 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 susceptibility to corn hybrids expressing single and pyramided Bt toxins during the following summer. This year (2022) bioassays used the offspring of WCR and NCR populations collected during 2021. The availability of Illinois rootworm populations collected the year before SSX PRO was commercialized presented an opportunity to assess the pre-exposure, baseline susceptibility of Illinois WCR and NCR populations to the new SSX PRO pyramid of Bt + RNAi.

With cooperation from Bayer CropScience, we received seed for three hybrids from the SSX PRO "family" in a similar genetic background: SSX PRO (pyramided hybrid expressing the Cry3Bb1 + Cry34/35Ab1 Bt toxins and RNAi), SmartStax® (SSX) (Bt pyramid expressing Cry3Bb1 + Cry34/35Ab1 Bt toxins), and VT Double PRO (VT2P) (non-Bt near isoline of SSX PRO and SSX). We also bioassayed WCR and NCR populations on single trait Cry3Bb1 and Cry34/35Ab1 hybrids (and appropriate non-Bt isolines).

<u>Summary</u>. Bioassays of Illinois populations of WCR (n=2 from Champaign Co. and n=1 from Warren Co.) and NCR (n=1 from Warren Co.) revealed that Cry3Bb1 resistance is widespread in WCR and NCR. Significantly reduced susceptibility to the Cry34/35Ab1 toxin was also detected, but it is more variable. Unlike larvae that survived on Cry3Bb1 hybrids, larvae

surviving on Cry34/35Ab1 had significant developmental delays (they were smaller) compared to those on non-Bt hybrids. The Illinois WCR and NCR populations also all exhibited significantly reduced susceptibility to the SSX Bt pyramid with significant developmental delays among most survivors. All WCR and NCR populations were susceptible to the SSX PRO Bt + RNAi pyramid and the few larvae that survived on SSX PRO generally experienced significant developmental delays. Notably, proportion survival for the Champaign Co. WCR population on SSX PRO (0.060 ± 0.014 , mean \pm SEM) was significantly greater than that of the susceptible control populations (0.004 ± 0.003), but it was still significantly less than the survival of either population on the non-Bt VT2P control (0.236 ± 0.032 and 0.239 ± 0.027), respectively. Champaign Co. WCR appear to have reduced background susceptibility to the SSX PRO compared to the other naïve NCR and WCR populations.

<u>Materials and Methods</u>. During summer 2021, suspected Bt resistant adult WCR populations were collected from the Agricultural and Biological Engineering (ABE) Farm, Research and Training Center on the University of Illinois Urbana-Champaign campus in Urbana, Ill. (40.070510, -88.214430; Champaign Co.) and from the University of Illinois Northwestern Illinois Agricultural Research and Demonstration Center in Monmouth, Ill. (40.934736, -90.724164, Warren Co.). A NCR population was also collected from the NIARDC location. Populations were collected where corn rootworm adults were abundant but were not necessarily associated with economic injury. All field-collected NCR and WCR populations were suspected to carry some level of Bt resistance to Cry3Bb1 and Cry34/35Ab1 Bt toxins. The beetles were maintained in the laboratory on corn silks and developing ears. Eggs were collected in petri-dishes of soil and stored at 6°C for \geq 5 mon. until needed for bioassays.

Single-plant Bt resistance bioassays were performed according to the method of Gassmann et al. (2011). In each bioassay, the proportions larval survival and the proportions of mature (3rd instar) larvae among survivors were compared between populations following exposure to Bt and non-Bt corn hybrids (**Table 1**). Each suspected-Bt resistant Illinois field population was tested alongside a Bt-susceptible laboratory population obtained from the USDA-ARS, North Central Agricultural Research Laboratory in Brookings, SD.

Corn rootworm 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). Populations were also evaluated for resistance to a trio of Bayer hybrids: SmartStax® PRO (SSX PRO), SmartStax® (SSX), and VT Double PRO (VT2P) (**Table 1**).

Corn plants for bioassay were grown in the greenhouse and inoculated with 10 newly emerged rootworm larvae (i.e., newly emerged larvae were transferred onto fine corn roots exposed at the base of each plant with a fine paintbrush) per cup at the V5-V6 stage (*ca.* 1 month after planting). Each rootworm field population was bioassayed along with a Bt-susceptible USDA laboratory population. There were 12 replicates per population × Bt hybrid combination (due to limited larvae, only 9 replicates of the Warren Co. WCR population could be completed). After 17-days of post-inoculation development, surviving larvae were extracted from bioassay cups into tubes of 85% ethanol using Berlese funnels, counted, and head capsule widths 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 each WCR and NCR field

population 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.** Bt resistance in Champaign Co. WCR.</u> The Champaign Co. WCR populations had equivalent survival on both the Cry3Bb1 and Cry34/35Ab1 Bt hybrids and the non-Bt isoline hybrids—a result consistent with the presence of Bt resistance (**Table 2**). Due to existing cross-resistance among Cry3 Bt toxins in WCR, these populations would also survive well on hybrids expressing Cry3 toxins other than Cry3Bb1 (i.e., mCry3A and eCry3.1Ab toxins). As expected, larvae from the USDA Bt-susceptible population had poor survival on hybrids expressing the Cry3Bb1 and Cry34/35Ab1 Bt toxins but survived on non-Bt isoline hybrids at significantly higher proportions.

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 incubation period on a Bt hybrid indicates that the larvae in a particular treatment were developing at a normal rate. The presence of 3rd instars among survivors from Cry3Bb1 roots is further evidence of their resistance to the Bt toxin. Most of the Bt-susceptible population's few larval survivors from Cry3Bb1 plants exhibited delayed development and had not reached the 3rd instar—a result consistent with a highly Bt susceptible population.

Among the Champaign Co. WCR larvae tested on the Cry34/35Ab1 hybrid, there was a high proportion of survivors but few had reached the 3rd instar. The presence of survivors with developmental delays indicates that the population is negatively affected by the Cry34/35Ab1 Bt toxin in their diet. We classify populations that have equivalent proportions of larval survival on a specific Bt hybrid and its non-Bt isoline, but have reduced proportions of 3rd instar larvae among the survivors (i.e., evidence of a developmental delay) as possessing significantly reduced susceptibility to the trait or hybrid. Delayed development is important as it may disadvantage survivors because their adult emergence will also be delayed. Compared to adults that emerge at a normal time, WCR adults that emerge late may have fewer opportunities to exploit high quality foods with narrow windows of availability (e.g., corn pollen, fresh corn silks). That disadvantage may also translate into fewer opportunities to mate and compromise their ability to maximize their production of eggs. The offspring of beetles with genes that provided better protection from larval developmental delays due to Bt exposure will outcompete less resistant surviving beetles. A WCR population with resistance to Cry34/35Ab1 would have larvae that survive in high proportions and develop at a normal rate when exposed to the 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.

Bioassay results for WCR populations evaluated on hybrids from the SSX PRO family were consistent with that 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 an outcome that was predictable based on survival patterns for the single Bt toxin components expressed in SSX (**Table 2**). In contrast, the USDA Bt susceptible populations had low survival on SSX indicating that they remain highly susceptible. Low 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. Knowing that Champaign Co. WCR are resistant to Cry3Bb1 toxin, we can assume 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 population.

The RNAi mode of action expressed in the SSX PRO hybrid is a novel mechanism for WCR management to which the local 2021 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 either the Champaign or the USDA Bt susceptible WCR 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.

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**) as was also observed for populations on SSX. The presence of developmental delays among the survivors of SSX PRO is a favorable outcome with respect to the durability of SSX PRO. However, reduced susceptibility to RNAi in a previously unexposed population is a concern since it may provide Champaign Co. WCR with a "head start" toward field-evolved resistance to the only mode of action that WCR have not already overcome.

<u>Bt resistance in Warren Co. WCR.</u> The proportion of surviving Warren Co. larvae and the proportion of 3rd instars among surviving larvae were not statistically different between the Cry3Bb1 and non-Bt hybrids (**Table 3**). When inoculated on the Cry34/35Ab1 hybrid, larvae from the Warren Co. WCR population survived as well on the Cry34/35Ab1 hybrid as they did on the non-Bt hybrid; however, the survival of the USDA Bt-susceptible population on the Cry34/35Ab1 hybrid was also not statistically different from the Warren Co. population on that hybrid. Poorer statistical resolution among the Bt treatments for this Warren Co. WCR may be due to only enough larvae to complete 9 of 12 replicates. Data for proportion of 3rd instars among the surviving larvae was more definitive; Warren Co. survivors from the Cry34/35Ab1 hybrid included significantly lower proportions of 3rd instar larvae than did survivors from non-Bt hybrids. The delayed development indicates that the Cry34/35Ab1 toxin likely still retains some efficacy against this WCR population, though it is reduced.

Evaluation of the Warren Co. WCR population on hybrids in the SSX PRO family revealed equivalent proportions of larval survival on the SSX and non-Bt isoline hybrids. This result suggests that the variability in the results for the single trait Cry34/35Ab1 hybrid actually obscured a significantly greater proportion of larval survival on Cry34/35Ab1 toxin. However, like the Champaign Co. WCR populations, larvae surviving on SSX hybrids experience significant developmental delays resulting in lower proportions of 3rd instar larvae—likely due to the effect of the Cry34/35Ab1 toxin.

When tested on the SSX PRO hybrid, the Warren Co., WCR population survived no better than the Bt-susceptible control population. Among the surviving larvae, there were significantly fewer 3rd instars than the same populations inoculated onto non-Bt hybrids. The Warren Co. WCR population appears to be highly susceptible to the SSX PRO hybrid, a condition that can be attributed to the presence of the RNAi mode of action.

<u>Bt resistance in Warren Co. NCR</u>. Like the Warren Co. WCR population, proportion larval survival on the Cry3Bb1 hybrid for the Warren Co. NCR population was equivalent to survival on the non-Bt isoline (**Table 4**). The USDA Bt susceptible NCR population also had proportion survival on the non-Bt isoline equivalent to that of the Warren Co. NCR population, but very low survival on the Cry3Bb1 hybrid. These data are consistent with low susceptibility to Cry3Bb1 toxin in this population. The proportions of 3rd instar larvae among the survivors from non-Bt isoline hybrids and among the Warren Co. NCR on the Cry3Bb1 hybrid were high, indicating that the Cry3Bb1 toxin had little or no effect on NCR larval development. However, the proportion of 3rd instars among the few survivors of the USDA Bt susceptible NCR population from the Cry3Bb1 hybrid was variable enough to make it impossible to discern any statistical differences between the other hybrids in the Cry3Bb1 trait family.

The results of the NCR bioassay for resistance to the Cry34/35Ab1 toxin were variable. The proportion larval survival of the Warren Co. NCR population on the Cry34/35Ab1 hybrid was significantly greater than that of the Bt-susceptible population; however, proportion survival was also significantly less than proportion survival of the Warren Co. NCR population on the non-Bt hybrid. This intermediate pattern of survival indicates significantly reduced susceptibility to Cry34/35Ab1 in the Warren Co. NCR population. That conclusion is supported by significantly lower proportions of 3rd instars among the Warren Co. NCR larvae that survived on the Cry34/35Ab1 hybrid.

When tested on the hybrids in the SSX PRO family, the Warren Co. NCR population's survival on the SSX hybrid was significantly greater than survival of the Bt susceptible NCR population on the same hybrid, but significantly less than survival of either population on the non-Bt hybrid. This pattern of intermediate proportion survival on SSX for Warren Co. NCR is consistent with the population's survival pattern and proportion of 3rd instars among surviving larvae from the Cry34/35Ab1 hybrid and the assumption that the Cry34/35Ab1 toxin is responsible for the SSX efficacy against NCR.

None of the inoculated larvae from the Warren Co. NCR population and only one 2nd instar larva from the Bt-susceptible NCR population survived on the SSX PRO hybrid. This result indicates that the Warren Co. NCR population is highly susceptible to the SSX PRO hybrid.

WCR and NCR corrected survival on Bt hybrids. 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. 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. CS values for the 2021 WCR and NCR populations tested above are presented in **Table 5**. CS for nearly all corn rootworm populations on the single and pyramided Bt hybrids exceeded 0.5 and were near or above 1.0 for Cry3Bb1—a further indication that Cry3Bb1

resistance is widespread and at a high level in both species. With few exceptions (e.g., Warren Co. NCR on the SSX hybrid) the highest CS values (those approaching or above 1.0) come from populations where there are no developmental delays among the Bt hybrid survivors.

Bt resistance bioassays have been used to evaluate the Bt susceptibility of WCR collected in Champaign Co. since 2013. From 2013 to 2021, 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. 7.4% per year (0.074 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 any level 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. 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. All the WCR and NCR field populations evaluated in 2022 were resistant to the Cry3Bb1 Bt toxin. High proportions of both larval survival and of mature 3rd instar larvae among surviving larvae indicate an absence of Cry3Bb1 Bt toxin efficacy against pest rootworms. Among these same populations, worrisome proportions of larval survival on the Cry34/35Ab1 hybrid and significantly delayed larval development among surviving larvae indicate that significantly reduced susceptibility to Cry34/35Ab1 is widespread. Resistance to the Cry34/35Ab1 toxin seems inevitable if trends continue. Thus, in pyramids of Cry3Bb1 and Cry34/35Ab1 Bt toxins (like SSX) the lack of Cry3Bb1 efficacy means that there is only one functional Bt mode of action available to protect to corn roots. The practical consequences of waning Bt efficacy of the Cry34/35Ab1 toxin are evident in bioassay results for the SSX pyramid. Significant developmental delays among surviving larvae from SSX hybrids (and later feeding/reproductive disadvantages resulting from delayed adult emergence) may be responsible for limiting the growth of these populations. Protecting what remains of Cry34/35Ab1 efficacy would help extend the utility of SSX hybrids. Furthermore, Cry34/35Ab1 toxin efficacy is crucial to preserving SSX PRO as a functional pyramid with two effective modes-of-action (due to resistance, the Cry3Bb1 mode of action is non-functional in the pyramid). Loss of Cry34/35Ab1 toxin efficacy would leave the SSX PRO hybrid solely dependent on the RNAi mode of action in a functionally single-trait hybrid. We know from the history of Cry3Bb1 toxin commercialization that relying on single-trait hybrids to manage corn rootworm populations (complicated by poor compliance with refuge and resistance management measures) exposed the toxin to heavy selection pressure, leading to rapid evolution of field resistance (Gassmann et al. 2011).

Larval survival of Champaign Co. WCR populations on the SSX PRO hybrid was significantly greater than that of the USDA susceptible populations on SSX PRO. Combined with proportion larval survival on the SSX hybrid that was not different from survival on the non-Bt isoline hybrid, we conclude that the Champaign Co. WCR populations possess natural genetic variation that allows them to survive exposure to the SSX PRO hybrid better than known susceptible populations. However, patterns of elevated larval survival are only part of the story. We observed significant delays in development among surviving larvae that were exposed to the Cry34/35Ab1 Bt toxin or Cry34/35Ab1 Bt toxin + RNAi in SSX and SSX PRO hybrids, respectively. Delayed larval development among survivors translates into greater exposure to mortality factors in the soil for larvae and other challenges associated with delayed adult emergence. A recent study documenting impacts of larval and adult exposure(s) to SSX PRO hybrids suggest that negative effects on WCR life history traits may translate into reduced growth of Bt-resistant WCR populations (Reinders et al. 2022). Documented larval developmental delays (and hypothesized negative impacts on WCR life history) following exposures to Cry34/35Ab1 Bt toxin may be contributing to currently low local WCR population densities.

Despite encouraging evidence that field-evolved resistance to Cry34/35Ab1Bt toxin is still incomplete, selection acting on the natural variation responsible for reduced background susceptibility to SSX PRO could lead to field-evolved resistance to SSX PRO hybrids over time. The threat to the efficacy of SSX PRO would be greatly magnified by resistance to the Cry34/35Ab1 Bt toxin. Implementing and adhering to best management practices (BMPs) (e.g., scouting fields to monitor WCR abundance, rotating fields with high WCR/NCR abundance to a soybean or another non-host crop, applying soil insecticide instead of planting Bt/RNAi hybrids when the WCR threat is low, etc.) at the outset of SSX PRO commercialization will be necessary to protect the efficacy of the new RNAi mode of action.

WCR are the primary corn threat across most of Illinois; however, the NCR was the original threat to Illinois corn productivity. Competition with the invading WCR reduced its importance beginning in the mid-1960s and 1970s. Economically significant NCR impacts have typically been confined to the northern third of Illinois. NCR can be especially troublesome because the populations of NCR eggs deposited in Illinois cornfields include an unknown proportion that can prolong their normal period of egg diapause (when eggs are quiescent in soil during the winter) and delay egg hatch for an additional 1, 2, 3, or more years after they are laid. Because of this "prolonged egg diapause", it is challenging to know if a given NCR population in corn will translate into sufficient eggs to establish a larval population capable of causing economic injury to corn roots during the following year (or the year after that, etc.). The difficulty of knowing whether an injurious population of larvae will emerge is further complicated by the evidence for NCR resistance and significantly reduced susceptibility to Cry3Bb1 and Cry34/35Ab1 Bt toxins, respectively. Furthermore, NCR population abundance seems to be increasing in N. Illinois. Resistance to the Cry34/35Ab1 toxin in burgeoning NCR populations would complicate the unpredictable impact of prolonged diapause. Adoption of monitoring to justify the use of products like SSX and SSX PRO will be critical to protecting yield potentials where NCR are the dominant species. However, developing improved monitoring protocols that account for prolonged diapause is also necessary to avoid blanket use of Bt hybrids because of uncertainty about the year-to-year NCR threat.

Given resistance to the Cry3Bb1 Bt toxin among Illinois WCR and NCR populations and the significantly declining efficacy of the Cry34/35Ab1 Bt toxin, it is troubling to realize how unsteady the foundation of Bt-toxin based corn rootworm management has become. Until commercialization of the SSX PRO Bt + RNAi pyramid in 2022, the viability of corn rootworm management with Bt traits depended on larval susceptibility to the Cry34/35Ab1 Bt toxin, a "natural resource" that is being steadily consumed by continuing selection associated with frequent planting of pyramided Bt corn hybrids. As welcome as a new mode of action is for

rootworm management, it is "cold comfort" that RNAi is pyramided with two Bt toxins (Cry3Bb1 and Cry34/35Ab1) that have compromised efficacy. The activity of the Bt toxins expressed in SSX PRO are expected to contribute significantly to the efficacy provided by the RNAi trait. The expected high efficacy predicted to result from the presence of three modes of action was used to justify incorporating only a modest (5%) integrated refuge in SSX PRO fields. However, if adult survivors from SSX PRO are more numerous than expected because one or more modes-of-action are ineffective, the population of potentially Bt-susceptible adults emerging from the 5% refuge may be far too few to dilute the impact of potentially resistant survivors emerging from SSX PRO plants across the rest of a field. Based on evidence that the Bt modes-of-action will only provide limited efficacy against some rootworm populations, the RNAi trait may come under heavy selection for resistance. In the face of this resistance threat, it is important that the SSX PRO pyramid be reserved for situations where corn rootworm abundance monitoring indicates that it is justified. Incorporating an RNAi product into an integrated rootworm management approach that includes pest scouting and other best management practices (e.g., rotation to soybean, use of soil insecticides, etc.) will be critical to prolong the efficacy of the RNAi technology.

Our rootworm bioassay data and trends provide information about the general resistance potential of populations, but they are no substitute for monitoring local beetle abundance and farm-scale awareness of local trait performance. Larval survival and development data for 2021 WCR and NCR populations indicate the presence of resistance to the Cry3Bb1 toxin and declining susceptibility to the Cry34/35Ab1 toxin. We also document NCR and WCR susceptibility to the new RNAi mode of action. It is important to remember that unless adult rootworm population abundance exceeds the economic threshold, subsequent larval feeding on corn roots is unlikely to cause economic damage-regardless of the population's resistance status. Avoiding unnecessary use of Bt and other management tactics will help prolong their utility. It is troubling that during a period when Champaign Co. and much of Illinois experienced very low WCR abundance, the efficacy of the "Cry3" toxins was lost and Cry34/35Ab1 toxin efficacy was significantly compromised (Figure 1). While favorable weather conditions have recently helped suppress Illinois rootworm populations (Tinsley et al. 2018), elsewhere in the Corn Belt large Bt resistant populations present practical management challenges (Unglesbee 2020, Gassmann 2021). The value of wasted trait efficacy will be sorely missed if and when Illinois rootworm population abundance rebounds.

Availability of a novel and effective mode of action against corn rootworms, presents a fresh opportunity for the agricultural community to practice wise stewardship of pyramided hybrids expressing RNAi. Given that many corn growers facing injurious Bt resistant rootworm populations may soon depend almost entirely on RNAi efficacy, the importance of using RNAi-expressing hybrids wisely cannot be emphasized strongly enough.

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Table 7. Bt corn hybrid information for seed used in 2022 single-plant, Bt-resistance bioassays of 2021 Illinois field-collected populations of the western corn rootworm (WCR) (*Diabrotica v. 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 |
| Cry34/35Ab1 | P1417 ³ | Single trait Bt | (+) Bt | Pioneer |
| | 2H723 ⁴ | non-Bt | non-Bt ⁷ | Mycogen |
| Cry3Bb1+Cry34/35Ab1+DvSnf7 | DKC 111-33 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. **Table 8.** Proportion larval survival and proportion 3rd instar larvae from single-plant, Bt-resistance bioassays on two Urbana, Illinois (Champaign Co.) populations of the western corn rootworm (WCR) (*Diabrotica v. virgifera* LeConte) collected in 2021 from an open field and emergence tents erected over plots of non-Bt corn.

| 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) ^a |
|-----------------|-----------------------------|--------------------------|----|--|----|---|
| Cry3Bb1 | Cry3Bb1 | Champaign Co. field pop. | 36 | 0.400 ± 0.038 a | 34 | 0.774 ± 0.044 b |
| | | USDA Bt susceptible pop. | 48 | $0.042 \pm 0.010 \; b$ | 16 | 0.281 ± 0.112 c |
| | Non-Bt isoline | Champaign Co. field pop. | 36 | 0.292 ± 0.028 a | 34 | 0.912 ± 0.036 a |
| | | USDA Bt susceptible pop. | 48 | 0.363 ± 0.032 a | 44 | 0.955 ± 0.032 a |
| Cry34/35Ab1 | Cry34/35Ab1 | Champaign Co. field pop. | 22 | 0.305 ± 0.042 a | 21 | 0.114 ± 0.051 b |
| | | USDA Bt susceptible pop. | 34 | $0.138 \pm 0.035 \ b$ | 17 | $0.018 \pm 0.013 \text{ b}$ |
| | Non-Bt isoline | Champaign Co. field pop. | 42 | 0.483 ± 0.044 a | 39 | 0.972 ± 0.026 a |
| | | USDA Bt susceptible pop. | 58 | 0.390 ± 0.034 a | 53 | 0.965 ± 0.018 a |
| Cry34/35Ab1 + | Cry34/35Ab1 + Cry3Bb1 | Champaign Co. field pop. | 35 | $0.060 \pm 0.014 \text{ bc}$ | 15 | $0.200 \pm 0.095 \text{ b}$ |
| Cry3Bb1 + RNAi | +RNAi | USDA Bt susceptible pop. | 46 | $0.004 \pm 0.003 \ d$ | 2 | $0.000 \pm 0.000 \ b$ |
| | Cry34/35Ab1 + Cry3Bb1 | Champaign Co. field pop. | 36 | 0.194 ± 0.043 ab | 19 | $0.225 \pm 0.072 \text{ b}$ |
| | · · · · | USDA Bt susceptible pop. | 48 | $0.025\pm0.008~cd$ | 10 | $0.200 \pm 0.133 \text{ b}$ |
| | Non-Bt isoline | Champaign Co. field pop. | 36 | 0.236 ± 0.032 a | 29 | 0.867 ± 0.048 a |
| | | USDA Bt susceptible pop. | 49 | 0.239 ± 0.027 a | 41 | 0.871 ± 0.043 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.
Table 9. Proportion larval survival and proportion 3rd instar larvae from single-plant, Bt-resistance bioassays on one Northern Illinois (Warren Co.) population of the western corn rootworm (WCR) (*Diabrotica v. virgifera* LeConte) collected in 2021 from an open field.

| 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) ^a |
|-----------------|-----------------------------|--------------------------|----|--|----|---|
| Cry3Bb1 | Cry3Bb1 | Warren Co. field pop. | 9 | 0.478 ± 0.049 ab | 9 | 0.917 ± 0.034 a |
| | | USDA Bt susceptible pop. | 48 | $0.042 \pm 0.010 \text{ c}$ | 16 | $0.281 \pm 0.112 \text{ b}$ |
| | Non-Bt isoline | Warren Co. field pop. | 9 | 0.656 ± 0.053 a | 9 | 0.928 ± 0.049 a |
| | | USDA Bt susceptible pop. | 48 | $0.363 \pm 0.032 \; b$ | 44 | 0.955 ± 0.032 a |
| Cry34/35Ab1 | Cry34/35Ab1 | Warren Co. field pop. | 9 | 0.367 ± 0.096 ab | 8 | $0.205 \pm 0.120 \text{ b}$ |
| | - | USDA Bt susceptible pop. | 34 | $0.138 \pm 0.035 \text{ b}$ | 17 | $0.018 \pm 0.013 \; b$ |
| | Non-Bt isoline | Warren Co. field pop. | 9 | 0.511 ± 0.107 a | 8 | $0.839 \pm 0.122 \text{ a}$ |
| | | USDA Bt susceptible pop. | 58 | $0.390\pm0.034~ab$ | 53 | $0.965 \pm 0.018 \; a$ |
| Cry34/35Ab1 + | Cry34/35Ab1 + Cry3Bb1 | Warren Co. field pop. | 9 | 0.011 ± 0.011 b | 1 | 0.000 b |
| Cry3Bb1 + RNAi | +RNAi | USDA Bt susceptible pop. | 46 | $0.004 \pm 0.003 \text{ b}$ | 2 | $0.000 \pm 0.000 \ b$ |
| | Cry34/35Ab1 + Cry3Bb1 | Warren Co. field pop. | 9 | 0.453 ± 0.075 a | 9 | $0.200 \pm 0.062 \text{ b}$ |
| | | USDA Bt susceptible pop. | 48 | $0.025 \pm 0.008 \ b$ | 10 | $0.200 \pm 0.133 \text{ b}$ |
| | Non-Bt isoline | Warren Co. field pop. | 9 | 0.411 ± 0.093 a | 8 | 0.967 ± 0.022 a |
| | | USDA Bt susceptible pop. | 49 | 0.239 ± 0.027 a | 41 | 0.871 ± 0.043 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.

| Bt trait family | Bt expressed in corn hybrid | NCR test population | n | Proportion larval survival (mean ± SEM) ^a | n | Proportion 3rd instar larvae (mean ± SEM) ^a |
|-----------------|-----------------------------|--------------------------|----|--|----|---|
| Cry3Bb1 | Cry3Bb1 | Warren Co. field pop. | 12 | 0.700 ± 0.051 a | 12 | 0.871 ± 0.111 a |
| | | USDA Bt susceptible pop. | 21 | $0.048 \pm 0.015 \ b$ | 8 | 0.500 ± 0.250 a |
| | Non-Bt isoline | Warren Co. field pop. | 12 | 0.733 ± 0.050 a | 12 | 0.946 ± 0.097 a |
| | | USDA Bt susceptible pop. | 23 | 0.687 ± 0.036 a | 23 | 0.944 ± 0.075 a |
| Cry34/35Ab1 | Cry34/35Ab1 | Warren Co. field pop. | 12 | $0.450 \pm 0.080 \text{ b}$ | 12 | 0.342 ± 0.116 b |
| | | USDA Bt susceptible pop. | 22 | 0.205 ± 0.046 c | 15 | $0.340 \pm 0.265 \text{ b}$ |
| | Non-Bt isoline | Warren Co. field pop. | 12 | 0.767 ± 0.041 a | 12 | 0.964 ± 0.075 a |
| | | USDA Bt susceptible pop. | 22 | $0.655\pm0.046~ab$ | 22 | 0.967 ± 0.086 a |
| Cry34/35Ab1 + | Cry34/35Ab1 + Cry3Bb1 | Warren Co. field pop. | 12 | 0.000 ± 0.000 c | 0 | |
| Cry3Bb1 + RNAi | +RNAi | USDA Bt susceptible pop. | 22 | $0.005 \pm 0.005 \text{ c}$ | 1 | 0.000 b |
| | Cry34/35Ab1 + Cry3Bb1 | Warren Co. field pop. | 12 | $0.333 \pm 0.048 \text{ b}$ | 12 | $0.200 \pm 0.091 \text{ b}$ |
| | | USDA Bt susceptible pop. | 22 | $0.000 \pm 0.000 \ c$ | 0 | |
| | Non-Bt isoline | Warren Co. field pop. | 12 | 0.825 ± 0.055 a | 12 | 0.888 ± 0.065 a |
| | | USDA Bt susceptible pop. | 22 | 0.700 ± 0.037 a | 21 | 0.827 ± 0.063 a |

Table 10. Proportion larval survival and proportion 3rd instar larvae from single-plant, Bt-resistance bioassays on one Northern Illinois (Warren Co.) population of the northern corn rootworm (NCR) (*Diabrotica barberi* (Smith and Lawrence)) collected in 2021 from an open field.

^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.

Table 11. Corrected western (WCR) and northern corn rootworm (NCR) larval survival on Bt traits expressed in corn hybrids used in 2022 Bt-resistance bioassays. Test larvae were the offspring of adults collected in 2021 from field populations in Champaign Co. and Warren Co. Illinois. Number of test population replicates x hybrid are indicated by n.

| | | | Corrected proportion larval survival (mean ± |
|----------------------------|-----------------------------|----------------|---|
| Rootworm population | Bt expressed in corn hybrid | n | SEM) ^a |
| Champaign Co. WCR | Cry3Bb1 | 3 | 1.393 ± 0.112 |
| | Cry34/35Ab1 | 2 ^b | 0.505 ± 0.130 |
| | Cry34/35Ab1 + Cry3Bb1 | 3 | 0.661 ± 0.309 |
| | Cry3Bb1 + Cry34/35Ab1+ RNAi | 3 | 0.251 ± 0.034 |
| Warren Co. WCR | Cry3Bb1 | 1 | 0.729 |
| | Cry34/35Ab1 | 1 | 0.718 |
| | Cry3Bb1 + Cry34/35Ab1 | 1 | 1.102 |
| | Cry3Bb1 + Cry34/35Ab1+ RNAi | 1 | 0.027 |
| Warren Co. NCR | Cry3Bb1 | 1 | 0.955 |
| | Cry34/35Ab1 | 1 | 0.587 |
| | Cry3Bb1 + Cry34/35Ab1 | 1 | 0.404 |
| | Cry3Bb1 + Cry34/35Ab1+ RNAi | 1 | 0.000 |

^a Corrected proportion larval survival is the quotient of proportion larval survival on a Bt maize hybrid divided by proportion larval survival on the corresponding non-Bt hybrid. A corrected survival 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.

^bOne replicate was lost due to low germination of Cry34/35Ab1 hybrid seed (2H695) intended for the bioassay of the ABE Farm Open Field WCR; the full bioassay was repeated with a different hybrid (P1417).



Figure 14. Linear regression of WCR corrected proportion larval survival (corrected survival, "C.S") on single-trait Bt corn hybrids for (n=39) Champaign Co. WCR populations from 2013-2021 field collections. 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.

Evaluations of insecticides and Bt hybrids for control of corn rootworm in Illinois, 2022

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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 either corn or 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 (3-11 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 Bt traits. 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 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 10 (Experiment H) or 5 (all other experiments) 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 a small-plot combine (Massey Ferguson 8XP, Kincaid Equipment, Haven, KS) with a built-in weight and moisture monitor (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 given in Table 3 for each individual experiment.

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A. Evaluation of Aztec HC on Non-CRW Bt and Pyramided CRW Trait Hybrids

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

Objective: To compare the performance of Aztec HC alone or in combination with pyramided Bt traits for control of corn rootworm (particularly western corn rootworm, Diabrotica virgifera virgifera) larval damage.

Summary: Aztec HC resulted in a significant reduction in node-injury ratings on every trait package we tested; this is a similar pattern to that observed in 2021, but a departure from previous years where insecticide typically did not reduce rootworm injury on pyramided Bt-RW corn. Percent consistency was similarly affected. Lodging occurred only at low frequencies in this trial, and there were no differences observed among treatments. Yields were impacted by treatment, with differences among hybrids.

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

| Seed coatings | G10L16-3220A: thiamethoxam (0.50 mg ai/seed) [Avicta Complete |
|------------------------------|---|
| | $500 + Vibrance^{a}$] |
| | DKC64-65: Clothianidin (0.50mg ai/seed) [Acceleron FALH2VQ ^b] |
| | DKC111-33: Clothianidin (0.5 mg ai/seed) [Acceleron |
| | FALZH2VQ ^b] |
| | P1055Q: Clothianidin (0.25mg ai/seed) + chlorantraniliprole (0.25 mg ai/seed) [LumiGEN ^c] |
| Previous crop | Trap crop: late-planted, non-Bt field corn inter-seeded with |
| - | pumpkins |
| Soil type | Thorp silt loam |
| Tillage | Conventional |
| Row spacing | 30 inches |
| Seeding Rate | 35,500 seeds per acre |
| Soil insecticide application | Granular in-furrow, SmartBox ^d research-scale granular applicator |
| Planting date | May 17 2022 |
| Emergence date | May 24 2022 |
| Herbicide | Pre-emerge: 32% UAN (50 gal/ac), Harness Xtra ^b (2 qt/ac) |
| | Post-emerge: Roundup PowerMAX ^b (32 oz/ac), FS MaxSupreme ^e (1 |
| | qt/ac), Sortion ^e (38 oz/ac) |
| Plot size | 4 rows (10 ft) wide by 30 ft long, 5 ft unplanted alleys |

Table A- 12. Plot information

^a Syngenta Crop Protection, Greensboro, NC; ^b Bayer CropScience, St. Louis, MO; ^c Corteva Agriscience, Wilmington, DE; ^d AMVAC Chemical Corporation, Los Angeles, CA; ^e Growmark, Inc., Bloomington, IL

 Table A- 13. Corn rootworm treatments

| Trt | Corn hybrid | Trait package | CRW Bt proteins | Soil Insecticide |
|-------------------|---------------------------|------------------|---|---|
| 1 | G10L16-3220A ^a | Agrisure | None | None |
| 2 | G10L16-3220A ^a | Agrisure | None | Aztec HC, 1.63 lb/a (8.9% tebupirimphos + 0.44% cyfluthrin) |
| 3 | P1055Q ^c | Qrome | mCry3A + Cry34/35Ab1 | None |
| 4 | P1055Q ^c | Qrome | mCry3A + Cry34/35Ab1 | Aztec HC, 1.63 lb/a (8.9% tebupirimphos + 0.44% cyfluthrin) |
| 5 | DKC64-65 ^b | VT Double Pro | None | None |
| 6 | DKC64-65 ^b | VT Double Pro | None | Aztec HC, 1.63 lb/a (8.9% tebupirimphos + 0.44% cyfluthrin) |
| 7 | DKC111-33 ^b | SmartStax Pro | Cry3Bb1 + Cry34/35Ab1 + | None |
| | | | DvSnf7 dsRNA | |
| 8 | DKC111-33 ^b | SmartStax Pro | Cry3Bb1 + Cry34/35Ab1 + | Aztec HC, 1.63 lb/a (8.9% tebupirimphos + 0.44% cyfluthrin) |
| | | | DvSnf7 dsRNA | |
| ^a Gold | len Harvest Seeds (S | Syngenta), Downe | r's Grove, IL; ^b Dekalb, Bayer | CropScience, St. Louis, MO; ^c Pioneer, Corteva |

^a Golden Harvest Seeds (Syngenta), Downer's Grove, IL; ^b Dekalb, Bayer CropScience, St. Louis, MO; ^c Pioneer, Agriscience, Johnston, IA

Table A- 14. 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.

| | | Treatment | | |
|------------------------------|---------|-----------|--------------------|--|
| Dependent Variable | Date | F | Р | |
| Plant stand (normal) | 6 June | 4.29 | 0.004 ^a | |
| Root injury rating (gamma) | 25 July | 25.01 | $< 0.001^{a}$ | |
| Percent consistency (normal) | 25 July | 10.32 | 0.001^{a} | |
| Percent lodging (normal) | 6 Oct. | 0.79 | 0.600 | |
| Yield (normal) | 30 Oct. | 6.83 | $< 0.001^{a}$ | |

Table A- 15. 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 (V3) | Node-injury rating (R1) | Percent consistency (R1) | Percent lodging (R6) | Yield |
|-----|----------------------|--------------------------|----------------------------|-----------------------------|-----------------------|-----------------------------|
| Trt | Treatment | 6 June 2022 | 25 July 2022 | 25 July 2022 | 6 Oct. 2022 | 30 Oct. 2022 |
| 1 | Agrisure | $38.0 \pm 0.8 \ abc^a$ | 1.33 ± 0.15 a | $5.0 \pm 5.0 \text{ d}$ | $1.0 \pm 1.0 \ a^{a}$ | $120.7 \pm 13.8 \text{ d}$ |
| 2 | Agrisure + | $34.3 \pm 2.3 \text{ d}$ | $0.44\pm0.07~c$ | $35.0 \pm 22.2 \text{ cd}$ | 0.0 ± 0.0 a | $150.9\pm8.7~\mathrm{c}$ |
| | Aztec HC (1.63 lb/a) | | | | | |
| 3 | Qrome | 39.9 ± 1.2 a | $0.78\pm0.10\ b$ | $10.0\pm5.8~d$ | 0.0 ± 0.0 a | 151.6 ± 6.6 c |
| 4 | Qrome + | $39.1\pm0.6~ab$ | $0.22\pm0.06~cd$ | $70.0\pm10.0~ab$ | 0.0 ± 0.0 a | $170.8 \pm 11.5 \text{ bc}$ |
| | Aztec HC (1.63 lb/a) | | | | | |
| 5 | VT Double Pro | $33.6\pm1.6\ d$ | 1.22 ± 0.14 a | $5.0 \pm 5.0 \text{ d}$ | 0.3 ± 0.3 a | $160.3 \pm 11.9 \text{ c}$ |
| 6 | VT Double Pro + | 35.5 ± 0.9 cd | $0.31\pm0.07~\text{c}$ | 55.0 ± 5.0 bc | $0.3 \pm 0.3 \ a$ | $170.9 \pm 7.0 \text{ bc}$ |
| | Aztec HC (1.63 lb/a) | | | | | |
| 7 | SmartStax Pro | 36.1 ± 0.4 bcd | $0.31\pm0.06\ c$ | 50.0 ± 17.3 bc | 0.3 ± 0.3 a | $190.3 \pm 2.7 \text{ ab}$ |
| 8 | SmartStax Pro + | 36.8 ± 0.9 abcd | $0.09\pm0.02\ d$ | $95.0 \pm 5.0 \text{ a}$ | 0.0 ± 0.0 a | 203.7 ± 11.2 a |
| | Aztec HC (1.63 lb/a) | | | | | |

B. Evaluation of Nurizma and Force Evo for corn rootworm control

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

Objective: To compare the performance of Nurizma (alone or in combination with SmartStax) and Force Evo for control of corn rootworm (particularly western corn rootworm, *Diabrotica virgifera virgifera*) larval damage.

Summary: Stand and root injury were affected by treatment. Stand was primarily impacted by the hybrid, with the SmartStax hybrid 64-64 generally having greater stands than the VT Double Pro hybrid 64-65. Root injury was reduced compared with the untreated control in plots that received Nurizma (1 oz) in combination with SmartStax or Force Evo (8 oz) in combination with VT Double Pro. Interestingly, SmartStax without insecticide (or with the lower 0.5 oz rate of Nurizma) was not statistically different from untreated VT Double Pro plots, an indication of resistance to the SmartStax Bt proteins at this site.

Funding: Project funding and pesticide materials for this trial were provided by BASF; seed was provided by Bayer CropScience. Additional pesticide materials were provided by Syngenta.

| Seed coatings | DKC64-65 ^a : Clothianidin (0.50mg ai/seed) [Acceleron FALH2VQ ^a] |
|------------------------------|---|
| | DKC64-64 ^a : Clothianidin (0.50mg ai/seed) [Acceleron FALH2VQ ^a] |
| Previous crop | Trap crop: late-planted, non-Bt field corn inter-seeded with pumpkins |
| Soil type | Thorp silt loam |
| Tillage | Conventional |
| Row spacing | 30 inches |
| Seeding Rate | 35,500 seeds per acre |
| Soil insecticide application | Liquid in-furrow at planting, 5 gal/acre application volume |
| Planting date | May 17 2022 |
| Emergence date | May 24 2022 |
| Herbicide | Pre-emerge: 32% UAN (50 gal/ac), Harness Xtra ^a (2 qt/ac) |
| | Post-emerge: Roundup PowerMAX ^a (32 oz/ac), FS MaxSupreme ^b (1 |
| | qt/ac), Sotrion ^b (38 oz/ac) |
| Plot size | 4 rows (10 ft) wide by 30 ft long, 5 ft unplanted alleys |

Table B- 1. Plot information

^a Bayer CropScience, St. Louis, MO; ^b Growmark, Inc., Bloomington, IL

 Table B- 2. Corn rootworm treatments

| Trt | Corn hybrid | Trait package | CRW Bt proteins | Soil Insecticide |
|-----|------------------------|---------------|------------------------|--|
| 1 | DKC 64-65 ^a | VT Double Pro | None | None |
| 2 | DKC 64-65 | VT Double Pro | None | Nurizma ^b (1oz/acre) (broflanilide 25.97% suspension concentrate) |
| 3 | DKC 64-64 ^a | SmartStax | Cry3Bb1 + Cry34/35Ab1 | Nurizma (1oz/acre) |
| 4 | DKC 64-64 | SmartStax | Cry3Bb1 + Cry34/35Ab1 | Nurizma (0.5oz/acre) |
| 5 | DKC64-65 | VT Double Pro | None | BAS 450 UM I ^b (1oz/acre) |
| 6 | DKC64-65 | VT Double Pro | None | BAS 450 UM I (0.5oz/acre) |
| 7 | DKC64-65 | VT Double Pro | None | Force Evo ^c (8 oz/acre) (tefluthrin 24.2% emulsifiable concentrate) |
| 8 | DKC 64-64 | SmartStax | Cry3Bb1 + Cry34/35Ab1 | None |

^a Bayer CropScience, St. Louis, MO; ^b BASF Corporation, Research Triangle Park, NC; ^c Syngenta Crop Protection, Greensboro, NC

| Table D- 5. Generalized linear mixed model statistics. Frobability distribution used in the analysis is given in parentileses. | Table B-3. Generalized linear mixed model statistics. Probab | bility distribution used in the analysis is given in parentheses. |
|---|--|---|
|---|--|---|

| Dependent Variable | Date | Treatment df | Error df | F | Р |
|------------------------------|----------|--------------|----------|------|----------------------|
| Plant stand (normal) | 6 June | 7 | 21 | 9.64 | < 0.001 ^a |
| Root injury rating (gamma) | 26 July | 7 | 21 | 3.01 | 0.024 ^a |
| Percent consistency (normal) | 26 July | 7 | 21 | 1.36 | 0.273 |
| Percent lodging (normal) | 30 Sept. | 7 | 21 | 1.86 | 0.127 |
| Yield (normal) | 2 Nov. | 7 | 21 | 0.55 | 0.788 |

Table B- 4. Mean (\pm 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 (V3) | Node-injury rating (R1) | Percent consistency (R1) | Percent lodging (R6) | Yield |
|-----|-----------------------|--------------------------|----------------------------|-----------------------------|-------------------------|--------------------|
| Trt | Treatment | 6 June 2022 | 26 July 2022 | 26 July 2022 | 30 Sept. 2022 | 2 Nov. 2022 |
| 1 | VT Double Pro | $34.5\pm0.5\ c^a$ | $1.10 \pm 0.15 \text{ a}$ | $10.0 \pm 10.0 \text{ a}$ | 17.5 ± 11.3 a | 177.6 ± 5.6 a |
| 2 | VT Double Pro + | $35.0\pm0.4\ c$ | 0.73 ± 0.13 abc | 30.0 ± 17.3 a | 1.3 ± 0.8 a | 176.9 ± 15.0 a |
| | Nurizma (1 oz) | | | | | |
| 5 | VT Double Pro + | $35.8\pm0.7\ c$ | 1.11 ± 0.14 a | $10.0 \pm 10.0 \text{ a}$ | $2.3 \pm 1.7 \ a$ | $183.5 \pm 9.3 a$ |
| | BAS 450 UM I (1 oz) | | | | | |
| 6 | VT Double Pro + | $34.6\pm0.9~c$ | 1.21 ± 0.11 a | 0.0 ± 0.0 a | $2.5 \pm 1.5 a$ | 179.5 ± 11.6 a |
| | BAS 450 UM I (0.5 oz) | | | | | |
| 7 | VT Double Pro + | $34.6 \pm 1.8 \text{ c}$ | $0.57\pm0.07~bc$ | 20.0 ± 14.1 a | 1.5 ± 0.6 a | 197.5 ± 3.8 a |
| | Force Evo (8 oz) | | | | | |
| 8 | SmartStax | $38.5 \pm 1.7 \text{ b}$ | 0.88 ± 0.13 ab | 20.0 ± 11.5 a | 4.3 ± 1.9 a | 184.6 ± 18.0 a |
| 3 | SmartStax + | $39.4\pm0.8\ ab$ | $0.43\pm0.07\ c$ | 40.0 ± 18.3 a | 0.0 ± 0.0 a | 191.7 ± 17.0 a |
| | Nurizma (1 oz) | | | | | |
| 4 | SmartStax + | $41.5 \pm 0.5 \ a$ | 1.10 ± 0.11 a | 0.0 ± 0.0 a | 1.0 ± 0.7 a | 193.5 ± 10.4 a |
| | Nurizma (0.5 oz) | | | | | |

C. Evaluation of SmartStax Pro for corn rootworm control

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

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

Summary: Stand, rootworm injury, percent consistency, and yield were affected by treatment, though rootworm injury was generally low in this field experiment. The 114-d RM VT Double Pro hybrid had a reduced stand compared with the other treatments. SmartStax Pro (both 111-d and 115-d RM hybrids) and SmartStax (114-d RM hybrid only) had reduced corn rootworm injury relative to the 112-d VT Double Pro hybrid. The 115-d RM SmartStax Pro hybrid also had reduced rootworm injury compared to the 114-d RM VT Double Pro hybrid, the 112-d RM SmartStax hybrid, and the 111-d RM SmartStax Pro hybrid. All SmartStax and SmartStax Pro hybrids yielded higher than the VT Double Pro hybrids, and the 115-d RM SmartStax Pro hybrid had a higher yield than the other hybrids tested.

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

| Seed coatings | Included ≤ 0.50 mg clothianidin per seed, plus a standard corn |
|--------------------------------|--|
| | fungicide package |
| Previous crop | Trap crop: late-planted, non-Bt field corn inter-seeded with pumpkins |
| Soil type | Thorp silt loam |
| Tillage | Conventional |
| Row spacing | 30 inches |
| Seeding Rate | 35,500 seeds per acre |
| Planting date | May 16 2022 |
| Emergence date | May 23 2022 |
| Herbicide | Pre-emerge: 32% UAN (50 gal/ac), Harness Xtra ^a (2 qt/ac) |
| | Post-emerge: Roundup PowerMAX ^a (32 oz/ac), FS MaxSupreme ^b (1 |
| | qt/ac), Sortion ^b (38 oz/ac) |
| Plot size | 4 rows (10 ft) wide by 30 ft long, 5 ft unplanted alleys |
| ^a Davon CronScience | t Louis MO: ^b Crowmark Inc. Plaamington II |

Table C-1. Plot information

^a Bayer CropScience, St. Louis, MO; ^b Growmark, Inc., Bloomington, IL

| Table C- 2. Corn | rootworm | treatments. |
|------------------|----------|-------------|
|------------------|----------|-------------|

| Trt | Trait package | CRW traits |
|------|--------------------------------------|--------------------------------------|
| 1 | VT Double Pro ^a , 114d RM | None |
| 2 | SmartStax ^a , 112d RM | Cry3Bb1 + Cry34/35Ab1 |
| 3 | SmartStax PRO ^a , 111d RM | Cry3Bb1 + Cry34/35Ab1 + DvSnf7 dsRNA |
| 4 | VT Double Pro, 112d RM | None |
| 5 | SmartStax, 1114d RM | Cry3Bb1 + Cry34/35Ab1 |
| 6 | SmartStax PRO, 115d RM | Cry3Bb1 + Cry34/35Ab1 + DvSnf7 dsRNA |
| 0.70 | | |

^a Bayer CropScience, St. Louis, MO

Table C-3. Generalized linear mixed model statistics; probability distribution used in the analysis is given in parentheses.

| 1 | Treatmen | t | | |
|---------|--|---|---|---|
| Date | df | Error df | F | Р |
| 2 June | 5 | 15 | 4.06 | 0.016 ^a |
| 25 July | 5 | 15 | 5.16 | 0.006^{a} |
| 25 July | 5 | 15 | 4.98 | 0.007^{a} |
| 4 Oct. | 5 | 15 | 2.03 | 0.132 |
| 30 Oct. | 5 | 15 | 13.09 | $< 0.001^{a}$ |
| | Date 2 June 25 July 25 July 4 Oct. | Date df 2 June 5 25 July 5 25 July 5 4 Oct. 5 | 2 June 5 15 25 July 5 15 25 July 5 15 4 Oct. 5 15 | DatedfError dfF2 June5154.0625 July5155.1625 July5154.984 Oct.5152.03 |

Table C-4. Mean (\pm 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 | Trait packages | 2 June 2022 | 25 July 2022 | 25 July 2022 | 4 Oct. 2022 | 30 Oct. 2022 |
| 4 | Non-CRW trait (VT2P); 112RM | $41.4\pm1.0\;a^a$ | 0.54 ± 0.12 a | $40.0 \pm 14.1 \ d$ | 0.0 ± 0.0 a | 193.7 ± 6.1 c |
| 2 | SmartStax; 112RM | $41.8 \pm 1.1 \text{ a}$ | $0.34\pm0.07\;ab$ | $60.0 \pm 11.5 \text{ bcd}$ | 0.3 ± 0.3 a | $219.3\pm5.3~b$ |
| 3 | SmartStax PRO; 111RM | 39.6 ± 1.9 a | $0.18\pm0.08\;b$ | 80.0 ± 8.2 ab | 0.0 ± 0.0 a | $231.0\pm7.0\ b$ |
| 1 | Non-CRW trait (VT2P) 114RM | 31.0 ± 5.1 ba | $0.36\pm0.08\;ab$ | $50.0 \pm 5.8 \text{ cd}$ | $0.5\pm0.3~a$ | $202.0\pm6.8~c$ |
| 5 | SmartStax; 114RM | $42.3 \pm 1.1 \text{ a}$ | $0.15\pm0.04~\text{bc}$ | 75.0 ± 5.0 abc | 0.0 ± 0.0 a | $223.9\pm6.4\ b$ |
| 6 | SmartStax PRO; 115RM | 40.1 ± 1.7 a | $0.06\pm0.02~\mathrm{c}$ | $90.0 \pm 5.8 \text{ a}$ | 0.0 ± 0.0 a | $249.9 \pm 9.3 a$ |
| 2 3 1 5 | SmartStax; 112RM SmartStax PRO; 111RM Non-CRW trait (VT2P) 114RM SmartStax; 114RM | $41.8 \pm 1.1 \text{ a}$ $39.6 \pm 1.9 \text{ a}$ $31.0 \pm 5.1 \text{ ba}$ $42.3 \pm 1.1 \text{ a}$ | $\begin{array}{l} 0.34 \pm 0.07 \text{ ab} \\ 0.18 \pm 0.08 \text{ b} \\ 0.36 \pm 0.08 \text{ ab} \\ 0.15 \pm 0.04 \text{ bc} \end{array}$ | 60.0 ± 11.5 bcd 80.0 ± 8.2 ab 50.0 ± 5.8 cd 75.0 ± 5.0 abc | 0.3 ± 0.3 a 0.0 ± 0.0 a 0.5 ± 0.3 a 0.0 ± 0.0 a | L L L |

D. Evaluation of Commercial and Pre-commercial Soil-applied Pesticides for Corn Rootworm Control

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

Objective: To evaluate the performance commercial and pre-commercial soil-applied liquid pesticides for control of corn rootworm (particularly western corn rootworm, *Diabrotica virgifera virgifera*) larval damage.

Summary: Rootworm pressure in this trial was low, and there were no differences in stand, node injury rating, percent consistency, percent lodging, or yield among treatments.

Funding: FMC Corporation provided project funding and pesticide materials. Bayer CropScience provided seed and maintenance herbicides.

| Corn hybrid (Bt proteins) | DKC64-65 ^a VT Double Pro (no CRW Bt traits) |
|------------------------------|--|
| Seed coatings | Clothianidin (0.50mg ai/seed) [Acceleron FALH2Q ^a] |
| Previous crop | Trap crop: late-planted, non-Bt field corn inter-seeded with pumpkins |
| Soil type | Thorp silt loam |
| Tillage | Conventional |
| Row spacing | 30 inches |
| Seeding Rate | 35,500 seeds per acre |
| Soil insecticide application | Trts. 2, 3, 4, 5, 6, liquid in-furrow at planting, 5 gal/acre application volume |
| | Trt. 7: Granular in-furrow, SmartBox ^b research-scale granular applicator |
| Planting date | 17 May 2022 |
| Emergence date | 24 May 2022 |
| Herbicide | Pre-emerge: 32% UAN (50 gal/ac), Harness Xtra ^a (2 qt/ac) |
| | Post-emerge: Roundup PowerMAX ^a (32 oz/ac), FS MaxSupreme ^c (1 |
| | qt/ac), Sortion ^c (38 oz/ac) |
| Plot size | 4 rows (10 ft) wide by 30 ft long, 5 ft unplanted alleys |

Table D- 1. Plot information

^a Bayer CropScience, St. Louis, MO; ^b AMVAC Chemical Corporation, Los Angeles, CA; ^c Growmark, Inc., Bloomington, IL

| Trt | Soil pesticide | | Active ingredient |
|-----|-----------------------------|----------------------------|--|
| 1 | Untreated | | |
| 2 | Ethos XB (8.5 oz/a) | Insecticide + Fungicide | 15.67% Bifenthrin + 5.5% <i>Bacillus amyloliquefaciens</i> strain D747 |
| 3 | XSK03-R002 (8.5 oz/a) | Plant Health | Pre-commercial |
| 4 | Capture LFR (8.5 | Insecticide + | 17.15% Bifenthrin + |
| | oz/a) + Zironar (6 oz/a) | Plant Health | 3.5% <i>Bacillus licheniformis</i> strain FMCH001 + 4% <i>Bacillus subtilis</i> strain FMCH002 |
| 5 | VNU30-R002 (8.5 oz/a) | Plant Health | Pre-commercial |
| 6 | Capture LFR (8.5 oz/a) | Insecticide | 17.15% Bifenthrin |
| 7 | Force 6.5G (2.3 lb/a) | Insecticide | 6.5% Tefluthrin |

Table D- 2. Corn rootworm treatments

^a FMC Corporation, Philadelphia, PA; ^bSyngenta Crop Protection, Greensboro, NC

Table D-3. Generalized linear mixed-model statistics; probability distribution used in the analysis is given in parentheses.

| | | Numerator | Denominator | | |
|------------------------------|---------|-----------|-------------|------|-------|
| Dependent Variable | Date | df | df | F | Р |
| Plant stand (normal) | 3 June | 6 | 18 | 0.24 | 0.957 |
| Root injury rating (gamma) | 25 July | 6 | 18 | 1.22 | 0.339 |
| Percent consistency (normal) | 25 July | 6 | 18 | 0.42 | 0.855 |
| Percent lodging (normal) | 4 Oct. | 6 | 18 | 2.27 | 0.083 |
| Yield (normal) | 3 Nov. | 6 | 18 | 1.50 | 0.234 |

Table D- 4. Mean (\pm 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) | ratings (R1) | consistency (R1) | lodging (R6) | Yield |
| Trt | Treatment | 3 June 2022 | 25 July 2022 | 25 July 2022 | 4 Oct. 2022 | 3 Nov. 2022 |
| 1 | Untreated | $33.4\pm0.5\ a^a$ | 0.30 ± 0.11 a | 65.0 ± 17.1 a | $0.3\pm0.3\ a$ | 193.6 ± 8.8 a |
| 2 | Ethos XB (8.5 oz/a) | 34.3 ± 0.8 a | $0.21\pm0.09~a$ | 75.0 ± 15.0 a | $0.0\pm0.0\;a$ | 206.6 ± 6.1 a |
| 3 | XSK03-R002 (8.5 oz/a) | $34.0\pm0.9~a$ | $0.15 \pm 0.03 \ a$ | 70.0 ± 10.0 a | $0.0\pm0.0\;a$ | $210.3 \pm 3.8 \text{ a}$ |
| 4 | Capture LFR (8.5 oz/a) + Zironar (6 oz/a) | $33.6\pm0.4\ a$ | $0.29\pm0.10\;a$ | 60.0 ± 18.3 a | $0.8\pm0.5~a$ | 195.1 ± 3.3 a |
| 5 | VNU30-R002 (8.5 oz/a) | $33.9 \pm 0.3 \text{ a}$ | 0.34 ± 0.11 a | 60.0 ± 18.3 a | $0.5\pm0.3~a$ | 198.3 ± 7.7 a |
| 6 | Capture LFR (8.5 oz/a) | $34.0\pm0.8\ a$ | $0.39\pm0.14~a$ | 50.0 ± 17.3 a | $0.0\pm0.0\;a$ | $197.4 \pm 7.1 \text{ a}$ |
| 7 | Force 6.5 G (2.3 lb/a) | $33.5\pm0.8\;a$ | $0.11\pm0.04~a$ | $80.0 \pm 11.5 \text{ a}$ | 0.0 ± 0.0 a | 211.1 ± 1.9 a |

E. Evaluation of 3RIVE insecticide formulations for control of corn rootworm larvae, 2022

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

Objective: To evaluate the performance of soil pesticides applied in-furrow using a researchscale 3RIVE applicator compared with standard liquid formulations for control of corn rootworm (particularly western corn rootworm, *Diabrotica virgifera virgifera*) larval damage.

Summary: Rootworm pressure in this trial was light, and there were no differences in nodeinjury ratings or other response variables among treatments.

Funding: FMC Corporation provided project funding and pesticide materials. Syngenta provided additional pesticide materials. Bayer CropScience provided seed and maintenance herbicides.

| Corn hybrid (Bt proteins) | DKC64-65 ^a VT Double Pro (no CRW Bt traits) |
|------------------------------|--|
| Seed coatings | Clothianidin (0.50mg ai/seed) [Acceleron FALH2Q] |
| Previous crop | Trap crop: late-planted, non-Bt field corn inter-seeded with pumpkins |
| Soil type | Thorp silt loam |
| Tillage | Conventional |
| Row spacing | 30 inches |
| Seeding Rate | 35,500 seeds per acre |
| Soil insecticide application | Trts. 2, 3, 4, 5, 6, 7, 9, 10, 11 Research-scale 3RIVE 3D ^b applicator in-furrow, 40 oz/acre application volume |
| | Trt. 8: Granular in-furrow, SmartBox ^c research-scale granular applicator |
| Planting date | 19 May 2022 |
| Emergence date | 26 May 2022 |
| Herbicide | Pre-emerge: 32% UAN (50 gal/ac), Harness Xtra ^a (2 qt/ac) |
| | Post-emerge: Roundup PowerMAX ^a (32 oz/ac), FS MaxSupreme ^d |
| | (1 qt/ac), Sortion ^d (38 oz/ac) |
| Plot size | 4 rows (10 ft) wide by 30 ft long, 5 ft unplanted alleys |

Table E- 1. Plot information

^a Bayer CropScience, St. Louis, MO; ^b FMC Corporation, Philadelphia, PA; ^c AMVAC Chemical Corporation, Los Angeles, CA; ^d Growmark, Inc., Bloomington, IL

| Table E- 2. Corn ro | ootworm treatments |
|---------------------|--------------------|
|---------------------|--------------------|

| Trt | Soil pesticide | | Active ingredient |
|-----|---|---------------|--|
| 1 | Untreated | n/a | n/a |
| 2 | VNU30-R003 3D ^a (8.5 oz/a) | Insecticide | Pre-commercial, suspension concentrate (SC) |
| 3 | Capture 3RIVE (8 oz/a) | Insecticide + | 17.68% Bifenthrin SC, |
| | + U8Z09-R007 3D (6 oz/a) | Biological | pre-commercial product SC |
| 4 | Xyway 3D ^a (11.8 oz/a) | Fungicide + | 26.4% Flutriafol SC, |
| | + U8Z09-R007 3D ^a (6 oz/a) | Biological | pre-commercial product SC |
| 5 | Xyway 3D ^a (11.8 oz/a) | Fungicide + | 26.4% Flutriafol SC, |
| | + VNU30-R003 3D ^a (8.5 oz/a) | Insecticide | pre-commercial product SC |
| 6 | Xyway 3D (11.8 oz/a) | Fungicide + | 26.4% Flutriafol SC, |
| | + CAPTURE 3RIVE (8 oz/a) | Insecticide | 17.68% Bifenthrin SC |
| 7 | Xyway 3D ^a (11.8 oz/a) | Fungicide + | 26.4% Flutriafol SC, |
| | + ETHOS 3D ^a (9.1 oz/a) | Fungicide | 15.67% Bifenthin + 5.5% Bacillus amyloliquefaciens strain D747 SC |
| 8 | Force 6.5 G ^b (2.3 lb/a) | Insecticide | 6.5% Tefluthrin granule |
| 9 | Capture 3RIVE ^a (8 oz/a) | Insecticide | 17.68% Bifenthrin SC |
| 10 | Ethos 3D ^a (9.1 oz/a) | Fungicide | 15.67% Bifenthrin + 5.5% Bacillus amyloliquefaciens strain D747 SC |
| 11 | Xyway 3D ^a (11.8 oz/a) | Fungicide | 26.4% Flutriafol SC |

^a FMC Corporation, Philadelphia, PA; ^bSyngenta Crop Protection, Greensboro, NC

Table E-3. Generalized linear mixed model analysis; probability distribution used in the analysis is given in parentheses.

| | | Treatment | Error | | |
|---|--------|-----------|-------|------|-------|
| Dependent Variable | Date | df | df | F | Р |
| Plant stand (normal) | 3 June | 10 | 30 | 2.12 | 0.055 |
| Root injury rating (beta ^b) | 8 Aug. | 10 | 30 | 1.78 | 0.109 |
| Percent consistency (normal) | 8 Aug. | 10 | 30 | 1.84 | 0.097 |
| Percent lodging (normal) | 6 Oct. | 10 | 30 | 1.00 | 0.465 |
| Yield (normal) | 2 Nov. | 10 | 30 | 1.29 | 0.280 |

^a Effect is significant at $\alpha = 0.05$; ^b Data were divided by 3 to express each value as the proportion of total roots pruned prior to analysis using a beta distribution because a statistical model using the gamma distribution did not converge, but are reported below as untransformed data (i.e. 0-3 node-injury ratings)

Table E-4. Mean (\pm 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) | ratings (R1) | consistency (R1) | lodging (R6) | Yield |
| Trt | Treatment | 3 June 2022 | 5 Aug. 2022 | 5 Aug. 2022 | 6 Oct. 2022 | 2 Nov. 2022 |
| 1 | Untreated | $40.9\pm0.5\ a^a$ | $0.04 \pm 0.01 \ a$ | $100.0 \pm 0.0 \text{ a}$ | 0.0 ± 0.0 a | $217.2 \pm 5.2 a^{a}$ |
| 2 | VNU30-R003 3D (8.5 oz/a) | $39.4 \pm 0.7 \ a$ | $0.08\pm0.04~a$ | $90.0 \pm 5.8 \; a$ | 0.0 ± 0.0 a | $214.0 \pm 5.1 \text{ a}$ |
| 3 | Capture 3RIVE (8 oz/a) + | 38.9 ± 0.1 a | $0.04\pm0.02~a$ | $95.0 \pm 5.0 \text{ a}$ | 0.0 ± 0.0 a | 228.0 ± 5.5 a |
| | U8Z09-R007 3D (6 oz/a) | | | | | |
| 4 | Xyway 3D (11.8 oz/a) + | $40.5 \pm 0.4 \; a$ | $0.05\pm0.02~a$ | 100.0 ± 0.0 a | 0.0 ± 0.0 a | 208.8 ± 2.5 a |
| | U8Z09-R007 3D (6 oz/a) | | | | | |
| 5 | Xyway 3D (11.8 oz/a) + | $40.8\pm0.7~\mathrm{a}$ | $0.05 \pm 0.01 \; a$ | 100.0 ± 0.0 a | 0.3 ± 0.3 a | 212.7 ± 5.7 a |
| | VNU30-R003 3D (8.5 oz/a) | | | | | |
| 6 | Xyway 3D (11.8 oz/a) + | $40.6\pm0.4~a$ | $0.05\pm0.01~\mathrm{a}$ | 100.0 ± 0.0 a | 0.0 ± 0.0 a | 214.9 ± 5.8 a |
| | Capture 3RIVE (8 oz/a) | | | | | |
| 7 | Xyway 3D (11.8 oz/a) + | $40.4 \pm 0.2 \ a$ | $0.14 \pm 0.04 \; a$ | 85.0 ± 5.0 a | 0.0 ± 0.0 a | 214.9 ± 2.5 a |
| | Ethos 3D (9.1 oz/a) | | | | | |
| 8 | Force 6.5 G (2.3 lb/a) | 39.8 ± 0.3 a | $0.05 \pm 0.01 \; a$ | 100.0 ± 0.0 a | 0.0 ± 0.0 a | 222.7 ± 5.0 a |
| 9 | Capture 3RIVE (8 oz/a) | 40.6 ± 0.7 a | $0.09 \pm 0.02 \ a$ | 85.0 ± 9.6 a | 0.3 ± 0.3 a | 211.3 ± 3.9 a |
| 10 | Ethos 3D (9.1 oz/a) | $40.5 \pm 0.5 \ a$ | $0.08 \pm 0.02 \; a$ | $95.0 \pm 5.0 \text{ a}$ | 0.0 ± 0.0 a | 211.7 ± 8.2 a |
| 11 | Xyway 3D (11.8 oz/a) | 40.6 ± 0.4 a | $0.08\pm0.02~a$ | $90.0 \pm 5.8 \text{ a}$ | 0.0 ± 0.0 a | 211.5 ± 5.2 a |

F. Evaluation of MBI-306 and commercial insecticides for corn rootworm control

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

Objective: To compare the performance of MBI-306 with commercial standards including Capture LFR and Force Evo for control of corn rootworm (particularly western corn rootworm, *Diabrotica virgifera virgifera*) larval damage in a non-Bt (for corn rootworm) corn hybrid.

Summary: While corn rootworm feeding pressure was moderate in this trial, variability within the untreated plots and relatively high levels of pruning in most of the insecticide-treated plots prevented statistical separation of the different insecticides we evaluated. Treatment MBI-306 (20 oz/a) resulted in elevated lodging compared with the other insecticides tested but was not different from the untreated plots. The other response variables we assessed did not differ among treatments.

Funding: Project funding, seed, and pesticide materials for this trial were provided by Marrone Bio Innovations (now Pro Farm Group Inc.)

| Corn hybrid (Bt proteins) | G10L16-3220A ^a |
|------------------------------|---|
| Seed coatings | thiamethoxam (0.50 mg ai/seed) [Avicta Complete 500 + |
| Previous crop | Vibrance ^b] Trap crop: late-planted, non-Bt field corn inter-seeded with |
| Soil type | pumpkins Thorp silt loam |
| Tillage | Conventional |
| Row spacing | 30 inches |
| Seeding Rate | 35,500 seeds per acre |
| Soil insecticide application | Liquid in-furrow, 5 gal/acre application volume |
| Planting date | 17 May 2022 |
| Emergence date | 24 May 2022 |
| Herbicide | Pre-emerge: 32% UAN (50 gal/ac), Harness Xtra ^c (2 qt/ac) |
| | Post-emerge: Roundup PowerMAX ^c (32 oz/ac), FS MaxSupreme ^d |
| | (1 qt/ac), Sortion ^d (38 oz/ac) |
| Plot size | 4 rows (10 ft) wide by 30 ft long with 5-ft unplanted alleys between |
| | plots |

Table F- 1. Plot information

^a Golden Harvest Seeds (Syngenta), Downer's Grove, IL; ^b Syngenta Crop Protection, Greensboro, NC; ^c Bayer CropScience, St. Louis, MO; ^d Growmark, Inc., Bloomington, IL

| Table F-2.0 | Corn rootworm | treatments |
|-------------|---------------|------------|
|-------------|---------------|------------|

| Trt | Material and Rate | Active ingredient | Formulation |
|-----|---|-------------------|-------------------------------|
| 1 | Untreated | N/A | N/A |
| 2 | Capture LFR ^a (8.5 fl. oz/a) | Bifenthrin 17.15% | Suspension concentrate (SC) |
| 3 | Capture LFR ^a (17 fl. oz/a) | Bifenthrin 17.15% | Suspension concentrate (SC) |
| 4 | Force Evo ^b (9.9 fl. oz/a) | Tefluthrin 24.2% | Emulsifiable Concentrate (EC) |
| 5 | MBI-306° (20 fl. oz/a) | Pre-commercial | Suspension concentrate (SC) |
| 6 | MBI-306° (15 fl. oz/a) | Pre-commercial | Suspension concentrate (SC) |
| 7 | MBI-306° (20 fl. oz/a) | Pre-commercial | Suspension concentrate (SC) |
| | + UBP-140 ^c (22 fl. oz/a) | | |

^a FMC Corporation, Philadelphia, PA; ^b Syngenta Crop Protection, Greensboro, NC; ^c Pro Farm Group, Davis, CA

Table F-3. Generalized linear mixed model statistics; probability distribution used in the analysis is given in parentheses.

| | | Numerator | Denominator | | |
|---------------------------------|---------|-----------|-------------|------|--------------------|
| Dependent Variable | Date | df | df | F | Р |
| Plant stand (normal) | 6 June | 6 | 18 | 1.00 | 0.454 |
| Root injury rating (gamma) | 25 July | 6 | 18 | 1.82 | 0.151 |
| Proportion consistency (normal) | 25 July | 6 | 18 | 0.85 | 0.547 |
| Proportion lodging (normal) | 5 Oct. | 6 | 18 | 2.99 | 0.033 ^a |
| Yield (normal) | 2 Nov. | 6 | 18 | 1.26 | 0.325 |

Table F- 4. Mean (\pm 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 (V3) | Node-injury ratings | Percent consistency | Percent lodging | Yield |
|-----|---|--------------------------|---------------------------|---------------------------|--------------------------|-----------------------|
| Trt | Treatment | 6 June 2022 | 25 July 2022 | 25 July 2022 | 5 Oct. 2022 | 2 Nov. 2022 |
| 1 | Untreated | $42.3\pm1.7~a^a$ | $1.12 \pm 0.20 \text{ a}$ | $20.0 \pm 11.5 \text{ a}$ | $5.8 \pm 5.1 \text{ ab}$ | $153.7 \pm 8.6 \ a^a$ |
| 2 | Capture LFR ^a (8.5 fl. oz/a) | $44.5 \pm 1.7 \text{ a}$ | 0.65 ± 0.13 a | $30.0 \pm 12.9 \text{ a}$ | $0.5\pm0.5\;b$ | 171.2 ± 6.9 a |
| 3 | Capture LFR ^a (17 fl. oz/a) | $43.5 \pm 1.2 \text{ a}$ | $0.78\pm0.14\;a$ | $35.0\pm15.0~a$ | $0.3\pm0.3\;b$ | 161.1 ± 14.6 a |
| 4 | Force Evo ^b (9.9 fl. oz/a) | $41.4\pm0.8~a$ | $0.39\pm0.09~a$ | 55.0 ± 17.1 a | $0.0\pm0.0\;b$ | 173.1 ± 17.6 a |
| 5 | MBI-306 ^c (20 fl. oz/a) | 40.4 ± 1.6 a | 1.13 ± 0.17 a | 20.0 ± 8.2 a | 11.8 ± 4.2 a | 141.2 ± 12.3 a |
| 6 | MBI-306 ^c (15 fl. oz/a) | 42.6 ± 1.7 a | 0.94 ± 0.18 a | $20.0\pm20.0\;a$ | $1.0\pm0.7~b$ | 176.3 ± 15.0 a |
| 7 | MBI-306 ^c (20 fl. oz/a) + | 43.4 ± 2.7 a | 0.81 ± 0.13 a | 20.0± 11.5 a | $1.3\pm0.6~b$ | 178.8 ± 5.3 a |
| | UBP-140 ^c (22 fl. oz/a) | | | | | |

G. Evaluation of liquid soil insecticides in combination with Bt trait packages

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

Objective: To compare the performance of insecticides including Plinazolin[®] technology (formulation A22466G), Force Evo, and Capture LFR alone or in combination with Bt trait packages for control of corn rootworm (particularly western corn rootworm, *Diabrotica virgifera*) larval damage.

Summary: Corn rootworm pressure was low in this trial, and there were no differences in rootinjury ratings, lodging, or yield. Stand was generally higher for the SmartStax corn hybrid tested than for the VT Double Pro or SmartStax Pro hybrids, but this did not appear to be a result of insect injury.

Funding: Project funding, pesticide materials, and seed for this trial were provided by Syngenta; additional seed was provided by Bayer CropScience, and additional pesticide materials were provided by FMC.

| Corn hybrid (CRW traits) | VT Double Pro DKC 64-65 ^a |
|---------------------------------------|---|
| | SmartStax DKC 64-64 ^a (Cry3Bb1 + Cry34/35Ab1) |
| | SmartStax Pro 111-33 ^a (Cry3Bb1 + Cry34/35Ab1 + DvSnf7 dsRNA) |
| Seed coatings | DKC64-64: Clothianidin (0.50mg ai/seed) [Acceleron FALH2VQ ^a] |
| - | DKC64-65: Clothianidin (0.50mg ai/seed) [Acceleron FALH2Q ^a] |
| | DKC 111-33: Clothianidin (0.50mg ai/seed) [Acceleron FALZH2VQ ^a] |
| Previous crop | Trap crop: late-planted, non-Bt field corn inter-seeded with pumpkins |
| Soil type | Thorp silt loam |
| Tillage | Conventional |
| Row spacing | 30 inches |
| Seeding Rate | 35,500 seeds per acre |
| Soil insecticide application | Granular in-furrow, SmartBox ^b research-scale granular applicator |
| Planting date | May 17 2022 |
| Emergence date | May 24 2022 |
| Herbicide | Pre-emerge: 32% UAN (50 gal/ac), Harness Xtra ^a (2 qt/ac) |
| | Post-emerge: Roundup PowerMAX ^a (32 oz/ac), FS MaxSupreme ^c (1 |
| | qt/ac), Sortion ^c (38 oz/ac) |
| Plot size | 4 rows (10 ft) wide by 30 ft long, 5 ft unplanted alleys |
| ^a Bayer CropScience St Lou | is $MO^{\circ b}$ AMVAC Chemical Corporation Los Angeles CA ^{\circ} |

Table G-1. Plot information

^a Bayer CropScience, St. Louis, MO; ^b AMVAC Chemical Corporation, Los Angeles, CA; ^c Growmark, Inc., Bloomington, IL

| Trait Package | Soil Insecticide | Active Ingredient | | | | |
|--|--|---|--|--|--|--|
| VT Double Pro ^a | None | n/a | | | | |
| VT Double Pro ^a | Force Evo ^b (10 fl. oz/a) | 24.2% Tefluthrin | | | | |
| VT Double Pro ^a | A22466G (Plinazolin [®] Technology) ^b (6.8 fl. oz/a) | Pre-commercial | | | | |
| VT Double Pro ^a | Capture LFR ^c (8 fl. oz/a) | 17.15% Bifenthrin | | | | |
| SmartStax ^a | None | n/a | | | | |
| SmartStax ^a | Force Evo ^b (8 fl. oz/a) | 24.2% Tefluthrin | | | | |
| SmartStax ^a | A22466G (Plinazolin [®] Technology) ^b (5 fl. oz/a) | Pre-commercial | | | | |
| SmartStax ^a | Capture LFR ^c (6.8 fl. oz/a) | 17.15% Bifenthrin | | | | |
| SmartStax Pro ^a | None | n/a | | | | |
| 10SmartStax Pro ^a Force Evo ^b (8 fl. oz/a)24.2% Tefluthrin | | | | | | |
| alb, Bayer CropSci | ence, St. Louis, MO; ^b Syngenta Crop Protection, Gre | ensboro, NC; ^c | | | | |
| | VT Double Pro ^a VT Double Pro ^a VT Double Pro ^a VT Double Pro ^a SmartStax ^a SmartStax ^a SmartStax ^a SmartStax ^a SmartStax Pro ^a | VT Double ProaNoneVT Double ProaForce Evob (10 fl. oz/a)VT Double ProaA22466G (Plinazolin® Technology)b (6.8 fl. oz/a)VT Double ProaCapture LFRc (8 fl. oz/a)SmartStaxaNoneSmartStaxaForce Evob (8 fl. oz/a)SmartStaxaA22466G (Plinazolin® Technology)b (5 fl. oz/a)SmartStaxaCapture LFRc (6.8 fl. oz/a)SmartStaxaA22466G (Plinazolin® Technology)b (5 fl. oz/a)SmartStaxaNone | | | | |

 Table G-2. Corn rootworm treatments

FMC Corporation, Philadelphia, PA

Table G-3. Generalized linear mixed model statistics; probability distribution used in the analysis is given in parentheses.

| | | Numerator | Denominator | | |
|---------------------------------|--------|-----------|-------------|-------|----------------------|
| Dependent Variable | Date | df | df | F | Р |
| Plant stand (normal) | 6 June | 9 | 27 | 10.16 | < 0.001 ^a |
| Root injury rating (gamma) | 3 Aug. | 9 | 27 | 1.63 | 0.156 |
| Proportion consistency (normal) | 3 Aug. | 9 | 27 | 0.77 | 0.642 |
| Proportion lodging (normal) | 6 Oct. | b | | | |
| Yield (normal) | 2 Nov. | 9 | 27 | 0.84 | 0.587 |

^a Effect is significant at $\alpha = 0.05$; ^b Statistical model failed, not significant

Table G- 4. Mean (\pm 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) | ratings | consistency | lodging | Yield |
| Trt | Treatment | 6 June 2022 | 3 Aug. 2022 | 3 Aug. 2022 | 6 Oct. 2022 | 2 Nov. 2022 |
| 1 | VT Double Pro | $36.6\pm0.7\ c^a$ | 0.12 ± 0.02 a | $85.0 \pm 9.6 a$ | 0.0 ± 0.0 a | 216.6 ± 7.1 a |
| 2 | VT Double Pro + | $36.3\pm0.5~\text{c}$ | $0.13\pm0.03~a$ | $80.0 \pm 14.1 \text{ a}$ | $0.0\pm0.0a$ | 212.4 ± 6.3 a |
| | Force Evo (10 fl. oz/a) | | | | | |
| 3 | VT Double Pro + | $36.3\pm0.6\ c$ | $0.15\pm0.03~a$ | $85.0 \pm 9.6 a$ | $0.0\pm0.0a$ | 219.6 ± 13.1 a |
| | A22466G (6.8 fl. oz/a) | | | | | |
| 4 | VT Double Pro + | $35.8\pm0.8~\text{c}$ | 0.16 ± 0.05 a | 75.0 ± 9.6 a | $0.0\pm0.0a$ | 228.3 ± 9.7 a |
| | Capture LFR (8 fl. oz/a) | | | | | |
| 5 | SmartStax | $39.1\pm0.2\ b$ | 0.10 ± 0.03 a | $85.0 \pm 9.6 a$ | $0.0 \pm 0.0a$ | 230.1 ± 4.3 a |
| 6 | SmartStax + | 41.1 ± 0.8 a | $0.07\pm0.02~a$ | $95.0 \pm 5.0 \text{ a}$ | $0.0\pm0.0a$ | $221.9 \pm 9.5 a$ |
| | Force Evo (8 fl. oz/a) | | | | | |
| 7 | SmartStax + | $40.3\pm0.6\;ab$ | 0.06 ± 0.02 a | $95.0 \pm 5.0 \text{ a}$ | $0.0\pm0.0a$ | $223.5 \pm 4.9 \text{ a}$ |
| | A22466G (5 fl. oz/a) | | | | | |
| 8 | SmartStax + | $38.9\pm0.4\ b$ | 0.11 ± 0.03 a | 80.0 ± 8.2 a | $0.0\pm0.0a$ | 224.4 ± 5.8 a |
| | Capture LFR (6.8 fl. oz/a) | | | | | |
| 9 | SmartStax Pro | $36.4\pm0.7~\text{c}$ | 0.09 ± 0.04 a | $95.0 \pm 5.0 \text{ a}$ | $0.0\pm0.0a$ | 231.9 ± 3.5 a |
| 10 | SmartStax Pro + | 36.1 ± 0.9 c | 0.06 ± 0.02 a | $95.0 \pm 5.0 \text{ a}$ | $0.0 \pm 0.0 a$ | 228.3 ± 1.7 a |
| | Force Evo (8 fl. oz/a) | | | | | |
| 0.3.6 | 0.11 1.1 .1 1 | • • • | 1:00 | 1 1 1 1 | 1 .1 1 01 | |

H. Large-plot evaluation of in-furrow soil insecticides for rootworm control

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

Objective: To compare the performance of Ampex EZ, Capture LFR, and Force 6.5G for control of corn rootworm (particularly western corn rootworm, *Diabrotica virgifera virgifera*) larval damage in a non-Bt (for rootworm control) corn hybrid.

Summary: While rootworm pressure in this trial was low, Ampex EZ (both 12 oz/a and 8 oz/a rates) and Force Evo (8 oz/a) resulted in reduced node-injury ratings compared with both the untreated plots and Capture LFR (17 oz/a). Percent consistency followed a similar pattern.

Funding: Project funding and insecticide materials were provided by Valent U.S.A., Walnut Creek, CA. Seed was provided by Bayer CropScience, St. Louis, MO. Additional insecticide materials were provided by FMC Corporation, Philadelphia, PA and Syngenta Crop Protection, Greensboro, NC.

| Corn hybrid (Bt proteins) | DKC 64-65 VT2P ^a (no CRW Bt trait) |
|------------------------------|---|
| Seed coatings | Clothianidin (0.50mg ai/seed) [Acceleron ^a FALH2Q] |
| Previous crop | Trap crop: late-planted, non-Bt field corn inter-seeded with pumpkins |
| Soil type | Thorp silt loam |
| Tillage | Conventional |
| Row spacing | 30 inches |
| Seeding Rate | 34,600 seeds per acre |
| Soil insecticide application | Liquid in-furrow, 5 gal/acre application volume |
| Planting date | 17 May 2022 |
| Herbicide | Pre-emerge: 32% UAN (50 gal/ac), Harness Xtra ^a (2 qt/ac) |
| | Post-emerge: Roundup PowerMAX ^a (32 oz/ac), FS MaxSupreme ^b |
| | (1 qt/ac), Sortion ^b (38 oz/ac) |
| Plot size | 4 rows (10 ft) wide by 380 ft long, planted in adjacent strips |

Table H- 1. Plot information

^a Bayer CropScience, St. Louis, MO; ^b Growmark, Inc., Bloomington, IL

| Table | H- | 2. | Corn | rootworm | treatments |
|-------|----|----|------|----------|------------|
|-------|----|----|------|----------|------------|

| Trt. | Material | Application | Active ingredient | Formulation |
|-------|---------------------------------------|--------------------|----------------------|--------------------------|
| 1 | Untreated | N/A | N/A | N/A |
| 2 | Capture LFR ^a (17 fl oz/a) | Liquid in-furrow | Bifenthrin | Suspension concentrate |
| | | | (1.5 lb. ai/gallon) | |
| 3 | Ampex EZ ^b (12 fl oz/a) | Liquid in-furrow | Clothianidin | Suspension concentrate |
| | | | (1.71 lb. ai/gallon) | |
| 4 | Force Evo ^c (8 fl oz/a) | Liquid in-furrow | Tefluthrin | Emulsifiable concentrate |
| | | | (2.1 lb ai/gallon) | |
| 5 | Ampex EZ^{b} (8 fl oz/a) | Liquid in-furrow | Clothianidin | Suspension concentrate |
| | _ 、 , , | - | (1.71 lb. ai/gallon) | - |
| a EMC | Comparation Philadalphia | DA, b Walant IIS A | Walnut Craals CA: C | Sun conto Cron |

^a FMC Corporation, Philadelphia, PA; ^b Valent U.S.A., Walnut Creek, CA; ^c Syngenta Crop Protection, Greensboro, NC

Table H-3. Generalized linear mixed model statistics; probability distribution used in the analysis is given in parentheses.

| | | Numerator | Denominator | | |
|------------------------------|--------|-----------|-------------|------|--------------------|
| Dependent Variable | Date | df | df | F | Р |
| Plant stand (normal) | 3 June | 4 | 12 | 0.29 | 0.876 |
| Root injury rating (gamma) | 8 Aug. | 4 | 12 | 5.85 | 0.008^{a} |
| Percent consistency (normal) | 8 Aug. | 4 | 12 | 3.77 | 0.033 ^a |
| Yield (normal) | 3 Nov. | 4 | 12 | 1.42 | 0.287 |

^a Effect is significant at $\alpha = 0.05$; ^b Statistical model failed (no variation in data), not significant

Table H- 4. Mean (\pm 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.

| Treatment | Stand (V3) 3 June 2022 | Node-injury rating 8 Aug. 2022 | Percent consistency 8 Aug. 2022 | Yield 3 Nov. 2022 |
|-----------------------|---------------------------|--------------------------------------|---------------------------------------|----------------------|
| Untreated | $40.6\pm0.2~a^a$ | $0.15 \pm 0.03 \text{ a}$ | $82.5\pm4.8\ b$ | 228.7 ± 5.6 a |
| Capture LFR (17 oz/a) | $40.4\pm0.4~a$ | $0.14\pm0.03~a$ | $85.0\pm6.5~b$ | 222.6 ± 5.8 a |
| Ampex EZ (12 oz/a) | $40.1\pm0.5~a$ | $0.05\pm0.01\ b$ | $97.5\pm2.5~a$ | 221.7 ± 4.6 a |
| Force Evo (8 oz/a) | $40.3\pm0.3~a$ | $0.09\pm0.01~ab$ | $92.5\pm2.5\ ab$ | 216.1 ± 5.0 a |
| Ampex EZ (8 oz/a) | $40.3\pm0.4\ a$ | $0.07\pm0.01\ b$ | $100.0\pm0.0\;a$ | 219.6 ± 3.3 a |

I. Evaluation of Ampex EZ for control of corn rootworm larval damage

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

Objective: To compare the performance of Ampex EZ with commercial standards for control of corn rootworm (particularly western corn rootworm, *Diabrotica virgifera virgifera*) larval damage in a non-Bt (for corn rootworm) corn hybrid.

Summary: While larval corn rootworm pressure in this trial was modest, we observed a reduction in node injury ratings compared with the untreated plots for all insecticide materials tested except Capture LFR. Aztec HC, both rates of Ampex EZ, and Nipsit Inside seed treatment resulted in a higher percent consistency than the untreated plots.

Funding: Project funding, seed, and pesticide materials for this trial were provided by Valent USA, Walnut Creek, CA. Additional maintenance herbicides were provided by Bayer CropScience, St. Louis, MO.

| Corn hybrid (Bt proteins) | Seed provided by Valent; no CRW trait |
|---------------------------|--|
| Seed coatings | Base fungicide: Maxim Quattro ^a (No insecticide except for Trt. 6) |
| Previous crop | Trap crop: late-planted, non-Bt field corn inter-seeded with pumpkins |
| Soil type | Thorp silt loam |
| Tillage | Conventional |
| Row spacing | 30 inches |
| Seeding Rate | 35,500 seeds per acre |
| Soil insecticide | Trts. 2, 3, 5, 7: Liquid in-furrow, 5 gal/acre application volume |
| application | Trt. 4: Granular in-furrow, SmartBox ^b research-scale granular |
| | applicator |
| | Trt. 6: Seed-applied insecticide |
| Planting date | 17 May 2022 |
| Emergence date | 24 May 2022 |
| Herbicide | Pre-emerge: 32% UAN (50 gal/ac), Harness Xtra ^c (2 qt/ac) |
| | Post-emerge: Roundup PowerMAX ^c (32 oz/ac), FS MaxSupreme ^d (1 |
| | qt/ac), Sortion ^d (38 oz/ac) |
| Plot size | 4 rows (10 ft) wide by 30 ft long with 5-ft unplanted alleys between |
| | plots |

Table I-1. Plot information

^a Syngenta Crop Protection, Greensboro, NC; ^b AMVAC Chemical Corporation, Los Angeles, CA; ^c Bayer CropScience, St. Louis, MO; ^d Growmark, Inc., Bloomington, IL

 Table I- 2. Corn rootworm treatments

| Trt | Material and Rate | Application | Active ingredient | Formulation |
|-----|---|----------------------|---|----------------------------------|
| 1 | Untreated | N/A | N/A | N/A |
| 2 | Capture LFR ^a (17 fl. oz/a) | In-furrow liquid | Bifenthrin (1.5 lb ai/gal) | Suspension concentrate (SC) |
| 3 | Force Evo ^b (10 fl. oz/a) | In-furrow liquid | Tefluthrin (2.1 lb. ai/gal) | Emulsifiable concentrate (EC) |
| 4 | Aztec HC ^c (1.63 lb/a) | In-furrow granule | Tebupirimphos (8.9%) + Cyfluthrin (0.44%) | Granule (G) |
| 5 | Ampex ^d (12 fl. oz/a) | In-furrow liquid | Clothianidin (1.71 lb ai/gal) | SC |
| 6 | Nipsit Inside ^d (1.25 mg/seed) | Seed treatment | Clothianidin (5 lb ai/gal) | Seed-applied |
| 7 | Ampex ^d (15 fl. oz/a) | In-furrow liquid | Clothianidin (1.71 lb ai/gal) | SC |

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

Table I-3. Generalized linear mixed model statistics; probability distribution used in the analysis is given in parentheses.

| | | Numerator | Denominator | | |
|------------------------------|----------|-----------|-------------|------|-------------|
| Dependent Variable | Date | df | df | F | Р |
| Plant stand (normal) | 6 June | 6 | 18 | 1.27 | 0.320 |
| Root injury rating (gamma) | 2 August | 6 | 18 | 5.02 | 0.004^{a} |
| Percent consistency (normal) | 2 August | 6 | 18 | 4.72 | 0.005^{a} |
| Percent lodging (normal) | 5 Oct. | 6 | 18 | 1.00 | 0.455 |
| Yield (normal) | 2 Nov. | 6 | 18 | 1.81 | 0.153 |
| | | | | | |

Table I- 4. Mean (\pm 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) | ratings | consistency | lodging | Yield |
| Treatment | 6 June 2022 | 2 Aug. 2022 | 2 Aug. 2022 | 5 Oct. 2022 | 2 Nov. 2022 |
| Untreated | $37.5\pm1.3~a^a$ | 0.66 ± 0.14 a | $30.0\pm17.3~b$ | 0.0 ± 0.0 a | 145.3 ± 10.1 a |
| Capture LFR ^a (17 fl. oz/a) | $35.3\pm0.5~a$ | $0.43\pm0.09\;ab$ | $35.0\pm9.6\ b$ | 0.0 ± 0.0 a | 164.7 ± 4.1 a |
| Force Evo ^b (10 fl. oz/a) | $37.9 \pm 1.2 \text{ a}$ | $0.24\pm0.05\ bc$ | $55.0\pm9.6\ ab$ | 0.0 ± 0.0 a | 164.6 ± 10.5 a |
| Aztec HC ^c (1.63 lb/a) | 35.4 ± 1.6 a | $0.14\pm0.05\;c$ | $85.0\pm5.0\;a$ | 0.3 ± 0.3 a | $180.4 \pm 8.7 \text{ a}$ |
| Ampex (12 fl. oz/a) | 34.8 ± 2.1 a | $0.13\pm0.03~\text{c}$ | $85.0\pm5.0\;a$ | 0.0 ± 0.0 a | 168.0 ± 5.4 a |
| Nipsit Inside (1.25 mg/seed) | 36.5 ± 1.2 a | $0.19\pm0.05\ c$ | $75.0\pm18.9~a$ | 0.0 ± 0.0 a | $183.9 \pm 9.1 \text{ a}$ |
| Ampex (15 fl. oz/a) | $36.8\pm0.8\ a$ | $0.15\pm0.03~\text{c}$ | $80.0 \pm 11.5 \text{ a}$ | 0.0 ± 0.0 a | 173.8 ± 14.4 a |

<u>J. Evaluation of Pyramided Bt Hybrids and Force Evo for Control of Corn rootworm –</u> <u>Monmouth, 2022</u>

Location: University of Illinois Northwestern Illinois Agricultural Research and Demonstration Center, Monmouth, IL (40.935349, -90.727886)

Objective: To compare the performance of Bt trait packages for control of western and northern corn rootworm larval damage.

Summary: While overall rootworm feeding pressure was low, the addition of a soil insecticide resulted in reduced corn rootworm injury ratings for all traits tested except SmartStax Pro, indicating some level of resistance to pyramided Bt traits at this location. All rootworm Bt traits except Duracade resulted in a reduction compared to the non-rootworm Bt control (VT Double Pro) when no insecticide was applied. Differences in yield did not always reflect differences in rootworm feeding (which is not surprising at the levels of pruning we observed), and likely had more to do with differences in corn hybrids, which were not all equivalent in terms of relative maturity, etc. Differences in percent consistency and lodging generally corresponded to differences in rootworm injury.

Funding: Seed and pesticide materials for this trial were provided by Syngenta and Bayer CropScience.

| Corn hybrid (Bt proteins) | See Table 2 |
|---------------------------|--|
| Seed coatings | DKC 64-65: clothianidin 0.50 mg/seed (Acceleron ^a FALH2Q) |
| - | DKC 64-64: clothianidin 0.50 mg/seed (Acceleron ^a FALH2VQ) |
| | DKC 111-33 clothianidin 0.5 mg/seed (Acceleron ^a FALZH2VQ) |
| | P1055Q: clothianidin (0.25 mg/seed) + chlorantraniliprole (0.25 mg/seed) (LumiGEN ^b) |
| | G10L16-5222A: thiamethoxam 0.5 mg/seed (Avicta Complete 500 + |
| | Vibrance ^c) |
| Previous crop | Trap crop: late-planted, non-Bt field corn inter-seeded with |
| | pumpkins |
| Soil type | Muscatune silt loam, Sable silty clay |
| Tillage | Conventional |
| Row spacing | 30 inches |
| Seeding Rate | 36,000 seeds per acre |
| Planting date | 12 May 2022 |
| Nitrogen | 210 lb/a N knifed in preplant (32% UAN) |
| Herbicide | Pre-emerge: Harness Xtra ^a (2.5 qt/a) |
| | Post-emerge: Laudis ^a (3 oz/a) + Atrazine (1 pt/a) |
| Plot size | 4 rows (10 ft) wide by 40 ft long, 5 ft unplanted alleys |
| | uis MO: ^b Corteva Agriscience Wilmington DF: ^c Syngenta Cron |

Table J- 1. Plot information

^a Bayer CropScience, St. Louis, MO; ^bCorteva Agriscience, Wilmington, DE; ^cSyngenta Crop Protection, Greensboro

Table J- 2. Corn rootworm treatments

| Trt. | Hybrid | Trait package | CRW Bt proteins | Soil Insecticide |
|------|---------------------------|---------------|--------------------------------------|---|
| 1 | DKC64-65 ^a | VT Double Pro | None | None |
| 2 | DKC64-65 ^a | VT Double Pro | None | Force Evo ^b , 8 fl. oz/a (24.2% tefluthrin EC) |
| 3 | DKC64-64 ^a | SmartStax | Cry3Bb1 + Cry34/35Ab1 | None |
| 4 | DKC64-64 ^a | SmartStax | Cry3Bb1 + Cry34/35Ab1 | Force Evo ^d , 8 fl. oz/a (24.2% tefluthrin EC) |
| 5 | DKC111-33 ^a | SmartStax Pro | Cry3Bb1 + Cry34/35Ab1 + DvSnf7 dsRNA | None |
| 6 | DKC111-33 ^a | SmartStax Pro | Cry3Bb1 + Cry34/35Ab1 + DvSnf7 dsRNA | Force Evo ^d , 8 fl. oz/a (24.2% tefluthrin EC) |
| 7 | P1055Q ^c | Qrome | mCry3A + Cry34/35Ab1 | None |
| 8 | P1055Q ^c | Qrome | mCry3A + Cry34/35Ab1 | Force Evo ^d , 8 fl. oz/a (24.2% tefluthrin EC) |
| 9 | G10L16-5222A ^d | Duracade | mCry3A + eCry3.1Ab | None |
| 10 | G10L16-5222A ^d | Duracade | mCry3A + eCry3.1Ab | Force Evo ^d , 8 fl. oz/a (24.2% tefluthrin EC) |

^a Dekalb, Bayer CropScience, St. Louis, Mo; ^b Syngenta Crop Protection, Greensboro, NC; ^c Pioneer, Corteva AgriScience, Johnston, IA; ^d Golden Harvest Seeds, Syngenta, Minnetonka, MN;

| Table J-3 . Generalized linear mixed model statistics; p | probability distribution u | used in the analysis is given | in parentheses. |
|---|----------------------------|-------------------------------|------------------|
| Tuble o Di Generalizea intear intea incael statistics, | sieedenney distriction e | | in parentitebeb. |

| | | Numerator | Denominator | | |
|------------------------------|---------|-----------|-------------|-------|--------------------|
| Dependent Variable | Date | df | df | F | Р |
| Plant stand (normal) | 13 June | 9 | 27 | 2.97 | 0.014 ^a |
| Root injury rating (gamma) | 13 July | 9 | 27 | 24.74 | $< 0.001^{a}$ |
| Percent consistency (normal) | 13 July | 9 | 27 | 6.73 | $< 0.001^{a}$ |
| Percent lodging (normal) | 5 Oct. | 9 | 27 | 3.60 | 0.005^{a} |
| Yield (normal) | 7 Oct. | 9 | 27 | 3.11 | 0.011 ^a |

Table J-4. Mean (\pm 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 (V6) | Node-injury ratings | Percent consistency | Percent lodging | Yield |
|-------|--------------------|---------------------------|----------------------------|----------------------------|--------------------------|----------------------------|
| Trt | Treatment | 13 June 2022 | 13 July 2022 | 13 July 2022 | 5 Oct. 2022 | 7 Oct. 2022 |
| 1 | VT Double Pro | $37.0\pm0.4\ ab^a$ | 0.73 ± 0.12 a | $20.0 \pm 14.1 \text{ e}$ | 2.5 ± 1.2 ab | 317.2 ± 7.7 abc |
| 2 | VT Double Pro + | 35.9 ± 0.2 ab | $0.31\pm0.09\ bc$ | 65.0 ± 9.6 cd | $1.3 \pm 0.6 \text{ bc}$ | 313.9 ± 5.6 bc |
| | Force Evo (8 oz/a) | | | | | |
| 3 | SmartStax | $36.1 \pm 0.4 \text{ ab}$ | $0.27\pm0.09~c$ | $65.0 \pm 20.6 \text{ cd}$ | 1.5 ± 0.5 bc | 315.1 ± 4.1 abc |
| 4 | SmartStax + | $35.8\pm0.6\ b$ | $0.06\pm0.02~e$ | 95.0 ± 5.0 ab | $0.8\pm0.3\;bc$ | $310.9\pm5.7~\mathrm{c}$ |
| | Force Evo (8 oz/a) | | | | | |
| 5 | SmartStax Pro | 36.9 ± 0.7 ab | $0.02\pm0.01~f$ | 100.0 ± 0.0 a | $0.0\pm0.0\;c$ | $328.3 \pm 2.1 \text{ ab}$ |
| 6 | SmartStax Pro + | $37.4 \pm 0.7 \text{ a}$ | $0.01\pm0.01\ f$ | 100.0 ± 0.0 a | $0.0\pm0.0\;c$ | $330.7 \pm 2.0 \text{ a}$ |
| | Force Evo (8 oz/a) | | | | | |
| 7 | Qrome | $35.9 \pm 0.6 \text{ ab}$ | $0.24\pm0.07~\mathrm{c}$ | 70.0 ± 5.8 bc | $1.8\pm0.8~bc$ | 304.6 ± 9.5 c |
| 8 | Qrome + | 34.1 ± 0.7 c | $0.08 \pm 0.02 \text{ de}$ | 90.0 ± 5.8 abc | $1.3 \pm 0.9 \text{ bc}$ | $310.4\pm6.5~\text{c}$ |
| | Force Evo (8 oz/a) | | | | | |
| 9 | Duracade | 35.9 ± 0.7 ab | 0.60 ± 0.11 ab | $40.0 \pm 14.1 \text{ de}$ | 4.0 ± 0.6 a | $301.1\pm4.7~\mathrm{c}$ |
| 10 | Duracade + | $35.9 \pm 0.3 \text{ ab}$ | $0.15\pm0.04\ cd$ | $75.0 \pm 5.0 \text{ abc}$ | $1.0 \pm 0.4 \ bc$ | 302.5 ± 4.1 c |
| | Force Evo (8 oz/a) | | | | | |
| 2 3 4 | 0 11 1 1 1 | 1 •.1 • | 1 1.00 | . 1 1 .1 | | 01 |

K. Corn rootworm trait demonstration – Freeport, 2022

Location: Highland Community College demonstration plots, Stephenson County, IL

Objective: To evaluate the performance of three corn rootworm trait packages in Stephenson County, IL

Summary: Overall corn rootworm larval pressure at this site was relatively low; however, SmartStax resulted in reduced root injury and greater consistency of control than either the non-Bt hybrid or Duracade, which were not different from each other.

Funding: Funding for this trial was provided by USDA-NIFA through the Crop Protection and Pest Management Program Grant Number 2021-70006-35476

Table K- 1. Plot information

| See Table 2 |
|--|
| G10L16-3220A ^a : thiamethoxam 0.5 mg/seed (Avicta Complete 500 + |
| Vibrance ^b) |
| G10L16-5222A ^a : thiamethoxam 0.5 mg/seed (Avicta Complete 500 + |
| Vibrance ^b) |
| DKC60-87 ^c : clothianidin 0.5 mg/seed (Acceleron ^c FALH2VQ |
| Corn |
| Fayette silt loam |
| Conventional |
| 30 inches |
| 12 May 2022 |
| 4 rows (10 ft) wide by 150 ft long, 5 ft unplanted alleys |
| |

^a Golden Harvest Seeds (Syngenta), Downer's Grove, IL; ^bSyngenta Crop Protection, Greensboro, NC; ^c Bayer CropScience, St. Louis, MO

Table K- 2. Corn rootworm treatments

| Hybrid | Trait package | CRW Bt proteins |
|---------------------------|--|------------------------|
| G10L16-3220A ^a | Agrisure (non-CRW Bt) | None |
| G10L16-5222A ^a | Duracade 5222A | mCry3A + eCry3.1Ab |
| DKC60-87 ^b | SmartStax | Cry3Bb1 + Cry34/35Ab1 |
| | and the state of t | ~ ~ |

^a Golden Harvest Seeds, Downer's Grove, IL; ^b Bayer CropScience, St. Louis, MO

Table K-3. Generalized linear mixed model statistics; probability distribution used in the analysis is given in parentheses.

| | | Numerator | Denominator | | |
|---------------------------------|--------|-----------|-------------|-------|--------------------|
| Dependent Variable | Date | df | df | F | Р |
| Root injury rating (gamma) | 2 Aug. | 2 | 6 | 21.79 | 0.002 ^a |
| Proportion consistency (normal) | 2 Aug. | 2 | 6 | 9.36 | 0.014 ^a |
| | | | | | |

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

Table K-4. Mean (\pm SE) node-injury rating (0-3 scale) of corn rootworm larval feeding injury and percent consistency (percentage of roots with a node-injury rating of less than 0.25).

| | Node-injury rating | Percent consistency |
|-----------------------|--------------------|-------------------------|
| Treatment | 2 Aug. 2022 | 2 Aug. 2022 |
| Agrisure (non-CRW Bt) | $0.46\pm0.09~a^a$ | $20.0\pm14.1~b$ |
| Duracade | 0.52 ± 0.06 a | $30.0\pm5.8~\mathrm{b}$ |
| SmartStax | $0.16\pm0.04\ b$ | 75.0 ± 9.6 a |
L. Corn rootworm trait demonstration – Oglesby, 2022

Location: Illinois Valley Community College demonstration plots, LaSalle County, IL

Objective: To evaluate the performance of three corn rootworm trait packages in LaSalle County, IL

Summary: Overall corn rootworm larval pressure at this site was low, and no differences were observed in root injury or consistency of control among the different hybrids we evaluated.

Funding: Funding for this trial was provided by USDA-NIFA through the Crop Protection and Pest Management Program Grant Number 2021-70006-35476

 Table L- 1. Plot information

| Corn hybrid (Bt proteins) | See Table 2 |
|---------------------------|--|
| Seed coatings | G10L16-3220A ^a : thiamethoxam 0.5 mg/seed (Avicta Complete 500 + |
| - | Vibrance ^b) |
| | G10L16-5222A ^a : thiamethoxam 0.5 mg/seed (Avicta Complete 500 + |
| | Vibrance ^b) |
| | DKC60-87 ^c : clothianidin 0.5 mg/seed (Acceleron ^c FALH2VQ |
| Previous crop | Corn |
| Soil type | Flanagan silt loam and Elpaso silty clay loam |
| Tillage | Conventional |
| Row spacing | 30 inches |
| Seeding rate | 34,500 |
| Planting date | 17 May 2022 |
| Plot size | 2 rows (5 ft) wide by 150 ft long |

^a Golden Harvest Seeds (Syngenta), Downer's Grove, IL; ^bSyngenta Crop Protection, Greensboro, NC; ^c Bayer CropScience, St. Louis, MO

| Table L- 2. Corr | n rootworm | treatments |
|------------------|------------|------------|
|------------------|------------|------------|

| Hybrid | Trait package | CRW Bt proteins |
|---------------------------|-----------------------|------------------------|
| G10L16-3220A ^a | Agrisure (non-CRW Bt) | None |
| G10L16-5222A ^a | Duracade 5222A | mCry3A + eCry3.1Ab |
| DKC60-87 ^b | SmartStax | Cry3Bb1 + Cry34/35Ab1 |
| | | |

^a Golden Harvest Seeds, Downer's Grove, IL; ^b Bayer CropScience, St. Louis, MO

Table L-3. Generalized linear mixed model statistics; probability distribution used in the analysis is given in parentheses.

| | Numerator | Denominator | | |
|--------|-----------|---------------|---|--|
| Date | df | df | F | Р |
| 2 Aug. | 2 | 6 | 3.94 | 0.081 |
| 2 Aug. | 2 | 6 | 5.01 | 0.064 |
| | 2 Aug. | Datedf2 Aug.2 | Date df df 2 Aug. 2 6 | Date df <i>f</i> 2 Aug. 2 6 3.94 |

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

Table L- 4. Mean (\pm SE) node-injury rating (0-3 scale) of corn rootworm larval feeding injury and percent consistency (percentage of roots with a node-injury rating of less than 0.25).

| | Node-injury rating | Percent consistency |
|-----------------------|---------------------------|---------------------|
| Treatment | 2 Aug. 2022 | 2 Aug. 2022 |
| Agrisure (non-CRW Bt) | $0.32\pm0.15~a^{a}$ | 55.0 ± 12.6 a |
| Duracade | 0.24 ± 0.04 a | 65.0 ± 5.0 a |
| SmartStax | $0.13 \pm 0.04 \text{ a}$ | 85.0 ± 5.0 a |

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

Biocontrol of rootworms using nematodes - Year 2

N. J. Seiter and J. L. Spencer

Location: University of Illinois Animal Science Farm, Urbana, IL

Objective: Year 2 -to determine the establishment success of entomopathogenic nematodes applied to a continuous cornfield. The long-term objective of this experiment is to examine the potential of entomopathogenic nematodes to act as a persistent biological control agent for corn rootworms that could complement the use of Bt traits and soil insecticides and reduce selection pressure for resistance to these tactics.

Summary: Entomopathogenic nematodes are tiny, parasitic animals that attack insects. Several species attack western and northern corn rootworm. Our colleagues have identified strains of these nematodes that are capable of persistent suppression of corn rootworm larval damage. We applied those nematodes to four plots (40 ft \times 400 ft) on 26 May 2021 within a long-term (> 10 years) continuous silage cornfield; these plots were interspersed with four untreated plots using a randomized complete block design (4 replicate blocks, 2 treatments). During Fall 2021, we documented successful establishment of the nematodes, with 42% of soil samples testing positive for Steinernema feltiae and 2% of samples testing positive for Heterorhabditis bacteriophora in plots where nematodes were applied (compared with 0 samples from the untreated plots which tested positive for either species; Year 1 report is available at https://go.illinois.edu/2021PestPathogenARB). When corn (hybrid RT57T85 VIP3111 [Bt traits: Cry1Ab, Vip3A, mCry3A]; Red Tail, Peak Ag Business, Hollandale, WI) reached the R1 stage (29 July 2022), we evaluated rootworm injury and found no difference in rootworm damage between the plots (Table 1). Overall rootworm pressure was low; during 2023, we will again document node-injury ratings, in addition to assessing the soil in these plots for entomopathogenic nematode activity.

Acknowledgements: Dr. Elson Shields and Tony Testa (Cornell University) provided the entomopathogenic nematodes from strains they have developed and maintained; they also performed laboratory bioassays to measure nematode establishment. Mike Katterhenry (Animal Sciences Farm Manager) and Henry Hoene (Dairy Farm Manager)planted and maintained the field.

Table 16. Node-injury ratings in plots either treated with entomopathogenic nematodes or left untreated.

| Treatment | Node-injury ratings ^a |
|-------------------|----------------------------------|
| Nematodes applied | 0.27 ± 0.04 |
| Untreated control | 0.27 ± 0.02 |

^a Node-injury ratings not different between treatments based on ANOVA (F = 0.01, df = 1, 3, P = 0.916)

Sticky Trap Orientation Affects Western Corn Rootworm Capture

Sagnika Das¹ and J.L. Spencer² ¹Department of Crop Sciences; sagnika2@illinois.edu ²Illinois Natural History Survey; spencer1@illinois.edu University of Illinois, Urbana-Champaign

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

Locations:

All study plots were located on University of Illinois farmland: 1. Agricultural and Biological Engineering (ABE) Farm, Urbana, IL (40.070777, -88.209591), 2. Cruze Farm, Champaign, IL (40.081331, -88.242600), and 3. Main Farm, Champaign, IL (40.087117, -88.230537)

Introduction:

Currently, 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. In the eastern Corn Belt, where most corn is grown in rotation with soybeans, effective WCR beetle monitoring techniques are needed because numbers of egg-laying beetles in soybean fields are related to the risk of larval injury in first-year corn. Monitoring beetle abundance using a set of Pherocon[®] AM sticky traps yields data important for making pest management decisions which can reduce the unnecessary application of insecticides or use of Bt hybrids. As part of a project to evaluate innovative tools to improve the adoption of integrated pest management-based monitoring, we are testing the use of an unmanned aerial vehicle (a UAV or drone) to remotely visit and photograph WCR beetles captured on Pherocon® AM sticky traps. Challenges associated with walking far out into soybean fields to check a number of sticky traps are often cited as a reason why monitoring WCR abundance is unpopular. If a UAV could be used to visit all the sticky traps in a field and return with high resolution photographs of each trap, it may be possible to identify and count captured WCR on the traps without walking repeatedly through the fields. Eliminating the need to repeatedly walk into the fields could make sticky trap monitoring more palatable to growers and/or their crop consultants.

In a preliminary study, we were able to identify and count beetles from UAV-acquired images of sticky traps in the field; however, standard vertically oriented sticky traps are difficult to approach with a UAV because their faces are often at canopy level. Approaching the canopy too closely increases the risk of entangling and crashing the UAV. Traps oriented at an angle could be approached from above with less crash-risk and photographed more easily, but a tilted trap orientation may affect capture efficacy. In this study, we tested the effect of trap orientation angle (i.e., vertical - 0°, 45°, 67°, & horizontal - 90°) on the numbers of beetles captured per trap. We will report on the relationship between trap angle and beetle capture and also consider whether beetle counts from top sides of angled traps (i.e. the only side a UVA could photograph from above) are representative of the total beetle captures from both sides of nearby vertically-oriented traps. If UAV-based observations take less time and provide data that are as predictable as those data obtained from personal visits to "standard" vertical traps, their use may increase adoption of IPM-based WCR monitoring.

Materials & Methods:

Field experiments were established at three University of Illinois, Urbana-Champaign soybean field locations (0.76 m row spacing). Angled trap treatments were distributed in groups (blocks) of four angled traps using a randomized complete block design with a total of 34 replicates distributed across the three locations. Pherocon® AM Unbaited Yellow Sticky Traps (Great Lakes IPM, Vestaburg, MI 48891) were mounted at four different angles (0°, 45°, 67°, & 90°) on 2.54 cm dia. 1.5 m tall PVC poles spaced *ca*. 11.5 m apart and installed in the soybean row. (Figure 1). A vertically oriented, 0° angle, sticky trap is the conventional orientation for traps used to monitor WCR beetles in soybean fields. At the other extreme, a 90° trap angle was oriented horizontally. 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 2). 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 2022). 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 nonparametric 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. The predictive value of the relationship between WCR/trap top/day (for all four trap angle treatments) vs total (i.e., top + bottom side) WCR/trap/day for the conventional vertically oriented (0°) traps was investigated using linear regression. All data analyses were performed using JMP Pro software 16.2.0 (2021 SAS Institute).

Results:

Total (combined top and bottom counts) WCR captures were significantly greater on the conventional 0° (vertical) sticky trap than on the other angled trap treatments. At the two locations (M2N and ABE Farms) where WCR were abundant, captures on sticky traps significantly decreased as the trap angle deviated from vertical (Figure 3). WCR abundance at the Cruze Farm was low; there were no treatment-based differences in WCR captures at that location.

WCR trapped on the bottom sides of angled traps cannot be photographed with a UAV. For UAV monitoring to be informative, WCR counts from the top sides of angled traps (WCR/trap top/day) should be representative of the total WCR/trap/day on conventional, vertically oriented (0°) sticky traps. We explored that relationship by regressing WCR/trap top/day for all angled trap treatments (including WCR/trap top/day for the "T" sides of the vertical traps) onto total WCR/trap top/day for the associated vertical trap in each treatment block. The relationship between WCR/trap top/day collected on the "T" side of angled traps was predictive of the total WCR/trap/day on an entire vertical trap. For vertical traps, the collection rate of WCR on the designated top sides (i.e., WCR/trap top/day collected on the "T" side) was highly predictive of the total WCR/trap/day on the entire vertical trap (Y=0.0027+2.00*X; R²=0.97). When

WCR/trap top/day for the 45°, 67°, & 90° angled traps was regressed against the total WCR/trap/day on vertical traps, the best fit was obtained with 45° traps (Y=0.1014+4.13 *X; R²=0.74), with progressively poorer fits for traps mounted at 67° (Y=0.1448+5.30*X; R²=0.63) and 90° (0.2089+7.41*X; R²= 0.60) (Figure 4). While significant linear relationships were present for each regression, the predictive value of the regression for the 45° trap tops vs. total WCR on vertical traps suggest that using sticky traps mounted on 45° degree mounts will yield results that are most predictive of results expected from standard vertically oriented (0°) traps

The ability to use angled sticky traps for monitoring will enable a UAV to approach & photograph a trap with less risk of crashing into the soybean foliage. Use of this innovative approach may facilitate greater adoption of sticky trap monitoring leading to more judicious use of management tactics (including new Bt corn hybrids) and prolong future product utility while reducing grower input costs and unnecessary use of pesticides. In addition to evaluating the effect of trap angle on WCR captures, we will also explore computer image analysis and visualization methods to enable automated and accurate counting of WCR in photographs taken with our UAV's 12 MP camera.

We do not expect that many growers would choose to individually adopt UAV-assisted pest monitoring on their farms. However, as crop consultants and advisors increasingly rely on UAVs for other types of on-farm monitoring and management tasks, UAV-assisted pest monitoring may be a service they could provide to clients. UAVs are increasingly used on and off the farm; we believe exploring new opportunities for their application in fields crops research will yield innovative solutions to many current challenges.

This study will be repeated in 2023.

Summary:

We conclude that mounting sticky traps at angles that deviate from the conventional (0°) vertical orientation significantly decreased WCR beetle captures. However, WCR collection data from the top sides of angled sticky traps is strongly predictive of total WCR/trap/day on conventional, vertically-oriented sticky traps.

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 Tim Lecher (Agricultural and Biological Engineering Farm, Urbana, IL) for assistance with planting, plot maintenance, and harvest. We also thank undergraduate student assistants, Jacob Burns and Madisen LeShoure, for assisting with plot maintenance and data collection.



Figure 15. Angled traps array in the Main Farm soybean field. Pherocon® AM Unbaited yellow sticky traps are mounted on 2.54 cm dia. 1.5 m PVC poles at four different angles.



Figure 16. 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 17. Mean WCR/trap/day (±SEM) vs. Trap angle for sticky traps placed in soybean at three University of Illinois farm locations from July-August, 2022. 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 18. Regression of weekly mean WCR/trap top/day for all trap angles vs. mean total WCR/trap/day on vertical traps. WCR captured on trap tops (or on the designated "top" of a vertical trap) were compared to total WCR captures on vertical traps to assess whether WCR captured on trap tops could be predictive of total WCR captured on conventional vertical sticky traps. Shaded areas are 95% confidence intervals. See text for details.

Evaluation of insecticide seed treatments for corn insect control

Location: University of Illinois Orr Agricultural Research and Demonstration Center, Baylis, IL (39.802890, -90.822473) **Study directors:** Nicholas Seiter and Ashley Decker

Objective: To compare the performance of corn insecticide seed treatment packages for control of corn insects and yield protection.

Materials and Methods: Field experiments were established in a randomized complete block design with 4 replicate blocks and 4 treatments. The experimental units were plots of corn (Table 1) that were 4 rows wide and 30 ft. long with 5 ft. of unplanted alley separating plots vertically. The treatments (Table 2) were different seed-applied insecticide packages. Plant stands were assessed on 14 June 2022 (growth stage V7). Plot vigor was assessed using a 1-9 scale (9 being best) on 14 June 2022 (growth stage V7). Yields were assessed for each plot on 27 September 2022 by harvesting rows 2 and 3 using a small-plot combine.

<u>Data Analysis</u>. Weights per plot were corrected to a standard weight at 15.5% moisture, then converted to bushels per acre using the standard bushel weight of 56 pounds. Plant stand, vigor, and yield were analyzed separately using a generalized linear mixed model (normal distribution) where replicate block was a random effect and treatment was a fixed effect.

Summary: The effect of treatment on stand, vigor, and yield was not statistically significant in this trial.

Funding: Funding and seed for this trial were provided by Bayer CropScience.

Acknowledgements: We thank Luke Merritt for assisting with planting, plot maintenance, and harvest. We also thank graduate students Yony Callohuari Quispe and undergraduate students Daniel Polski, Joseph Heier, and Will Foulke for assisting with plot maintenance and data collection.

Table 17. Plot information

| Corn hybrid (Bt | DKC64-34 ^a (SmartStax, Cry3Bb1 + Cry34/35Ab1) |
|-----------------|---|
| proteins) | |
| Seed coatings | Treatments, see Table 2 |
| Previous crop | Corn |
| Soil type | Clarksdale silt loam |
| Tillage | Conventional |
| Row spacing | 30 inches |
| Seeding Rate | 36,000 seeds per acre |
| Planting date | 10 May 2022 |
| Herbicide | Pre-emerge: 32% UAN (50 gal/ac), Lexar EZ (3 qt/a) ^b |
| Plot size | 4 rows (10 ft) wide by 30 ft long, 5 ft unplanted alleys |
| 3 D 1 11 D C C | |

^a Dekalb, Bayer CropScience, St. Louis, MO; ^b Syngenta Crop Protection, Greensboro, NC

Table 18. Experimental treatments

| Trt. | Seed coatings |
|-------------------|--|
| 1 | Untreated |
| 2 | Acceleron Basic ^a (Poncho 600 0.25 mg a/seed, Proline 480 SC 0.021 mg a/seed, Fluoxastrobin FS480 0.021 mg a/seed, |
| | Allegiance FL 0.006 mg a/seed, Precise S Finisher 1006 196 ml/100kg) |
| 3 | Acceleron Basic+ ^a (Poncho 600 0.50 mg a/seed, Proline 480 SC 0.021 mg a/seed, Fluoxastrobin FS480 0.021 mg a/seed, |
| | Allegiance FL 0.006 mg a/seed, Precise S Finisher 1006 196 ml/100kg) |
| 4 | Acceleron Elite ^a (Poncho Votivo 0.60 mg a/seed, Proline 480 SC 0.084 mg a/seed, Fluoxastrobin FS480 0.084 mg a/seed, |
| | Allegiance FL 0.006 mg a/seed, D 310 0.021 mg a/seed, Precise S Finisher 1006 196 ml/100kg) |
| ^a Baye | r CropScience, St. Louis, MO |

| Dependent | | Numerator | Denominator | | |
|--------------|----------|-----------|-------------|------|-------|
| Variable | Date | df | df | F | Р |
| Plant stand | 14 June | 3 | 9 | 1.11 | 0.393 |
| Vigor rating | 14 June | 3 | 9 | 1.73 | 0.231 |
| Yield | 27 Sept. | 3 | 9 | 0.60 | 0.631 |

 Table 19. Generalized linear mixed model statistics.

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

Table 20. Mean (± Standard error [SE]) stand in number of plants per 17.5 ft. of row

| Trt. | | 14 June 2022 |
|------|------------------|--------------------|
| | Treatment | (V7) |
| 1 | Untreated | $33.1 \pm 1.3 a^a$ |
| 2 | Acceleron Basic | 34.6 ± 0.5 a |
| 3 | Acceleron Basic+ | 35.1 ± 0.7 a |
| 4 | Acceleron Elite | $34.8 \pm 0.6 a$ |

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

Table 21. Mean (\pm SE) Vigor rating (subjective 1-9 scale where 9 is best)

| Trt. | | 14 June 2022 |
|------|------------------|-------------------|
| | Treatment | (V7) |
| 1 | Untreated | $7.0\pm0.0~a^a$ |
| 2 | Acceleron Basic | $7.5 \pm 0.5 \ a$ |
| 3 | Acceleron Basic+ | $7.5 \pm 0.3 \ a$ |
| 4 | Acceleron Elite | 7.8 ± 0.3 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 22. Mean (\pm SE) corn yield in bushels per acre, corrected to 15.5% moisture

| Trt. | | 27 September |
|------|------------------|---------------------------|
| _ | Treatment | 2022 |
| 1 | Untreated | $228.8\pm9.1~a^a$ |
| 2 | Acceleron Basic | $241.0 \pm 7.9 \text{ a}$ |
| 3 | Acceleron Basic+ | $237.9 \pm 4.6 \text{ a}$ |
| 4 | Acceleron Elite | $235.5 \pm 9.8 \text{ a}$ |

^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 insecticide seed treatments for control of early season soybean insects

Study directors: Nicholas Seiter and Ashley Decker **Location:** University of Illinois Orr Agricultural Research and Demonstration Center, Baylis, IL (39.802890, -90.822473)

Objective: To compare insecticide seed treatments for insect control in soybean seedlings

Materials and Methods: Field experiments were established in a randomized complete block design with 4 replicate blocks and 4 treatments. The experimental units were plots of soybeans (Table 1) that were 4 rows wide and 30 ft. long with 5 ft. of unplanted alley separating plots vertically. The treatments (Table 2) were different combinations of seed-applied insecticides. Plant stands were assessed on 14 June (growth stage V4) by counting the number of plants in a 17.5 row-ft section in rows 2 and 3 of each plot. Plant Vigor was assessed using a 1-4 scale (4 being best) on 14 June (growth stage V4). Yields were assessed for each plot on 19 October 2022 by harvesting rows 2 and 3 using a small-plot combine.

<u>Data Analysis</u>. Weights per plot were corrected to 13% moisture, then converted to bushels per acre using the standard bushel weight of 60 pounds. Plant stand, vigor, and yield were analyzed separately using a generalized linear mixed model (normal distribution) where treatment was considered a fixed effect and replicate block was considered a random effect.

Summary: Stand was reduced in the untreated plots relative to all three seed treatment packages; however, vigor and yield were not affected by treatment in this trial. While there was little to no insect damage observed in this trial, deer damage was readily observed.

Funding: Seed and funding for this trial were provided by Bayer CropScience, St. Louis, MO.

Acknowledgements: We thank Luke Merritt for assisting with planting, plot maintenance, and harvest. We also thank graduate students Yony Callohuari Quispe and undergraduate students Daniel Polski, Joeseph Heier, and Will Foulke for assisting with plot maintenance and data collection.

| Soybean | AG47XF0 ^a |
|---------------|---|
| variety | |
| Seed coatings | Insecticides Table 2 |
| Previous crop | Soybean |
| Soil type | Clarksdale silt loam |
| Tillage | Conventional |
| Row spacing | 30 inches |
| Seeding Rate | 146,000 seeds per acre |
| Planting date | 10 May 2022 |
| Herbicide | Pre-emerge: Authority Assist (10fl oz/a) ^b , Dual II Magnum ^c (1.5 |
| | pt/ac), Roundup Powermax ^a (22 fl oz/ac) |
| | Post-emerge: Warrant Ultra (48fl oz/a) ^a , Cheetah (35 fl oz/a) ^d , AMS |
| | (2 lb/ac) |
| Plot size | 4 rows (10 ft) wide by 30 ft long, 5 ft unplanted alleys |

 Table 23. Plot information

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

Table 24. Experimental treatments

Trt. Insecticide seed coatings

| 1 | Fungicide-only (Proline 480 SC, 0.012 mg a/seed, Fluoxastrobin FS480 0.012 mg |
|---|---|
| | a/seed, Allegiance FL 0.025 mg a/seed) |

- 2 Gaucho (Proline 480 SC, 0.012 mg a/seed, Fluoxastrobin FS480 0.012 mg a/seed, Allegiance FL 0.025 mg a/seed, Gaucho 600FS 0.12 mg a/seed)
- 3 Gaucho + Buteo Start (Proline 480 SC, 0.012 mg a/seed, Fluoxastrobin FS480 0.012 mg a/seed, Allegiance FL 0.025 mg a/seed, Gaucho 600FS 0.12 mg a/seed, Buteo Start FS 480 0.045 mg a/seed)
- 4 Evergol Energy + Gaucho (Evergol Energy 0.019 mg a/seed, Gaucho 600 FS 0.12 mg a/seed)

^a All treatments include the same fungicide base seed coating, see Table 1 ^b Bayer Crop Science, St. Louis, MO

Table 25. Generalized linear mixed model statistics. Each analysis had 9 total degrees of freedom (Treatment = 3 df, Error = 6 df)

| | Numerator | Denominator | | |
|---------|--------------------|---|---|-------------------------------------|
| Date | df | df | F | Р |
| 14 June | 3 | 9 | 4.24 | 0.040^{a} |
| 14 June | 3 | 9 | 0.14 | 0.935 |
| 19 Oct. | 3 | 9 | 1.55 | 0.268 |
| | 14 June 14 June | Date df 14 June 3 14 June 3 | 14 June 3 9 14 June 3 9 | DatedfdfF14 June394.2414 June390.14 |

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

| | 14 June 2022 |
|-------------------------|---------------------------|
| Treatment | (V4) |
| Fungicide-only | $89.9 \pm 6.5 \ b^{a}$ |
| Gaucho | 107.8 ± 3.4 a |
| Gaucho + Buteo Start | $107.8 \pm 3.9 \text{ a}$ |
| Gaucho + Evergol Energy | $109.0 \pm 3.1 \text{ a}$ |

Table 26. Mean (± Standard error [SE]) stand in number of plants per 17.5 ft. of row

^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 27. Mean (\pm SE) Vigor rating (1-4 scale with "4" being best).

| | 14 June 2022 |
|-------------------------|-------------------|
| Treatment | (V4) |
| Fungicide-only | $3.3\pm0.5~a^{a}$ |
| Gaucho | $3.3 \pm 0.3 a$ |
| Gaucho + Buteo Start | $3.3 \pm 0.3 a$ |
| Gaucho + Evergol Energy | $3.0 \pm 0.4 a$ |

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

Table 28. Mean (± SE) soybean yield in bushels per acre, corrected to 13% moisture

| Treatment | 19 October 2022 |
|-------------------------|--------------------------|
| Fungicide-only | $59.2 \pm 2.4 \ a^{a}$ |
| Gaucho | 59.9 ± 1.0 a |
| Gaucho + Buteo Start | $63.0\pm0.5~\mathrm{a}$ |
| Gaucho + Evergol Energy | $62.0 \pm 2.0 \text{ a}$ |

^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 foliar-applied insecticides for control of soybean insect pests, 2022

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Location: University of Illinois Crop Sciences Research and Education Center (40.083117, - 88.228210)

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

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 conventional and pre-commercial insecticides applied on 16 August 2022 (soybean stage R5) using a CO2-powered backpack sprayer with a 10-foot spray boom (Table 1). Population densities of all insect pests were assessed on 19 August (3 days post-application, stage R6), 23 August (7 days post-application, stage R6), and 30 August (14 days post-application, stage R6), by taking 20 sweeps per plot using a standard 15 inch-diameter polyester sweep net swung perpendicular to the rows through the soybean canopy. On 30 August (R6), 18 soybean leaflets per plot (ten each from the upper, middle, and lower third of the plant canopy) were collected and evaluated for percent defoliation using a mobile phone app designed for this purpose (Bioleaf, <u>http://bioleaf.icmc.usp.br/</u>). Plots were visited on 6 September (21 days post-application), but the trial had reached stage R7 and sampling was discontinued.

Data analysis. Insect counts per 20 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*], Japanese beetle [adults, *Popillia japonica*], and green cloverworm [larvae, *Hypena scabra*]), and percent defoliation were analyzed separately using a generalized linear mixed model (distribution listed separately for each dependent variable), 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 bean leaf beetle compared with the untreated control plots at 3-, 7-, and 14-days following application. Percent defoliation of the soybean canopy was also reduced in all the insecticide treatments, though insect defoliation was well below economically damaging levels. Other insect population densities were generally low; only green cloverworm (at 7- and 14-days following application) was impacted by the insecticide treatment.

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

Acknowledgements: We thank Nick Eisenmenger, Darin Joos, and Alan Tammen for assistance with planting and plot maintenance. In addition, we thank graduate students Yony Callohuari Quispe and undergraduate students Will Foulke, Daniel Polski, and Joseph Heier for assisting with plot maintenance and data collection.

| Soybean variety | P18T91E ^a |
|-----------------------|--|
| Previous crop | Corn |
| Soil type | Drummer silty clay loam |
| Tillage | No-till |
| Row spacing | 30-inch |
| Seeding rate | 140,000 seeds per acre |
| Planting date | 29 April 2022 |
| Herbicide | 28 April (pre-emerge): Zidua Pro ^b (6 oz/a) and Glory ^c (16 oz/a) |
| | 9 June (post-emerge): Enlist One ^d (2 pts/a) and Liberty ^b (36 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 16 Aug. 2022 (R5); 20-inch nozzle spacing, 30 psi, 2.5 mph |
| | ground speed, TeeJetXR8001VS ^e extended range flat fan nozzle tips |

Table 29. Plot information

^a Pioneer, Corteva Agriscience, Johnston, IA; ^b BASF Corporation, Research Triangle Park, NC; ^c ADAMA, Raleigh, NC; ^d Corteva Agriscience, Indianapolis, IN; ^e Spraying Systems Co., Glendale Heights, IL

Table 30. Insecticide treatments

| | | Active ingredient and |
|------|--|---------------------------------|
| Trt. | Material and rate | formulation |
| 1 | Untreated | n/a |
| 2 | Plinazolin [®] Technology ^a A21550 CP (0.684 fl. oz/a) | Pre-commercial |
| 3 | Plinazolin [®] Technology ^a A21550 CP (1.03 fl. oz/a) | Pre-commercial |
| 4 | Warrior II ^a (1.96 fl. oz/a) | lambda-cyhalothrin (2.08 lbs |
| | | ai per gal), capsule suspension |

^a Syngenta Crop Protection, Greensboro, NC

| Date F P |
|--|
| binomial distribution) ^a 19 Aug. 12.99 0.001 ^b |
| 23 Aug. $26.30 < 0.001^{b}$ |
| 30 Aug. 6.63 0.012 ^b |
| 1 distribution) $30 \text{ Aug.} 4.71 0.031^{\text{b}}$ |
| ; normal distribution) ^a 19 Aug. 0.74 0.554 |
| 23 Aug. 3.00 0.088 |
| 30 Aug. 1.65 0.246 |
| listribution) ^a 19 Aug. 0.70 0.574 |
| 23 Aug. 0.73 0.560 |
| 30 Aug. 1.00 0.436 |
| 1 distribution) ^a 19 Aug. 3.57 0.060 |
| 23 Aug. 6.94 0.010 ^b |
| 30 Aug. 7.08 0.010 ^b |
| listribution) a 19 Aug. 0.70 0.5 23 Aug. 0.73 0.5 30 Aug. 1.00 0.4 1 distribution) a 19 Aug. 3.57 0.0 23 Aug. 6.94 0.0 |

Table 31. Generalized linear mixed model statistics. Each analysis had 12 total degrees of freedom (Numerator = 3 df, Denominator = 9 df). Insecticide treatment was the lone fixed effect. Probability distribution used in the analysis is listed in parentheses for each dependent variable.

^a Insect count per 20 sweeps using a sweep net; ^b Effect is significant at $\alpha = 0.05$; ^c No analysis, count = 0 for all plots

Table 32. Mean (± standard error [SE]) bean leaf beetle (BLB, *Certotoma trifurcata*, Coleoptera:Chrysomelidae) adults per 20 sweeps and percent defoliation of soybean canopy

| | | BLB 19 Aug. (R5) | BLB 23 Aug. (R6) | BLB 30 Aug. (R6) | Defoliation 30 Aug (R6) |
|------|------------------|-------------------------|--------------------------|-------------------------|----------------------------|
| Trt. | Treatment | 3 DAA ^a | 7 DAA | 14 DAA | 14 DAA |
| 1 | Untreated | $19.5 \pm 4.9 \ a^{b}$ | 27.5 ± 5.2 a | 15.8 ± 6.5 a | 4.2 ± 0.3 a |
| 2 | A21550 CP | $2.5 \pm 1.0 \text{ b}$ | $2.5 \pm 1.0 \text{ bc}$ | $1.8 \pm 1.1 \text{ b}$ | 2.6 ± 0.3 b |
| | (0.684 fl. oz/a) | | | | |
| 3 | A21550 CP | 1.5 ± 3.8 b | $3.8\pm0.5\;b$ | $1.0 \pm 1.0 \text{ b}$ | $2.5\pm0.6\ b$ |
| | (1.03 fl. oz/a) | | | | |
| 4 | Warrior II | $0.5\pm0.5\;b$ | $0.5\pm0.3~c$ | $0.8\pm0.5\;b$ | $2.7\pm0.4\ b$ |
| | (1.96 fl. oz/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 ($\alpha = 0.05$)

| Trt. | Treatment | 19 Aug. (R5) 3 DAA ^a | 23 Aug. (R6) 7 DAA | 30 Aug. (R6) 14 DAA |
|------|----------------------------|------------------------------------|-----------------------|------------------------|
| 1 | Untreated | $1.0 \pm 1.0 \ a^{b}$ | 2.0 ± 0.6 a | 1.5 ± 1.2 a |
| 2 | A21550 CP (0.684 fl. oz/a) | $0.3\pm0.3\ a$ | 1.3 ± 0.5 a | 0.3 ± 0.3 a |
| 3 | A21550 CP (1.03 fl. oz/a) | $0.8\pm0.3\ a$ | $0.5\pm0.3~a$ | 0.3 ± 0.3 a |
| 4 | Warrior II (1.96 fl. oz/a) | 0.0 ± 0.0 a | $0.8\pm0.5\;a$ | $0.0 \pm 0.0 \ a$ |

Table 33. Mean (\pm SE) total stink bug (Hemiptera: Pentatomidae) adults and nymphs per 20 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 34. Mean (\pm SE) total Japanese beetle (*Popillia japonica*, Coleoptera: Scarabaeidae)adults per 20 sweeps

| | | 19 Aug. (R5) | 23 Aug. (R6) | 30 Aug. (R6) |
|------|----------------------------|--------------------------|-----------------|-------------------|
| Trt. | Treatment | 3 DAA ^a | 7 DAA | 14 DAA |
| 1 | Untreated | $1.3\pm0.9~\mathrm{a^b}$ | 1.0 ± 1.0 a | $1.3 \pm 0.3 \ a$ |
| 2 | A21550 CP (0.684 fl. oz/a) | $0.5\pm0.3\ a$ | 0.3 ± 0.3 a | $0.0\pm0.0\;a$ |
| 3 | A21550 CP (1.03 fl. oz/a) | $0.8\pm0.8\;a$ | 0.3 ± 0.3 a | $0.0\pm0.0\;a$ |
| 4 | Warrior II (1.96 fl. oz/a) | 0.0 ± 0.0 a | $0.0\pm0.0\;a$ | 0.0 ± 0.0 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 35. Mean (± SE) total green cloverworm (*Hypena scabra*, Noctuidae: Erebidae) larvae per20 sweeps

| | | 19 Aug. (R5) | 23 Aug. (R6) | 30 Aug. (R6) |
|------|----------------------------|-----------------------|----------------|-----------------|
| Trt. | Treatment | 3 DAA ^a | 7 DAA | 14 DAA |
| 1 | Untreated | $2.5 \pm 1.2 \ a^{b}$ | $2.3\pm0.9\;a$ | 1.3 ± 0.3 a |
| 2 | A21550 CP (0.684 fl. oz/a) | 0.3 ± 0.3 a | $0.0\pm0.0\;b$ | $0.0\pm0.0\;b$ |
| 3 | A21550 CP (1.03 fl. oz/a) | 0.0 ± 0.0 a | $0.0\pm0.0\;b$ | $0.3\pm0.3\;b$ |
| 4 | Warrior II (1.96 fl. oz/a) | 0.3 ± 0.3 a | $0.0\pm0.0\;b$ | $0.3\pm0.3\;b$ |

^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 ($\alpha = 0.05$)

University of Illinois Plant Clinic – Agronomic Crops Report, 2022

Diane Plewa, Plant Clinic Director and State IPM Coordinator

The University of Illinois Plant Clinic received 1,863 samples in 2022. 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.

1160 field crop samples were received, comprising approximately 62.3% of all samples in 2022. 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. 504 soil samples for nematode testing and 583 plant samples for pest and pathogen diagnosis were received. Of those 583 plant samples, 362 were corn, 198 were soybean, 13 were industrial hemp, 8 were wheat, 1 was alfalfa, and 1 was sorghum. These samples included field crop samples submitted by farmers and crop consultants, and samples processed for phytosanitary certification. Fungal diseases were predominant this year compared to bacterial or viral diseases.

The most common corn diseases diagnosed were Gray Leaf Spot (32% of corn samples were infected with this disease), Yellow Leaf Blight (23.5%), Physoderma Brown Spot (23.2%), Common Rust (22.4%) and Northern Corn Leaf Blight (15.7%). 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. Of the corn vermiform soil samples submitted, Lesion and Spiral nematodes were the most frequently detected (84.8% of samples each), followed by Lance (45.5%), Dagger (33.3%) and Stunt (24.2%).

For soybean samples, the most common diseases diagnosed were Purple Seed Stain and Leaf Blight (26.3%), Downy Mildew (23.7%), and Anthracnose, Frogeye Leaf Spot, and Soybean Vein Necrosis Virus (17.2% each). Root rots caused by Phytophthora, Pythium, and Rhizoctonia were found earlier in the season, with 15.7% of soybean samples diagnosed with one or more of these pathogens. Red Crown Rot, a fairly new disease, was confirmed on a single sample. 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.

Corn earworm was the most prevalent problem on hemp, with Exserohilum leaf spot, fungal stem cankers (specific identification pending), Botrytis gray mold, and mites also confirmed on hemp samples.

50% of the wheat samples were diagnosed with Septoria leaf spot/blotch, and 37.5% were diagnosed with Pythium root rot. Bacterial leaf blight and Rhizoctonia root rot were also confirmed on wheat samples.

Downy mildew, thrips, and Rhizoctonia were confirmed on the single alfalfa sample, while Rough leaf spot was confirmed on the single sorghum sample.

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