NATIONAL SOYBEAN

Advancing Nematode Management for the Future

NEMATODE CONFERENCE

2022

Program Book

December 14–16 • Savannah, Georgia

Presented by

The American Phytopathological Society

in partnership with

The SCN Coalition

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National Soybean Nematode Conference 2022

Use **#NSNC** on social

POSTER LISTINGS

NEMATODE SURVEYS

1. **M. S. Kidd. Connecting field history and nematode community structure to soybean cyst nematode distributions across Pennsylvania.
2. N. M. Kleczewski. A survey of soybean cyst nematode densities and phenotypes in Illinois 2018 and 2020.
3. **K. Mehl. Surveys for plant-parasitic nematodes in Kentucky soybean fields.
4. **S. O. East. Monitoring Missouri SCN populations.
5. G. Yan. *Pratylenchus dakotaensis*, a recently named root-lesion nematode species from soybean fields in North Dakota.
6. **K. Goode. A survey of plant-parasitic nematodes in Georgia soybean fields in 2021.

HOST RESISTANCE

7. **K. Goode. Resistance to *Meloidogyne incognita-1* from cultivar Forrest is located on *Glycine max* chromosome 10.
8. *M. Usovsky. Fine-mapping of a major novel quantitative trait locus on chromosome 2 in PI 90763 that contributes to SCN resistance.
9. **V. Gamage. Functional characterization of a novel gene on chromosome 2 in PI 90763 involved in SCN resistance.
10. *C. Meinhardt. Pragmatic breeding for improving broad soybean cyst nematode resistance with the *rhg2* gene.

NEMATODE GENETICS AND GENOMICS

11. **R. Dhakal. Developing a recombinase polymerase amplification assay for rapid detection of the new root-lesion nematode, *Pratylenchus dakotaensis* on soybean.
12. **K. Kwon. Genome scan for selection signatures reveals candidate soybean cyst nematode virulence genes.

NEMATODE BIOLOGY

13. **E. L. Wlezien. Understanding the pattern of emergence and movement of soybean cyst nematode males.
14. **L. Docherty. Long term storage of *Heterodera glycines* cysts.
15. **R. Yazdani Fazlabadi. Management of soybean cyst nematode using cover crops.

NEMATODE MANAGEMENT

16. G. Yan. Evaluation of cover crops for their effects on hatching and root penetration of soybean cyst nematode.
17. H. M. Kelly. The impact of cover crop management decisions on nematode reproduction rates.
18. **A. Yaghoubi Akbar. Evaluation of different sources of soybeans as a 'Trap Crop' for soybean cyst nematode under greenhouse conditions.
19. K.M. Bissonnette. Applied management of soybean cyst nematode with nematode-protectant seed treatments: a multi-state study.
20. *M. Batista da Silva. Effect of nematicides and resistant varieties on damage caused by cyst and root-knot nematodes in soybeans.
21. **P.S. Yates. A phytochemical-based approach for soybean cyst nematode management.
22. **A. Alnasrawi. The effect of *Bacillus subtilis* expressing a plant elicitor peptide on nematode infection on soybean.

**Young Professional (research staff or postdoctoral research associate)* ***Graduate Student*

Past meeting programs can be found here:

National SCN Conferences

Year	Dates	Location
1995	March 8 - 9	Ames, IA
1999	January 7 - 8	Orlando, FL
2002	July 16 - 17	St. Louis, MO
2008	March 6 - 7	Tampa, FL
2016	December 13 - 15	Coral Gables, FL
2022*	December 14 - 16	Savannah, GA

* National Soybean Nematode Conference

Thank you for Joining Us for the National Soybean Nematode Conference 2022

Defeating soybean nematodes takes an army and a multifaceted strategy, which is why The SCN Coalition and American Phytopathological Society welcome you—the academia and industry scientists, students, crop advisers, farmers, grower organizations, crop protection professionals, ag media and more—in the fight. It is this multitude of perspectives that is essential to the meaningful exchange of information and ideas as well as the development of a well-rounded plan for the future.

We've made big strides in managing soybean nematodes

This conference will highlight the value and impact of research, the power of public-private partnerships and celebrate the fruits of that labor. These efforts save U.S. soybean farmers hundreds of millions of dollars each year.

Researchers have made advances in high-quality nematode reference genomes, discovered novel genetic resistance, advanced new seed treatments and are applying modern molecular tools for genetic modification of soybeans, to name just a few accomplishments. The National Soybean Nematode Strategic Plan (NSNSP) and The SCN Coalition that were developed after the 2016 conference resulted in unified messaging and increased active management of soybean cyst nematodes (SCN) and other nematodes affecting soybeans.

This conference will serve as a milestone for the many farmers, scientists and media specialists who have dedicated their resources to one of the most impactful public-private partnership and awareness campaigns in U.S. agriculture, The SCN Coalition. We hope to build on those efforts to expand or facilitate new partnerships that ultimately result in improved management tools and strategies that put more money in growers' pockets.

Now it's time to plan for the future

After managing SCN using basically one tool – SCN-resistant varieties with the same source of PI 88788 resistance – for 20 years, the pest has evolved. More aggressive SCN populations that can overcome our main management tool are now widespread. Making farmers aware of this resistance to the resistance is critical, as is the need to advance new solutions for battling soybean nematodes, hence the theme of this year's NSNC: Advancing Nematode Management for the Future.

While SCN remains the No. 1 yield-grabbing pathogen of the soybean crop in North America, soybean farmers in the Southern U.S. face additional threats from lesion, reniform and southern root-knot nematode. This conference will cover and address the solutions needed for all parasitic soybean nematodes.

The conference will also lay the foundation for the development of the next five-year strategic research plan, in addition to fostering the next generation of young professionals who will develop tools to fight nematodes.

About The SCN Coalition

The SCN Coalition is a public/checkoff/private partnership formed to increase the number of farmers who are actively managing SCN. Our goal is to increase soybean farmers' profit potential and realize higher yields. Partners in The SCN Coalition include university scientists from 28 states and Ontario, grower checkoff organizations, including the North Central Soybean Research Program, United Soybean Board and several state soybean promotion boards, and corporate partners including BASF, Bayer, Growmark, Nufarm, Pioneer (Corteva), Syngenta, Valent and Winfield United.

What's your number?
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The SCN Coalition™
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Special Thanks to The SCN Coalition

A special thank you to the The SCN Coalition Program Committee Members and their organizations for their collaboration and support of this important conference.

George Bird

Professor Emeritus
Michigan State University

Carl Bradley

Professor
University of Kentucky

Julianne Johnston

Counselor
MorganMeyers

Sam Markell

Professor
North Dakota State University

Melissa G. Mitchum, Chair

Professor
University of Georgia

Albert Tenuta

Field Crop Pathologist
Ontario Ministry of Agriculture, Food and Rural Affairs

Greg Tylka

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Special Thanks

A special thank you to Albert Tenuta and all of our sponsors.
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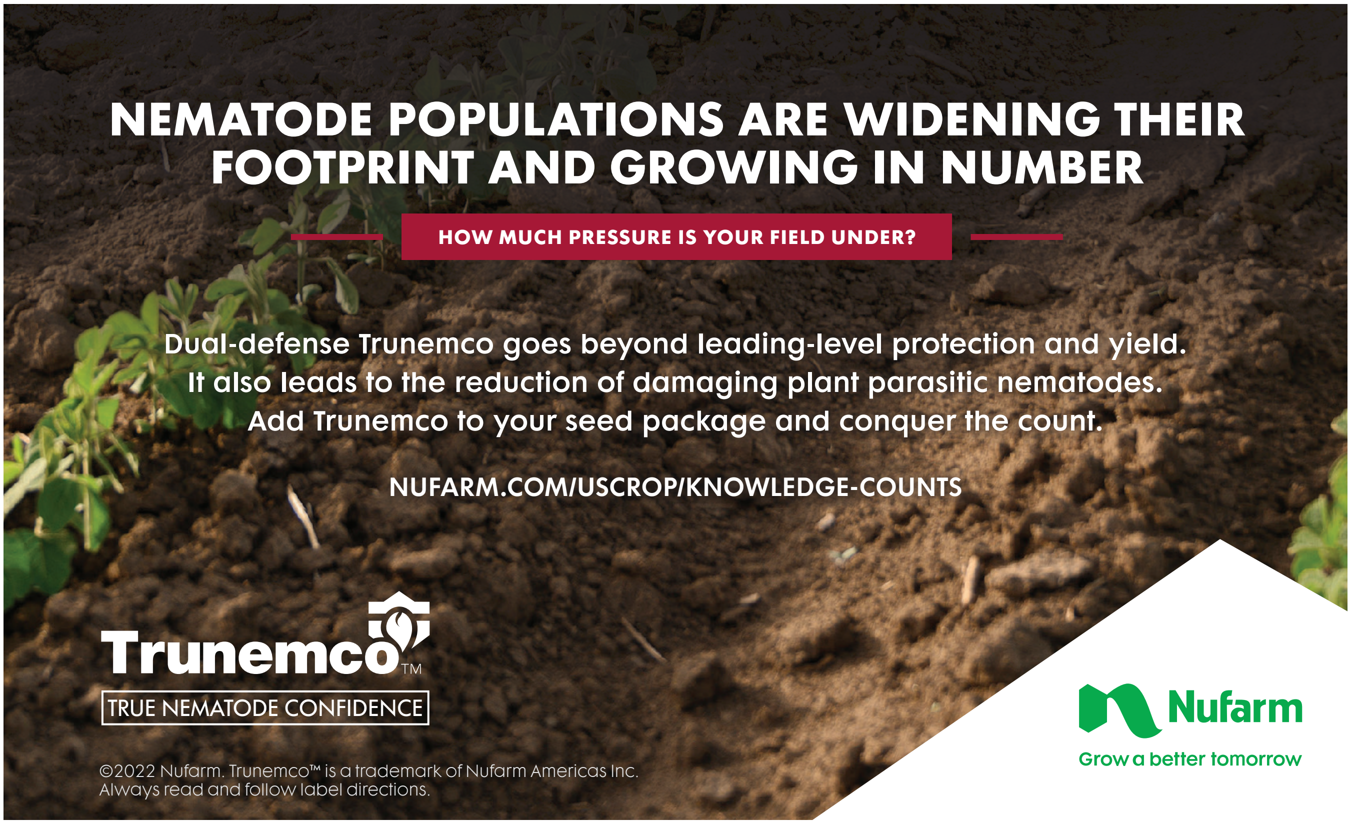
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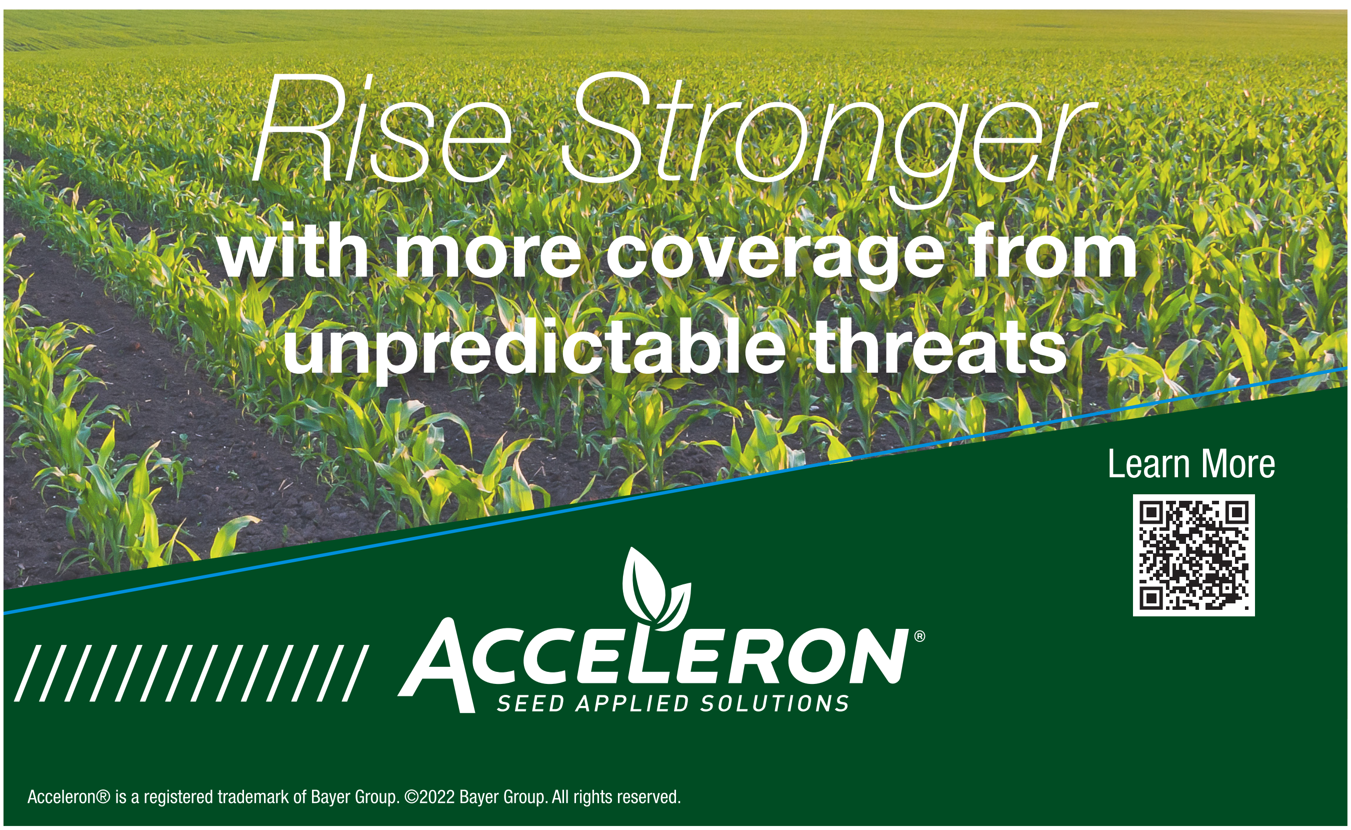
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NATIONAL SOYBEAN NEMATODE STRATEGIC PLAN 2018-2022

What's your number?
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The United Soybean Board (USB) and the North Central Soybean Research Program (NCSRP) have joined forces on a national research, education and outreach effort on nematodes affecting soybeans. Their **ultimate goal is to maximize farmer profitability and sustainability** in the face of **increasing nematode threats**.

The National Soybean Nematode Strategic Plan was developed by a team of scientists from throughout the soybean-producing regions of the US and Canada to guide current and future nematode research, after a USB/NCSRP review identified gaps, needs and opportunities. The objective is to coordinate and support complementary projects and programs to develop short- and long-range solutions for parasitic nematode control. These encompass the spectrum of basic and applied research and Extension aimed at increasing and applying molecular, genetic, biological and agronomic understanding of the host, pest, environment and cropping systems for durable integrated nematode management. The USB and NCSRP have established **six goals and anticipated benefits for soybean farmers**.

GOAL 1: Develop genomic and genetic tools, resources and data. (Nematode focus)

- Develop high-quality reference genomes and transformation technology to improve genetic research on plant-parasitic nematodes.
  - Allows researchers to identify and characterize nematode genes and find vulnerabilities of nematodes to chemical, biological, genetic and bioengineered control as new management tools for farmers.
- Develop a quick soil test that lets farmers identify and characterize soybean cyst nematode (SCN) field populations as production threats, then work with seed and crop protection suppliers to provide targeted management prescriptions.

GOAL 2: Discover, leverage and enhance native nematode resistance in soybean. (Soybean focus)

- Characterize host genetics and host-nematode interactions to improve the understanding of resistance mechanisms for best management strategies.
- Improve and diversify existing resistance sources that are already available to farmers, including maximizing yield potential and combining or stacking resistance genes.
- Identify and evaluate new sources of genetic resistance and breed them into high-yielding backgrounds in all maturity groups for targeted management options.
- Develop multi-nematode- (such as root-knot and reniform) resistant germplasm for farmers in the Southern US.

GOAL 3: Engineer resistance using molecular tools to generate or improve nematode resistance in soybean. (Transgenic focus)

- Advance transgenic and gene editing technologies and tools for more efficient and effective engineered resistance.
- Develop new transgenic sources of nematode resistance for farmers.
  - Identify and modify: soybean plant disease-susceptibility genes; parasitism genes in nematodes; and the mechanism in non-host plants that prevents nematode parasitism
- Stack new engineered resistance with native resistance from traditional breeding to provide farmers with novel modes of action.

GOAL 4: Assess the impacts of new management practices on nematode population dynamics. (Management focus)

- Optimize and confirm the effects of various agronomic practices.
  - Rotation with non-host crops
  - Rotation with different sources of resistance
  - Management of other soybean diseases
  - Effects of cover crops
- Identify soil, root and rhizosphere microbes that naturally control nematodes, and develop tools and methods for farmers to use these in nematode management.
- Evaluate products and practices for nematode management.
  - Effectiveness and economics of different production practices, chemical and biological control agents and seed treatments
  - Variety performance trials assessing nematode control, overall plant health and yield

GOAL 5: Conduct nematode surveys for improved diagnostics and economic impact. (Information focus)

- Update national surveys of plant-parasitic nematodes against the major resistance source lines to help farmers plant the most effective sources of resistance for their fields.
- Standardize sampling and processing of soil samples for more accurate results for farmers.
- Provide farmers with population type data and variety recommendations quickly.
- Improve modeling tools and risk management platforms for estimates of potential soybean yield losses and economic impact of using various nematode management practices.

GOAL 6: Foster Extension education and outreach. (Audience focus)

- Increase awareness and a sense of urgency among farmers for nematode threats and management recommendations in the short and long term.
- Customize nematode management recommendations for farmers and advisors in different geographic regions.
  - Newly emerging SCN regions (Dakotas, Northeast US and Canada)
  - Established SCN regions (North Central states and Ontario)
  - Mixed nematode regions (Southern US)
- Develop farmer-friendly classification language for genetically diverse nematode populations to improve management recommendations.
- Standardize germplasm and variety labeling for farmers and advisors.
- Streamline test plots for farmers to assess lines and seed treatments.

The comprehensive version of the Strategic Plan is on page 60.

For further information and progress updates on the USB/NCSRP National Soybean Nematode Strategic Plan, visit **www.soybeanresearchinfo.com** or **www.soybeanresearchdata.com**.

IGNITING MORE SOYBEAN GROWERS TO ACTIVELY MANAGE SCN

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Brewing in the soil was a rising population of soybean cyst nematodes (SCN) stealing soybean yields, and many growers didn't realize it. They were planting SCN resistant varieties, but the nematodes in their fields were becoming resistant to the source of resistance known as PI 88788.

THE IMPACT of a public-private partnership.

The SCN Coalition was formed to raise awareness of the SCN resistance problem, its impact on yield and to move more growers to actively managing SCN – the No. 1 yield-grabbing pathogen of the soybean crop in North America.

The Coalition has grown to include university scientists from 28 states and Ontario, Canada, soybean grower checkoff organizations including the North Central Soybean Research Program, the United Soybean Board and several state soybean promotion boards, and corporate partners including BASF, Bayer, Growmark, Nufarm, Pioneer (Corteva), Syngenta, Valent and Winfield United.

Financial and in-kind support from these partners helps deliver information to soybean growers and advisors on how they can best actively manage SCN on their farms.

MEASURING soybean grower knowledge.

A 2015 quantitative study of nearly 1,100 soybean growers in 17 states revealed they aren't fully aware of the impact the weakening of SCN resistance can have on yield or that new management tools like nematode-protectant seed treatments and soybean varieties with different sources of resistance such as Peking were available.

5.1 BU. PER ACRE YIELD LOSS — GROWER PERCEPTION

14 BU. PER ACRE YIELD LOSS — RESEARCH BASED

GROWER PERCEPTION OF SCN YIELD LOSS VS. REALITY

On average, growers believe SCN reduces soybean yield by 5.1 bu. per acre. Data from 15 years of variety trial experiments in growers' fields in Iowa revealed that increased reproduction of SCN populations on PI 88788 resistant varieties can decrease yield by as much as 14 bu. per acre,[1] which represents a 23% yield loss.

THE COALITION unifies partners.

Prior to launching the Coalition at the 2018 Commodity Classic, partners were equipped with an online resource center, social media campaign and a comprehensive digital tool kit that made SCN resistance, testing and management relevant to farmers and the advisors who serve them.

MEDIA OUTREACH multiplies the message.

Regular press releases and media interviews keep active management messaging in front of the audience. Since its launch, the Coalition has established a 15.24% share of discussion through its traditional media outreach to result in **21.4 million potential impressions** among North America's soybean growers and agronomists. The Coalition won the 2019 Best of Show National Agri-Marketing Association (NAMA) award in Public Relations for its media relations campaign.

Visit ***TheSCNcoalition.com*** for more information.

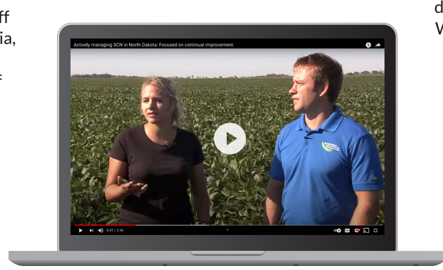
LET'S TALK TODES

VIDEO SERIES highlights active management.

The "Let's Talk Todes" video series was launched the fall of 2020 featuring scientists talking about best management practices. During a six-week period during harvest, these videos generated more than 1.7 million impressions and 900,000 video views.

Videos featuring growers, checkoff leaders and scientists from Georgia, Iowa, Missouri and North Dakota highlighted active management of SCN, while videos in Arkansas expanded the active management message to additional soybean nematode pests more common in southern states.

A collection has also been added that explains the importance of checkoff-funded research.



LOCAL EXTENSION EDUCATION efforts expand.

Coalition experts across the U.S. and Ontario, Canada, have ramped up educational efforts to soybean growers about the importance of active SCN management. Efforts include sampling programs, Extension publications, field days and virtual meetings, directly reaching more than 10,000 soybean growers per year. Working together reduces duplication and improves efficiencies.

GROWER ACTIVATION on SCN management strategies improves.

The Coalition repeated the quantitative study in 2020 with nearly 1,000 soybean growers in 17 states. Coalition messaging about active management resonated with growers.

	2015	2020
GROWERS ROTATING SOURCES OF GENETIC SCN RESISTANCE	39%	49%
GROWERS IDENTIFYING PEKING AS A SOURCE OF RESISTANCE	15%	25%
GROWERS USING NEMATODE-PROTECTANT SEED TREATMENTS	22%	40%
GROWERS ROTATING NON-HOST CROPS (I.E., CORN, WHEAT)	71%	77%
GROWERS PLANTING SCN-RESISTANT SOYBEAN VARIETIES	59%	66%

TRUSTED SOURCE of information.

The 2020 survey revealed growers view their seed dealer, ag media and university/extension expert as one of their top sources for making SCN management decisions.

HEARD IT FROM AG MEDIA	43%
HEARD IT FROM THEIR UNIVERSITY/EXTENSION EXPERT	38%
HEARD IT FROM THEIR SEED DEALER	37%

LEARNING something new.

We asked some new questions in the 2020 survey that were not asked in 2015 and learned a majority of growers agreed that checkoff-funded research was important to bringing new tools to better manage SCN. Most recalled Coalition-specific messages:

RECALLED "ROTATION TO NON-HOST CROP"	76%
RECALLED "ROTATE RESISTANT VARIETIES"	65%
RECALLED "CONSIDER A NEMATODE-PROTECTANT SEED TREATMENT"	66%
RECALLED "ACTIVELY MANAGE SCN"	55%

ACTIVE MANAGEMENT ignites yield and growers' bottom line.

The projected economic impact of The SCN Coalition is staggering. Depending on the tool(s) growers use, 6% to 18% more are actively managing SCN than in 2015. Surveyed growers report capturing an additional 5.1 bu. per acre, adding $48.45 per acre to their bottom line based on an average price of soybeans of $9.50 during that time. But research demonstrates[1] that depending on the level of SCN reproduction occurring on resistant soybean varieties in growers' fields, up to 23% more yield may have been recouped by actively managing SCN.

THAT'S TENS OF THOUSANDS OF GROWERS, MILLIONS OF ACRES AND HUNDREDS OF MILLIONS OF DOLLARS.

1. McCarville, M.C., Marett, C.C., Mullaney, M.P., Gebhart, G.D., and Tylka, G.L. Increase in Soybean Cyst Nematode Virulence and Reproduction on Resistant Soybean Varieties in Iowa From 2001 to 2015 and the Effects on Soybean Yields. *Plant Health Progress.* 2017. 18(3):146-155.

Visit ***TheSCNcoalition.com*** for more information.

WEDNESDAY, DECEMBER 14, 2022

3:00 - 8:00 pm **Registration & Poster Setup**
Foyer and Madison Ballroom, DeSoto

5:00 – 6:00 pm **Navigating the SCN Genome: An SCNBase Workshop**
Sponsored by the North Central Soybean Research Program
Rick Masonbrink, *Genome Informatics Facility, Iowa State University*
Madison Ballroom, DeSoto

6:30 – 9:00 pm **'Toasts of Savannah' Networking Reception – Food, Drinks and Meet Forrest Gump**
Sponsored by Syngenta
Harborview Room, DeSoto

THURSDAY, DECEMBER 15, 2022

5.5 CEU Credits – IPM (3), Crop Mgmt (2), Precision Ag (0.5)

7:00 – 8:00 am **Breakfast Buffet**
Sponsored by Bayer
Madison Ballroom, DeSoto

7:30 - 6:00 pm **Registration**
Foyer, DeSoto

8:00 - 10:00 am 8:00 am **Welcome**
Oglethorpe Ballroom
Melissa Mitchum, *Organizing Committee Chair, University of Georgia*

8:05 am **Introductory Remarks**
Invited Virtual Speaker: Edwin Anderson, *Executive Director, North Central Soybean Research Program & Sr. Director of Research, Iowa Soybean Association*

OPENING PLENARY I
Sponsored by the University of Georgia College of Agricultural and Environmental Sciences
Introduction: George Bird, Michigan State University

8:15 am **Digital Agriculture to Enhance Sustainability of Agricultural Systems**
Bruno Basso, *Michigan State University*

Session I: The Nematode Landscape & Economic Impact – *Sponsored by Cotton Incorporated*
Session Moderator: Kaitlyn Bissonnette, *Cotton Incorporated*

8:45 am **The SCN Coalition: Advancing Nematode Management with a Public-Private Partnership**
Keynote Speaker: Sam Markell, *North Dakota State University*

9:15 am **The Economics of SCN-Resistance and Virulence: Where We Have Been and Where We are Headed**
Invited Virtual Speaker: Mike McCarville, *BASF*

9:30 am **Impact and Management Challenges of the Southern Root-Knot Nematode**
Invited Speaker: Travis Faske, *University of Arkansas*

	9:45 am **Prevalence and Impact of Root Lesion Nematodes in Soybean** Invited Speaker: Ann MacGuidwin, *University of Wisconsin-Madison*
10:00 – 10:15 am	**Break** *Sponsored by FMC and the United Soybean Board* *Foyer*
10:15 – 11:30 am	**Session II: Applications of Nematode Genomics and Genetics** *Sponsored by the North Central Soybean Research Program* *Session Moderator:* Darcy Telenko, *Purdue University* 10:15 am **SCN Genomics, Applications and Future Perspectives** Keynote Speaker: Benjamin Mimee, *Agriculture and Agri-Food Canada* 10:45 am **Recent Advancements in Molecular Detection and Quantification of Soybean Cyst and Root-Lesion Nematodes** Invited Speaker: Guiping Yan, *North Dakota State University* 11:00 am **DNA-based Pathogen Detection in Commercial Row Crops: An Introduction to Pattern Ag's Approach to Risk Prediction** Selected Speaker: Joshua Kling, *Pattern Ag* 11:15 am **Genome Scan for Selection Signatures Reveals Candidate Soybean Cyst Nematode Virulence Genes** Selected Speaker: Kheeman Kwon, Ph.D. student, *University of Georgia*
11:30 am – NOON	**Ag Media-Led Panel Discussion: The Future of Molecular-Based Nematode Diagnostics for Prescriptive Management** *Sponsored by GROWMARK* *Moderator: Willie Vogt, Farm Progress* Panelists: Mike Tweedy, Vice-President of Sales, *Pattern Ag* Nathan Kleczewski, Plant Disease and Entomology Specialist & Technical Agronomist, *GROWMARK* Max Wenck, Wisconsin Farmer and Director of Agriculture, *MorganMyers*
NOON – 1:30 pm	**Lunch & Poster Session/Exhibits** *Madison Ballroom* *Sponsored by Iowa Soybean Research Center, Illinois Soybean Center, Center for Soybean Research at Ohio State University, Missouri Soybean Center, Purdue University Soybean Center*
1:30 – 2:30 pm	**Session III: On the Horizon: New Approaches for Nematode Resistance** *Sponsored by the United Soybean Board* *Session Moderator: Andrew Bent, University of Wisconsin* 1:30 pm **A Transgenic Approach for the Enhancement of Nematode Resistance in Soybeans** *Keynote Speaker: Julia Daum, BASF* 2:00 pm **A New Epigenetic-Based Approach for the Discovery of Major SCN Resistance Genes** Invited Virtual Speaker: Tarek Hewezi, *University of Tennessee* 2:15 pm **Dissecting the Role of a Plant Elicitor Peptide from Soybean Modulating the Plant Response to Pathogenic Nematodes** Selected Speaker: Payal Sanadhya, Post-Doc, *University of Arkansas*

2:30 pm **Discovery of Novel Effector Gene Candidates for Engineering Root-Knot Nematode Resistance in Soybean**
Selected Speaker: Raquel Rocha, Post-Doc, *University of Georgia*

2:45 – 3:00 pm **Break**
Sponsored by FMC and the North Central Soybean Research Program
Foyer

3:00 – 4:15 pm **Session IV: Advances in Soybean Resistance to Nematodes**
Sponsored by the United Soybean Board
Session Moderator: Andrew Scaboo, *University of Missouri*

3:00 pm **Progress in Controlling Soybean Cyst Nematode through Genetic Resistance**
Keynote Speaker: Brian Diers, *University of Illinois*

3:30 pm **Underground Battle: Breeding for Multiple Nematode Resistance in Soybean**
Invited Speaker: Zenglu Li, *University of Georgia*

3:45 pm **Fine Mapping of a Major Novel Quantitative Trait Locus on Chromosome 2 in PI 90763 that Contributes to SCN Resistance**
Selected Speaker: Mariola Usovsky, *University of Missouri*

4:00 pm **Dissection and Manipulation of Soybean *rhg1* SCN Resistance**
Selected Speaker: Andrew Bent, *University of Wisconsin*

4:15 pm **Strategic Rotations of Resistance Genes to Combat Soybean Cyst Nematode Virulence**
Selected Speaker: Monica Pennewitt, Ph.D. student, *Iowa State University*

4:30 – 5:00 pm **Ag Media-Led Panel Discussion: The Future of the Diversity, Certification, Labeling, and Deployment of Genetic Resistance**
Sponsored by the North Dakota Soybean Council
Moderator: Pam Smith, DTN/Progressive Farmer
Panelists: Don Kyle, Breeding Lead, Eastern U.S. Soybean Market, *Corteva*
Geeta Menon, Head of Global Soybean Breeding, *BASF*
John Freeman, Farmer and Chair, *Arkansas Soybean Promotion Board*
Chandra Langseth, *North Dakota Farmer*

5:00 – 6:00 pm **Happy Hour Poster Session with Authors**
Sponsored by Nufarm
Madison Ballroom

7:00 – 10:00 pm **'Tastes of Savannah'** Networking Dinner - Enjoy Southern Delicacies, Cocktails, and Entertainment while Building and Renewing Connections
Sponsored by BASF
OFF-SITE - SoHo South, 12 W Liberty St.

FRIDAY, DECEMBER 16, 2022

3.5 CEU Credits – IPM (2.5), Crop Mgmt (0.5), Precision Ag (0.5)

7:00 – 8:00 am **Breakfast Buffet**

Sponsored by Grain Farmers of Ontario, Iowa Soybean Association, North Dakota Soybean Council, Ohio Soybean Council, Missouri Soybean Association, Minnesota Research and Promotion Council
Madison Ballroom

7:30 - 9:30 am **Registration**
Foyer, DeSoto

8:00 – 9:45 am **Session V: Advances in Nematode Management**
Sponsored by the United Soybean Board
Session Moderator: Carl Bradley, *University of Kentucky*

8:00 am **Challenges in Advancing Soybean Nematode Management: Opportunities to Grow**
Keynote Speaker: Greg Tylka, *Iowa State University*

8:30 am **Nematode Parasitic Fungi for Biological Control of Soybean Cyst Nematode**
Invited Speaker: Kathryn Bushley, *USDA-ARS*

8:45 am **A Multidisciplinary Approach to Manage the Simultaneous Threat of Soybean Cyst Nematode and other Pathogens in the Field**
Invited Speaker: Horacio Lopez-Nicora, *Ohio State University*

9:00 am **Advancing Soybean Nematode, Sudden Death Syndrome, and Other Early Season Disease Protection through Employing the Latest Seed-Applied Technology**
Selected Speaker: Dale Ireland, *Syngenta*

9:15 am **Industry Highlights**
An Introduction to Zironar Biofungicide/Bionematicide, Matthew Pye, *FMC*
TRUNEMCO™ Nematode Management in Soybeans, Jeff Kaiser, *Nufarm*
Aveo®: Valent's Biological Answer to Nematodes, Will Griffin, *Valent*

9:45 – 10:15 am **Break**
Sponsored by Valent
Foyer

10:15 – 11:15 am **Ag Media-Led Panel Discussion - Envisioning the Next 10 Years of Soybean Nematode Management: Challenges & Opportunities**
Sponsored by Michigan Soybean Promotion Committee and The United Soybean Board
Moderator: Julianne Johnston, Senior Counselor, MorganMyers
Panelists: Mac Marshall, Vice President, Market Intelligence, *United Soybean Board*
Will Holmes, Global Seedcare Product Manager, *Syngenta*
Mike Langseth, Farmer and Past Secretary, *North Dakota Soybean Council*
Alan Moore, Farmer and Past Member, *Michigan Soybean Promotion Committee*

11:15- 11:30 am **Q&A with Audience**

CLOSING PLENARY II
Sponsored by the University of Georgia College of Agricultural and Environmental Sciences
Introduction: Melissa Mitchum, *University of Georgia*

11:30 am - Noon **Digital Tools for Prescriptive Agriculture**
Tom Eickhoff, Chief Science Officer, *Climate LLC and Digital Farming at Bayer Crop Science*

Noon **Closing Remarks and Adjourn**

HONORARY SPEAKER

Edwin J. Anderson

Sr. Director of Research – Iowa Soybean Association (ISA)
Executive Director – North Central Soybean Research Program (NCSRP)

Ed Anderson is an Iowa farm kid who earned his B.S. in Agricultural Biochemistry from Iowa State University and his PhD in Molecular Plant Virology / Plant Pathology at the University of Missouri. After a postdoc at the University of Florida, he was an Assistant Professor at the University of Arkansas prior to joining Pioneer Hi-Bred Intl. He also worked for Monsanto Company for a short time earlier in his career.

In his roles with ISA and NCSRP, Ed has opportunities to work with many talented farmers, staff, and researchers across the commodity, public and private sectors. His passion for farming, basic and applied research, and the soybean industry drives him to pursue collaborative activities with the best and brightest for advancing farming, science, and technology.

Distinguished Service

awarded to

Edwin Anderson, Ph.D.

In grateful recognition and sincere appreciation of his dedicated support of soybean-checkoff-funded SCN research and his commitment to sustained success of The SCN Coalition.

presented on

December 15, 2022

at the

National Soybean Nematode Conference

PLENARY SPEAKER (OPENING)

Bruno Basso

John A. Hannah Distinguished Professor of
Earth and Environmental Sciences
Michigan State University

Bruno Basso is an agronomist and crop systems modeler. His research deals with the long-term sustainability, Digital Agriculture, Circular Bioeconomy, and resilience of agricultural systems. He focuses on assessing and modeling spatial and temporal variability of crop yield, soil organic carbon, GHG emission, water, and nutrients fluxes across agricultural landscapes under current and future climates. He holds global patents on AI, remote sensing, and crop model systems to evaluate land productivity and environmental sustainability.

He is the cofounder and chief scientist of CIBO Technologies, a start-up operating in the space of regenerative agriculture. He is a Fellow of the American Association for the Advancement of Science (AAAS); Soil Science Society of America (SSSA); American Society of Agronomy (ASA).

Bruno received his Ph.D. from Michigan State University.

"Digital Agriculture to Enhance Sustainability of Agricultural Systems"

Crop production systems in the United States need to be transformed into more circular and sustainable systems to address the simultaneous challenges of resource depletion, environmental degradation, and increasing demand for food under the threat of climate change. New "big data" and sensor technology research has shown potential for more effective assessment of spatial and temporal variability of soil properties and crop growth. These scientific and technological advances suggest a number of alternative pathways to more sustainable agricultural systems, including improved spatial and temporal management of existing cropping systems, as well as system changes that involve new crops and alternative land uses. The talk presents a novel approach to enhance sustainability of agricultural systems using an integrated approach based on big-data analytics through remote sensing and crop modeling. The widespread adoption of these systems by the large-scale commercial farms that produce most of the row crops in the U.S. will depend critically on their profitability relative to the current linear system.

KEYNOTE SPEAKER

Sam Markell

Professor and Extension Plant Pathologist
North Dakota State University, Fargo, ND, USA

The focus of Sam's research and Extension program is to develop and deliver disease management tools and information to soybean, sunflower, canola, flax, dry edible bean and pulse crop growers. His program emphasizes the mentorship of graduate students and young professionals who will help meet the needs of tomorrows agriculture. Since 2015, Sam has co-led the SCN Coalition, a public-private partnership awareness campaign whose objective is to reduce economic loss suffered to soybean cyst nematode.

"The SCN Coalition: Advancing Nematode Management with a Public-Private Partnership"

The combination of evolving and expanding *Heterodera glycines* populations with low awareness and active management among growers have resulted in soybean cyst nematode (SCN) remaining the greatest yield-limiting biological factor in North American soybean production. In response, a public-private partnership of Universities, agro-chemical companies and grower organizations named "The SCN Coalition" was built with a spirit of shared resources, shared successes and the shared goal of limiting losses to SCN. Since its launch in 2018, The SCN Coalition has generated over 30 million potential impressions through agricultural media, garnered over 2M views of videos produced in the 'Let's Talk Todes' series, and its committed partners continue to multiply messaging to growers through numerous mediums. The impact of the SCN Coalition was measured by conducting national surveys of growers in 2015 and 2020. In 2020, over 50% of growers recalled all primary coalition messages, and reported agricultural media, university/Extension experts and seed dealers as their top sources of SCN information. Between 2015 and 2020, 6% to 18% more growers reported utilizing a management tool(s) for SCN. Using conservative estimates, the increases in active management are resulting in economic gains of >$100M annually for U.S. soybean growers. The SCN Coalition may serve as an example of how a public-private partnership that shares resources, successes and a vision can facilitate a change in modern agriculture that has a remarkable financial impact on growers.

INVITED VIRTUAL SPEAKER

Michael McCarville

Trait Development Manager, BASF, Omaha, NE, USA

Michael McCarville is a nematologist who researches the management of plant-parasitic nematodes in soybean cropping systems. He focuses on their economic consequences for farmers and options for sustainable management. This includes assessing plant resistance traits; their efficacy, durability, and value to the production system.

Michael is a trait development manager at BASF responsible for nematode resistance. He received his Ph.D. from Iowa State University.

"The Economics of SCN-Resistance and Virulence: Where We Have Been and Where We are Headed"

Soybean cyst nematode (SCN) is widely cited as the most economically damaging pathogen of soybean in the United States. Yield losses to SCN are commonly cited at between $1 to $1.5 billion USD per year. These losses occur despite farmers growing SCN-resistant varieties on >95% of acres across the major Midwest soybean producing region. Yield losses on SCN-resistant varieties can occur either under high SCN pressure and/or when SCN populations have adapted to overcome native SCN-resistance genes. The SCN resistance source PI 88788 has been used extensively to manage SCN over a vast area for >20 years. Today it is far more common to encounter populations with elevated levels of reproduction on PI 88788, then it is to find non-adapted SCN populations. Adaptation to PI 88788 is also not a static trait for an SCN population. Populations of SCN continue to increase in their ability to reproduce on PI 88788 each year. In this talk we will cover (1) historical estimates of yield loss to SCN, (2) estimates of yield loss to SCN today, and (3) estimates of the trajectory at which yield loss to SCN will increase over the next decade. Building a robust and durable management strategy requires an appreciation for the potential size and scope of our SCN challenge in the future.

INVITED SPEAKER

Travis Faske

Professor and Extension Plant Pathologist
University of Arkansas System, Division of Agriculture, Lonoke, AR, USA

Travis' applied research and Extension program aims to develop and extend disease management solutions against fungal diseases and plant-parasitic nematodes in a variety of row crops: corn, cotton, soybean, and peanut. In nematology, his program annually evaluates early maturity, soybean cultivars that are marketed as resistant and advanced genotypes against the southern root-knot nematodes in the field. Additionally, his program evaluates the biological response of plant-parasitic nematodes to nematicides and the impact of seed- and soil-applied nematicides in corn, cotton, and soybean.

"Impact and Management Challenges of the Southern Root-Knot Nematode"

Several species of root-knot nematode (*Meloidogyne* spp.) can infect and reproduce on soybean in the U.S. The southern root-knot nematode, *M. incognita* (Kofoid and White), Chitwood, is the most widespread species and therefore causes the greatest total damage to U.S. soybean production. Root-knot nematodes are recently recognized as one of the top three most yield-limiting soybean diseases across the southern U.S. Because *M. incognita* has a wide host range including most rotational crops: corn, cotton, and grain sorghum, nematode densities are often sustained or increased for the subsequent soybean crop. Currently, seed-applied nematicides provide limited nematode suppression and yield protection on susceptible or partially resistant cultivars. While *M. incognita*-resistant cultivars are available in later maturity groups (MG V to VII), resistance is limited, partially resistant at best in early MG (III to IV) soybean cultivars. Early MG have been popular in the southern U.S., especially the mid-southern states; however, these partially resistant cultivars are often underutilized due commercial availability and tolerance to post-emergence herbicides. The development and deployment of improved southern root-knot nematode management tools are vital to mitigate grain yield loses for current and future soybean producers across the southern U.S.

INVITED SPEAKER

Ann MacGuidwin

Professor of Plant Pathology
University of Wisconsin, Madison, WI, USA

Ann MacGuidwin has studied the biology, ecology, and management of root lesion nematodes for nearly four decades. Her research ranges from focused experiments under controlled conditions to studies of native populations in the field. The broad host range of root lesion nematodes has provided an opportunity for Ann to work with many crops and commodity groups. She also studies the soybean cyst nematode and participates in a nematode testing program that has served Wisconsin soybean producers for 25 years.

"Prevalence and Impact of Root Lesion Nematodes in Soybean"

Root lesion nematode is a common name shared by over 100 species in the genus *Pratylenchus*. *Pratylenchus* spp. occur on every continent except Antarctica and impact soybean everywhere it is grown. At least eight species damage soybean in the U.S., as well as crops rotated with soybean. They are highly successful parasites with an incredible versatility for diet, mode of parasitism, and tolerance of environmental conditions. Surveys show they are the first or second most prevalent nematode pest of corn and among the top three nematode pests of soybean. Speciation of *Pratylenchus* is rarely practiced for field samples, so the impact of most species is known only from greenhouse studies. The exceptions to this are *P. penetrans* and *P. brachyurus* with wide distributions in temperate and subtropical climates, respectively. Field studies using endemic populations showed a yield impact that was corroborated by greenhouse experiments. In Wisconsin, we reported a 4.5% decline in yield for an initial population density of 155 *P. penetrans* per 100 cm^3 soil. Stress imposed by *P. penetrans* was demonstrated at V2 and continued through harvest, with reductions in pod number, seed number, and seed weight related to nematode population densities at planting. The impact of five other *Pratylenchus* species known to occur in Wisconsin has yet to be addressed in field studies. Given that >75% of farms tested positive for root lesion in our soybean nematode testing program, even a modest reduction in yield at the field level translates into a sizable impact for the state.

KEYNOTE SPEAKER

Benjamin Mimee

Nematologist, Agriculture and Agri-Food Canada,
Saint-Jean-sur-Richelieu, QC, CANADA

Benjamin Mimee is a research scientist in Nematology at Agriculture and Agri-Food Canada. His research focuses on the development of integrated pest management systems for plant-parasitic nematodes and a better understanding of plant-nematode interactions. He is particularly interested in elucidating the mechanisms of virulence in resistance-breaking populations of cyst nematodes and developing genomics-based tools for their control.

"SCN Genomics, Applications and Future Perspectives"

B. Mimee (1), D. Ste-Croix (2), (1) Agriculture and Agri-Food Canada, Saint-Jean-sur-Richelieu, QC, CANADA; (2) Agriculture and Agri-Food Canada, Saint-Jean-sur-Richelieu, CANADA

Plant-parasitic nematodes are major threats to crop productivity with considerable economic impact. Having co-evolved alongside plants, they have developed highly efficient mechanisms to evade natural plant immunity and deployed resistance genes. Fortunately, recent advances in omics have greatly contributed to our understanding of these mechanisms. The publication of reference genomes has revealed a lot about the acquisition of pathogenicity genes, species evolution, and gene organization. Combined with functional analyzes and gland sequencing, the repertoire of parasitism genes (effectors) has greatly expanded and new control methods, such as RNA interference, are currently being tested. Plant-nematode interactome predictions have also revealed new susceptibility genes that are being investigated using gene editing. New tools such as single-nematode sequencing and long-read technologies have started to reveal the complexity of mechanisms used to overcome plant resistance and the plasticity of genomes. Alternative splicing, copy number variations, and other epigenetic mechanisms were observed among populations and may be linked to virulence. The discovery of new regulatory elements, such as conserved promoter motifs and miRNAs, are also promising with potential implications for nematode control. Together, these advances open the door to a new generation of molecular diagnostic tools and the deployment of new types of resistance. Precise management through the prescription of custom solutions will increase yields and reduce the selection and dispersal of virulence alleles.

INVITED SPEAKER

Guiping Yan

Associate Professor, Department of Plant Pathology
North Dakota State University, Fargo, ND, USA

Guiping's research focuses on detection, biology and management of soybean cyst nematode and other plant-parasitic nematodes that negatively affect production of field crops such as soybean, potato, corn, dry bean, field pea, wheat, and sugarbeet. Her intensive field surveys led to the first discovery of ten new species occurring in North Dakota and Minnesota, including two new root-lesion nematode species impacting soybeans. Her team develops molecular assays for identifying nematode species to improve detection efficiency and capacity, which is important for management of nematode diseases. She teaches a graduate course on Plant Nematology and has supervised nine M.S. and Ph.D. students as the major supervisor.

"Recent Advancements in Molecular Detection and Quantification of Soybean Cyst and Root-lesion Nematodes"

Soybean cyst nematode (SCN; *Heterodera glycines*) and root-lesion nematodes (*Pratylenchus* spp.) are important pests on soybean (*Glycine max* (L.) Merr.). Morphological discrimination between species of *Pratylenchus* and between SCN and other nematodes of the *H. schachtii sensu stricto* group is not only difficult and time-consuming, but also requires expertise in nematode taxonomy. Recent advances in molecular techniques have presented a viable alternative to the traditional diagnostic methods. With the aid of DNA sequencing, two new root-lesion nematode species that had never been reported in the literature were recently detected in soybean fields of North Dakota. One of the species has been named *Pratylenchus dakotaensis* and the other remains unnamed. Conventional PCR and real-time PCR assays were developed to facilitate species-specific identification of *P. dakotaensis*. A recombinase polymerase amplification assay is being developed for rapid detection of this species from infested fields. Molecular assays based on a nematode-secreted CLAVATA gene were also developed to differentiate SCN from morphologically similar sugar beet cyst nematode and other nematodes, and to quantify SCN directly from DNA extracts of field soils. These assays improve efficiency and capacity to detect these species and require no expertise in nematode taxonomy and morphology, and may serve as useful diagnostic tools in research, diagnostic labs, and extension services for recommending effective management measures against these nematodes.

KEYNOTE SPEAKER

Julia Daum

Nematologist and Senior Program Leader in Trait Research,
BASF, Morrisville, NC, USA

A key focus area for BASF Trait Research is to discover and evaluate novel traits for their potential to protect crops and improve yield. In her role as the Program Leader for Nematode Control, Julia led the BASF research team that identified a novel Cry14 protein with efficacy against nematodes. The team then confirmed that the Cry14 trait provides excellent control of Soybean Cyst Nematode (SCN) in soybean field studies and is currently developing the trait into the first GM solution for nematode control.

"A Transgenic Approach for the Enhancement of Nematode Resistance in Soybeans"

Soybean cyst nematode (SCN) is a leading cause of soybean damage and yield loss in North America, resulting in an estimated $1.5 billion in economic loss to growers each year. The need for new solutions for controlling SCN is becoming increasingly urgent due to the slow decline in effectiveness of the widely used native soybean resistance source PI88788. We recently reported that a *Bacillus thuringiensis* delta-endotoxin, Cry14Ab, controls SCN in transgenic soybean. This 130 kDa Cry toxin was discovered using an *in vitro C. elegans* 96-well bioassay and has an approximate EC_{50} of 7 ug/ml, which is similar to that of other *C. elegans*-active Cry toxins. The toxin damages the intestine, and fluorescently labeled Cry14Ab binds to the intestinal lining, suggesting the mechanism of action is similar to that of insect-active Cry proteins. Soybean plants expressing Cry14Ab and challenged with SCN show a significant reduction in the number of SCN cysts per plant compared to control plants in 30-day greenhouse assays. Field trials in SCN-infested soil also show a reduction in the SCN egg population density and an increase in soybean yield compared with control plants. These results demonstrate that the Cry14Ab protein has excellent potential to control SCN in commercial soybean. This new nematode resistance trait technology will provide a new tool to help growers protect their soybean crop and manage SCN populations.

INVITED VIRTUAL SPEAKER

Tarek Hewezi

Professor of Plant Molecular Biology, Department of Plant Sciences
University of Tennessee, Knoxville, TN, USA

Tarek's research focuses on deciphering the mechanisms of action of cyst and root-knot nematode effectors and their impacts on plant growth and development. His laboratory is also interested in understanding the epigenetic regulation of plant response to parasitic nematodes in soybean, Arabidopsis, and tomato by combining molecular biology with cell biology, biochemistry, genetic and genomic approaches.

"A New Epigenetic-Based Approach for the Discovery of Major SCN Resistance Genes"

DNA methylation is an inducible and stably inherited epigenetic mark that impacts various development traits and plant-pathogen interactions. Here, we describe a new epigenetic-based approach to identify major genes controlling soybean resistance against soybean cyst nematode (SCN, *Heterodera glycines*). DNA methylation patterns of a pair of SCN-resistant and -susceptible isogenic soybean lines and their parental lines were profiled at a single nucleotide resolution. Stable trans-generational inheritance of specific DNA methylation patterns unique to the resistant or susceptible isogenic lines were identified. Additionally, novel nonparental DNA methylation variants specific to the isogenic lines were discovered. These DNA methylation variants were detected in the promoter and gene-body regions of 212 protein-coding genes. Overexpression of a set of these genes using transgenic hairy root system supported their function as major SCN resistance genes. The key functions of these genes in controlling soybean resistance to SCN were further confirmed using stable transgenics. Homozygous T3/T4 lines overexpressing two of these genes in the highly SCN-susceptible cultivar "Williams 82" showed extreme resistance against various SCN Hg Types (races).

KEYNOTE SPEAKER

Brian Diers

Charles Adlai Ewing Endowed Chair of Soybean Genetics and Breeding in the Department of Crop Sciences at the University of Illinois Urbana-Champaign, Urbana, IL, USA

In his role as Professor, Brian currently teaches plant breeding and conducts research on soybean breeding and genetics. His research focuses on improving disease and pest resistance, seed quality, and yield potential of soybean. His breeding program is developing nonGMO varieties for commodity and specialty markets with an emphasis on developing varieties with high oleic acid and low linolenic acid oil. He is a fellow of the Crop Science Society of America, the American Society of Agronomy, and the American Association for the Advancement of Science.

"Progress in Controlling Soybean Cyst Nematode through Genetic Resistance"

Soybean cyst nematode (SCN) is estimated to cause the greatest yield loss of any soybean disease or pest in the USA. The utilization of SCN resistance in soybean varieties has reduced these losses and has been critical for profitable production of soybean in the presence of SCN. Most SCN resistant varieties in the Midwestern USA have their resistance originating from the SCN resistance source PI 88788. Resistance from this source has been widely used because it has provided good control of SCN, reduced yield losses, and has been successfully deployed into high yielding cultivars. However, overuse of this resistance has resulted in nematode populations evolving so they can overcome PI 88788 resistance and most nematode populations in fields can partially overcome this resistance. To counter this, breeders are developing varieties with additional sources of resistance such as PI 437654 (Hartwig) and Peking. Genetic research has shown that many resistance sources have genes in common and the most important gene conferring resistance is *Rhg1*. PI 88788 and Peking have unique forms of this gene that allow these sources to control different populations of SCN. For long term control of SCN, there is a need to develop varieties with novel resistance and we have found that combinations of resistance genes from different sources provide strong resistance. Additionally, there is a need to have varieties with different combinations of resistance genes that can be used in rotations to further slow the progress of the SCN overcoming resistance in cultivars.

INVITED SPEAKER

Zenglu Li

Professor, Georgia Seed Development Professorship in Soybean Breeding and Genetics in the Department of Crop and Soil Sciences at the University of Georgia

Zenglu Li earned his Ph.D. degree in Plant Breeding and Genetics from University of Illinois at Urbana-Champaign and obtained his postdoctoral training from the University of Georgia. He worked as a Research Scientist in molecular breeding at DuPont Pioneer for six years and then as a Corn Genotyping Lead and Soybean Discovery Breeding Lead at Monsanto from 2006 to 2012. During his time at Monsanto, Li was the recipient of two Above & Beyond Awards and one Research Innovation Award. Li joined the University of Georgia faculty in 2012. His research focuses on the development of improved soybean cultivars by integrating classical breeding with genomic technology, trait/QTL/gene discovery, and molecular breeding. He has published over 80 peer-reviewed papers and received the D.W. Brooks Award for Excellence in Research from the University of Georgia in 2021.

"Underground Battle: Breeding for Multiple Nematode Resistance in Soybean"

Z. Li, M. G. Mitchum, University of Georgia, Athens, GA, USA

Root-knot nematodes (RKNs) including *Meloidogyne incognita*, *M. arenaria*, and *M. javanica* are a significant threat to soybean production, particularly in the sandy or sandy loam soils of the Southern USA, while soybean cyst nematode (SCN) is the most yield-limiting pathogen of soybean in the U.S. Although cultural practices in soybean production fields can help reduce some of the yield loss from nematode damage, these soil-borne pathogens can survive in the soil for many years. Development and use of nematode resistant cultivars is the most economical and effective means to control nematode damage in soybean production. A combination of resistance to both RKN and SCN is one of most important traits for new commercial varieties in the Southern USA. One major and one minor QTL associated with resistance to *M. incognita* were identified on chromosomes 10 and 18, respectively, and robust SNP markers have been developed. Following the discoveries of the *Rhg1* and *Rhg4* genes for SCN resistance, SNP marker assays significantly associated with these genes have been developed. Based on these discoveries, marker-assisted selection in early generations coupled with greenhouse screening in advanced generations has been implemented in the soybean breeding workflow to more efficiently select for nematode resistance. A series of soybean cultivars with multiple nematode resistance have been successfully developed and commercialized. With new QTL discovered for SCN resistance, a new breeding strategy for nematode resistance through molecular breeding has been established and will be discussed.

KEYNOTE SPEAKER

Greg Tylka

Morrill Professor, Department of Plant Pathology and Microbiology
Iowa State University, Ames, IA, USA

Greg Tylka earned B.S. and M.S. degrees in biology from California University of Pennsylvania and a Ph.D. degree in plant pathology from the University of Georgia. Tylka joined the Iowa State University faculty in February 1990. He currently holds the title of Morrill Professor at Iowa State and has research and extension responsibilities that focus almost exclusively on the biology and management of the soybean cyst nematode. He also is the founding director of the Iowa Soybean Research Center.

"Challenges in Advancing Soybean Nematode Management: Opportunities to Grow"

Plant-parasitic nematodes significantly reduce soybean yields annually. Farmers can lose hundreds of dollars per acre when nematode population densities are high and management strategies are ineffective. Among the nematodes most damaging to soybeans are the soybean cyst nematode, the root-knot nematode, and reniform nematode. Other species, such as root-lesion nematode, also can cause significant yield losses. And some nematodes interact with other pathogens to exacerbate soybean yield losses. Major improvements and innovations in soybean nematode management have been slow to materialize because of numerous and varied impediments. Challenges include, but are not limited to, lack of recognition of nematodes as serious soybean pests, the diverse biology of parasitism of nematodes that feed on soybean, lack of complete, detailed scientific understanding of host-parasite relationships, unavailability or ineffectiveness of soybean resistance to the nematodes, variable performance of nematode-protectant seed treatments, and lack of diversity in cropping systems. Overcoming these obstacles requires a range of actions including sustained educational outreach to farmers and crop advisors, a major shift in soybean breeding priorities among seed companies, and increased and sustained funding for basic and applied research. It is highly unlikely that all of the stated challenges will be overcome, especially in the short term. But even small, incremental improvements in management of nematode parasites of soybean represent a valuable opportunity to increase or "grow" farmer income.

INVITED SPEAKER

Kathryn Bushley

Research Molecular Biologist and Curator of ARSEF, USDA-ARS

Kathryn Bushley is a fungal biologist whose research focuses on harnessing fungal pathogens of nematodes and insects for biological control of agricultural pests. As an assistant professor at University of Minnesota, Dr. Bushley's laboratory isolated and screened hundreds of fungi for activity against the SCN and characterized the ecological dynamics of nematode parasitic fungi in response to different crop rotation schemes. Dr. Bushley currently leads the USDA-ARS entomopathogenic fungal collection (ARSEF), which includes over 14,000 fungal parasites of both nematodes and insects. Her research focuses on characterizing the genomic and metabolic diversity of these fungi and developing nematotode parasitic fungi as viable biocontrol agents or sources of biopesticides for control of SCN.

"Nematode Parasitic Fungi for Biological Control of Soybean Cyst Nematode"

D. G. Kim (1), D. Haarith (2), N. Strom (3), C. Salomon (4), K. Bushley (5), (1) Washington University, St. Louis, St. Louis, MO, USA; (2) University of Wisconsin-Madison, Madison, WI, USA; (3) Diversigen, New Brighton, MN, USA; (4) Center for Drug Design, Minneapolis, MN, USA; (5) USDA/ARS, Ithaca, NY, USA

The soybean cyst nematode (*Heterodera glycines*; SCN) is a major pathogen of soybean in the U.S. and globally. Fungi parasitic towards nematodes occupy unique niches in agricultural soils and show potential for use as either living biocontrol agents or as sources of targeted biopesticides for control of SCN. Nematode trapping fungi are best known for the charismatic structures they use to actively capture nematode prey but other types of nematode parasitic fungi, including those attacking nematode eggs (egg parasites) and those parasitizing juvenile worms (endoparasites), have received less attention. Work in my laboratory has sequenced and isolated microbes found within SCN cysts and within soybean roots to better understand the abundance and dynamics of nematode parasitic fungi in agroecosystems in response to different crop rotation regimes. We identified fungi that colonize soybean roots without causing disease (endophytes) which either antagonize SCN or enhance soybean defense responses. Bioassays testing for ability to directly parasitize SCN eggs and/or to inhibit egg hatch has distinguished between isolates that parasitize and kill living nematode juveniles within eggs versus those that secrete bioactive secondary metabolites or enzymes with toxicity towards SCN. Greenhouse testing has identified isolates that also perform well *in-planta* to control reproduction of SCN. As many of these fungi colonize soybean roots as endophytes, they show potential as seed coats or root bio-inoculants when applied alone or in combination with active compounds to protect against SCN.

INVITED SPEAKER

Horacio Lopez-Nicora

Assistant Professor
Department of Plant Pathology, The Ohio State University,
Columbus, OH, USA

Horacio is a plant pathologist, nematologist, and applied statistician committed to improving and better protecting soybean health. His research is driven by the intertwined goals of ensuring food stability and helping growers manage diseases that affect yield. Ultimately, he would like to develop integrated plant health strategies for growers by uncovering novel insights into the interactions, ecophysiology, and population biology of soybean pathogens. He has more than a decade of experience working with soybean cyst nematode and other soilborne pathogens that threaten soybean production.

"A Multidisciplinary Approach to Manage the Simultaneous Threat of Soybean Cyst Nematode and Other Pathogens in the Field"

Both *Heterodera glycines*, the soybean cyst nematode (SCN), and the fungus *Macrophomina phaseolina*, causal agent of soybean charcoal rot, are economically important soybean pathogens. The concomitant effect of these pathogens on soybean in the Midwest production region is not known. We examined the simultaneous effect of these pathogens on soybean in three different studies. The first was a survey to determine the distribution and abundance of both pathogens in agricultural fields across Ohio. Soil samples were collected from soybean fields; SCN and *M. phaseolina* were extracted and quantified from each soil sample. More than 77% of the samples tested positive for the presence of both pathogens. In the second study, fields with different levels of each pathogen were identified during three growing seasons. From each field, soybean yield and abundance of SCN and *M. phaseolina* were obtained and used in a multiple spatial regression analysis. Results revealed a significant interaction effect between SCN and *M. phaseolina* on soybean yield for fields with high initial population densities of both pathogens. Finally, we planted SCN-resistant and -susceptible soybean lines with homogeneous genetic backgrounds in experimental fields infested with both pathogens. Both SCN and *M. phaseolina* reduced soybean yield asymptomatically, and the impact of SCN resistance was dependent on SCN virulence but also population density. The findings of these projects will help improve integrated pest management and make recommendation to growers for a sustainable crop production.

PLENARY SPEAKER (CLOSING)

Tom Eickhoff

Chief Science Officer, Climate LLC and Digital Farming at Bayer Crop Science, St. Louis, MO, USA

As Chief Science Officer, Tom leads the Science organization at Climate LLC and Digital Farming at Bayer Crop Science, where he drives the company's research and development efforts in data science, modeling, sensing, and field research. The capabilities developed within the Science organization enable operational insights backed by the integration of vast amounts of real field data into Climate models.

Most recently, as the Senior Director of Science Implementation at Climate LLC, Tom led the testing and application of Climate Science in our global field operations and with our customers, in order to ensure successful execution of Science research. Tom brings to his role more than 14 years of strategic leadership at Bayer in the development and implementation of research and technology deployment that directly benefits farmers.

Tom holds a BS in Agronomy, and a Masters and Ph.D in Entomology from the University of Nebraska.

Talk Title: "Digital Tools for Prescriptive Agriculture"

Data is ubiquitous in agriculture; from binder-filled shelves to digital platforms, it always has been. The efficient management of data toward a more prescriptive approach to farming has become essential in recent years, as the power to leverage data at scale has led to agronomic modeling that delivers recommendations to farmers on key productivity-impacting factors like seed selection and crop protection management. Into the future, these agronomic modeling approaches will drive relationships between farmers and agtech companies to further optimize the use and performance of these inputs while enabling more precise applications to manage yield robbing pests.

“THE FUTURE OF MOLECULAR-BASED NEMATODE DIAGNOSTICS FOR PRESCRIPTIVE MANAGEMENT”

Thursday, December 15
11:30 a.m. - 12:00 p.m.

Moderator:

Willie Vogt
Farm Progress

Panelists:

Mike Tweedy
Vice-President of Sales
Pattern Ag

Nathan Kleczewski
Plant Disease and Entomology Specialist
& Technical Agronomist
GROWMARK

Max Wenck
Wisconsin Farmer and
Director of Agriculture
MorganMyers

Mike Tweedy was raised on a multi-generational farm in Southern Illinois founded in the late 1700's. He earned his B.S. and M.S. in Agronomy from Southern Illinois University. Over the expanse of his career, he has worked for multi-national ag companies in a variety of executive roles. Starting in 2010, he shifted his career focus to small and large start-ups, most recently in the ag tech sector. Currently, Mike serves as the Vice President Sales at Pattern Ag, and leads the Midwest commercial team. Mike and his family currently reside in the Atlanta Georgia area.

Nathan Kleczewski provides GROWMARK member companies and growers with education, troubleshooting, and outreach materials to address key plant disease and insect related issues throughout the U.S. and Canada. As part of his role, he also evaluates new and emerging technologies for inclusion in member offerings or potential company investment. Dr. Kleczewski has extensive experience with research in applied plant disease management, having served as a Field Crop Plant Pathologist at the University of Illinois from 2017-2021 and an Extension Plant Pathologist at the University of Delaware from 2013-2017.

Max Wenck and his wife Linda operate a cash grain and registered beef cattle operation in southeastern Wisconsin and manage a commercial cow-calf ranching operation in northwestern South Dakota. They are also co-owners of MorganMyers, a strategic communications firm that builds, promotes and protects brands in the agriculture and food industries. As director of agriculture at MorganMyers, Max has helped introduce Roundup Ready Soybeans and Roundup Ready Corn, helped pass the national soybean checkoff referendum creating the United Soybean Board and helped create and launch The SCN Coalition. Max has degrees in animal science and communications from South Dakota State University.

"THE FUTURE OF THE DIVERSITY, CERTIFICATION, LABELING, AND DEPLOYMENT OF GENETIC RESISTANCE"

Thursday, December 15
4:30 - 5:00 p.m.

Moderator:

Pam Smith
DTN/ Progressive Farmer

Panelists:

Don Kyle
Breeding Lead
Eastern U.S. Soybean Market
Corteva

Geeta Menon
Head of Global Soybean Breeding
BASF

John Freeman
Farmer and Chair
Arkansas Soybean Promotion Board

Chandra Langseth
North Dakota Farmer

Don Kyle is a Soybean Breeder and the Breeding lead for the Eastern US Soybean Market. He is located in Princeton, IL. His soybean breeding research has focused on developing improved soybean varieties for maturity groups 2 and 3. He has spent extensive time identifying sources of resistance, improving germplasm, and developing molecular breeding tools for improved agronomic and disease resistance in soybean. He also maintains a close relationship with soybean producers and agronomists to provide improved soybean management practices with modern soybean genetics and crop inputs.

Geeta Menon is the Head of Global Soybean Breeding at BASF. In this role, she leads a multi-functional customer-focused team to development of superior germplasm, and a sustainable commercial product pipeline employing advanced Breeding technologies. Geeta received her PhD in Plant Breeding/Crop Science from North Carolina State University, and has 20 years of experience bringing technology and products to the farmers.

John Freeman has a passion for farming and his personal work ethic that comes from his dad. While in high school, John worked on the farm alongside his dad where he developed a strong appreciation for the hard work it takes to be a farmer. By the time John left home to attend the University of Arkansas, he had already been bitten by the farming bug. After graduating with a degree in ag business in 1989, he returned to the family farm eager to plant his first soybean crop and hasn't missed a season since. Over his years of farming, John has had first hand experience dealing with soybean cyst nematodes (SCN) over the years and more recently, root knot nematodes (RKN) on his 2500 acre family farm.

Chandra Langseth raises soybeans, corn and alfalfa in southeast North Dakota with her husband and in-laws. She is a faculty member in the Agriculture Department at North Dakota State College of Science and previously worked as an extension agent. Chandra holds a Masters in Soil Science from North Dakota State University and is a Certified Crop Advisor.

"ENVISIONING THE NEXT 10 YEARS OF SOYBEAN NEMATODE MANAGEMENT: CHALLENGES AND OPPORTUNITIES"

Friday, December 16
10:15 - 11:15 a.m.

Moderator:

Julianne Johnston
Senior Counselor
MorganMyers

Panelists:

Mac Marshall
Vice President
Market Intelligence
United Soybean Board

Will Holmes
Global Seedcare Product Manager
Syngenta

Mike Langseth
Farmer and Past Secretary
North Dakota Soybean Council

Alan Moore
Farmer and Past Member
Michigan Soybean Promotion Committee

Mac Marshall serves as the Vice President, Market Intelligence for the United Soybean Board (USB). In this capacity, Mac works with USB leadership to evaluate and establish long-term strategic initiatives in support of advancing domestic and international market opportunities for the U.S. soybean industry while serving as an industry source of market information and analysis. Prior to joining USB, Mac served as global market analysis and trade lead at Bayer Crop Science, where he worked on international market access issues as part of a global agricultural policy team. Mac has also held roles in Monsanto's Corporate Strategy group and within the federal government as both a staff and supervisory economist at the U.S. Bureau of Labor Statistics. He holds a B.A. in economics from Vassar College and an M.A. in applied economics from Johns Hopkins University.

Will Holmes is a Global Product Manager with Syngenta Seedcare and is responsible for managing the overall nematicide seed treatment portfolio for Syngenta and to support the messaging around the awareness of the issues caused by plant parasitic nematodes. A graduate of Newcastle University, having studied Agriculture, Will joined British Sugar as a Graduate Trainee. The following 5 years were spent as an Area Manager advising growers on crop management and beet campaign logistics. Since joining Syngenta in 2003, Will has held a range of commercial roles in the UK, culminating as the Head of Sales & Marketing for UK, Ireland and Nordics. In 2021 the move to his current role involved relocating the family to Basel in Switzerland. In addition to his work at Syngenta, he is a non-Executive Director of MDS Ltd., a graduate training programme provider for the fresh produce and food sector.

Mike Langseth raises soybeans, corn and alfalfa in SE North Dakota with his wife Chandra and dad Paul. He is a past Secretary of the North Dakota Soybean Council and past Chairman of Northern Soy Marketing. He is a graduate of the University of Minnesota.

Alan Moore is a proud fifth generation farmer and third generation seedsman, who farms approximately 2000 acres of certified corn, soybean, triticale, and wheeler rye seed in Elsie, Michigan; On the same ground the Moore family homesteaded in 1857. Alan spent his childhood on the farm, in 1973, Alan graduated from Michigan State University, and began his career focusing on expanding Moore Seed Farm through innovative partnerships and practices. Some of these accomplishments include securing a proprietary cereal rye variety which serves both the international and domestic markets, expanding the farms seed production and conditioning capacities, creating innovative partnerships in the sugar industry, and his focus and dedication to serving the soybean community, he has served on soybean boards from local to national for over forty years.

APPLICATION OF NEMATODE GENOMICS AND GENETICS

DNA-based pathogen detection in commercial row crops: an introduction to Pattern Ag's approach to risk prediction

*J. KLING (1), T. Newell (2), (1) Pattern Ag, CA, USA; (2) Pattern Ag, CO, USA

Pattern Ag was founded with the belief that a deeper understanding of the biology of soil was the key to unlocking productivity and efficiency gains in crop production. Pattern Ag's service samples grower fields and returns a sub-field assessment of bacterial and archaeal diversity, their potential for agronomically relevant metabolisms, and the risk of key pathogens present to growers on an easy to use, comprehensive platform that assess the opportunities and threats a field will face next season. While our focus has been in the Midwestern US, in the next year we will have expanded into the southern US and Brazil, providing growers with key insights on pest and pathogen risk and fertility planning. Our Pressure Panel includes the detection of soybean cyst nematode (SCN) using a high-throughput qPCR assay. We have focused on this nematode as it is estimated to have caused more than twice as much yield loss than any other soybean disease. Pattern Ag's methods for detecting SCN DNA in soil has measured SCN abundance on 210,000 acres (and counting) across the Midwestern United States. By providing a low cost test of SCN pressure in their fields, coupled with an evaluation of soilborne pathogens and corn rootworm, our growers have strong insights into their rotation strategy and identify which management interventions to apply the season before economic damage has occurred. We will present how we developed and validated our test as one component of a large-scale program designed to increase per acre profitability for commercial growers.

Genome scan for selection signatures reveals candidate soybean cyst nematode virulence genes

**K. KWON (1), J. Viana (2), K. Walden (3), M. Hudson (2), M. G. Mitchum (1), (1) University of Georgia, Athens, GA, USA; (2) University of Illinois, Urbana, IL, USA; (3) University of Illinois, Carver Biotechnology Center, Urbana, IL, USA

Soybean cyst nematode (SCN), a soybean pest effectively managed through resistant cultivars, is constantly under selection pressure for host resistance adaptation. This natural selection is accelerated by repeated planting of the same resistance sources leading to a widespread problem of virulence. Resistance to SCN HG type 0 (Race 3) in PI 548402 (Peking) and PI 437654 requires an epistatic interaction between *Rhg1* (*rhg1-a*) and *Rhg4*, mediated by an α-SNAP and a serine hydroxymethyltransferase, respectively. It remains unknown which nematode genes are responsible for virulence on this type of resistance. To identify the genomic regions and candidate genes responsible for SCN virulence, we conducted a cost-effective population genomic approach for whole genome-resequencing of pools of individuals (Pool-Seq) for two pairs of avirulent and virulent SCN populations adapted to the *rhg1-a/Rhg4*-mediated resistance independently derived from Peking and PI 437654.

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We calculated the locus-by-locus fixation indices (FST) to assess the population differentiation and signatures of selection. Multiple genomic regions spanning several chromosomes revealed strong signatures of selection. Some candidate regions were detected in both pairs of SCN populations, while others were unique genomic regions under selection in each contrast. Identifying SCN virulence genes will help understand the mechanisms by which the nematode mediates host-pathogen interactions to overcome soybean resistance, and may contribute to the development of molecular markers for rapid virulence screening of a SCN-infested field.

ON THE HORIZON: NEW APPROACHES FOR NEMATODE RESISTANCE

Dissecting the role of GmPEP3, a plant elicitor peptide from soybean in modulating the plant response to pathogenic nematodes

*P. SANADHYA, A. Alnasrawi, F. L. Goggin, University of Arkansas, Fayetteville, AR, USA

Soybean (*Glycine max* (L.) is an important legume crop that provides a sustainable source of protein and oil globally. Plant-parasitic nematodes (PPNs) are major disruptive pests of soybean, and particularly soybean cyst nematode (SCN) is primarily responsible for major yield losses in US, despite the availability of management techniques like crop rotation and SCN-resistant varieties. There is a dire need to explore sustainable strategies to enhance nematode resistance in soybean. Plant elicitor peptides (Peps) are damage-associated molecular patterns (DAMPs) derived from precursor proteins (PROPEPs); Peps activate and amplify the innate immunity of plants against pathogens. We have previously characterized three Peps from soybean (GmPep1, GmPep2, and GmPep3). Exogenous seed application of GmPeps significantly improved resistance to pathogenic nematodes. Prior results showed that overexpression of PROPEP genes in transgenic *Arabidopsis* plants conferred resistance against root knot nematodes (RKN). In this study, we generated transgenic soybean lines constitutively overexpressing GmPROPEP3 in a susceptible soybean cultivar 'Magellan'. T1 Transgenic plants were assayed by quantitative real-time PCR (qRT-PCR) to identify single copy insertion lines. Two independent single-copy homozygous T2 lines are further investigated for their morphology, physiology, and SCN infection rates. This study will help us to explore the potential of Peps to impart the resistance against PPNs in soybean.

Discovery of novel effector gene candidates for engineering root-knot nematode resistance in soybean

*R. ROCHA (1), R. S. Hussey (1), L. Pepi (2), P. Azadi (2), M. G. Mitchum (1), (1) University of Georgia, Athens, GA, USA; (2) Complex Carbohydrate Research Center - University of Georgia, Athens, GA, USA

The root-knot nematode (RKN), *Meloidogyne incognita*, is a major threat to soybean production in the

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Southern United States. RKNs secrete effector proteins produced in a single dorsal gland (DG) and two subventral gland (SvG) cells through a stylet into root tissues. These effector proteins give rise to giant feeding cells that serve as the sole source of nutrition for the nematode to complete its life cycle. Elucidating the effector profiles of the gland cells has been a focus for identifying proteins required for RKN parasitism. Prior gland isolation studies focused on juvenile stages when the SvG glands are more active. Here, we developed a protocol to enrich for DG cells of adult females by manually cutting female heads from the body, sonication/vortexing to dislodge the contents inside the heads, and filtering using cell strainers. Comparative transcriptome profiling of pre-parasitic second-stage juveniles, female heads, and DG was conducted using RNA sequencing, and a glycoproteomic analysis was conducted in parallel on DG samples. An effector mining pipeline identified 83 unique candidates based on the presence of a predicted signal peptide and lack of transmembrane domains or shared homology to proteins in free-living nematodes. Of the 83 candidate effectors, 28 were also identified by glycoproteomics. Taken together, we have identified potential novel effector candidates that may have essential roles during later stages of RKN-soybean interactions, thus providing a promising source of future control targets for the development of RKN-resistant soybean cultivars.

ADVANCES IN SOYBEAN RESISTANCE TO NEMATODES

Fine-mapping of a major novel quantitative trait locus on chromosome 2 in PI 90763 that contributes to SCN resistance

*M. USOVSKY (1), M. Triller (1), C. Meinhardt (1), N. Dietz (1), V. Gamage (2), P. Basnet (1,3), B. Dhital (1), A. Nguyen (1), Q. Song (4), J. Gillman (5), K. Bilyeu (5), M. G. Mitchum (2), A. Scaboo (1), (1) University of Missouri, Columbia, MO, USA; (2) University of Georgia, Athens, GA, USA; (3) University of Wisconsin, Madison, WI, USA; (4) ARS-USDA, Beltsville, MD, USA; (5) ARS-USDA, Columbia, MO, USA

The first identification of genetic resistance to soybean cyst nematode (SCN) in soybean was over 60 years ago, yet a comprehensive understanding of the genetic control of resistance has been elusive. Recently, research with *rhg1-a* (*GmSNAP18*), *rhg2* (*GmSNAP11*), and *Rhg4* (*GmSHMT8*) in PI 90763 revealed epistatic interactions responsible for broad resistance to multiple HG types, however these three genes alone did not explain differences in female index between PI 90763 and Peking to SCN HG type 1.2.5.7 (Race 2). The objectives of this research were to identify unknown QTL in PI 90763 conferring resistance to SCN HG type 1.2.5.7 (Race 2). In a RIL population developed from a bi-parental cross between PI 90763 and Peking, a novel and major QTL on chromosome 2 was identified. A detailed analysis of different gene/allele combinations revealed that the Chr.2 QTL reduces female index scores to three SCN populations in combination with *GmSNAPs* at *rhg1-a* and *rhg2*. The addition of *Rhg4* broadened resistance to HG type 0 (Race 3). This QTL was fine-mapped to a 218 Kbp region containing 34 genes and *GmSNAP02*, a paralogous gene of *GmSNAP18* and *GmSNAP11*, was identified as the best candidate. A comparison of whole genome resequencing reads of *GmSNAP02* between PI 90763

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and Peking revealed a pattern of mismatched read ends in PI 90763, which was absent from Peking, suggesting an insertion in *GmSNAP02* in PI 90763. The presence of this insertion was confirmed by PCR and a developed TaqMan assay. Current work is focused on determining how the insertion contributes to soybean resistance.

Dissection and manipulation of soybean rhg1 SCN *resistance*

A. F. BENT (1), S. HAN (2), Y. Du (1), D. Haarith (1), (1) University of Wisconsin, Madison, WI, USA; (2) Zhejiang University, Hangzhou, CHINA

We previously discovered that *rhg1* exhibits copy number variation of a ~30kb segment that encodes four different genes. One of those *rhg1* genes encodes α-$SNAP_{Rhg1}$, also known as GmSNAP18, which we and others have reported on extensively. However, using gene silencing in transgenic root cultures, we showed that two other *rhg1-b* genes contribute to SCN resistance. One of those genes encodes AAT_{Rhg1}, a putative amino acid transporter. 1) We have found that AAT_{Rhg1} protein abundance increases along the nematode penetration path (whereas α-$SNAP_{Rhg1}$ abundance increases within syncytia). These separate root sites suggest separate modes of action, which may help account for the multi-decade durability of *rhg1-b* (which still contributes partial resistance against most HG 2.5.7 SCN populations). 2) We have used transgenic plants that silence AAT_{Rhg1} expression to show that the *AAT*$_{Rhg1}$ QTL contribution to resistance remains against an HG 2.5.7 SCN population whose female index is over 60 on the parental *rhg1-b* soybean line. In other words, the other *rhg1-b* genes apparently are what this nematode population has overcome. 3) We also report that overexpressing either α-$SNAP_{Rhg1}$HC or α-$SNAP_{Rhg1}$LC in an elite line carrying Peking-type SCN resistance elevates resistance against HG 0 and HG 2.5.7 SCN, but not against an HG 1.3.6.7 population. In large greenhouse studies we detected no impacts on soybean yield or protein/oil composition from the overexpression of α-$SNAP_{Rhg1}$HC or α-$SNAP_{Rhg1}$LC.

Strategic rotations of resistance genes to combat soybean cyst nematode virulence

**M. G. PENNEWITT (1), P. Basnet (2), B. Diers (3), M. G. Mitchum (4), A. Scaboo (2), G. L. Tylka (1), (1) Iowa State University, Ames, IA, USA; (2) University of Missouri, Columbia, MO, USA; (3) University of Illinois Urbana-Champaign, Urbana, IL, USA; (4) University of Georgia, Athens, GA, USA

Resistant varieties are critical for reducing soybean yield loss from the soybean cyst nematode (SCN). Prolonged, widespread use of soybeans with PI 88788 resistance (*rhg1-b*) has resulted in increased virulence of SCN populations on this extremely common source of resistance. Rotating soybean genotypes with different combinations of resistance genes has shown promise in lowering SCN population densities and preventing increases in virulence in greenhouse experiments. The objective of this three-state project was to evaluate how rotations of soybean lines containing various resistance gene combinations affect SCN population densities and the virulence of SCN populations in the field.

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Microplot experiments were established in Illinois, Iowa, and Missouri. Treatments included continuous planting of a susceptible genotype, soybean genotypes derived from a single source of resistance, and novel genotypes containing pyramided resistance alleles. Additional treatments studied were two-year rotations of genotypes containing pyramided alleles with resistance derived from a single source. To date, results have varied among locations, but in general SCN population densities increased in most microplots and year-to-year differences occurred among plots with rotated soybean genotypes. Microplots containing soybeans with pyramided alleles had lower population densities, especially those with soybean genotypes that included greater allele combinations. Virulence increased across most treatments, including microplots that were rotated with pyramided allele resistance types.

ADVANCES IN NEMATODE MANAGEMENT

Advancing soybean nematode, sudden death syndrome and other early season disease protection through employing the latest seed-applied technology

D. IRELAND (1), J. A. Simmons (2), A. C. M. Simon (3), (1) Syngenta Crop Protection, Wildwood, MO, USA; (2) Syngenta Crop Protection, Vero Beach, FL, USA; (3) Syngenta Crop Protection, IL, USA

Soybean Cyst Nematode (SCN) is estimated as the number one pathogen in US soybean. Agricultural economists estimate most years the US soybean grower loses more to SCN than the next five soybean pathogens added together (Koenning & Wrather, 2010). One of the most recent additions to a comprehensive SCN management program is using a seed-applied nematicide (SAN). In combination with all other management tools, a SAN offers additional protection and potentially reduces the heavy reliance on single genetic SCN-resistance sources. Since healthy root development is vital to establishing the most stable yield potential, SANs have been one of the most anticipated and rapidly adopted new seed-applied technologies offered in recent years. Under moderate to heavy SCN pressure TYMIRIUM™ technology (0.075 mga/seed) seed treatment in soybean outperformed fluopyram (FLPM 0.15 mga) by an average of +1.7 bu/A driven by a 71 percent win record (n=72; 2015, 2017-2021). Under the same conditions TYMIRIUM technology (0.075 mga) outperformed ABA (0.15 mga) by an average of +2.0 bu/A with a 79 percent win record (n=85; 2015-2021). Under moderate to heavy Sudden Death Syndrome infection TYMIRIUM technology (0.075 mga) outperformed FLPM (0.15 mga) by an average of +4.8 bu/A leading to a 91 percent win record (n=23; 2018-2021). TYMIRIUM technology also statistically reduces early-season Septoria Brown Spot, Frogeye Leaf Spot and Target Spot when compared to the Check treatment. When registered, TYMIRIUM technology will deliver a new level of soybean protection performance across multiple pathogens.

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NEMATODE SURVEYS

Poster #1

Connecting field history and nematode community structure to soybean cyst nematode distributions across Pennsylvania

**M. S. KIDD (1), A. Murillo-Williams (2), D. K. Weerasooriya (3), A. A. Collins (4), P. Esker (3), (1) The Pennsylvania State University, State College, PA, USA; (2) Penn State University, Bellefonte, PA, USA; (3) The Pennsylvania State University, University Park, PA, USA; (4) Penn State University, Manheim, PA, USA

Soybean cyst nematode (SCN, *Heterodera, glycines*) is the most threatening pathogen to soybean production. Its impacts are increasing as SCNs expand their geographical range due to climate change creating more suitable habitats. Their current distribution is still unknown, and their spatial arrangement is specifically curious in Pennsylvania with only two counties (Lancaster and York) testing positive out of 67 counties. In 2019, we established a free testing program. To date, we have tested hundreds of samples. Several samples tested positive for SCN with up to 125 eggs per 250 cm^3 of soil. For those fields, we coordinated with the Pennsylvania Department of Agriculture to re-sample and re-test positive fields. Participants have also provided a field history record with their soil samples, including agronomic practices, common weeds, and past and current diseases. The distribution and success of SCN (or lack thereof) might depend on one or more of the field history components. Production practices used by Pennsylvania growers, e.g., tillage, are interesting as they might explain why SCNs are not being observed or have limited population numbers in certain areas compared to other states. Furthermore, the samples are also being tested for other nematodes including lesion, stunt, spiral, dagger, pin, stubby root, ring, and root-knot, so that the effects of nematode community structure can be explored. By analyzing these listed factors, we may be able to prevent disease and improve management recommendations for SCN and other plant parasitic nematodes across Pennsylvania.

Poster #2

A survey of soybean cyst nematode densities and phenotypes in Illinois 2018 and 2020.

N. M. KLECZEWSKI (1), A. Colgrove (2), D. Bowman (3), C. J. Harbach (4), D. E. Plewa (2), (1) Growmark Inc, Bloomington, IL, USA; (2) University of Illinois, Urbana, IL, USA; (3) University of Illinois, Champaign, IL, USA; (4) University of Illinois Extension, Monmouth, IL, USA

In 2021, over 672 million bushels of soybeans were produced in Illinois (IL), valued at over 8.8 billion USD. Despite estimates stating that soybean cyst nematode (SCN) causes the largest and most consistent yield losses in the state, no recent information on relative abundances and phenotypes of SCN in IL exists. To address this need, a survey of soybean fields was conducted in 2018 and 2020 in IL. A total of 95 soybean fields representing 46 counties were arbitrarily sampled across both years.

Samples were taken at harvest, with a minimum of 10 soil subsamples collected and pooled for each field. Eggs of SCN were extracted and quantified following standard protocols. Samples having at least 500 eggs per 100cc in 2018 and 200 eggs per 100 cc soil in 2020 were accepted for immediate inclusion in an HG Type Test assessment. SCN eggs were detected in 87% of sampled fields, with population densities ranging from 0-13,168 eggs/100 cc soil. Twenty-one percent of samples contained more than 2000 eggs per 100 cc soil, levels considered to be at high risk for yield loss in IL whereas 24% contained egg counts at moderate yield loss risk (500-1,999 eggs 100 cc soil). All 52 samples included in the Hg type tests had a female index of 10% or greater on PI88788. Conversely, this threshold was exceeded just three times on PI548402 (Peking). If the results are extrapolated, our data indicate that over 4 million soybean acres may be negatively impacted by SCN in IL, and over 6 million acres not adequately controlled by PI88788-derived resistance.

Poster #3

Surveys for plant-parasitic nematodes in Kentucky soybean fields

**K. MEHL, C. A. Bradley, University of Kentucky, Princeton, KY, USA

Soybean cyst nematode (SCN; *Heterodera glycines*) has been present in Kentucky for approximately 60 years and is still estimated to be the most-damaging pathogen of soybean in the state. Despite this, it has been several years since a formal survey has taken place in the state to determine SCN population levels and HG types. In addition, other plant-parasitic nematodes, such as lesion (*Pratylenchus* spp.), reniform (*Rotylenchulus reniformis*), and root knot (*Meloidogyne* spp.), have been reported to affect soybean yields in other states, but no recent surveys have been conducted in Kentucky soybean fields to determine their presence. An ongoing survey was initiated in 2018 for SCN and in 2020 for other plant-parasitic nematodes in Kentucky soybean fields. The SCN survey revealed that, from 360 fields representing 35 counties, SCN was present in 80% of the fields surveyed, with populations ranging from 0 to 18,400 eggs/100 cm^3 soil. So far, HG type results are available from only 8 fields, which revealed HG Types 2.5.7 and 5.7 in 7 and 8 fields, respectively. Results from the 2020 survey for other plant-parasitic nematodes (45 fields representing 16 counties) revealed that dagger (*Xiphinema*), lance (*Hoplolaimus* spp.), lesion, and stunt (*Tylenchorhynchus* spp.) nematodes are present in Kentucky soybean fields. These surveys are ongoing, which will provide opportunities for additional fields to be surveyed.

Poster #4

Monitoring Missouri SCN populations

**S. O. EAST, J. De Oliveira Barizon, M. Biggs, M. Bish, University of Missouri, Columbia, MO, USA

Soybean cyst nematode (SCN); *Heterodera glycines*) ranked 2nd highest in a recent survey of Missouri agriculture professionals and farmers when asked about soybean diseases that were most concerning. SCN was first confirmed in southeast MO in 1956 and is now in every soybean-growing county in the state. In spring 2022, we collected 92 samples from 23 fields in 12 Missouri counties to investigate current SCN densities in different management systems. Only one selected field had a known history of high SCN populations. Each field was divided into 4, ~20 acre sections. GPS coordinators for each section were recorded along with winter annual weed densities per 0.5 m^2, tillage programs, crop rotation, and elevation. Soil was sampled prior to planting for SCN egg counts. Average SCN egg densities for fields planted to corn in 2021 was 1,227 per 250 cm^3 soil. Fields planted to soybean in 2021 averaged 4,987 per 250 cm^3 soil. Three fields had corn planted in 2021 and cereal rye seeded over the winter with each composite sample from having no detectable SCN eggs. Those three fields were located in central and southwest Missouri and were planted to soybean in 2022. We are currently resampling fields to assess end-of-season SCN counts. We also plan to conduct virulence testing on a subset of collected populations to compare female indices from 2022 with results from a 2015-2016 statewide survey conducted by Mitchum et al. Comparisons will be useful in helping farmers understand the current utility (or increasingly lack thereof) of PI 88788 as a management tool for SCN resistance.

Poster #5

Pratylenchus dakotaensis, a recently named root-lesion nematode species from soybean fields in North Dakota

G. YAN, North Dakota State University, Fargo, ND, USA

Root-lesion nematodes (RLN; *Pratylenchus* spp.) are important nematode pests on soybean. In 2015 and 2016, soil samples collected from a soybean field in North Dakota were found to contain RLN. Morphological measurements and molecular characterization revealed this nematode is distinct in both morphology and DNA sequences from other known *Pratylenchus* spp. This new species was officially reported in North Dakota in 2017, and was named *Pratylenchus dakotaensis* in 2021 and also found in neighboring fields. Three genomic regions were sequenced and PCR-RFLP was performed to distinguish this species from other nematode species. Phylogenetic trees were constructed to ascertain the relationship with other *Pratylenchus* spp. This species is different from closely related *Pratylenchus* spp. such as *P. convallariae*, *P. pratensis*, *P. fallax*, and *P. flakkensis*. A greenhouse bioassay conducted with the RLN-infested soil on soybean cultivar Barnes demonstrated that this RLN was able to infect and reproduce on Barnes with an average reproductive factor of 5.02. Additionally, greenhouse experiments with 20 other soybean cultivars were performed, and seven of the cultivars were ranked as moderately resistant, nine were moderately susceptible, four were susceptible, but none of the cultivars tested were classified as resistant. These results demonstrated that the *P. dakotaensis* population from North Dakota is virulent on soybeans. More research work on host resistance, nematode survey, and impact of this new species on soybean growth and yield is warranted.

Poster #6

A survey of plant-parasitic nematodes in Georgia soybean fields in 2021

M. G. Mitchum (1), B. Averitt (1), **K. GOODE (1), K. Martin (1), K. Lance (1), M. Mitchell (1), R. S. Hussey (1), G. B. Jagdale (1), R. Kemerait (2), (1) University of Georgia, Athens, GA, USA; (2) University of Georgia, Tifton, GA, USA

Soybean fields in Georgia were surveyed for plant-parasitic nematodes (PPNs) during the 2021 growing season. The frequency and population density of ten PPN taxa were determined in 144 soil samples collected from soybean fields located within 31 Georgia counties. Spiral nematode (*Helicotylenchus* spp.) was the most prevalent nematode (85%), followed by lesion (*Pratylenchus* spp., 71%), stubby-root (Trichodoridae, 69%), ring (Criconematidae, 54%), root-knot (*Meloidogyne* spp., 49%), stunt (*Tylenchorhynchus* spp., 11%), reniform (*Rotylenchulus* spp., 8%), cyst (Heteroderidae, 8%), dagger (*Xiphinema* spp., 4%), and lance (*Hopolaimus* spp., 2%). Fourteen samples from nine Georgia counties were confirmed to have the soybean cyst nematode, *Heterodera glycines* (SCN), based on evidence of reproduction on soybean. HG type tests determined the virulence of each SCN population on resistant soybean. All SCN populations tested reproduced at a female index ≥10% on PI 88788. HG type 2.- was the most frequent (57%), followed by HG type 1.2.- (29%) and HG type 1.2.3.- (14%). *Meloidogyne incognita* was the most frequently identified species of root-knot nematode (80%), followed by *M. arenaria* (28%), and *M. javanica* (6%). *Meloidogyne incognita* and *M. arenaria* were identified together in 14% of the samples. Our survey results serve to 1) raise awareness of PPNs among Georgia soybean producers to inform future management decisions and 2) improve information available to soybean breeders as they move forward with their efforts to incorporate multi-nematode resistance into improved soybean cultivars.

HOST RESISTANCE

Poster #7

Resistance to Meloidogyne incognita-1 from cultivar Forrest is located on Glycine max chromosome 10

**K. GOODE, T. Nienow, Z. Li, M. G. Mitchum, University of Georgia, Athens, GA, USA

The southern root-knot nematode (RKN), *Meloidogyne incognita*, poses a major threat to soybean production in the Southern United States. The first soybean resistance gene identified, Resistance to *M. incognita-1* (*Rmi1*) was previously identified as a single additive gene for RKN resistance in the resistant cultivar Forrest, but never mapped to a specific genomic region. Four hundred seventy-four F3 progeny derived from a cross between Bossier and Forrest were evaluated for RKN resistance using gall scoring and genotyped using KASP markers previously identified for RKN resistance. RKN resistance is

significantly associated with the marker on chromosome 10 ($P<0.001; R^2 = 0.5$). Eighteen F2:3 families segregating for this marker were phenotyped for resistance and genotyped, confirming the association with the marker on chromosome 10 ($P<0.001$; $R^2 = 0.6$). These results indicate that *Rmi1* is located on chromosome 10 in the region most frequently identified as a major QTL for RKN resistance. The causal gene(s) for RKN resistance are yet to be identified. Sequencing of newly annotated genes in the candidate region has identified additional SNPs between resistant and susceptible soybean RILs differing in their response to RKN infection. RNA isolated from infected and uninfected roots of both RILs was used to identify one differentially expressed gene and one differentially spliced gene at *Rmi1* between the resistant and susceptible genotypes. These findings, coupled with CRISPR gene editing, will be used to identify the causal gene(s) for RKN resistance.

Poster #8 (see abstract above)

Fine-mapping of a major novel quantitative trait locus on chromosome 2 in PI 90763 that contributes to SCN resistance

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Poster #9

Functional characterization of a novel gene on chromosome 2 in PI 90763 involved in SCN resistance

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Fine mapping of a major novel quantitative trait locus on chromosome 2 in PI 90763 identified *GmSNAP02*, an α soluble NSF attachment protein gene paralogous with *GmSNAP18* (*rhg1*) and *GmSNAP11* (*rhg2*), as the best candidate for resistance to soybean cyst nematode (SCN) HG type 1.2.5.7 (Race 2). An insertion in *GmSNAP02* in PI 90763 was confirmed, but how the function of *GmSNAP02* contributes to resistance is unclear. Here we investigated the functional consequence of this insertion on transcription of *GmSNAP02*. For this, PI 90763, Peking, and two RILs from a cross between PI 90763 and Peking differing at *GmSNAP02* were inoculated with SCN HG type 1.2.5.7. Root tissues of mock-inoculated and infected roots were harvested at three days post-inoculation for RNA isolation followed by qRT-PCR analysis using *GmSNAP02*-specific primers. *GmSNAP02* expression was significantly up-regulated in Peking and 19AS-84-5-81-4 (susceptible RIL), but not PI 90763 or 19AS-84-5-81-8 (resistant RIL), in response to SCN infection. In addition, we were unable to amplify

GmSNAP02 full-length transcripts from PI 90763. Visual inspection of acid fuchsin-stained roots revealed premature degeneration of feeding sites in PI 90763 leading to impaired development of SCN. Our results suggest that the insertion in *GmSNAP02* may result in a C-terminal truncation of the protein and concomitant mis-regulation of expression in response to infection leading to resistance. CRISPR gene editing for targeted knock out of *GmSNAP02* in select genotypes is underway to confirm a role for this gene in resistance to SCN.

Poster #10

Pragmatic breeding for improving broad soybean cyst nematode resistance with the rhg2 gene

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The *GmSNAP11* gene at the *rhg2* locus has long been considered to play a minor role in soybean cyst nematode (SCN) resistance. Recent discoveries have revealed a major role of *rhg2* in conferring resistance to virulent SCN populations. Resistance involving *rhg2* is imparted through a unique epistatic interaction with *rhg1-a*, and broader resistance can be cumulatively obtained with additional SCN resistance loci such as *Rhg4*. Here we illustrate how *rhg2* can be efficiently utilized in a soybean cultivar development program to provide robust SCN resistance, as well as our efforts to integrate improved seed yield, using targeted gene combinations with *rhg2*, *rhg1-a*, and *Rhg4* that are effective against virulent SCN populations. The two- and three-gene model breeding strategy of *rhg1-a*, *rhg2*, and *Rhg4* gene pyramiding provides a clear, achievable, and relatively fast solution to diversify commercially available soybean cultivars.

NEMATODE GENETICS AND GENOMICS

Poster #11

Developing a recombinase polymerase amplification assay for rapid detection of the new root-lesion nematode, Pratylenchus dakotaensis on soybean

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A recombinase polymerase amplification (RPA) assay was developed to detect and identify a newly identified root-lesion nematode species (*Pratylenchus dakotaensis*) on soybean in North Dakota (ND). Species-specific primers and probes were designed, targeting the internal transcribed spacer region of the nematode. The specificity of primers and probe was evaluated in in-silico analysis and lab experiments. The RPA assay with Basic and Exo kits (TwistDx) was able to detect *P. dakotaensis* from DNA extracted from nematodes at 39.5°C in 20 minutes. RPA-Exo kit was more sensitive and did not require a purification step as compared to the Basic kit and was used for further experiments. The specificity test showed that only *P. dakotaensis* DNA and none of the other 12 control species tested, were amplified above the threshold level. Sensitivity analysis revealed that the assay could detect an equivalent of 1/32 of a single nematode DNA extracted from artificially infested sterile soil. To validate the result, the RPA assay was tested with 19 field soil samples collected from two counties in ND. It showed a similar trend between amplification values observed in RPA-Exo and nematode counts of *P. dakotaensis* observed in the samples using the traditional microscopic method. This assay only amplified soil DNA extracts of *P. dakotaensis*-infested field samples and did not amplify DNA from field soils infested with other *Pratylenchus* spp. The RPA assay developed in this study can help in the rapid detection of this nematode species for effective nematode control.

Poster #12 (see abstract above)

Genome scan for selection signatures reveals candidate soybean cyst nematode virulence genes

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NEMATODE BIOLOGY

Poster #13

Understanding the pattern of emergence and movement of soybean cyst nematode males

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Males and females of the soybean cyst nematode (SCN), *Heterodera glycines*, must mate for reproduction to occur. Adult SCN males emerge from soybean roots and move into the soil to mate with adult SCN females that are partially exposed on the root surface. Experiments were conducted to study the pattern of emergence of SCN males from roots and to determine if various compounds attracted or repelled the males (chemotaxis). In initial experiments, males emerged from roots beginning 12 days after infection (DAI) and were collected and counted daily through 20 DAI. Most males emerged 15 DAI, and numbers decreased in the days thereafter. In other experiments, males were collected every 8 hours within each day, and there was no consistent daily pattern of emergence. Chemotaxis of males was tested using 0.001 M and 0.01 M HCl, KOH, and NaOH; 1% and 10% glycerol;

and serial dilutions of vanillic acid, the reported sex pheromone produced by SCN females, from 10^{-4} to 10^{-12} M. Males collected from 15 to 17 DAI were used in chemotaxis experiments because they were most abundant and active. Males that moved towards or away from treatments in chemotaxis chips in laboratory experiments were counted. Males collected 16 DAI were repelled by 0.001 M HCl and 17 DAI were repelled by 10% glycerol. Additional studies of male chemotaxis are planned using unmated SCN females of specific ages. Understanding the movements of SCN males may reveal if there is a peak mating period, knowledge which may be useful in developing management strategies aimed at disrupting reproduction of SCN. (Reproduced by Permission)

Poster #14

Long term storage of Heterodera glycines cysts

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Effective long-term storage of biological samples is often a difficult process. The dormancy of *Heterodera glycines* cysts makes storage easier, but methods could still be improved. The current method is to mix cysts into soil in a cone-tainer and store them in a freezer. This can take up significant freezer space and requires extracting the cysts from soil to use them. Cryopreservation is a long term storage method often used in nematology. Cryopreservation methods require soaking the nematodes in a cryoprotection agent such as glycerin, then freezing the samples using liquid nitrogen. This method uses juvenile nematodes and does not take advantage of the protective nature of the cyst. Other research has found that *Globodera* cysts can be stored dry for long periods of time in a freezer. We are conducting an experiment to identify new storage methods for *Heterodera glycines*. Cysts were stored in 15 mL tubes that were dry, contained water, or contained various concentrations of glycerin. Glycerin concentrations ranged from 5-15%. A cone-tainer with soil was used as a control. Cysts will be stored at -15°C for 3 months, 6 months, and 1 year. The effectiveness of the method will be tested by thawing and culturing the cysts on a susceptible soybean plant. Cyst count after 45 days in a growth room will be compared across treatments. This should provide a simpler and more efficient storage method for *Heterodera glycines* cysts.

NEMATODE MANAGEMENT

Poster #15

Management of soybean cyst nematode using cover crops

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Soybean cyst nematode (SCN) is the number one yield robber in soybeans and has been a major problem for soybean growers across the United States. SCN causes an estimated $40 million in losses each year in Michigan. Planting resistant varieties and using pesticides are common management strategies for SCN. However, SCN populations have adapted to the resistance cultivars, and using nematicides is not very effective. To investigate the effect of different cover crops (Oat, Oilseed radish, Red clover, Mustard, and Cereal rye) and their blends with SCN trap soybeans (PI437654) on the SCN population, a randomized complete block trial with four replicates was designed under greenhouse and field conditions. In the greenhouse, cover crop pots were inoculated with 6000 SCN eggs after one week of planting. Two months after inoculation, the cover crops were cut and susceptible soybeans were planted and after two months, the number of SCN was determined. SCN populations were counted before cover crop planting and before soybean planting in the field. In the greenhouse, all treatments significantly reduced the number of SCN eggs compared to susceptible soybean as a control. However, there was no significant difference between cover crops and fallow in the number of eggs before soybean planting in the field. Two trials are ongoing to further investigate the effects of different cover crops on the SCN population in the field. From these experiments, we expect to determine which cover crop provides the most effective control of SCN to provide alternative management suggestions to growers.

Poster #16

Evaluation of cover crops for their effects on hatching and root penetration of soybean cyst nematode

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The use of non-host cover crops can be an alternative strategy for managing soybean cyst nematode (SCN). Cover crops may reduce SCN populations by acting as trap crops which promote the hatching and/or penetration by second-stage juveniles (J2s) without completing their life cycle. Two greenhouse experiments were conducted to assess ten cover crops for their impact on SCN hatching and penetration into the roots. These cover crops except turnip cv. Purple Top were selected from our previous microplot trials and showed reductions in SCN populations. For each experiment, crops were planted in naturally infested soil in two separate sets to be harvested at 15 and 30 days after planting (DAP). SCN susceptible soybean cv. Barnes and unplanted natural soil (fallow) were used as controls. Faba bean cv. Petite, a non-host of SCN, was found to have the highest hatching rate among the cover crops, which was similar to soybean. Red clover cv. Allington and turnip also showed significantly high hatching compared to fallow. Root staining revealed that the greatest number of J2s penetrated the faba bean roots 15 DAP, followed by soybean and winter rye cv. ND Dylan. While J2s penetrated all tested crops, they could not complete their development to become adult females except in soybean and turnip. The number of SCN inside the faba bean roots 30 DAP was significantly lower than in faba bean 15 DAP and soybean 30 DAP, indicating significant nematode death post-penetration. These results suggest that faba bean affects SCN and has the great potential to act as a trap crop for managing SCN.

Poster #17

The impact of cover crop management decisions on nematode reproduction rates

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Many growers plant cover crops ahead of soybean production. However, factors that accompany cover crop/soybean management can produce unexpected effects on agronomic traits, nematodes (plant parasites, fungivores, bacterivores, omnivores, predators), and other soil fauna (rotifers, tardigrades, mites, oligochaetes, Collembola). During the 2020-2021 season, a randomized strip-block (criss-cross) trial, with 4 replicates, was conducted in Madison County, TN, USA consisting of three factors: 1) cover crop mixes (fallow, five-way mix without *Brassica* spp., and six-way mix with *Brassica* spp.); 2) cover crop termination timing (three weeks before planting and at planting); and 3) seed treatments (fungicide-only, insecticide-only, fungicide/insecticide, and fungicide/insecticide/nematicide). Soil samples were taken at four time points. Seedling emergence, biomass, yield, and the soil faunal community were analyzed. The rate of reproduction of soybean cyst nematode (*Heterodera glycines*) was shown to be significantly greater in late cover crop termination plots. Conversely, the rate of reproduction in fungivores and bacterivores was lower in late cover crop termination plots. The results from this trial will help growers make management decisions, and this experiment serves as a good example of what can be done in other cropping systems such as corn and cotton in relation to cover crops and soil communities.

Poster #18

Evaluation of different sources of soybeans as a 'Trap Crop' for soybean cyst nematode in greenhouse condition

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Soybean cyst nematode (SCN) is an important limiting factor of soybean yield in the United States. For many years, plant resistance was very effective in controlling SCN. However, SCN has adapted to genetic resistance and is able to reproduce on these varieties. Evaluation of alternative strategies for SCN management is very important. To evaluate different resistance sources (SCN susceptible, Peking, PI88788, PI437654) as a trap crop, two randomized complete block trials with four replicates and a fallow control were designed under greenhouse conditions. Resistance sources pots were

inoculated with 5000 SCN eggs after two weeks of planting. The plants in the first experiment were cut three weeks after inoculation and four weeks after inoculation in the second experiment and susceptible soybeans were planted. The number of SCN was determined after one month. The results in the first experiment showed that susceptible, Peking and fallow treatments significantly reduced the number of eggs compared to PI88788. Peking and fallow treatments have the lowest number of cysts while the differences were statistically insignificant. In the second experiment, Peking and PI437654 significantly reduced the number of cysts and eggs. Two experiments are ongoing to further investigate the effects of different resistance sources on the SCN population in the greenhouse. From these experiments, we expect to determine which soybean resistance sources provide the most effective control of SCN as a trap crop to provide alternative management suggestions to growers.

Poster #19

Applied management of soybean cyst nematode with nematode-protectant seed treatments: a multi-state study

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Bold font denotes shared first authorship; Author affiliations at the time the study was conducted.

Soybean cyst nematode (SCN; *Heterodera glycines*) is an important yield limiting pathogen of soybean (*Glycine max*) that impacts soybean production across the Midwest, Mid-southern U.S. and Canada. Nematode-protectant seed treatments, chemical and biological, are commonly used to mitigate yield losses against SCN, but their impact in the field across North America is lacking. A standard protocol was used to assess the impact of nematode-protectant seed treatments over three years in 13 U.S. States and one Canadian province. These data were used to evaluate early- and full-season SCN reproduction and soybean yield for six nematode-protectant seed treatment products compared to a fungicide + insecticide base and non-treated check. Results of the study indicated that no one seed treatment stood out from all others for management of SCN. Statistically, fewer SCN females were extracted from roots at 30-35 days post-planting using ILEVO-treated seed compared to Clariva- or Aveo-treated seed when SCN initial populations were high. However, these differences did not equate to differences in soybean yield. Additionally, there was no effect of nematode-protectant seed treatments to suppress

early-season SCN reproduction when SCN initial populations were low or medium.

Poster #20

Effect of nematicides and resistant varieties on damage caused by cyst and root-knot nematodes in soybeans

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Soybean growers in Virginia experience damage from both RKN (root-knot) and SCN (soybean cyst) nematodes to vary degrees each year. With the advent of new nematicides and resistant varieties, our goals were to investigate nematicides and resistant varieties alone and in combination to reduce damage to RKN and SCN. In 2021, we investigated the SCN susceptible variety AG54XF0 with and without the seed treatment ILeVO, and in-furrow AgLogic15G (3.5 lb, 5lb, and 7 lb). Treatments were randomized block designed with 4 replications per treatment. At 16 days after planting (DAP), all rates of AgLogic 15G improved plant vigor compared to nontreated plots and those with the ILeVO. However, there was no differences among treatments for nematode populations and yield. Currently, field trials are being conducted evaluating variety resistance and nematicides in both RKN and SCN-infested fields. Both trials used randomized factorial designs with either 6 (SCN) or 8 (RKN) replications per treatment. Soil samples from each plot were collected at planting and will be collected at harvest for nematode identification and enumeration. Above ground symptoms assessed at 75 DAP demonstrated that the RKN and SCN-resistant varieties suffered less visual damage alone or when with nematicide seed treatment and in-furrow. Reduced visual damage was observed in moderately susceptible varieties when AgLogic was applied compared to seed treatment nematicides and nontreated plots. Damage was not reduced in susceptible varieties. Data on root infestation, nematode populations and yield will be presented.

Poster #21

A phytochemical-based approach for soybean cyst nematode management

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Soybean is one of the most economically important agricultural crops worldwide. However, soybean crops are annually decimated by the soybean cyst nematode (SCN), *Heterodera glycines*, resulting in massive crop yield and economic revenue losses. While conventional agricultural practices (crop rotation, pesticides) are generally effective short-term, they pose as growing threats to human and environmental health and may be limited by their efficacy and target specificity. Recently, phytochemical-based solutions aimed at managing crop pests have gained research interest. Notably, phenolic acid compounds have been shown to accumulate in SCN-resistant genotypes during infection and induce nematocidal activity *in vitro*. However, it is unclear whether these effects are observed *in vivo* or elicit any negative effects

on plant growth traits. To address these questions, we employed a phytochemical-based seed coating application on soybean seeds using phenolic acid derivatives (4HBD; 2,3DHBA) at variable concentrations and examined plant growth traits under non-infected or SCN infected conditions, as well as SCN inhibition against two SCN types. Neither phenolic acid compound negatively affected soybean growth traits in non-infected or SCN-infected plants. Furthermore, 2,3DHBA significantly reduced nematode cyst counts in Race 2-infected plants with increasingly higher chemical concentrations. These findings suggest that a concentration-dependent phytochemical-based approach may serve as an effective SCN management strategy while also offering a safer, more sustainable solution.

Poster #22

The effect of Bacillus subtilis expressing a plant elicitor peptide on nematode infection on soybean

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Soybean is the fourth largest crop worldwide, and it is the second largest crop in the US. However, soybean-cyst nematodes (SCN) pose a significant threat to this vital crop, and cause yield losses of more than $1 billion annually. Therefore, there is a pressing need to develop alternative management strategies for this pest. Plant elicitor peptides (Peps) are widely-conserved signals that are produced by plants in response to pathogens and other stresses, and that stimulate broad-spectrum defenses against pathogens and herbivores. Eight putative Peps have been found in soybean. A previous study demonstrated that treating soybean seeds with in vitro-synthesized soybean Peps (GmPep1, GmPep2, and GmPep3) reduces nematode infections. In this study, we introduce an alternative method to deliver Peps to soybean plants using a bacterial expression system. A common plant growth-promoting rhizobacterium, *Bacillus subtilis*, was engineered to express and excrete GmPep3, and was applied to soybean seeds. Here, we present data on bacterial establishment on root systems, and its effects on plant growth, productivity, and SCN infection. *B. subtilis* seed treatments represent a promising tool to deliver Peps or other bioactive peptides to plants throughout the course of development for sustained nematode protection.

National Coordinated Soybean-Nematode Research Program

STRATEGIC PLAN 2018-2022

Implementing Research, Education, and Outreach to Impact Grower Profitability and Sustainability in the Face of Increasing Nematode Threats

The United Soybean Board (USB) and North Central Soybean Research Program (NCSRP) have joined forces on a coordinated national research, education and outreach effort on nematodes. Their ultimate goal is to maximize farmer profitability and sustainability in the face of increasing nematode threats.

The National Soybean Nematode Strategic Plan was developed by a team of scientists from throughout the soybean-producing regions of the US and Canada to guide current and future nematode research, after a USB/NCSRP review identified gaps, needs and opportunities. The objective is to coordinate and support complementary projects and programs to develop short- and long-range solutions for parasitic nematode control. These encompass the spectrum of basic and applied research and Extension aimed at increasing and applying molecular, genetic, biological and agronomic understanding of the host, pest, environment and cropping systems for durable integrated nematode management. The USB and NCSRP have established six goals and anticipated benefits for soybean farmers.

PATHOGEN FOCUS- THE NEMATODE

Goal 1: Develop Genomic and Genetic Tools, Resources, and Data

1.1 Generate a high-quality reference SCN genome with annotation

Anticipated Products:

- A high quality SCN genome sequence assembly that meets generally accepted standards.
- Integration of the SCN sequence assembly with a genetic map.
- Annotated SCN genome sequence using available RNAseq data and other bioinformatic methods.
- Publicly available genome release via data portals such as SoyBase and Nematode.net.
- A published scientific paper describing the genome sequence of SCN.
- A standardized method for submitting data with a process for data curation.
- Steering committee for the SCN genome consortium is formed to assure continued progress by guiding strategic aims, informing funding agencies and supporting grant applications.

1.2 Develop genetic tools to analyze the SCN genome

Anticipated Products:

- Genome sequences of SCN inbred and field populations differing for HG type.

- A catalogue of SNPs that can be used for virulence gene identification and population type assay development.
- Methods to associate nematode phenotypes with regions of the SCN genome.
- Publicly available genetic map and sequence polymorphisms, integrated with genome, released via data portals such as SoyBase, and Nematode.net.
- Training modules for use of the SCN genome database by researchers.

1.3 Develop comprehensive gene expression data for SCN and conduct comparative studies to assess SCN population differences

Anticipated Products:

- RNAseq data representing different developmental stages, nematode organs, environments, and conditions (e.g., nematodes infecting susceptible vs. resistant soybeans, nematodes infecting plants exposed to various abiotic stresses, etc.).
- An SCN gene atlas developed from RNAseq analyses, which includes a complete list of all genes expressed, their expression patterns throughout development, alternative splice products, and co-regulated genes and networks.
- Understanding of genetic differences among SCN populations including SNPs associated with SCN virulence and host range of nematodes isolated from different geographical regions.
- Identification of genetic markers for SCN virulence.
- Development of a nematode molecular diagnostic tool for HG population typing.
- Publicly available data access via portals such as SoyBase and Nematode.net.

1.4 Identify nematode genes required for successful establishment of the parasitic association with soybean

Anticipated Products:

- Gene targets highly specific to plant-parasitic nematodes.
- Gene targets essential for nematode parasitism to which nematodes are unlikely to adapt.
- Novel resistance genes that confer broader resistance for multiple, or all populations of a nematode species.
- Gene targets that can be combined by rotation or pyramiding to increase producer options.

1.5 Establish a national SCN genetic repository and distribution center

Anticipated Products:

- A sustainable facility to house and rear SCN populations.
- Identified coordinator to oversee facility operations.
- Consolidation of existing resources into a central facility.
- Optimized protocols to ensure quality control and timely resource distribution.
- Establishment of a web-based submission and request process.

HOST FOCUS-THE SOYBEAN PLANT

Goal 2: Discover, Leverage, and Enhance Native Nematode Resistance in Soybean

2.1 Diversify nematode resistance in soybean by maximizing known genetic resources and discovering new ones

Anticipated Products:

- Genetic markers and gene positions for known and new native resistance sources to be used in marker-assisted selection and developing increased host resistance to nematodes.
- Reduced introgression regions for resistance genes to eliminate and/or minimize yield drag, with particular attention to Peking and PI 437654 type resistance.
- New sources of resistance for SCN and other nematodes identified and evaluated by screening diverse soybean germplasm, including wild relatives, through employing modern genetic methods.
- Clearly defined gene combinations that provide resistance to a broad range of SCN populations and to root knot and reniform nematodes, for geographies where they are found.

2.2 Develop soybean lines with different sources of resistance to combat nematode virulence shifts

Anticipated Products:

- Agronomically improved germplasm with new and unique combinations of nematode resistance genes that can be used as a source of nematode resistance in breeding programs.
- Multi-nematode resistant germplasm for the southern US.
- Field testing new varieties, germplasm and soybean lines in development.

2.3 Improve understanding of soybean resistance mechanisms to increase durability of native resistance

Anticipated Products:

- Understanding of *Rhg1* and *Rhg4* mechanisms.
- Identification and study of new alleles and new allele combinations.
- Characterization and isolation of genes with large effects against SCN at known loci other than those from PI 88788 and Peking, such as from PI 567516C, *G. soja* PI 468916, and PI 437654.
- Characterization and isolation of genes for resistance to other soybean nematodes.

2.4 Develop and employ functional genomic tools to associate candidate genes with nematode resistance

Anticipated Products:

- Mutant populations spanning a diverse set of nematode resistant germplasm sources.
- Optimized mutation mapping pipelines to identify genes associated with nematode resistance.

- Cloned and characterized genes responsible for QTLs available for germplasm development.
- Optimized protocols for site-directed mutagenesis and genome editing tools such as CRISPR/cas9 for testing potential targets.
- Improved genetic complementation technologies.

Goal 3: Engineer Resistance Using Molecular Tools to Generate or Improve Nematode Resistance in Soybean

3.1 Develop additional needed tools

Anticipated Products:

- Improved gene introduction methods for whole plants, that include enhancing efficiencies in different genetic backgrounds and multiple gene stacks.
- Identified or designed promoters, validated for tissue specificity and utility.
- Improved CRISPR gene editing tools for soybean with emphasis on allele replacement or base-pair modification.

3.2 Advance soybean gene targets

Anticipated Products:

- New methods and pipeline to test function of prioritized host targets identified in goal 2.
- New targets and new alleles with native resistance are combined to develop broad-based, durable resistance.
- Identification of susceptibility genes and evaluation as targets for modification and breeding durable resistance.
- Stacking of resistance and/or modified susceptibility genes under the control of tissue-specific or nematode-inducible promoters for the development of elite crop plants with novel nematode resistance.
- Intellectual property protection of discoveries to allow for future research investment by industry.

3.3 Advance nematode gene targets

Anticipated Products:

- New methods and pipeline to test function of prioritized pathogen targets identified in goal 1.
- Intellectual property protection of discoveries to allow for future research investment by industry.

3.4 Investigate the utility of non-host resistance mechanisms, including plant, microbial or synthetic sources, for increasing the genetic diversity of resistance in soybean

Anticipated Products:

- Understanding of non-host crop plant resistance mechanisms to nematodes.
- Identification of novel resistance genes to nematodes.
- Novel resistance genes transferred from species other than soybean to combat nematodes.

MANAGEMENT FOCUS: THE GROWER

Goal 4: Assess the Impacts of New Management Practices on Nematode Population Dynamics

4.1 Characterize soil and nematode microbiomes (endosymbiont, viral, bacterial and fungal pathogens) for better management of nematodes

Anticipated Products:

- Understanding of the temporal and spatial mechanisms of nematode suppression in natural soil.
- Effective biological entities identified from suppressive soils.
- Tools and methods to utilize biological entities as control agents are developed.
- Soil health indicators in relation to nematode management are determined.
- Microbiome in relation to nematode populations and control are better understood.

4.2 Evaluate agronomic cultural practices and effect on nematode population dynamics and resistance

Anticipated Products:

- Effective use of cover crops is determined.
- Utility of trap crops is better understood.
- Benefit of rotation with non-host crops is established.
- Effect of blending soybean cultivars on nematode populations and resistance is determined.
- Effects of soybean rotations with different sources of SCN resistance and/or susceptible soybean is better understood.

4.3 Assess interactions of nematodes with biotic and abiotic stresses

Anticipated Products:

- Interaction between SCN and SDS and other fungal diseases is better understood.
- Relationships between nematodes and other biotic stresses (insects, weeds, pathogens) are determined.
- Relationships between nematodes and fertility factors, pH, soil moisture are established.

4.4 Coordinate unbiased evaluation of products and best management practices for nematodes

Anticipated Products:

- Comparative testing of chemical and biological control agents.
- Data is collected and used to evaluate the economic benefits of chemical and biological control agents for nematode management.
- Population level understanding of interactions between nematodes and biological antagonists.
- Variety performance trials.

Goal 5: Conduct Nematode Surveys for Improved Diagnostics and Economic Impact

5.1 Conduct nematode surveys

Anticipated Products:

- Industry wide, standardized sampling and processing protocol for field testing nematodes.
- Coordinated field surveys across states employing the same methodology to allow for state to state statistical analysis.
- Publication of maps of nematode distribution and population types.

5.2 Develop improved high-throughput SCN phenotyping methods

Anticipated Products:

- Development of improved image analysis software programs to count SCN females.
- Standardization of methodology and reporting, adopting latest developments for SCN phenotyping and genotyping.

5.3 Assess economic impact and risk

Anticipated Products:

- Improved estimates of potential soybean yield losses caused by nematodes for each soybean producing state in the United States.
- Improved real world impact assessment of yield and economic loss due to nematodes.
- Identification of the most useful sources of resistance for a specific state and region.
- Economic impact for growers using different cultural practices.

Goal 6: Foster Extension, Education and Outreach

6.1 Develop farmer-friendly SCN classification scheme

Anticipated Products:

- A revised classification scheme that describes differences among SCN field populations and changes over time to soybean producers in a way that provides improved understanding and better adoption of management recommendations.
- Adoption of this revised classification scheme by soybean breeders who develop SCN-resistant cultivars.

- A common language around SCN population assessment (Agribusiness, Public Research, Extension, Farm Advisors, and Growers).
- Faster turnaround time for providing producers with SCN population type data and variety recommendations for better SCN management.
- Reduced cost of SCN population typing analysis.

6.2 Improve grower awareness and communication

Anticipated Products:

- An SCN Resistance Management and Awareness Communication Strategy that incorporates research, data and advances achieved in Goals 1–5.
    - Growers will know the level and distribution of SCN in their fields, the SCN population types and aggressiveness in their fields, the source of resistance they are planting, and how to effectively utilize management options.
    - Customized campaigns for different regions such as newly emerging SCN regions (Dakotas, Canada), established regions (North Central), mixed nematode regions (Southern).
    - Economic assessments incorporated into management recommendations to aid grower decision-making processes.
- Grower perceptions surveys to assess impact of education and other strategies conducted.
- Simplified test plots are made available for growers to assess lines and/or seed treatments.
- Germplasm and variety labeling is standardized so growers and farm advisors can readily understand the background genetics, nematode resistance source and resistance level to different SCN population types.

To track the researchers' progress toward these goals, visit www.soybeanresearchinfo.com or www.soybeanresearchdata.com.

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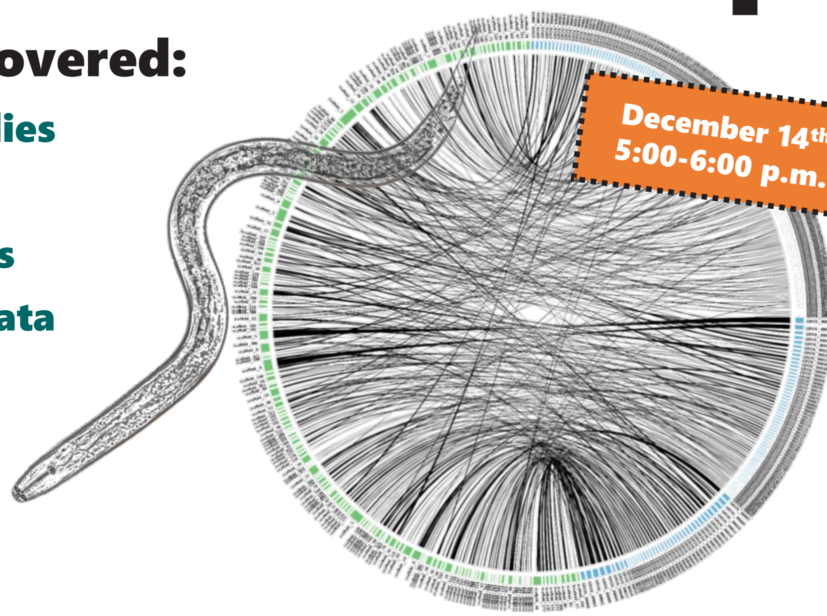
2022 National Soybean Nematode Conference

Advancing Nematode Management for the Future

SCNBase Workshop

Topics to be covered:

- Genome assemblies
- Gene models
- Gene annotations
- Transcriptome data
- Effector data
- Jbrowse
- Downloads
- Tutorials



December 14th
5:00-6:00 p.m.

Instructor:

Dr. Rick Masonbrink
Associate Scientist
Genome Informatics Facility
Iowa State University

Sponsored by: NCSRP NORTH CENTRAL SOYBEAN RESEARCH PROGRAM

The workshop will start with an overview of the data and tools available for the soybean cyst nematode (SCN; *Heterodera glycines*) on SCNBase, followed by a review of new data that is currently in the works. Next, a tutorial on how to interact with each of the interconnected bioinformatics tools by touching on each aspect of the data available using a few relevant genes will be provided. Because SCNBase has a lot of unique data, there will be a review on the data types and how they are helpful toward understanding the parasitism and biology of *H. glycines*. Because the genomics of SCN are always under constant development, an example of how to use different data types to infer putative changes in gene structure that may not be present in the current genome annotations will be explored. The last portion of the workshop will be dedicated to fielding questions and suggestions for improvements to SCNBase.

The SCN Coalition™

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