**Project/Activity Number:** NC1197

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

**Period Covered:** 08/05/2020-08/04/2021

**Annual Meeting Date:** 07/23/2021-07/24/2021

**Participants:** Jefferson Barizon,Kaitlyn Bissonnette, Rodrigo Borba Onofre, Carl Bradley, Emmanuel Byamukama, Senyu Chen, Ann MacGuidwin, Tamra Jackson-Ziems, Haddish Melakeberhan, Marisol Quintanilla, Nathan Schroeder, Tim Todd, Greg Tylka, Guiping Yan, Lei Zhang

**Brief summary of minutes of annual meeting:** Uploaded separately

**Accomplishments:** Plant-parasitic nematodes (PPNs) continue to be a major constraint to crop production in the north-central region and beyond. The NC1197 multistate group is assessing strategies for the control of PPNs. Special attention is given to plant-parasitic nematodes of corn and soybean.

**Objective 1. Develop, evaluate, improve, and integrate management techniques for plant-parasitic nematodes in the north-central region to increase grower profitability.**

A. Evaluate interactions of plant-parasitic nematodes with germplasm of economically important plants.

B. Assess intraspecific variability in nematode virulence and pathogenicity.

C. Evaluate new commercial products and innovative strategies for the control of SCN, root-lesion and other plant-parasitic nematodes.

D. Develop innovative methods to detect and quantify plant-parasitic nematodes

Participants in Illinois, Iowa, Kansas, Minnesota, and North Dakota screened soybean lines for resistance to soybean cyst nematode. In Kansas, 220 advanced breeding soybean lines were screened against SCN resistance in 2020. 87% of the early maturing and 27% of the late maturing were rated resistant or moderately resistant to HG Type 7 SCN screening population while only 26 and 27% of the early and late maturing lines, respectively, were rated resistant or moderately resistant to SCN. They also performed alfalfa cyst nematode trial and found no differences among varieties. They performed root invasion of male and female alfalfa cyst nematode on several hosts and found hairy vetch in addition to alfalfa allowed higher number of males and cyst development. In Minnesota, they evaluated 36 private and public soybean lines against SCN HG type 7 in the greenhouse and all were resistant or moderately resistant to the HG type 7. They also evaluated 13 soybean varieties with Peking as the source of resistance and 10 were resistant or moderately resistant to HG type 2.5.7. They are a screening Pennycress germplasm against SCN HG type 7. A longer-term study on intraspecific variability in nematode virulence and pathogenicity is still on-going. In Iowa, 207 SCN commercial resistant varieties were evaluated under naturally SCN infested fields. The majority of the varieties had PI88788 resistance while only 16 had Peking resistance. Varieties with Peking resistance had the lowest end of season SCN population densities for all the locations tested.

In Illinois, interaction of plant-parasitic nematodes with perennial Glycine spp was investigated. They found that both *Meloidogyne incognita* (root-knot), and *Rotylenchulus reniformis* (reniform nematode have both shared and unique interactions along the susceptibility continuum compared with SCN. In some cases, resistance was superior to that found in resistant soybean. No resistance was found to *P. penetrans* in any perennial Glycine accession.

Participants in North Dakota, Indiana, Kentucky, and Wisconsin performed plant parasitic nematode surveys. North Dakota and Indiana screened for SCN populations for HG types. In North Dakota, out of 73 SCN populations screened, HG type 0 was the most common (36%) followed by HG type 7 (27%) and 2.5.7 (19%). In Indiana, a survey to determine occurrence of HG types in the state was carried out. They report 100% of the 124 soil samples were positive for SCN. HG typing is still on-going. In Kentucky, surveys for plant parasitic nematodes were performed in soybeans and corn. They found SCN prevalence of 75%. Other plant parasitic nematodes found were dagger nematodes (7% of the fields), 27% of the fields were infested with lance nematodes, 33% were infested with lesion nematodes, 98% were infested with spiral nematodes and 2% were infested with stunt nematodes. In Wisconsin, 57% of the 629 farms tested in 2019-2020 survey were positive for SCN compared to 17% of the 447 farms tested during the first survey 20 years ago (1989-99). In South Dakota, 35% of the samples tested were SCN positive fields in 2020 (n=310)

.

In North Dakota, two experiments to evaluate resistance levels of soybean varieties against new species of root lesion nematode (*Pratylenchus dakotaensis*). The combined results of all the trials indicated that seven of the cultivars were moderately resistant, nine of the cultivars and the local cultivar Barnes were moderately susceptible, and four of the cultivars were susceptible. However, none of the cultivars evaluated were classified as resistant.

In Michigan, parasitic variability (PV) for northern root knot nematode was studied with particular emphasis on how presence or absence of the nematode relates to mineral and muck soils and soil food web (SFW) conditions. This study for the first time established that *Meloidogyne hapla* was present in disturbed and degraded conditions in both soil groups. On-going are analyses to establish the relationship between PV and SFW and soil biophysicochemical conditions.

Participants from Iowa, Missouri, South Dakota, North Dakota, Illinois, Minnesota, Kansas, Kentucky performed nematode protectant seed treatment studies. In Missouri, multiple nematode-protectant seed treatment products were evaluated as part of multi-state trial. At present, approximately 30 site-years of data have been collected across 12 states and 1 Canadian province. In Iowa, 27 field experiments to study nematode-protectant seed treatments on soybean yields and SCN population were done. The 2020 experiments showed variable effect on yield by Aveo, Trunemco and Saltro but no significant effect on SCN reproduction factor. In Kentucky, no differences were observed between nematicide seed treatments compared to the base treatment. In Illinois, Poncho Votivo and iLeVo (fluopyram) were evaluated on corn nematodes and they found the treatments reduced lesion nematode populations during early corn growth. Total plant-parasitic nematode numbers were not affected and we observed no change in yield. In North Dakota, new nematicide Vydate was tested against stubby root nematode, the vectors of the *Tobacco rattle virus* in potatoes and found Vydate showed significant reduction in the virus incidence and severity. In Minnesota, 7 experimental nematicide seed treatments were evaluated for SCN management in soybeans.

Participants from North Dakota and Wisconsin participated in developing innovative methods to detect and quantify plant parasitic nematodes. A rapid and accurate PCR-based method was developed for detecting and identifying a new species of root-lesion nematode (*Pratylenchus* *dakotaensis*) recently discovered in a soybean field in North Dakota. In Wisconsin, they developed a molecular identification PCR protocol for *Pratylenchus spp* differentiation.

**Objective 2. Determine interactions of nematodes with other pests and pathogens and the impact of nematodes on plant and soil health.**

North Dakota, Minnesota, Michigan, and Wisconsin participated in this objective. A micro-plot study was conducted to evaluate the effects of *Pratylenchus penetrans* and *Fusarium oxysporum* on growth and yield of ‘Red Norland’ potato in North Dakota. Their research demonstrated the potential damage by the presence of both pathogens. In Minnesota, a simulated cold environment in growth chamber and freezer was used to study whether any life stage of SCN in pennycress roots can survive at low temperature and frozen conditions. Experiments were initiated at one field site in 2019, and another field site in 2020 to study effect of planting dates of oilseed cover crop pennycress on the SCN population densities in Corn-Pennycress/Soybean-Corn production systems. In Michigan, they are applying the SFW model to assess the effect of land use and cropping systems on soil health outcomes and using the Fertilizer Use Efficiency (FUE) model to assess the potential sustainability of the outcomes. In Wisconsin, a study to determine damage function for soybean yield loss due to *Pratylenchus penetrans* (Pp) was carried out. They quantified the impact of Pp to the early growth and yield of soybean in field and greenhouse conditions. They have also made the first attempt to estimate yield loss caused Prateylenchus spp in soybeans based on counts in soil samples and also greenhouse relative yield loss caused by Pp. They estimated yield loss to be 0.77% across Wisconsin in 2020.

**Objective 3. Develop and disseminate research-based information on the biology and management of plant-parasitic nematodes of economically important crops in the NCR.**

Iowa, South Dakota, Illinois, Wisconsin, North Dakota, Kansas, Indiana, Missouri, and Kentucky are participating in the 2nd SCN coalition. The 2nd coalition is sponsored by USB, NCSRP and several private Ag industries. The goal of the 2nd coalition is to encourage soybean growers to test their soils so they can know the SCN population in their soils and also to rotate PI88788 SCN resistance with other sources of resistance. In several participating states, testing for SCN is free for soybean producers, courtesy of the checkoff dollars from the respective states. In Kansas, information on level of resistance in commercial soybean cultivars is published annually at <http://www.agronomy.k-state.edu/services/crop-performance-tests/soybean/>. The results obtained from this project have been used in classroom training for crop diseases and for training of certified crop advisors. For Minnesota, the SCN research data were used in SCN extension activities at the 2021 University of Minnesota Southern Research and Outreach Center Agronomy Field Day (virtual). Also the 2020 SCN variety test data were published in "2020 Soybean Field Crop Trials Results". In Missouri, a SCN webinar series was put on by the University of Missouri and the University of Kentucky over 3, one-hour sessions covering SCN basics, genetics, and management during the 2020 winter period. In Iowa, a list of 849 soybean varieties resistant to SCN for 2020 was compiled and made available on the internet.

In Illinois, Dr. Schroeder is currently digitizing the electron micrograph collection of Dr. Burt Endo (USDA). These data comprise approximately 40,000 individual images. His team has scanned approximately 15,000 of these and annotated approximately 1,000. Annotated images are uploaded to the open access IL Data Bank <https://databank.illinois.edu/>.

All states in the group have given extension talks and published extension articles recommending management practices for plant parasitic nematodes as indicated in the publication list below.

**Outputs:**

Thirty one peer reviewed publications, 21 Extension articles, and one book chapter published on the biology and management of PPNs.

**Impact Statements**

* Surveys of SCN field populations for virulence to sources of resistance were conducted.
* Over 500 soybean varieties and lines were tested for resistance to the soybean cyst nematode (SCN). Information on resistance levels of commercial soybean cultivars populations of SCN provides growers with information necessary to increase profitability of soybean production in SCN-infested environments.
* Nine different seed-treatments with putative protective effects against PPNs were evaluated in field, greenhouse, and microplot trials.
* Experiments evaluated cover crops for the control of and potential host status for PPNs.
* New molecular techniques leading to easier diagnosis of PPNs were developed. New molecular detection and identification methods provide rapid and sensitive diagnostic methods, improve nematode detection efficiency, and are essential for nematode management.
* 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.
* Knowledge of the prevalence of SCN and HG Types is guiding soybean breeding efforts and providing soybean producers with information vital to variety selection.
* Information on the distribution and host range of plant parasitic nematodes species will be used to improve recommendations for reducing nematode losses various crops through crop rotation and cover crop selection.
* Current information on the efficacy of nematode-protectant seed treatment products is being disseminated at grower meetings and field days to improve knowledge-based management decisions.
* A damage function representing the relationship between soybean yield loss and initial population densities of *P*. *penetrans* was developed for Wisconsin.
* Information on pennycress as a host of SCN has been provided to producers when using this crop as a cover crop in SCN infested fields.

**Refereed Publications:**

1. Acharya, K., Yan, G. P**.**, and Berti, M. T. 2020. Evaluation of diverse cover crops as hosts of two populations of soybean cyst nematode, *Heterodera glycines*. Crop Protection 135: 105205, https://doi.org/10.1016/j.cropro.2020.105205.
2. Acharya, K., Yan, G. P., and Plaisance, A. 2021. Effects of cover crops on population reduction of soybean cyst nematode, *Heterodera glycines*. Plant Disease 105: 764-769, doi: 10.1094/PDIS-08-20-1778-RE.
3. Alasmary, Z., T. Todd, G.M. Hettiarachchi, T. Stefanovska, V. Pidlisnyuk, K. Roozeboom, L. Erickson, L. Davis and Zhukov, O. 2020. Effect of soil treatments and amendments on the nematode community under Miscanthus growing in a lead contaminated military site. Agronomy 10:1727; doi:10.3390/agronomy10111727.
4. Androwski, R. J., Asad N, Wood J, G., Hofer A, Locke S, Smith C. M., Rose B, and Schroeder, N. E.2020. Mutually exclusive dendritic arbors in *C. elegans* neurons share a common architecture and convergent molecular cues. PLOS Genetics. 16(9):e1009029
5. Bali, S., Hu, S., Vining, K., Brown, C., Majtahedi, H., Zhang, L., Gleason, C. and Sathuvalli, V. (2021) Nematode Genome Announcement: Draft genome of Meloidogyne chitwoodi, an economically important pest of potato in the Pacific Northwest. Molecular Plant-Microbe Interactions doi.org/10.1094/MPMI-12-20-0337-A
6. Bali, S., Zhang, L., Franco, J and Gleason, C. (2021) Biotechnological advances with applicability in potatoes for resistance against root-knot nematodes. *Current Opinion in Biotechnology* 70, 226-233
7. Bali, S., Zhang, L., Franco, J and Gleason, C. (2021) Biotechnological advances with applicability in potatoes for resistance against root-knot nematodes. Current Opinion in Biotechnology 70, 226-233
8. Bali,S., Hu, S., Vining, K., Brown, C., Majtahedi, H., Zhang, L., Gleason, C. and Sathuvalli, V. (2021) Nematode Genome Announcement: Draft genome of Meloidogyne chitwoodi, an economically important pest of potato in the Pacific Northwest. *Molecular Plant-Microbe Interactions* doi.org/10.1094/MPMI-12-20-0337-A
9. Chowdhury, I. A. and Yan, G. P. 2021. Development of real-time and conventional PCR assays for identifying a newly named species of root-lesion nematode *(Pratylenchus dakotaensis)* on soybean. International Journal of Molecular Sciences22: 5872, https://doi.org/10.3390/ijms22115872.
10. Haarith D., Kim D. G., Chen S., and Bushley K. E. 2021. Growth chamber and greenhouse screening of promising in vitro fungal biological control candidates for the soybean cyst nematode (*Heterodera glycines*). Biological Control 160:104635. doi.org/10.1016/j.biocontrol.2021.104635.
11. Habteweld, A., Brainard, D. Kravchenko, A. Parwinder, P.S. and Melakeberhan, H. (2020). Characterizing nematode communities in carrot fields and their bioindicator role for soil health. *Nematropica* 50: 201-210.
12. Habteweld, A., Brainard, D. Kravchenko, A. Parwinder, P.S. and Melakeberhan, H. (2020). Effects of integrated application of plant-based compost and urea on soil food web, soil properties, and yield and quality of a processing carrot cultivar. *Journal of Nematology* 52. DOI: 10.21307/jofnem-2020-11.
13. Han J, Schroeder NE,and N Kleczewski. 2021. A survey of plant-parasitic nematodes in Illinois corn fields, 2018 and 2020. Plant Health Progress. Accepted.
14. Handoo, Z. A.,Yan, G. P., Kantor, M. R., Huang, D., Chowdhury, I. A., Plaisance, A., Bauchan, G. R., and Mowery, J. D. 2021. Morphological and molecular characterization of *Pratylenchus dakotiensis* n. sp. (Nematoda: Pratylenchidae), a new root-lesion nematode species on soybean in North Dakota, USA. Plants 10: 168, https://doi.org/10.3390/plants10010168.
15. Harbach, C.J., E.B. Wlezien, and G.L. Tylka. 2021. A mechanistic approach to assessing the potential for cover crops to serve as trap crops for the soybean cyst nematode. Plant Disease 105:1136-1142. https://doi.org/10.1094/PDIS-05-20-0964-RE
16. KC, A., Yan, G. P., Acharya, K., Plaisance, A., and Khan, M. F. R. 2021. Occurrence of plant-parasitic nematodes in sugarbeet fields of North Dakota and Minnesota. Crop Protection 142: 105503, https://doi.org/10.1016/j.cropro.2020.105503.
17. Lartey, I., A. Kravchenko, T. Marsh, and H. Melakeberhan (2021). *Meloidogyne hapla* occurrence relative to nematode trophic group abundance and soil food web conditions in soils and regions of selected Michigan vegetable production fields. *Nematology* 23: <https://DOI.org/10.1163/15685411-bja10091>
18. Legner, C.M., G.L. Tylka, and S. Pandey. 2021. Robotic agricultural instrument for automated extraction of nematode cysts and eggs from soil to improve integrated pest management. Scientific Reports 11:3212. https://doi.org/10.1038/s41598-021-82261-w.
19. Mao, L., Liu, Y. J., Zhang, J. J., Okerblad, J., Chen, S. Y., and Johnson, N. C. 2021. Soil biota suppress maize growth and influence root traits under continuous monoculture. Plant and Soil 461:441-455. doi.org/10.1007/s11104-021-04848-6.
20. Melakeberhan, H., G. Bonito, A.N. Kravchenko (2021). Application of nematode community analyses-based models towards identifying sustainable soil health management outcomes: A review of the concepts. Soil Systems 5, 32. <https://doi.org/10.3390/soilsystems5020032>
21. Melakeberhan, H., Z. Maung, L. Lartey, S. Yildiz, J. Gronseth, J. Qi, G.N. Karuku, J.W., Kimenju, C. Kwoseh, and T. Adjei-Gyapong (2021). Nematode community-based soil food web analysis of Ferralsol, Lithosol and Nitosol soil groups in Ghana, Kenya and Malawi reveals distinct soil health degradations. *Diversity* 13: 101. <https://doi.org/10.3390/d13030101>
22. Saikai, K., and MacGuidwin, A. 2020. Difference in lesion formation by male and female *Pratylenchus penetrans*. Journal of Nematology 52:1-9. DOI: <https://doi.org/10.21307/jofnem-2020-090>
23. Saikai, K., and MacGuidwin, A. 2020. Intraspecific variation in phenotypic and phylogenetic features among *Pratylenchus* *penetrans* isolates from Wisconsin, USA. Journal of Nematology 52:1-17. :<https://doi.org/10.21307/jofnem-2020-102>
24. Shi, A. N., Gepts, P., Song, Q. J., Xiong, H. Z., Michaels, T. E., and Chen, S. Y. 2021. Genome-wide association study and genomic prediction for soybean cyst nematode resistance in USDA common bean (*Phaseolus vulgaris*) core collection. Frontiers in Plant Science 12:624156. doi: 10.3389/fpls.2021.624156.
25. Subbotin, S. A., **Yan, G. P.**, Kantor, M., and Handoo, Z. 2021.On the molecular identity of *Paratylenchus nanus* Cobb, 1923 (Nematoda: Tylenchida). Journal of Nematology 52: 1-7, DOI: https://doi.org/10.21307/jofnem-2020-127.
26. Sun, M., Chen, S., and Kurle, J. 2021. Interactive effects of soybean cyst nematode, arbuscular-mycorrhizal fungi, and soil pH on chlorophyll content and plant growth of soybean. Phytobiomes Journal. 10.1094/PBIOMES-03-21-0024-R.
27. Thuo, A. K., Karuku, G. N., Kimenju, J. W., Kariuku, G. M., Wendot, P. K. and Melakeberhan, H. (2020). Seasonal variation of nematode assemblage and diversity on selected soil groups in Kenya: Vertisols, Cambisols and Arenosols. *Tropical and Subtropical Agroecosystems* 23 (2):
28. Thuo, A. K., Karuku, G. N., Kimenju, J. W., Kariuku, G. M., Wendot, P. K. and Melakeberhan, H. (2020). Factors influencing the relationship between nematode communities and edaphic factors on selected soil groups in Kenya: Vertisols, Cambisols and Arenosols. *Tropical and Subtropical Agroecosystems* 23(2):
29. Tylka, G.L. and C.C. Marett. 2021. Known distribution of the soybean cyst nematode, *Heterodera glycines*, in the United States and Canada in 2020. Plant Health Progress 22:72-74. doi.org/10.1094/PHP-10-20-0094-BR.
30. Upadhaya, A., **Yan, G. P.**, Secor, G., and Robinson, A. 2020. Effects of co-inoculation with *Pratylenchus penetrans* and *Fusarium oxysporum* on growth and yield of potato cultivar Red Norland. American Journal of Potato Research97:246-255. <https://doi.org/10.1007/s12230-020-09770-8>.
31. Vieira, P., Peetz, A., Mimee, B., Saikai, K., Mollov, D., MacGuidwin, A., Zasada, I., and Nemchinov, L. G. 2020. Prevalence of the root lesion nematode virus (RLNV1) in populations of *Pratylenchus penetrans* from North America. Journal of Nematology 52:1-10.

**Book chapter:**

1. Inglis, D. A., Riga, E., and Yan, G. P. 2021. Diseases caused by nematodes, Pages 61-66 in Compendium of Pea Diseases and Pests, third edition, APS Press, St. Paul, MN, U.S.A.

**Extension publications**

1. Berti, M. and Yan, G. P. 2020. Reducing soybean cyst nematode with brown mustard and winter camelina. North Dakota Soybean Council 2020 Research Report.
2. Bissonnette, K.M. Missouri Soybean Disease Guide. 2nd Edition. Missouri Soybean Merchandizing Council. Winter 2021.
3. Bissonnette, K.M., Tenuta, A., and Faske, T. Soybean cyst nematode. Crop Protection Network. April 2021
4. Byamukama, E. and Strunk, C. 2019. Consider SCN sampling this spring. SDSU Extension Newsletter published May 2021.
5. Byamukama, E., and Strunk, C. 2020. Fall is a good time to test your soil for SCN. SDSU Extension Newsletter published August 2020.
6. Byamukama, E., Strunk, C., and Tande, E. 2020. Soybean cyst nematode in South Dakota: History, biology and management. Factsheet, SDSU Extension.
7. Chen, S. Strategies for managing the changing HG Types of the soybean cyst nematode. University of Minnesota Southern Research and Outreach Center Agronomy Tour, June 22, 2021. (Virtual
8. Evin, B., Frost, K., Kinkel, L., MacGuidwin, A., Knuteson, D., Gevens, A, Larkin, B. Disease Suppressive Soils <https://potatosoilhealth.cfans.umn.edu/education>
9. Evin, B., Frost, K., Robinson, A., Pasche, J., Knuteson, D., Gevens, A., MacGuidwin, A., Hao, J. A Brief Overview of Soil-borne Pathogens & Pests in Potato Production Systems <https://potatosoilhealth.cfans.umn.edu/education>
10. Frost, K., Evin, B., Marks, M., MacGuidwin, A., Knuteson, D. Biofumigation:Is it a viable alternative? [https://potatosoilhealth.cfans.umn.edu/education](https://potatosoilhealth.cfans.umn.edu/education" \t "_blank)
11. Gleason, C., MacGuidwin, A., and Knuteson, D. Nematodes for Soil Health <https://potatosoilhealth.cfans.umn.edu/education>.
12. Markell, S., Yan, G. P., and Nelson, B. 2020. Soybean cyst nematode distribution in North Dakota. North Dakota State University Cooperative Extension Service Publication - Crop and Pest Report. Issue 4: Pp 8-11.
13. Melakeberhan, H. and S. Kekaire (2021). Managing Nematodes, Cover Crops, and Soil Health in Diverse Cropping Systems: MSUE Extension Bulletin (E3457). <https://www.canr.msu.edu/resources/managing-nematodes-cover-crops-and-soil-health-in-diverse-cropping-systems>
14. Tylka, G. 2020. Fall is a great time to sample fields for SCN - especially in 2020. Iowa State University Integrated Crop Management News (7 October 2020).
15. Tylka, G. 2020. SCN-resistant soybean varieties for Iowa - by the numbers. Iowa State University Integrated Crop Management News (23 November 2020).
16. Tylka, G. 2020. Soybean varieties with SCN resistance other than PI 88788. Iowa State University Integrated Crop Management News (7 December 2020).
17. Tylka, G. 2021. ISU SCN-resistant Soybean Variety Trial Program results for 2020 (11 January 2021).
18. Tylka, G. 2021. Sampling corn fields to assess potential for yield loss from plant-parasitic nematodes. Iowa State University Integrated Crop Management News (8 June 2021).
19. Tylka, G. 2021. SCN in Iowa: a serious problem that warrants renewed attention. Iowa State University Integrated Crop Management News (11 June 2021).
20. Tylka, G.L. and M. P. Mullaney. 2020. Soybean cyst nematode-resistant soybeans for Iowa. Iowa State University Extension Publication PM 1649, 26 pp. https://lib.dr.iastate.edu/extension\_pubs/100
21. Tylka, G.L., G.D. Gebhart, C.C. Marett, and M.P. Mullaney. 2020. Evaluation of soybean varieties resistant to soybean cyst nematode in Iowa – 2020. Iowa State University Extension, publication. IPM-52, 24 pp. <https://lib.dr.iastate.edu/extension_pubs/99>.
22. Yan, G. P.,Neupane, K., and Plaisance, A. 2020.Screening cover crops for managing the root-lesion nematode, *Pratylenchus**penetrans*, 2020 Research Reports. Pages 131-143, Minnesota Area II Potato Research and Promotion Council and Northern Plains Potato Growers Association.