Project Final Report for: Development and Expansion of Disease Management Decision-Making Tools Across Multiple Soybean Regions, Year 3 (January 31, 2026)

Uniform fungicide trial. Uniform soybean foliar fungicide field trials were conducted in nineteen different states during the 2025 growing season (data from two projects were combined, where 11 states participating as collaborators in this project, and 8 states participating through a different regional project), in which fourteen treatments and a nontreated check were evaluated. In total, fourteen treatments were evaluated, which included a nontreated control. All fungicides were applied at the R3 growth stage (beginning pod), except for a few treatments that were applied at the R5 growth stage (beginning seed) or applied twice at R3 and R5.

Data from 22 field sites have been statistically analyzed so far (Fig. 1). Across these 22 sites primary disease pressure came from frogeye leaf spot (FLS; caused by *Cercospora sojina*) and Septoria brown spot (SBS; caused by *Septoria glycines*). All treatments except Oxidate reduced FLS severity compared to the nontreated control, and all treatments except Badger, Affiance, "generic Quilt" (R5), and Oxidate reduced SBS severity compared to the nontreated control.

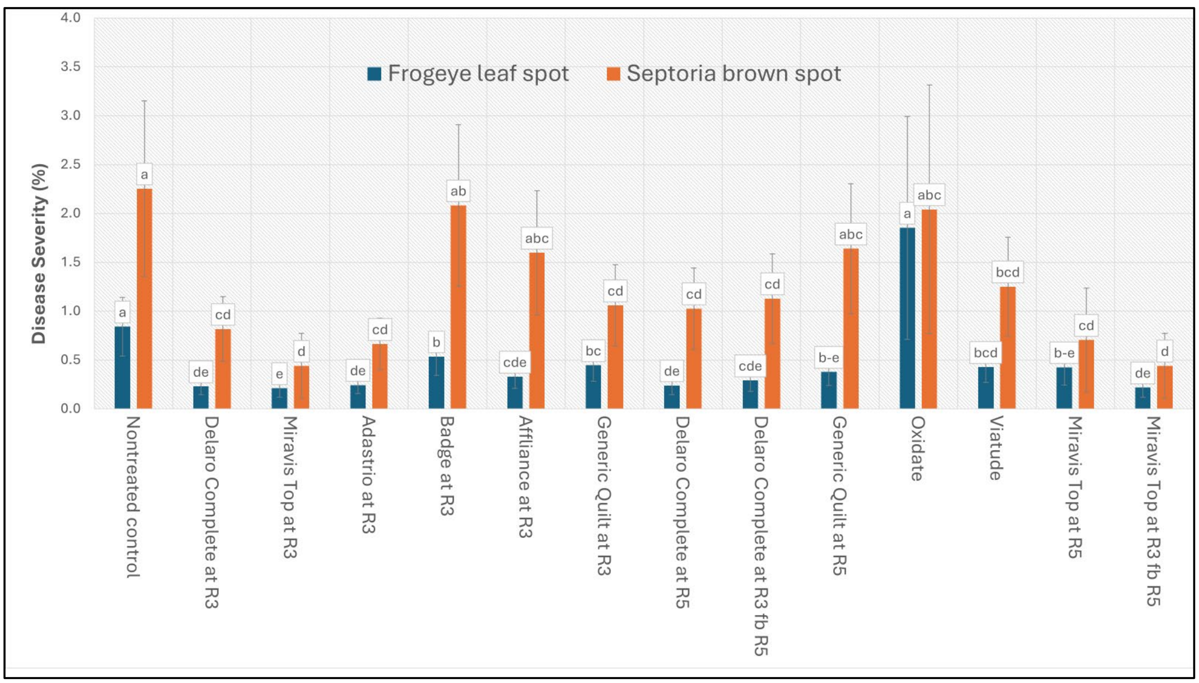

Fig. 1. Effect of foliar fungicide treatments on frogeye leaf spot and Septoria brown spot severity across soybean field trials conducted across 22 sites in 2025.

Averaged across all locations, only plots treated with Affiance (R3), Delaro Complete (R3+R5 and R5 alone), "generic Quilt" (R5), Oxidate, Viatude, Miravis Top (R3+R5 and R5 alone) resulted in a significantly greater yield than the nontreated control (Fig. 2).

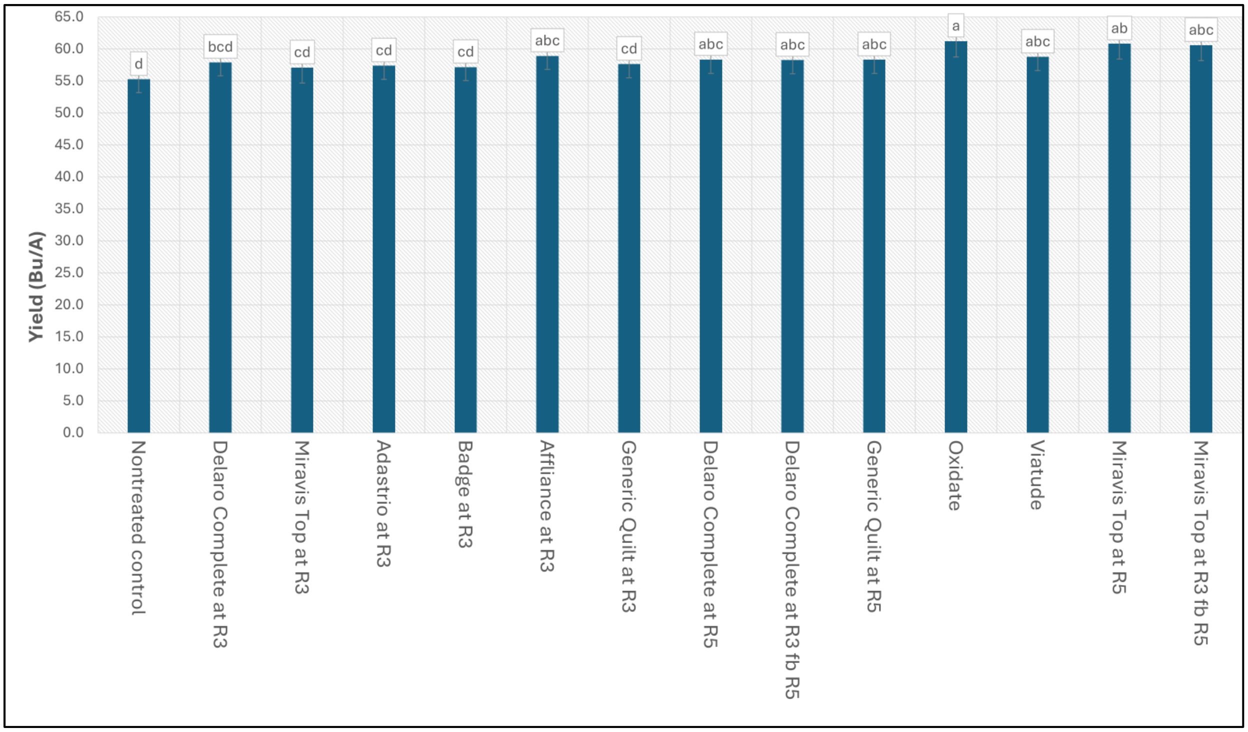

Fig. 2. Effect of foliar fungicide treatments on soybean yield across field trials conducted across 222 sites in 2025.

The data from the uniform fungicide trial are being used to help revise the 2026 edition of the Crop Protection Network Soybean Foliar Fungicide Efficacy Guide. In addition, the data from these trials are being used to test, adjust, and optimize disease prediction models.

Spore trap network and quantification of foliar soybean pathogens. Spore traps were deployed in soybean fields across thirteen different locations in 2025. Spore samples were collected at two different heights weekly. The samples were sent in bulk to the Smith Laboratory (University of Wisconsin), where DNA currently is being extracted from the 2025 spore samples. For the spore samples collected in 2023 and 2024 (3,339 trap samples in total), all DNA have been extracted, and the Smith Lab is developing an assay to enumerate spores of *Cercospora sojina* (FLS pathogen). The Thomas-Sharma Lab (LSU) has developed assays to enumerate spores of the species of *Cercospora* that cause Cercospora leaf blight and spores of the target spot pathogen (*Corynespora cassiicola*).

For detection of *C. cassiicola*, initially six DNA samples from Dr. Carl Bradley's lab (University of Kentucky) of *C. cassiicola* were used to evaluate a primer that was developed previously by Ciampi-Guillardi et al. (2020). Both conventional and quantitative PCR (qPCR) was used to amplify the samples (Fig. 3-4).

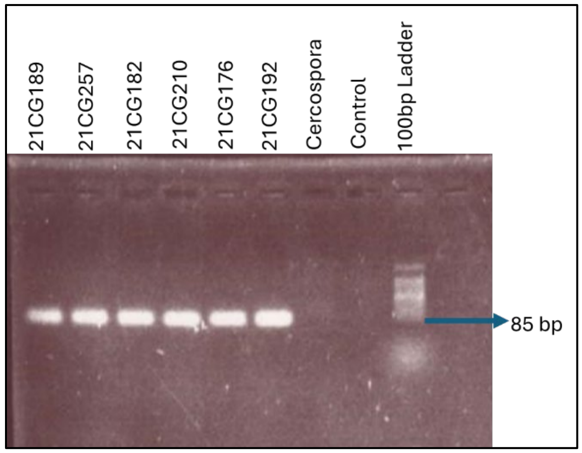

Fig. 3. Gel Image of conventional PCR using the DNA of *Corynespora cassiicola* for the validation of primers developed by Ciampi-Guillardi et al 2020.

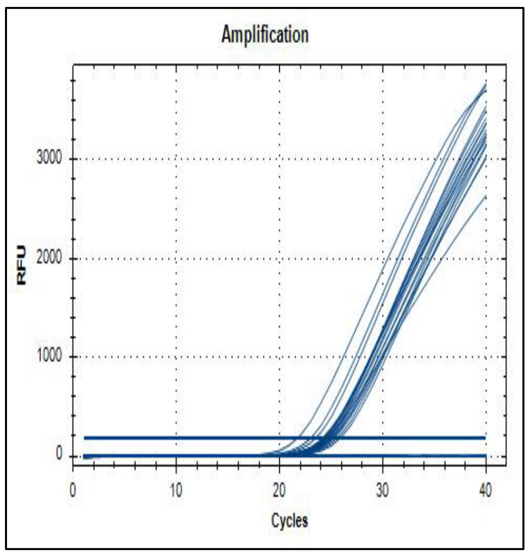

Fig. 4. Amplification image of qPCR using the DNA of *Corynespora cassiicola* for the validation of primers developed by Ciampi-Guillardi et al 2020.

Following this, six additional DNA samples were received from Dr. Alejandro Rojas' lab (Michigan State University) and were also used to perform the qPCR using the same primers, making a total of 12 DNA samples. The image of the qPCR is shown in Fig. 5.

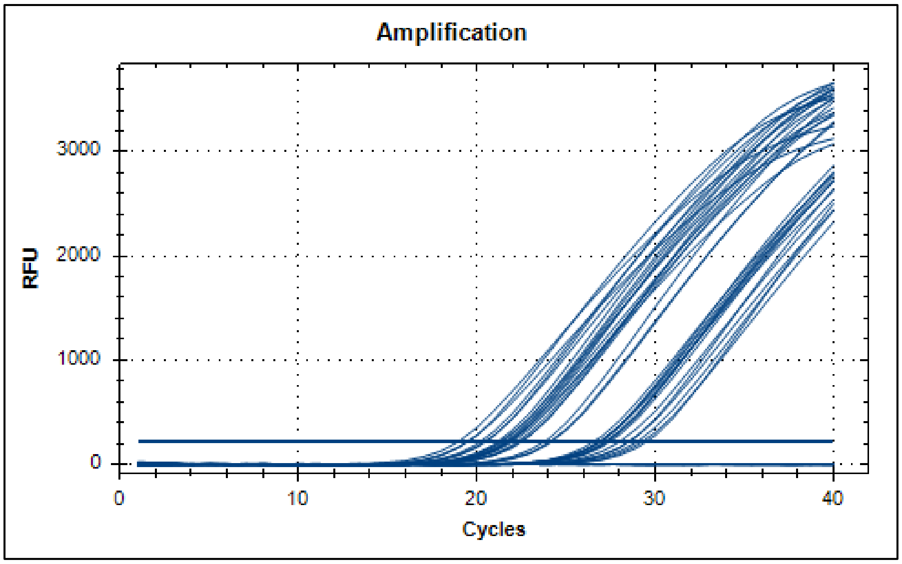

Fig. 5. Amplification of DNA of 12 *Corynespora cassiicola* using the assay developed by Ciampi-Guillardi et al 2020.

Once USDA-APHIS permits were received, the Thomas-Sharma Lab was able to receive 23 isolates from Dr. Bradley's and Dr. Rojas' laboratories. These isolates are currently being used for spore production and validation of the same primers for use on spore trap samples.

For detection of species of *Cercospora* that cause Cercospora leaf bligth, DNA samples from spore traps deployed in 2023 and 2024 were used in the Thomas-Sharma Lab in duplicate to detect *C.* cf. *flagellaris*, *C.* cf. *sigesbeckiae,* and *C. kikuchii* using in house qPCR assays. **A primary finding of this study is although CLB is not generally an economically damaging disease in northern soybean growing regions of the U.S., spores of the pathogens are present in most states.** This suggests that a combination of environment and host genetics is likely to limit the impact of the pathogen in northern states.

The specific findings by year are shown below:
<u>2023:</u>

- A total of 1032 DNA samples were received
- The DNA samples were from 20 states: Alabama, Arkansas, Delaware, Florida, Iowa, Indiana, Kentucky, Louisiana, Michigan, Mississippi, Missouri, North Carolina, North Dakota, Nebraska, Ohio, Penssylvania, Tennessee, Virginia, Wisconsin and Minnesota.
- There were differences in the species detected in different states (Table 1):
    - None of the species was detected in Minnesota
    - Only *C. flagellaris* was detected in Alabama, Florida, Mississippi, Ohio, Virginia, Wisconsin, Michigan, and North Dakota
    - *C. flagellaris* and *C. kikuchii* were detected in North Carolina, Arkansas and Tennessee

    - *C. flagellaris* and *C. sigesbeckiae* were detected in Iowa, Louisiana, Missouri, and Delaware
    - *C. flagellaris*, *C. sigesbeckiae,* and *C. kikuchii* were detected in Indiana, Kentucky, Pennsylvania, and Nebraska
- Overall, *C. flagellaris* (77%) was the predominant species detected across all spore trap samples, followed by *C. sigesbeckiae* (16%) and *C. kikuchii* (7%) (Fig. 6).
- *C. flagellaris* reached the highest spore numbers (Fig. 7). For all three pathogen species, it was common to detect Log_{10} 3-5 (1000-100,000) spores.
- There were differences in the pattens of spore detection during the season in different states. In Wisconsin and Michigan spores were detected earlier in the season, while in Delaware and Florida, spores were detected towards the end of the season (Fig. 8).

Table 1. Summary of the three Cercospora leaf blight pathogen species detected from soybean fields across the U.S. in 2023.

S/No.	**States**	***C. flagellaris***	***C. sigesbeckiae***	***C. kikuchii***
1	Minnesota	.	.	.
2	North Carolina	✓	.	✓
3	Arkansas	✓	.	✓
4	Tennessee	✓	.	✓
5	Indiana	✓	✓	✓
6	Kentucky	✓	✓	✓
7	Pennsylvania	✓	✓	✓
8	Nebraska	✓	✓	✓
9	Iowa	✓	✓	.
10	Louisiana	✓	✓	.
11	Missouri	✓	✓	.
12	Delaware	✓	✓	.
13	Alabama	✓	.	.
14	Florida	✓	.	.
15	Mississippi	✓	.	.
16	Ohio	✓	.	.
17	Virginia	✓	.	.
18	Wisconsin	✓	.	.
19	Michigan	✓	.	.
20	North Dakota	✓	.	.

✓: Indicate the detection of the pathogen in the state; **“.”**: the pathogen was not detected.

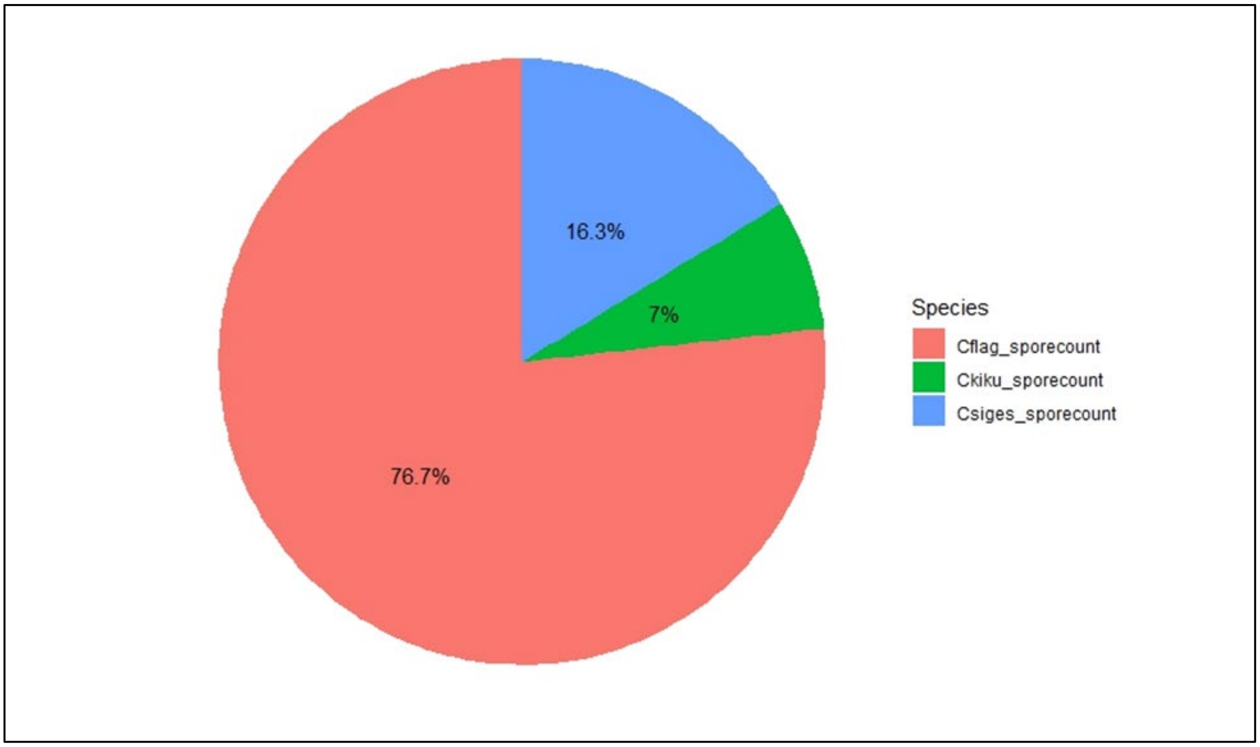

Fig. 6. Percentage of spore samples that showed the presence of the three species of *Cercospora* causing Cercospora leaf blight on soybean, across 19 states in 2023.

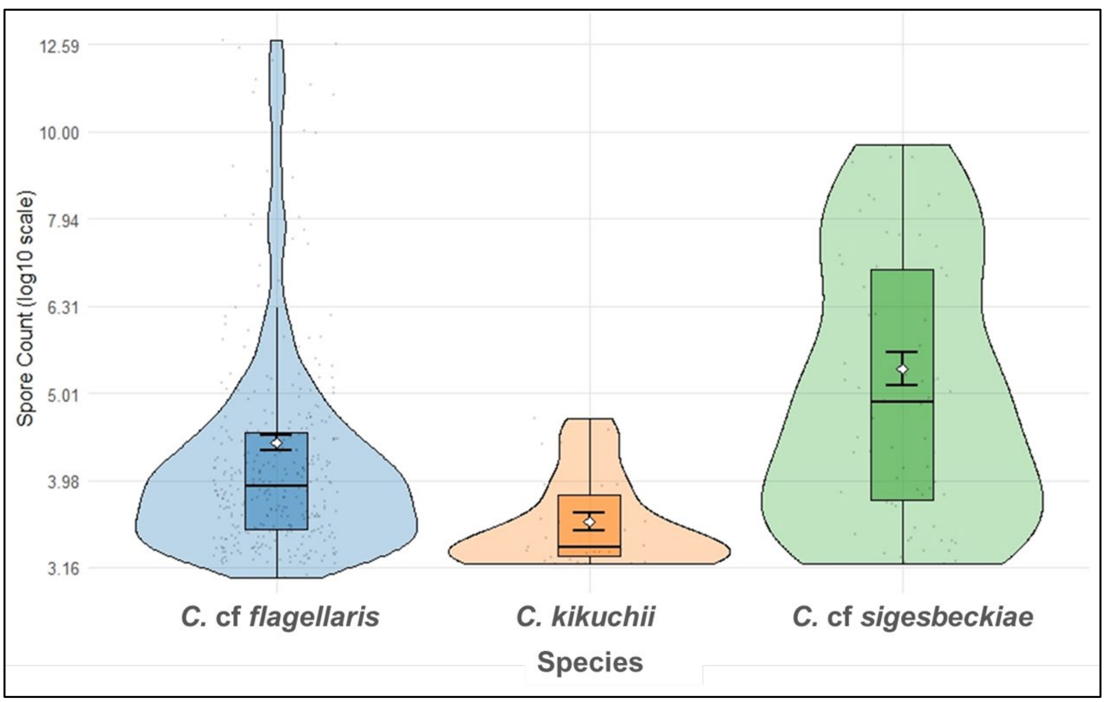

Fig. 7. The overall distribution of *Cercospora* species causing Cercospora leaf blight on soybean across 19 states in 2023.

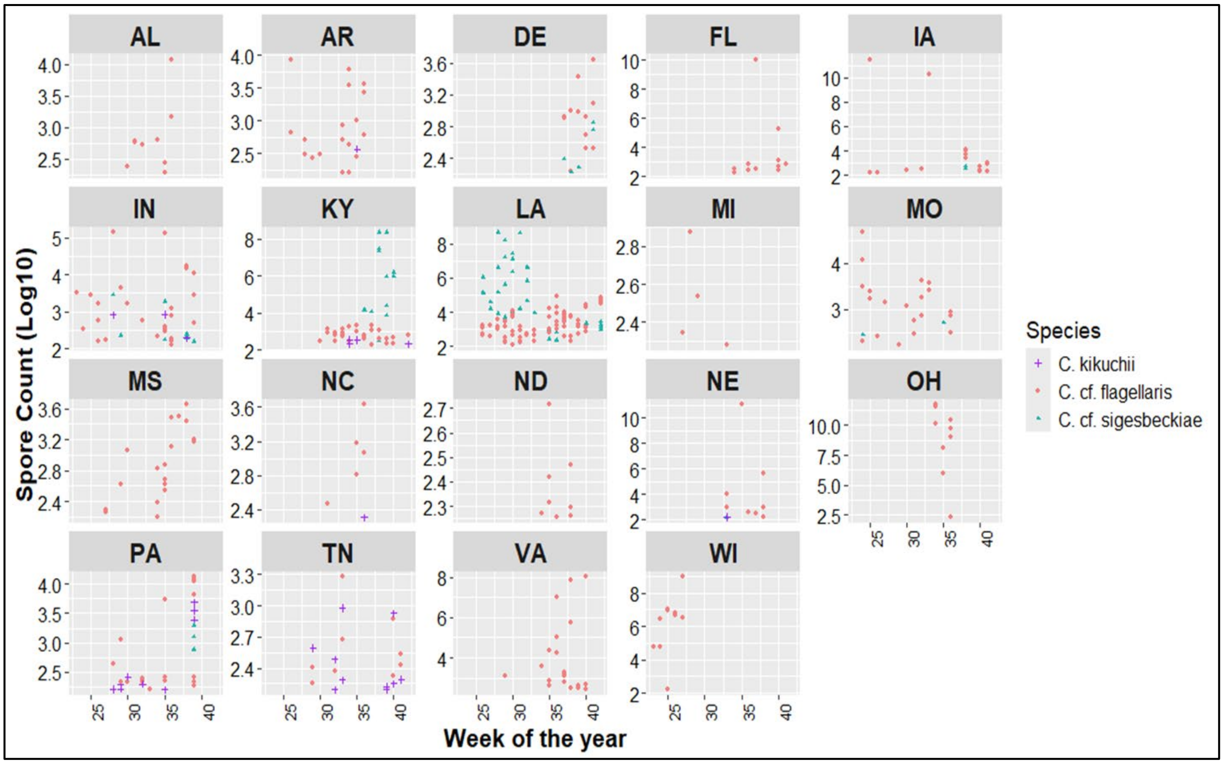

Fig. 8. Seasonal distribution of soybean Cercospora leaf blight pathogens across each of the 19 states from the third week of June to the second week of October 2023.

<u>2024:</u>

- A total of 1138 DNA samples were received
- The DNA samples were from 20 states, viz; Alabama, Arkansas, Delaware, Illinois, Iowa, Indiana, Kentucky, Louisiana, Michigan, Mississippi, Missouri, North Carolina, North Dakota, Nebraska, Ohio, Penssylvania, Tennessee, Oklahoma, Wisconsin and Minnesota. **Note that this year, no samples were received from Florida and Virginia, but samples were obtained from Illinois and Oklahoma.**
- There were differences in the species detected in different states (Table 2), but the pattern was different from 2023. Spores were detected in Minnesota in 2024. Other specific observations include,
  - *C. sigesbeckiae* was detected in all 20 states
  - *C. flagellaris* was detected in 19 states except Oklahoma
  - *C. kikuchii* was detected in 13 states but not in Arkansas, Indiana, Minnesota, North Dakota, Nebraska, Ohio, and Wisconsin.
- In 2024 as well majority of the spore trap samples had *C. flagellaris* (50%), while *C. sigesbeckiae* (36.9%) and *C. kikuchii* (12.3%) was detected at lower levels. (Fig .9)
- In 2024, *C. sigesbeckiae* reached higher numbers more frequently than *C. flagellaris* which remained in the Log_{10} 3-4 (1000-10,000 spore) range more frequently (Fig. 10).
- Unlike 2023, spores were detected throughout the season in Wisconsin and Michigan. Similar to 2023, most spores in Delaware were detected towards the end of the season (Fig. 11).

Table 2. Summary of the three CLB pathogen species detected from soybean fields across the U.S. in 2024.

S/No.	States	*C. sigesbeckiae*	*C. flagellaris*	*C. kikuchii*
1	Alabama	✓	✓	✓
2	Delaware	✓	✓	✓
3	Iowa	✓	✓	✓
4	Illinois	✓	✓	✓
5	Kentucky	✓	✓	✓
6	Louisiana	✓	✓	✓
7	Michigan	✓	✓	✓
8	Missouri	✓	✓	✓
9	Mississippi	✓	✓	✓
10	North Carolina	✓	✓	✓
11	Pennsylvania	✓	✓	✓
12	Tennessee	✓	✓	✓
13	Arkansas	✓	✓	.
14	Indiana	✓	✓	.
15	Minnesota	✓	✓	.
16	North Dakota	✓	✓	.
17	Nebraska	✓	✓	.
18	Ohio	✓	✓	.
19	Wisconsin	✓	✓	.
20	Oklahoma	✓	.	✓

✓: Indicate the detection of the pathogen in the state; "**.**": the pathogen was not detected.

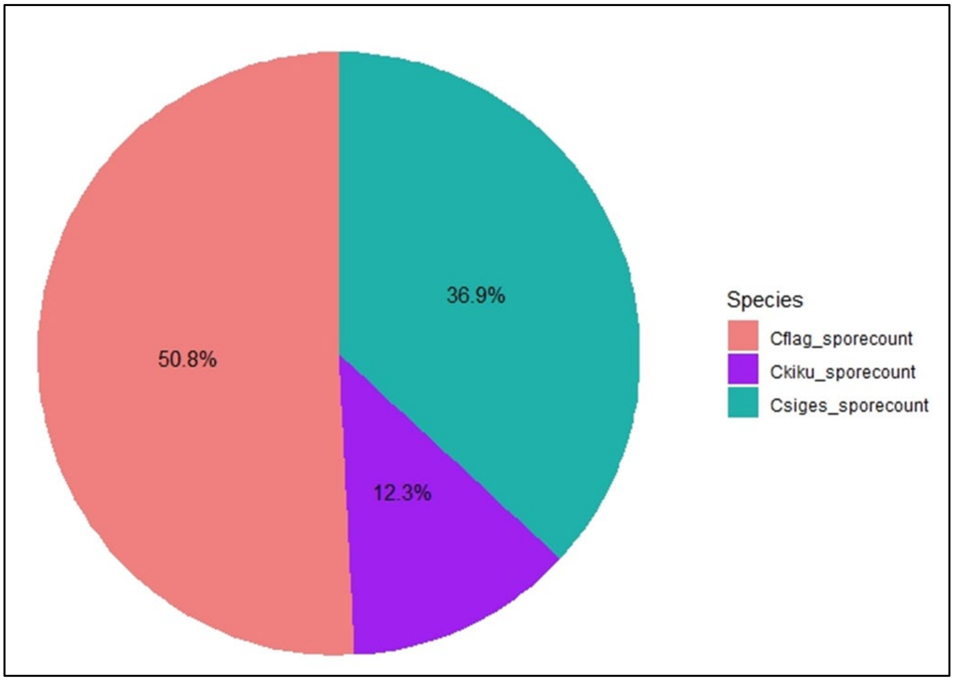

Fig. 9. Percentage of spore samples that showed the presence of the three species of *Cercospora* causing Cercospora leaf blight on soybean, across 20 states in 2024.

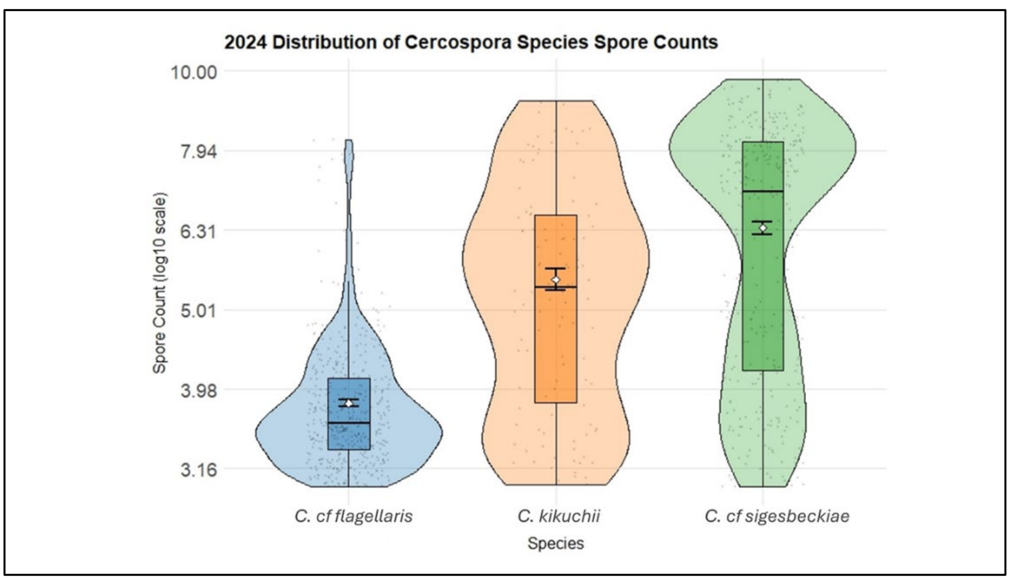

Fig. 10. The overall distribution of *Cercospora* species causing Cercospora leaf blight on soybean across 20 states in 2024.

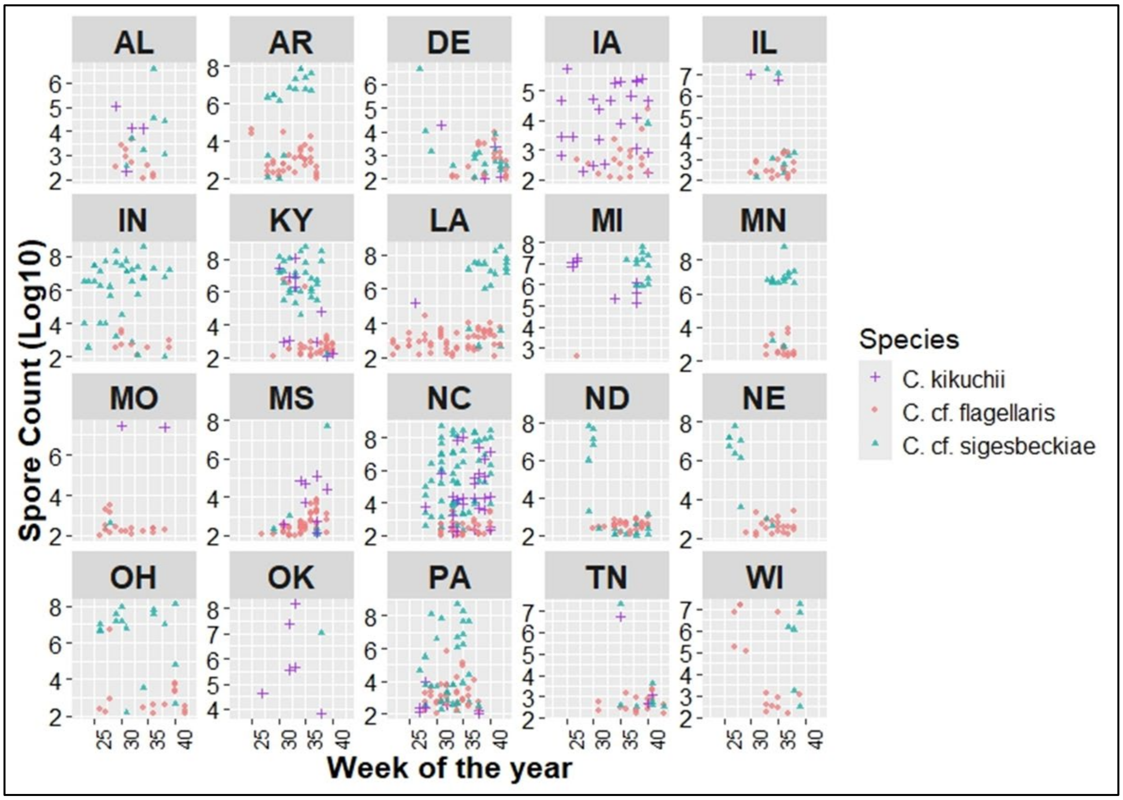

Fig. 11. Seasonal distribution of soybean Cercospora leaf blight causal pathogens across each of 20 states from the third week of June to the second week of October 2024.

Predictive modeling of soybean foliar diseases. The greatest success in this area was the launch of the frogeye leaf spot model that was available for use in the 2025 growing season. This tool is available on the Crop Protection Network website (https://cropprotectionnetwork.org/), and has a user-friendly interface where multiple fields (locations) can be added to monitor risk during critical stages (typically between R1 and R5 growth stages). Figure 12 shows the frogeye leaf spot risk output from the model for five locations in Kentucky during the 2025 growing season. Soybean farmers across the U.S. are now able to utilize this tool to help them make better informed decisions for management of frogeye leaf spot. The frogeye leaf spot risk tool continues to be validated through field trial protocols that are being conducted across multiple states where FLS risk thresholds of 40%-60% are being evaluated as "triggers" for fungicide application. So far, these validation trials have shown that the risk tool has been accurate in predictive FLS risk across a large geography. In addition to the FLS risk tool, the initial building blocks have been assembled from this project for subsequent development of risk models for Cercospora leaf blight and target spot.

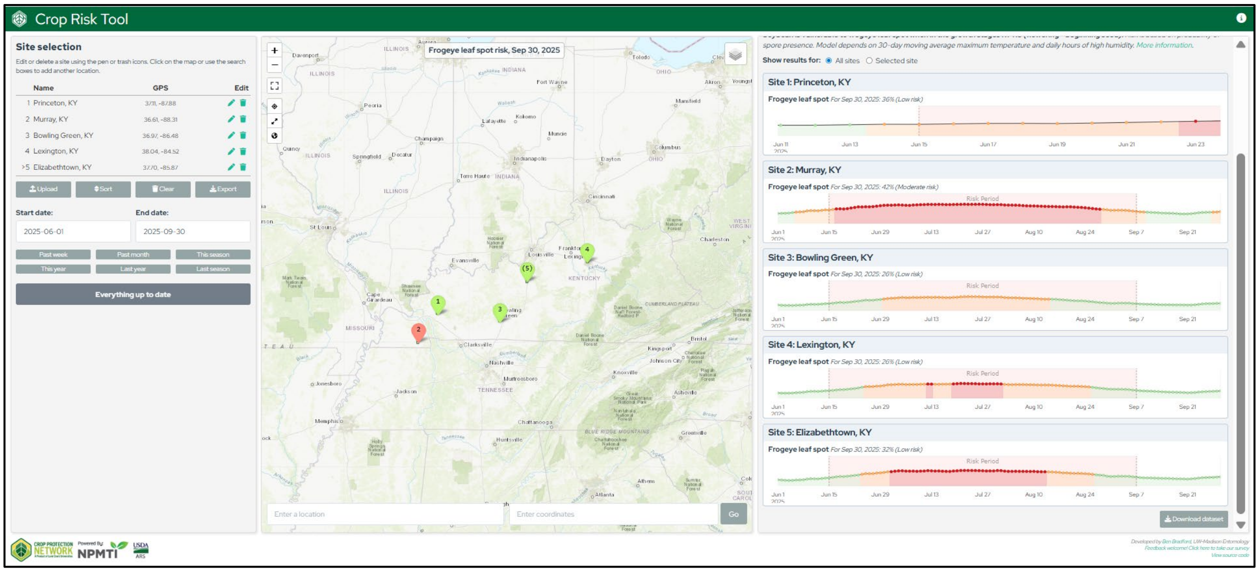

Fig. 12. Interface and output from the frogeye leaf spot risk tool available on the Crop Protection Network (https://cropprotectionnetwork.org/), showing the risk of frogeye leaf spot in five fields in Kentucky during the 2025 growing season.

Abstracts presented at scientific meetings in 2025:

Dalha A. I., Allen, T.W., Amie, J., Betts, A.K., Bish, M., Bond, J.P., Bradley, C.A., Chilvers, M.I., Collins, A.A., Doyle, V.P., Esker, P.D., Fakhoury, A.F., Faske, T.R., Hyzer, L., Jimenez Beitia, F., Kelly, H.M., Langston, D.B., Lopez-Nicora, H., Malvick, D.K., Mangel, D., Mathew, F.M., Mueller, D.S., Price, P.P., Richardson, A., Rojas, J.A., Sikora, E.J., Small, I., Smith, D.L., Telenko, D.E.P., Webster, R.W., Wilkerson, T., Yerukala, S., Richards, J.K., Thomas-Sharma, S. 2025. Exploring airborne inoculum of *Cercospora* spp. and *Corynespora cassicola* in soybean fields across the U.S. Annual Meeting of the Southern Soybean Disease Workers, Pensacola Beach, FL, February 26, 2025.

Dalha A. I.., Allen, T.W., Amie, J. , Betts, A.K., Bish, M., Bond, J.P., Bradley, C.A., Chilvers, M.I., Collins, A.A., Doyle, V.P., Esker, P.D., Fakhoury, A.M., Faske, T.R., Hyzer, L., Jiménez-Beitia, F. E., Kelly, H.M., Langston, D.B., Lopez-Nicora, H.D., Malvick, D.K., Mangel, D., Mathew, F.M., Mueller, D.S., Price, P.P., Richardson, A., Rojas, J.A., Sikora, E.J., Small, I. M., Smith, D.L., Telenko, D.E.P., Webster, R.W., Wilkerson, T., Yerukala, S., Richards, J.K., and Thomas-Sharma, S. Investigating the timing of airborne conidia of Cercospora spp. in soybean fields across twenty states in the U.S. Plant Health 2025 (American Phytopathological Society Meeting), Honolulu, HI, August 2-5, 2025.

Gonzalez-Acuna, J. F., Allen, T. W., Bish, M. D., Bradley, C. A., Camiletti, B. X., Dangal, N. K., Fakhoury, A., Faske, T. R., Kelly, H. M. Y., Lopez-Nicora, H., Lux, L., Malvick, D. K., Mangel, D., Markell, S. G., Mueller, D. S., Scherer, J. M., Sikora, E. J., Price, P. P., Sattler, J., Smith, D. L., Telenko, D. E. P., Webster, R. W. 2025. Annual Meeting of the Southern Soybean Disease Workers, Pensacola Beach, FL, February 26, 2025.

Gonzalez-Acuna, J. F., Allen, T. W., Bish, M. D., Bradley, C. A., Camiletti, B. X., Dangal, N. K., Fakhoury, A. M., Faske, T. R., Kelly, H. M. Y., Lopez-Nicora, H. D., Lux, L., Malvick, D. K., Mangel, D., Markell, S. G., Mueller, D. S., Scherer, J. M., Sikora, E. J., Price, P. P., Sattler, J., Smith, D. L., Telenko, D. E. P., Webster, R. W. 2025. Predictive modeling and field evaluation for a smarter approach to manage frogeye leaf spot of soybean in the U.S. CANVAS 2025 (Tri-Societies Meeting), Salt Lake City, UT, November 9-12, 2025.

Peer-reviewed manuscript submitted in 2025:

Gonzalez-Acuna, J. F., Allen, T. W., Bish, M. D., Bradley, C. A., Camiletti, B. X., Chilvers, M., Dangal, N. K., Diaz-Arias, M. M., Fakhoury, A. M., Faske, T. R., Gleason, M. L., Hansen, B. C., Kelly, H. M. Y., Lopez-Nicora, H. D., Lux, L., Malvick, D. K., Mangel, D., Markell, S. G., Mueller, D. S., Price, P. P., Renfroe-Becton, H., Scherer, J. M., Sikora, E. J., Smith, D. L., Striegel, A., Tekenko, D. E. P., and Webster, R. W. 2025. Exploring the environment-related risk of frogeye leaf spot (caused by *Cercospora sojina*) in soybean across U.S. regions through logistic regression and machine learning models. Scientific Reports (submitted).

Reference:

Ciampi-Guillardi, M., Ramiro, J., Duarte de Moraes, M. H., Goldoni Barbieri, M. C., and Massola Jr., N. S. 2020. Plant Disease 104:3002-3009. https://doi.org/10.1094/PDIS-02-20-0231-RE.