Annual Report for NC 1197

Project/Activity Number: NC-1197

Project/Activity Title: Practical Management of Nematodes on Corn, Soybean, and Other Crops of Regional Importance

Period Covered: July 2022 – June 2023

Submission Date of This Report: September 15th 2023

Annual Meeting Date(s): July 13th – 15th, 2023, Columbus Ohio

Accomplishments

Objective 1: Develop, evaluate, improve, and integrate management techniques for plant-parasitic nematodes in the North Central Region to increase grower profitability.

Survey of plant-parasitic nematodes

As part of detecting, assessing virulence of plant-parasitic nematodes, and developing effective management strategies, various surveys were conducted in the collaborating states. Samples representing 12 IL counties are being processed. Although variable over time, dagger, lance, lesion, root-knot, spiral, and stunt nematodes were detected in 59 corn fields representing 16 KY counties. Soybean cyst nematode (SCN) was detected in 80% of samples from 35 KY counties. In these fields, 42% had 1- 499 eggs/100 cc soil, 15% had 500 - 1,999 eggs/100 cc soil, 22% had 2,000 - 9,999 eggs/100 cc soil, and 1% had at least 10,000 eggs/100 cc soil. Limited HG typing has indicated that 88% have HG Type 2.5.7 (female index on PI 88788 ranging from 13-48%), and 12% have HG Type 5.7. HG typing is still ongoing and preliminary results only represent a small portion of the samples. A survey of Ontario soybean fields revealed the presence of HG Type 1 (up to 30-40% FI) and HG Type 2 (up to 60-70% FI). In 66 OH counties, SCN was detected in 65% of samples and more than 85% of the SCN populations reproduced on PI 88788 at levels 30 – 60% compared to a susceptible soybean. In WI, 92% and 36% of soybean fields were positive for root-lesion and SCN, respectively. HG Type 2 was the most prevalent SCN present. Soybean yield loss due to *P. penetrans* was estimated at 2.8 - 7.6%. In MI, long-term studies on SCN adaptation show that it remains barely detectable many years after being introduced at damaging levels into a new location under till/no-till and corn-soybean rotations with SCN-resistant and -susceptible cultivars. Following previous studies on northern root-knot nematode (NKRN) occurrence, Soil Food Wed (SFW) model, NRKN parasitic variability (PV) and soil health conditions, they identified microbial communities associated with presence or absence of *M. hapla* and/or soil health degradation categories. Thus, laying a foundation for in-depth understanding the mechanisms of *M. hapla* PV in cropping systems.

Evaluation of cultivars and germplasm for nematode resistance

A combination of PI 88788 being the main source of SCN resistance in US soybeans and many variants of SCN populations (HG Types) that break resistance and presence of multi-taxa in the same production systems is a major challenge. On-going are studies that assess soybean accessions and cultivars as resistant, moderately resistant, moderately susceptible, and susceptible for SCN and other nematodes. In ND, 13 out of 149 accessions from the USDA Soybean Germplasm Collection Center, Illinois were resistant to HG Type 2.5.7, one of the common virulent SCN populations in the state. Out of 44 commercial seeds obtained from growers, 9%, 11%, 30%, and 50% had resistance, moderate resistance, moderate susceptibility, and susceptible reaction to HG Type 2.5.7. Out of 47 commercial varieties, 13%, 19%, 45%, and 23% showed resistant, moderately resistant, moderately susceptible, and susceptible reactions. In KS, 275 KSU breeding lines and 53 commercial lines were tested. Approximately 53% and <10% of the 275 lines were resistant/moderately resistant to HG Type 7 and HG Type 2, respectively. Out of the 53 private entries, 30% and 9-17% were resistant or moderately resistant to HG Type 7 and HG Type 2, respectively. In IN, 42 SCN populations were tested in re-designed SCN virulence type test and revealed that HG Type 2.5.7. and 1.2.5.7 accounted for 64% and 14% of the SCN populations, respectively. In OH, scientists evaluated the source of SCN resistance (Peking and PI 88788) and showed 85% of SCN populations have >10% reproduction on PI 88788. More than 100 commercially available soybean varieties were screened in 2022 and currently in 2023. These varieties are part of the Ohio State University soybean performance trial. In NE, scientists are working on SCN and conducting HG Type testing to determine HG Types of SCN in the state and evaluating population densities of plant-parasitic nematodes associated with crown rot of corn. In MN, extensive studies are going on to determine short and long-term changes in SCN virulence under PI 88788, Peking, and PI 437654 sources. Collectively, the HG Type test results highlighted the importance of rotating soybean varieties with different types of resistance and identifying new sources of resistance for sustainable management of SCN. In IL, perennial *Glycine* spp. were assessed against *Pratylenchus penetrans* (lesion), *Meloidogyne incognita* (root-knot), and *Rotylenchulus reniformis* (reniform nematode) and showed no resistance to *P. penetrans*. While *M. incognita* and *R. reniformis* had shared and unique interactions along the susceptibility continuum compared with SCN, resistance was superior to that found in resistant soybean.

Evaluation of nematode-protectant seed treatments

Efficacy of commercial products on root-parasitic nematodes and soil-borne pathogens have been studied under field and greenhouse conditions. In ND, Vydate showed consistently significant reductions in the incidence and severity of corky ringspot disease (CRS) on potato. CRS is caused by *Tobacco rattle virus* vectored by stubby-root nematodes. In KY, evaluations of commercially available nematode-protectant seed treatments in corn fields with moderate to severe levels of lance, lesion and spiral nematodes, and SCN are on-going. In IL field trials, Poncho Votivo and iLeVo (fluopyram) reduced lesion nematode populations during early corn growth. There was no effect on total plant-parasitic nematode numbers or yield. Laboratory trials determined that *P. penetrans* is susceptible to fluopyram exposure with a 2-hour EC50 value of 3.66 µg/ml. However, there was substantial variation in the susceptibility of *P. penetrans* among life-stages with younger stages being more susceptible. In NE they tested seed treatments in corn for nematode management. In Ontario, Canada, they included cover crop effects on nematodes and seed treatment testing for nematode management. In OH, on-going are studies to elucidate effects of volatile nematicides on potential biocontrol agents such as *Pseudomonas* and *Aphelencoides* (fungal-feeding nematodes), used to control biofilms in hydroponic systems, and *Pleurotus* species (oyster mushrooms) for the control of plant-parasitic nematodes.

Development of innovative methods to detect and quantify plant-parasitic nematodes

The nematodes of economic significance include sedentary inside roots (SCN and root-knot) and many migratory (root-lesion) species within roots and between root and soil. The accuracy of detecting nematodes, critical to quantifying nematode-induced yield loss, therefore, depends on simultaneous assaying soil and roots. In WI, an initial population (Pi)-based modeling study for the first time showed that there was a 0.01987% yield loss per nematode in greenhouse and 0.02930$ yield loss in the field. This study establishes a significant step towards developing quantitative damage threshold for nematodes. In ND, a SYBR green-based quantitative real-time PCR (qPCR) assay was developed for detection and quantification of *P. scribneri* in potato roots. The assay used a previously reported primer pair (ITS-2F/ITS-2R) and it proved to be specific and sensitive, detecting as low as 1/128th equivalents of a *P. scribneri* individual per 0.2 g of potato roots. The assay had high correlation observed between the *P. scribneri* densities determined microscopically and the densities detected by qPCR in artificially inoculated and naturally infected root samples. A time-course experiment conducted in the greenhouse using qPCR detected *P. scribneri* in potato roots as early as five days after planting. The results correlated well with the microscopic observations and were complemented further with root-staining. Another PCR assay has been improved to differentiate SCN from sugar beet cyst nematode (SBCN) and other nematode species and to quantify SCN from DNA extracts of field soils. SCN and SBCN-specific qPCR primers were designed from a nematode-secreted CLAVATA gene and used for the assay. There was a high correlation between the SCN numbers estimated from naturally infested field soils by conventional methods, and the numbers quantified using the SYBR Green I-based qPCR assay.

<u>Objective 2:</u> Determine the relationships among nematode population characteristics, crop injury, and soil health.

A combination of nematode mode of reproduction (amphimictic or parthenogenesis), interaction with soil pathogens, and production landscapes with varying degrees of soil health degradation is a complex problem to sort through when designing solutions to the problem. On-going are studies using molecular tools, short- and long-term green and field studies, and conceptual decision-making models making strides towards addressing the challenges. In California, they utilized the Arabidopsis-cyst nematode interaction as a model system to cut hundreds of microscopic root segments containing syncytium and identified 1,000 nematode-origin proteins that were consistently present in all infected root samples but absent in the uninfected control roots. This is the first attempt to directly identify nematode secretory proteins from the host proteome. They are currently identifying host genes in major crop plants, such as soybean, that are targeted by essential nematode secretory proteins. They aim to redesign these proteins in order to inhibit their binding to nematode secretory proteins without compromising their natural functions. In Minnesota, experiments were initiated at one field site in 2019, and two field sites in 2022 to study effect of planting dates of oilseed cover crop pennycress on the SCN population densities in corn-pennycress/soybean-corn production system. Two field sites were also established to study monoculture and rotation of SCN-resistant soybean and susceptible soybean on soil fungal communities associated with SCN suppression. Soil samples were taken to identify major nematophagous fungi. Their roles in suppression of SCN field population and potential as biological control agents are assessed.

In Michigan, on-going are long-term studies to understand the effects of tillage, cropping systems, and soil amendments affect nematode, nutrient and soil health management. These studies are structured to generate integrated datasets to identify health soils within the definition of a healthy soil is one that generates 3 desirable sets of ecosystem services (ESs): *a*) improve soil structure, physicochemistry, nutrient cycling, and water holding capacity; *b*) suppress pests and diseases while increasing beneficial organisms in the same environment; and ***c*)** improve biological functioning and crop yield. Several foundational publications have been generated by applying three decision-making models: a) the SFW model to assess agroecosystem suitability of the outcomes, b) the Fertilizer Use Efficiency (FUE) model to assess the potential sustainability of the outcomes, and c) the Integrated Productivity Efficiency (IPE) to identify sustainable soil health outcomes at a resolution that accounts for multiple ESs and the SFW functions.

Objective 3: Develop and disseminate research-based information on the biology and management of plant-parasitic nematodes of economically important crops in the North Central Region.

The 2022 National Soybean Nematode Conference was held in Savannah, GA, December 14-16, 2022. The 3-day meeting featured over 100 attendees, expert speakers, and several networking opportunities. This meeting was coordinated by some of the members involved in this project. Many of the PIs in this project participated in this meeting for information dissemination. The conference was very successful, as observed by the results of a post-conference survey sent to attendees. This survey indicated that 94.7% of the attendees agreed that the conference was successful in sharing and discussing developments related to nematodes that feed on soybean. In addition, attendees responded that compared to other meetings recently attended, the conference had a mean rating of 4.5 (on a 1-5 scale, where 1=poor and 5=excellent) for program content. Over 40 abstracts were presented at the conference through oral and poster presentations. Abstracts are available at: https://doi.org/10.1094/PHYTO-113-1-S1.1.

An SCN survey was conducted in 2022 throughout the state of ND using a ‘free’ sampling program. Succinctly, growers received SCN sample bags at the Extension county offices, sampled fields, and submitted samples to a partner lab. Data were mailed to growers directly, data was sent to NDSU and density maps with egg counts were developed. In SD, promotion of SCN testing and changing of HG Types occurred in 10 different state events and reached to about 2,500 people. Roughly 80,000 people in SD have heard messaging about the risks associated with SCN through promotion at events and radio programs. In KS, information on the level of resistance in commercial soybean cultivars to SCN populations is published annually and the results obtained from this project have been used in classroom training for crop diseases and for training of certified crop advisors. In MN, 2022 SCN variety test data were published in "2022 Soybean Field Crop Trials Results." In KY, results from the corn nematode surveys was presented at the Pest Management Field Day. In Michigan, workshops and seminars were done to overcome the considerable intra- and cross-disciplinary gaps and barriers towards broad application of the research models developed in this project. In IL, scientists are currently digitizing the electron micrograph collections. These data comprise approximately 55,000 individual images of nematodes. They have scanned approximately 30,000 of these and annotated approximately 2,000. Annotated images are uploaded to the open access IL Data Bank https://databank.illinois.edu/.

Impacts (bullet points please):

- The 2022 National Soybean Nematode Conference was initiated and coordinated to share and discuss developments related to nematodes that feed on soybean in cooperation with other scientists.
- The soybean cyst nematode (SCN) resistant variety trial data have been provided to growers for managing SCN.
- Information on resistance levels of commercial soybean cultivars to populations of SCN provides growers with information necessary to increase profitability of soybean production in SCN-infested environments.
- Characterization of SCN virulence patterns and results of research on resistance-based management practices and durability of resistance sources is being used to improve management recommendations.
- Current information on the efficacy of nematode control products is disseminated at various grower meetings and field days to improve knowledge-based management decisions.
- SCN-resistant soybean germplasm lines have been used for breeding SCN-resistant soybean cultivars.
- The studies on the relationships among nematode population characteristics, crop injury, and soil health provide quantitative and integrated data base that are critical to understanding nematode parasitic variability cropping systems and soil health management decision-making to benefit growers and the environment.
- New DNA-based protocols on detection, identification and quantification of plant-parasitic nematode species have been published for unrestricted use to improve nematode species detection efficiency and capacity.
- Research findings and key nematode information are shared with growers and public groups through peer-reviewed journals, extension publications, various websites, radio programs, and SCN Coalition to promote managing SCN and other nematodes of importance in the region.

Publications:

Book chapters:

Chowdhury, I.A., Yan, G.P., and Khan, M. 2022. Diseases caused by nematodes on the sugar beet, in V. Misra, S. Srivastava and A. K. Mall (ed.), Sugar Beet Cultivation, Management and Processing, Volume 1, Springer Nature Singapore Pte Ltd. (ISBN: 978-981-19-2729-4; https://doi.org/10.1007/978-981-19-2730-0), pp. 737-750.

Lopez-Nicora, H.D., Peng, D., Saikai, K., Rashidifard, M. 2023. Nematode problems in maize and their sustainable management. In: Khan, M. R. and Quintanilla, M. (eds.) *Diseases of Crops and their Sustainable Management*. Academic Press, Elsevier, London, UK.

McMullen, M., Todd, T., and De Wolf, E. 2023. Diseases of Wheat. Pp. 357-371 *in* C.A. Hollier, G.B. Padgett, and M.A. Draper (eds.). Diseases of Field Crops. The American Phytopathological Society, St. Paul, MN.

Simon, A.C.M., Lopez-Nicora, H.D., and Niblack, T.L. 2021. Impact of plant parasitic nematodes on maize in mid-western USA: An unrecognized or ignored threat to production. In: Sikora, R. A., Desaeger, J., and Molendijk, L. (eds.) *Integrated Nematode Management: State-of-the-art and vision for the future*. CAB International, Wallingford, UK.

Refereed journal articles:

Acharya, K. and Yan, G.P. 2022. Screening of early maturing soybean accessions for resistance against HG Type 2.5.7 of soybean cyst nematode, *Heterodera glycines*. Plant Health Progress 23:166-173. https://doi.org/10.1094/PHP-07-21-0105-RS.

Airs, P.M., Vaccaro, K., Gallo, K.J., Dinguirard, N., Heimark, Z.W., Wheeler, N.J., He, J., Weiss, K.R., Schroeder, N.E., Huisken, J., and Zamanian, M. 2022. Spatial transcriptomics reveals antiparasitic targets associated with essential behaviors in the human parasite *Brugia malayi.* PLOS Pathogens 18(4):e1010399. https://doi.org/10.1371/journal.ppat.1010399.

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Arora, D. and Yan, G.P. 2022. Early detection and temporal dynamics of *Pratylenchus scribneri* infection in potato roots determined using quantitative PCR and root staining. Phytopathology 112:1776-1782. https://doi.org/10.1094/PHYTO-10-21-0412-R.

Chowdhury, I.A., Yan, G.P., Kandel, H., and Plaisance, A. 2022. Population development of the root-lesion nematode *Pratylenchus dakotaensis* on soybean cultivars. Plant Disease 106:2117-2126. https://doi.org/10.1094/PDIS-11-21-2444-RE.

Critchfield, R., King, J., Bonkowski, J., Telenko, D., Creswell, T., and Zhang, L. 2023. Characterization of Virulence Phenotypes of *Heterodera glycines* during 2020 in Indiana. Journal of Nematology. (In press).

Faske, T.R., Mueller, J., Ole Becker, J., Bernard, E.C., Bradley, C., Bond, J., Desager, J., Eisenback, J., Grabau, Z., Hu, J., Kemerait, R., Koehler, A., Lawrence, K., Mehl, H., Rudolph, R. E., Sikora, E. J., Thomas, S., Walker, N., Wheeler, T., Wrather, A. J., Ye, W., and Zhang, L. 2023. Summarized distribution of the southern root-knot nematode, *Meloidogyne incognita*, in field crops in the United States. Plant Health Progress. https://doi.org/10.1094/PHP-04-23-0031-BR.

Faske, T.R., Mueller, J.D., Becker, J.O., Bernard, E., Bradley, C. A., Bond, J.P., Desaeger, J., Eisenback, J.D., Joseph, Grabau, J., Hu, J., Kemerait, R. C., Koehler, A., Lawrence, K., Mehl, H., Rudolph, R.E., Sikora, E., Thomas, S., Walker, N.R., Wheeler, T., Wrather, J.A., Ye, W., and Zhang, L. 2023. Summarized distribution of the southern root-knot nematode, *Meloidogyne incognita*, in field crops in the United States. Plant Health Progress. https://doi.org/10.1094/PHP-04-23-0031-BR.

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Han, J., Bowen, C.R., Ugarte, C.M., Schroeder, N.E., and Hartman, G.L. 2022. Plant-parasitic and free-living nematodes in organically farmed soybean fields in Illinois. Plant Health Progress. 23:227-234. https://doi.org/10.1094/PHP-06-21-0096-S.

Han, J., Locke, S.P., Herman, T.K., Schroeder, N.E., and Hartman, G.L. 2022. Evaluation of perennial *Glycine* species for response to *Meloidogyne incognita, Rotylenchulus reniformis,* and *Pratylenchus penetrans.* Journal of Nematology. 54:e2022-1.

Hasan, M.S., Chopra, D., Damm, A., Koprivova, A., Kopriva, S., Meyer, A., Mueller-Schuessele, S.J., Grundler, F., and Siddique, S. 2022. Glutathione contributes to plant defense against parasitic cyst nematodes. Molecular Plant Pathology 23:1048-1059.

Hoerning, C., Chen, S.Y., Frels, K., Wyse, D., Wells, S., and Anderson, J. 2022. Soybean cyst nematode population development and its effect on pennycress in a greenhouse study. Journal of Nematology 54:20220006. doi: 10.2478/jofnem-2022-0006.

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Neupane, K., Yan, G. P., and Plaisance, A. 2022. Evaluation of cover crops for reducing *Heterodera glycines* populations in microplot experiments. Nematology 24:1017-1029. DOI 10.1163/15685411-bja10188.

Siddique, S., Coomer, A., Baum, T., and Williamson, V.M. 2022. Recognition and response in plant–nematode interactions. Annual Review of Phytopathology 60:143-162.

Siddique, S., Radakovic, Z., Hiltl, C., Pellegrin, C., Baum, T., Beasley, H., Bent, A,, Chitambo, O., Chopra, D., Danchin, E., Grenier, E., Habash, S., Hasan, M.S., Helder, J., Hewezi, T., Holbein, J., Holterman, M., Janakowski, S., Koutsovoulos, G., Kranse, O,, Lozano-Torres, J., Maier, T., Masonbrink, R., Mendy, B., Reimer, E., Sobczak, S., Sonawala, U., Sterken, M., Thorpe, P., Steenbrugge, J.V., Zahid, N., Grundler, F.M.W., and Eves-van den Akker, S. 2022. The genome and lifestage-specific transcriptomes of a plant-parasitic nematode and its host reveal susceptibility genes involved in trans-kingdom synthesis of vitamin B5. Nature Communications 13:6190.

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Extension and outreach:

Bradley, C.A. 2022. Management of soybean cyst nematode starts with soil sampling this Fall. Kentucky Pest News, October 18, 2022. https://kentuckypestnews.wordpress.com/.

Chowdhury, I.A., Yan, G.P., Halvorson, J., Thapa, A., Halvorson, M., and Markell, S. 2022. Soybean cyst nematode (SCN). North Dakota State University Extension Bulletin PP1732, 8 pages.

Gerber, C.K. 2023. Corn & soybean field guide 2023 edition. Purdue University Extension.
Strunk, C. 2022. Know Soybean Cyst Nematode, Numbers Matter! https://extension.sdstate.edu/know-soybean-cyst-nematode-numbers-matter. South Dakota State University Extension.

Yan, G.P., Nelson, B., Osorno, J., and Kaur, H. 2022. Soybean cyst nematode resistance evaluation in dry bean varieties, Northarvest Bean Grower Magazine 28 (2): 36-39 (Research edition 2022).

Media:

Webinar with 8 attendees, promoted SCN testing and resistance on two different radio stations with approximate reach of 75,000 South Dakotans (South Dakota State University Extension).

Other:

Conference Abstracts:

Dhakal, R., Chowdhury, I., Plaisance, A., and Yan, G.P. 2022. Developing a recombinase polymerase amplification assay for rapid detection of the new root-lesion nematode, *Pratylenchus dakotaensis* on soybean. National Soybean Nematode Conference, Savannah, Georgia, December 14-16, 2022.

Goraya, M. and Yan, G.P. 2022. Development of a recombinase polymerase amplification assay for rapid detection of the stubby root nematode, *Paratrichodorus allius*. Pages 63-64 in Program & Abstracts of 61th Annual Meeting of the Society of Nematologists, Anchorage, Alaska, September 26-30, 2022.

Kakaire, S., Sanchez, A., Sacbaja, A., Chan, C., Sipes, B.S., and Melakeberhan, H. 2022. Adopting integrated nematode-soil health management in smallholder potato farmers in the Highlands of Guatemala. 7th *International Congress of Nematology*, Nice, France.

Lartey, I., Kravchenko, A., Bonito, G., and Melakeberhan, H. 2022. Parasitic variability of *Meloidogyne hapla* relative soil groups and soil health conditions. *61st Annual Meeting of the Society of Nematologists*. Anchorage, Alaska.

Mehl, K., and Bradley, C.A. 2023. Surveys for plant-parasitic nematodes in Kentucky soybean fields. Phytopathology 113:S1.8 (Abstract). https://doi.org/10.1094/PHYTO-113-1-S1.1.

Melakeberhan, H. and Habteweld, A. 2022. Using nematode community-based models as integration platforms for developing sustainable soil health. *61st Annual Meeting of the Society of Nematologists* (SON). September 29, Anchorage, Alaska.

Neupane, K. and Yan, G.P. 2022. Hosting and population reduction abilities of cover crops to the root-lesion nematode *Pratylenchus penetrans*. American Phytopathological Society Annual Meeting, Pittsburgh, PA, August 6-10, 2022. (Abstr.) Phytopathology 112:S3.143-144. https://doi.org/10.1094/PHYTO-112-11-S3.1.

Neupane, K., Yan, G.P., and Plaisance, A. 2022. Evaluation of cover crops for their effects on hatching and root penetration of soybean cyst nematode. National Soybean Nematode Conference, Savannah, Georgia, December 14-16, 2022.

Poudel, D. and Yan, G.P. 2022. Assessment of breeding lines for resistance to soybean cyst nematode (*Heterodera glycines*) and their copy number variation at *Rhg1* locus. Pages 89-90 in Program & Abstracts of 61th Annual Meeting of the Society of Nematologists, Anchorage, Alaska, September 26-30, 2022.

Yan, G.P. 2022. *Pratylenchus dakotaensis*, a recently named root-lesion nematode species from soybean fields in North Dakota. National Soybean Nematode Conference, Savannah, Georgia, December 14-16, 2022.

Yan, G.P. 2022. Recent advancements in molecular detection and quantification of soybean cyst and root-lesion nematodes. National Soybean Nematode Conference, Savannah, Georgia, December 14-16, 2022.

Workshops and Seminars:

Melakeberhan, H. and Habteweld, A. 2022. Expanding indicator qualities of nematodes to identify sustainable soil health. 7th *International Congress of Nematology*, (ICN) May 2, Nice, France. https://www.alphavisa.com/icn/2022/replay-monday-2-may-miles-ICN2022.php.

Melakeberhan, H. and Habteweld, A. 2022. Using nematode community-based models as integration platforms for developing sustainable soil health. *61st Annual Meeting of the Society of Nematologists* (SON). September 29, Anchorage, Alaska.

Melakeberhan, H. 2022. Nematodes and soil health management. *Great Lakes Expo 2022, Soil Health and Cover Cropping Session.* December 7, Grand Rapids, Michigan. 2022 Education Program – Great Lakes Expo Conference Site (glexpo.com). Soil-Health-Cover-Crop-Nematodes-and-Soil-Health-Management_Melakeberhan_12_07_2022_2pm.pdf (glexpo.com).

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