2015 Annual Report, Multistate Project NE-1040

Title: Plant-Parasitic Nematode Management as a Component of Sustainable Soil Health Programs in Horticultural and Field Crop Production Systems

Period Covered: 10-2014 to 09-2015

Date of this report: 20 September 2017

Annual Meeting Dates: 21-22 October 2015

Accomplishments

Objective 1: Develop effective and economically-viable cultural management tactics for plant-parasitic nematodes based on host resistance, nematode antagonistic rotation or cover crops, soil amendments and biological agents.

Samples from potentially *Meloidogyne hapla* suppressive soils associated with *Pasteuria* were provided to Dr. Don Dickson in Florida for experimental purposes. We had previously observed a decline of populations of the northern root-knot nematode *Meloidogyne hapla* over time in field plots infested with the nematode since 1995 and repeatedly inoculated with the pathogen. *Pasteuria* endospores were observed on the cuticles of *M. hapla* juveniles exposed to soil and endospore-filled females were observed. Dr. Dickson was unable to repeat these results with *M. hapla* from Florida.

Biocontrol fungi were examined for impact on cyst nematodes. *Arthrobotrys* spp. *Purpureocilium lilacinus, Trichoderma harzianum* or *Plectosphaerella cucumerina* were allowed to grow over *Globodera tabacum* cysts in water agar for two weeks. Cysts were then removed, hatched in *Solanum ptychanthum* root diffusates and crushed to count remaining encysted juveniles. Hatch in diffusates was greater for three of the fungi than the control (agar alone). There were no differences in the residual encysted juveniles remaining in cysts, but the controls had fewer hatched and residual J2 than two of the biocontrol fungi. We did not count the J2 that hatched in the agar over the two weeks, but it would suggest that *Arthrobotrys* spp. and *Purpureocilium lilacinus* inhibited hatch of cysts while in the plates during the two weeks of fungal exposure. This agrees with a previous finding by our collaborator that *P. lilacinus* delayed the development and maturity of *Globodera pallida* on potatoes. Further experiments in pots and the influence of the fungi on hatch are under way.

Pepper breeding lines under development by the USDA Vegetable Lab in Charleston, SC were provided by Dr. Judy Thies for evaluation against *Meloidogyne hapla* in Connecticut. Two S4 lines had been screened against *M. hapla* in SC and were quite resistant. We evaluated 20 replicate pots of each of these lines and a susceptible control pepper variety 'California Wonder' in the greenhouse in pots and in the field over two growing seasons. All transplants were inoculated with 6,000 eggs and juveniles of *Meloidogyne hapla.* Root weights in the field plots for 1390 and 1348 were one third to one half of the weight of California Wonder, respectively. Galling of line 1348 was less than California Wonder in pots and in the field, but galls per g root

were not different. Line 1390 did not appear to be resistant to *M. hapla*. These results differ from the results of evaluations conducted in South Carolina and, together with differences in *Pasteuria* infection and development may indicate very significant differences in host range and other characteristics between the populations of *M. hapla*. This should be an investigation in the future, especially if the resistance in the pepper lines is utilized in future variety development.

SCN-resistant variety trials indicated that SCN Type 2 populations are increasing and the utility of Pl88788 derived cultivars is decreasing. The highest bean yields were associated with Pl548402 derived cultivars. BCN resistant cultivar research demonstrated that cultivars marketed as resistant are BCN tolerant and not BCN resistant. 2014 seed treatment research with Votive® (Bacillus firms) from Bayer and Clariva® (*Pasteuria nishizawae*) from Syngenta provided soybean cyst nematode (SCN) control and associated yield increases in some, but not all, field test locations. In all cases, however, the positive response was only associated with SCN resistant varieties. Sugar beet yield increases with Clariva® were marginal and impacts on beet cyst nematode were not detectable. Numerous cover greenhouse trials were conducted for host status analysis in relation to SCN and BCN. The results clearly indicated that host status for both nematodes is cover crop cultivar and not plant species specific. New long-term potato early-dying and cherry replant cover crop trials were initiated for the discovery of methodologies designed to replace current approaches. A six-year tart cherry orchard floor management trial resulted in significantly higher cherry yields than other management systems. In a cherry orchard replant soil amendment trial with compost (surface and in the planting hole applied) and mulch, the greatest first-year tree growth was associate with Starter 101® compost applied in the planting hole. In a greenhouse trial with SCN-infested soil and a SCN-susceptible cultivar, BioChar applied at 1.0 ton per acre had no impact on soybean growth or SCN populations. When the same cultivar was planted in 100 percent BioChar, shoot growth was initially stimulated and after 60 days the root systems were 4.5-fold greater than those associated with the untreated control, even in the absence of nitrogen fixation bacteria.

A pre-plant ground cover of tall fescue has been recommended as an alternative to chemical pesticides for nematode suppression in Georgia peach orchards. Root and shoot extracts from tall fescue cultivar Jesup (Max-Q) were subsequently shown to be active against *Meloidogyne incognita*. To identify active chemical components, extract fractions from tall fescue roots were evaluated for nematotoxicity.

Trap crops are being developed for nonchemical control of cyst nematodes. A solanaceous weed, sticky nightshade (*Solanum sisymbriifolium*), is being evaluated to control potato cyst nematodes *Globodera pallida*. Because of the difficulties in working with this regulated pathogen, we are conducting experiments with the closely related tobacco cyst nematode *G. tabacum* as a model system. We compared root diffusates from broadleaf cigar wrapper tobacco (*Nicotiana tabacum*), eastern black nightshade (*Solanum ptychanthum*), and sticky nightshade (*Solanum sisymbriifolium*) on egg hatch and subsequent development of the tobacco cyst nematode, *Globodera tabacum*. Root diffusates were prepared from 2 g of root of four-week-old plants soaked in 100 ml of distilled water for 2.5 hours, filtered and frozen. *Solanum ptychanthum* root diffusates stimulated juvenile hatching from eggs in cysts over 4 weeks more than root diffusates of *S. sisymbriifolium* or *N. tabacum*. Tobacco increased hatch by four times compared to water alone. *S. sisymbriifolium* stimulated twice and *S. ptychanthum* three times the

hatch of that for *N. tabacum*. *G. tabacum* juveniles were observed in stained roots of both *N. tabacum* and *S. sisymbriifolium* and development to adult females occurred within four weeks in tobacco but not *S. sisymbriifolium*. Cysts were extracted from roots and soil in pots that had been planted to *N. tabacum* or *S. sisymbriifolium* for 12 weeks and cysts crushed to count encysted juveniles. Final population densities were 324 *G. tabacum* J2 per 100 cm^3 soil for tobacco and 4.5 *G. tabacum* J2 per 100 cm^3 soil for *S. sisymbriifolium*. Sticky nightshade, *Solanum sisymbriifolium*, stimulates tobacco cyst nematode hatch better than tobacco but unlike eastern black nightshade, does not allow significant reproduction in roots, indicating that it may be an effective trap crop for management of *G. tabacum*. In addition, *G. tabacum* may be useful as a substitute model for the quarantined pathogen *Globodera pallida* for trap cropping with *S. sisymbriifolium* under field conditions.

Studies on the effects of oilseed radish and mustard as cover crops and corn and soybeans as rotation crops with sugar beets on nematodes and soil health suggest that the outcomes are soil type-specific. On-going are studies on cover crop use in vegetable and field crop production systems.

Objective 2: Evaluate cultural management procedures for plant-parasitic nematodes in relation to their impacts on the sustainability of soil health: with special research to the utility of nematode community structure as an indicator of overall soil quality and their roles in plant nutrient cycling.

Both NE-1040 and the Michigan Potato Industry must be considered as true pioneers in the current Soil Health and cover Crop Movements. An eight-year, 54-acre potato soil health trial has been established at a large commercial potato farm. The research involves two soil biologists, a molecular biologist, an agricultural economist and an environmental sensing specialist from MSU, in addition to the farm owner and two private consultants. The molecular analysis of the soil biology has documented the complexity of both the bacterial and fungal components of the ecosystem. A drone was crashed during the initial stages of the 2015 above-ground monitoring protocol. A two-day Michigan Potato Soil Health researcher and educator-only meeting was held in the spring of 2015 as a follow-up to the original 2012 workshop. As a result of this initiative, three publications, one Extension, one research review and one crop ecology are in preparation.

As part of developing sustainable alternatives to broad-spectrum nematicides, this study tested the hypotheses that compost amendment would enhance soil food web structure index (SI), improve soil biological and physicochemical properties, and increase carrot (*Daucus carota*) yield and quality, but these effects would differ by compost type and rate of application. Plant (PC) and animal waste (AC) compost was applied to supply 135, 203, and 270 kg N/ha for a processing carrot cv 'Cupar'. Urea (UR) and non-amended check (CK) were included as controls. The nematode community was analyzed from soil samples collected at approximately 4-week intervals in the 2012-2014 growing seasons. Soil respiration (SR) and physicochemical properties were determined from soils collected at planting and harvest. Compost amendments except AC at 203 kg N/ha significantly ($P \leq 0.05$) increased SI at 132 days after planting (DAP) in 2012 compared with the rest of 2012 sampling dates in Cupar, but this effect was not observed in UR and CK. At 133 DAP in 2013, all treatments significantly increased ($P \leq 0.05$) SI

compared with the previous sampling dates in 2012 and 2013. Compost amendments significantly increased P and pH compared with UR while UR significantly increased NO_3-N compared with compost amendments at the end of 2013 growing season. There was no difference in total yield and carrot quality among treatments in Cupar. Multiple factor analysis (MFA) showed positive correlation between SI and calcium, magnesium, cation exchange capacity and soil pH while negative correlation was observed for total unmarketable carrot yield in which dimension 1(33.30 %) and dimension 2 (12.60 %) represent the first and second best summary of the variability of the information. Overall, results suggest that compost amendments improved SI compared with UR. Compost amendments also increase pH in average from 7.2 to 7.7 and phosphorus in average from 53 to 61 ppm after two years. MFA result supports the importance of SI as an indicator of soil health and carrot quality. Overall, results support the tested hypotheses and suggest that the compost-based improvements in soil food web structure may lead to increases in ecosystem services provided by the soil food web.

A four-year field experiment was completed in 2012 at two locations in southern Minnesota to study the effects of cultivation and/or application of crop rotation/general biocides on natural soil suppressiveness to the soybean cyst nematode (SCN). This project represents collaboration between Senyu Chen (MN) and Deborah Neher (VT). An analysis of covariance was performed for mid-season all 4 years with NH_4, NO_3, and % organic matter as covariables. Crop rotation had more impact on breaking suppression than did tillage or biocide applications, and the major effect was observed for the fungivorous and bacterivorous nematodes. High throughput sequencing results suggest that microbial community consortia are likely involved in biological control instead of single genera or species. Extracellular enzyme analyses suggest that microbial communities produce more collegenase in no-till than cultivated soils and with continuous cultivation of soybean than rotated with corn. Collagenase is an enzyme that can damage nematode cuticle.

The effects of long-term corn-soybean crop sequences on nematode community and corn soybean yield were studied in a field site that was established in 1982 in Minnesota. The crop sequences were: (i) five-year rotation of each crop such that both crops are in years 1, 2, 3, 4, and 5 of monoculture every year; (ii) annual rotation of each crop with both crops planted each year; (iii) continuous monoculture of each crop; (vi) annual rotation of two different cultivars of each crop. From 2010 to 2014, half of each plot was treated with nematicide. Plant-parasitic nematodes were determined at planting, midseason, and harvest each year. In 2013 and 2014, nematode community including free-living nematodes in each plot was assessed. Nematicide (aldicarb) was effective against plant-parasitic nematodes, but also had negative effects on fungivores, shifting the nematode community to a lower ecological succession. Crop sequences strongly affected plant-parasitic nematodes, but also affected fungivores, bacterivores, nematode community diversity, maturity, and enrichment. *Heterodera glycines*, *Pratylenchus* spp., *Helicotylenchus* spp., and *Xiphinema* spp. are major plant-parasitic nematodes in the field. Crop sequence affected soybean and corn yields, which decreased with increasing number of years of monoculture. The nematicide aldicarb effectively reduced nematode population densities and increased both soybean and corn yields. Cropping systems in corn supported significantly greater fungivore populations, fungal decomposition pathways, more diversity, and a more mature ecosystem compared to soybean systems. Soybean systems supported significantly greater

bacterivore populations and a more disturbed, enriched ecosystem. These differences between corn and soybean systems demonstrate that each crop has a distinct impact on the soil ecosystem.

A research project has been initiated to study crop sequences effect on fungal and bacterial communities in the cysts of the SCN with cultural methods as well as metagenomic analysis. Fungi and bacteria have been isolated from the cysts in 2014, and they will be identified with morphological characteristics and DNA sequences.

Composts made of varying feedstocks and maturity were evaluated for their ability to suppress Rhizoctonia damping-off disease on radish in a bioassay. Feedstock quality alters relative competition between pathogen and biocontrol. Feedstock containing hardwood bark had the greatest suppressiveness. Mature composts are more suppressive than immature composts ($P<0.05$). As one of several biological indicators, the Maturity Index of nematode communities was evaluated as a biological indicator to predict suppression of Rhizoctonia. The compost with hardwood bark (H) as the primary C component contained greater succession maturity (MI) index values than other feedstocks including poultry waste (P), mixed food waste (F), dairy manure/silage (M) only, and mixture poultry and food waste (FB) ($p < 0.0001$).

Objective 3: Provide educational materials and programs on cultural management of plant-parasitic nematodes based on host resistance, nematode antagonistic rotation or cover crops, soil amendments and biological agents.

D. Neher co-taught PSS 268 Soil Ecology as an upper division course at University of Vermont. Laboratory exercises were designed as an experiment on land management practices of tillage and organic amendments. This work was presented as a poster at the Soil Ecology Society meeting: Cutler, A.J., Weicht, T.R., and **Neher, D.A.** Trade-off between the value of hands-on experience and quality data, Colorado Springs 8-11 June 2015. Deb Neher also gave a presentation on soil ecology at the Rock Point school in Burlington on 12 October 2015.

In partial fulfillment of this objective, a Nematode Short Course for AgriBusiness was held at Michigan State University on July 20, 2015. In addition to general sessions on nematology and soil health, there were breakout sessions on cover crops and host plant resistant management, with presenters from Iowa State University, Ohio State University, the University of Wisconsin and the Connecticut Agricultural Experiment Station , in addition to those from Michigan State University. The Short Course had 70 participants and included a cover crop field demonstration trial at the end of the day. In addition, a MSU NE-1040 representative will have been involved in approximately 40 invited soil health presentations since the initial one at the Washington State Horticultural Society meeting in December 2012 and those scheduled for the winter of 2015. The project has taken the opportunity to provide extensive leadership in training and professional development in the areas of soil health and cover crops. This has involved university, government and private sector research scientists in addition to graduate students, agribusiness representatives and growers. The NE 1040 results have been distributed to the agricultural community through a Short Course, workshops, meeting sessions, farm tours, demonstration trials, the release of preliminary data in handout format and a national webcast.

Dr. LaMondia spoke about 'The use of cover crops for management of root-knot, root-lesion and dagger nematodes as part of a day-long workshop 'Nematology Short Course for Agribusiness' sponsored by NE-1040 that was held at Michigan State University (August 20).

Michigan State continues to deliver science-based messages on the need for and what it takes to get healthy soils to growers and stakeholders at their annual reporting sessions and other science outlet avenues:
http://agbioresearch.msu.edu/news/no_matter_how_you_slice_it_healthy_soil_is_important?utm_source=MSU+AgBioResearch+E-Newsletter&utm_campaign=d2b52059b8-Futures_Spring_Summer_2015&utm_medium=email&utm_term=0_766437723c-d2b52059b8-230134969

Bird, G. 2015. *National SCN Management Webcast*, July 8, 2015, Plant Health Network, American Phytopathological Society.

Additional outreach activities associated with NE 1040 in 2015:

Neher, D. A. Nematode communities as ecological indicators of ecosystem health. Invited Symposium speaker, Organization of Nematologists of Tropical America, Varadero, Cuba, 18-22 May 2015.

Neher, D.A. Nematodes and microarthropods as environmental indicators in terrestrial and wetland soils in Connecting Phytobiomes with Soil and Plant Health symposium, Tri-Societies Annual meeting, Minneapolis, 15-19 November 2015.

Neher, D.A. and Steel, H. Biodiversity and ecological succession as indicators of compost maturity and quality. Oral presentation, Global Soil Biodiversity Conference, Dijon, France, 2-5 December 2014

Fang, L., and **Neher, D.A.** Biological indicators of compost-mediated disease suppression against the soilborne plant pathogen *Rhizoctonia solani*, Oral Presentation, Soil Ecology Society, Colorado Springs, 8-11 June 2015.

Milestones Accomplished

• Soil health meeting held in New York/Michigan focusing on report cards for soil health. Planning is currently underway to hold meetings immediately prior to the annual Society of Nematologists meeting in Michigan in 2015, combining both 2014 and 2015 milestones.

• Molecular characterization of *Melodoigyne graminis* and *Subanguina radicicola* populations. Research is in progress.

Impacts:

1. Determining the factors that contribute to suppression of plant-parasitic nematode populations by tall fescue will aid in optimizing use of this cover crop for managing nematodes.
2. The identification and use of biological controls and rotation crops that reduce plant parasitic nematode populations will assist in the development of effective nonchemical management.
3. Differences in reaction to *Pasteuria* isolates and resistance genes in pepper may be used to differentiate races of *Meloidogyne hapla*.
4. *Globodera tabacum* may be useful as a substitute model for the quarantined pathogen *Globodera pallida* for trap cropping with *S. sisymbriifolium* under field conditions.
5. Studies at Michigan State University provide an understanding of the biology of soil-plant-nematode-nutrient interactions that will lead to developing integrated and agro-biologically based nematode and soil health management strategies.
6. Knowledge of long-term agricultural practices on soil biological activities and crop productivities is aiding in the development of long-term effective strategies for management of plant-parasitic nematodes in the soybean-corn production system in the Midwest.

Publications since last report:

Bird, G. 2015 Biological protection solutions. Proceedings of the Annual Meeting of the Society of Nematologists. p.39.

Cassida, K., **Melakeberhan, H.**, Robertson, P. and Snapp, S. 2015. No matter how you slice it, healthy soil is important. Michigan State University, AgBioResearch Features. http://agbioresearch.msu.edu/news/no_matter_how_you_slice_it_healthy_soil_is_important?utm_source=MSU+AgBioResearch+E-Newsletter&utm_campaign=d2b52059b8-Futures_Spring_Summer_2015&utm_medium=email&utm_term=0_766437723c-d2b52059b8-230134969. Posted on July 26, 2105.

Elmer, W. H. and **J. A. LaMondia**. 2014. Comparison of saline tolerance of genetically similar species of *Fusarium* and *Meloidogyne* recovered from marine and terrestrial habitats. Estuarine, Coastal and Shelf Science 149:320-324. http://authors.elsevier.com/sd/article/S0272771414002650

Fang, L. 2015. Biological indicators of compost-mediated disease suppression against the soilborne plant pathogen *Rhizoctonia solani.* Master's Thesis, University of Vermont.

Habteweld, A., Brainard, D., Ngouajio, M., Kravchenko, A., Grewal, S. P. and **Melakeberhan, H.** 2015. Impact of compost amendments on soil food web, soil physicochemical properties and carrot yield. 54th Annual Meeting of the Society of Nematologists Program Abstracts. 103.

LaMondia, J. A. 2014. Plant parasitic nematodes in irrigation water. Chapter 9. Pages 83-95 in: Biology, Detection, and Management of Plant Pathogens in Irrigation Water. C. X. Hong, G. W. Moorman, W. Wohanka, and C. Büttner, eds. American Phytopathological Society, St. Paul, MN.

LaMondia, J. A. 2015. Hatch stimulation and host status of tobacco (*Nicotiana tabacum*), eastern black nightshade (*Solanum ptychanthum*), and sticky nightshade (*Solanum sisymbriifolium*) to the tobacco cyst nematode, *Globodera tabacum*. Journal of Nematology 47:251-252.

Maredia, K., **G. Bird**, D. Landis, F. Zalom, J. Landis, M. Kennelly, M. El-Bouhssini, N. Saidov, Aitmatov. 2015. Ecologically-Based Integrated Pest Management Programs for Food Security Crops in Central Asia, pp 154-172 (in) Environmental Crisis in Central Asia. E. Freeman and M. Neuzil (eds), Routledge Press, 195 pp.

Maung, Z.T.A., Poindexter, S., Clark, G, Stewart, S, Hubbell, L. and **Melakeberhan, H.** 2015. Effects of rotation and cover crops on nematode communities and soil health in different sugar beet production soils. 54th Annual Meeting of the Society of Nematologists Program Abstracts. 64.

Meyer, S.L., Zasada, I.A., Rupprecht, S.M., Vangessel, M., Hooks, C., Morra, M., Everts, K. 2015. Mustard seed meal for management of root-knot nematode and weeds in tomato production. HortTechnology. 25(2):192-202.

Nair, M.G., Seenivasan, N., Liu, Y., Feick, R.M., Maung, Z.T.A. and **Melakeberhan, H.** 2015. Leaf constituents of *Curcuma* spp. suppress *Meloidogyne hapla* and increase bacterial-feeding nematodes. *Nematology* 17:353-361.

Neher, D.A., Muthumbi, A.W.N., and Dively, G.P. 2014. Impact of coleopteran-active Bt corn on non-target nematode communities in soil and decomposing corn roots. *Soil Biology and Biochemistry* 76: 127-135.

Neher, D.A., Weicht, T.R., and Dunseith, P. 2015. Compost for management of weed seeds, pathogen, and early blight on brassicas in organic farmer fields. *Agroecology and Sustainable Food Systems* 39:3-18.

Powers, T. O., **E. C. Bernard**, T. Harris, R. Higgins, M. Olsen, M. Lodema, P. Mullin, L. Sutton, and K. S. Powers. 2014. COI haplotype groups in *Mesocriconema* (Nematoda: Criconematidae) and their morphospecies associations. Zootaxa, Vol. 3827(2): 101-146.

Shu, C., Jiang, X., Cheng, X., Wang, N., **Chen, S.**, Xiang, M., and Liu, X. 2015. Genetic structure and parasitization-related ability divergence of a nematode fungal pathogen *Hirsutella minnesotensis* following founder effect in China. Fungal Genetics and Biology doi:10.1016/j.fgb.2015.02.005.

Shu, C., Lai, L., **Chen, S.**, Xiang, M., and Liu, X. 2015. Functional response of the fungus *Hirsutella rhossiliensis* to the nematode, *Heterodera glycines*. Science China, Life Science 58:704-712 doi: 10.1007/s11427-015-4868-6.

Warner, F., A. Tenny and **G. Bird**. 2015. *SCN (HG) Type Testing: What's the Deal?* Michigan Soybean News 7:4-7.

Zhao, X., and **Chen, S.** 2015. Decomposition of dead eggs of *Heterodera glycines* in soils. Nematropica 45:113-117.

Multistate Project NE-1040 Termination Report

Title: Plant-Parasitic Nematode Management as a Component of Sustainable Soil Health Programs in Horticultural and Field Crop Production Systems

Period Covered: 10-01-2010 to 09-30-2016

Date of this report: 21 September 2017

Annual Meeting Dates: 06-07 October 2016

Participants: Provide a list of those who attended each meeting, their institutions, and their e-mail addresses. As an alternative, list the URL for the meeting minutes if that report contains the list of those who were present. And, if available, add the address for the listserver as well.

Project or Activity Leadership: Chair: E. Bernard, ebernard@utk.edu;
Secretary: R. Wick, rlwick@umass.edu

Brief summary of minutes of annual meeting: Present: Deborah Neher (host), Ernest Bernard (Presiding), Robert Wick (Secretary), Jim LaMondia, Haddish Malakeberhan, Jim Kotcon, Don Dickson, George Abawi, Nathanial Mitkowski, Senyu Chen, Tom Weicht, Elisha Allen-Perkins, Tucker Andrews and Olivia Shrantz

October 6:

Vermont (T. Weicht): Impacts of disturbance in Vermont agricultural fields, ecological indicators and function in soil systems. Physical properties, respiration protozoa nematodes microarthropods, ecoenzyme kinetics. Comparing newly tilled soil with high output organic and low output organic. Teach students nematode trophic groups. Two week crash course on learning nematodes.

Massachusetts (E. Allen-Perkins) Nematode communities on organic, hybrid and conventional golf courses. Golf courses are near each other. Compared putting greens, fairways and rough. Putting greens were creeping bentgrass. Averaged over year, total nematodes varied in putting greens and rough but not in fairways (between the different courses). Herbivores were highest on the putting green on the hybrid course and in the rough the conventional had the highest population of herbivores with no difference between hybrid and organic courses. Bacterivores had a more or less opposite trend than the herbivores. Organic courses in general had a higher maturity index and lower for the plant parasites. Organic management adds more structure to the food web.

Michigan (G. Bird) Carrots: for root lesion nematode, Nimitz, MeloCon (*Paecilomyces lilacinus*) Majestene (killed *Burkholderia*) Vydate twice as good as the control. Carrots. Vydate was best. 92% others were 83%, control 45%. Applied by spraying on the ground. (Nimitz applied by label 55% when done several weeks before) most effective when sprayed at planting but this is off-label. Soybean cyst nematode (SCN) resistance is a problem in the Midwest

because of overuse of resistant soybean cultivars. 95% of SCN is considered aggressive so it's a looming problem. APS is sponsoring a workshop on resistance management. Beet Cyst Rootknot (BCN) management economics. Have tolerance in cultivars. Tolerant cultivars nearly triple the net crop worth and even more with a seed-treatment with Clorida (*Pasteuria*). Potato cyst nematode occurs in Kyrgyzstan and Tajikistan, looking for resistance. For Soil Health Action Research, having growers identify production and follow up with 14 different soil health indicators developed at Cornell. Only three of the 14 health indicators correlated highly with the growers opinions: water-stable aggregate, nitrogen mineralization, active carbon.

Michigan (H. Melakeberhan) Sustainable soil health programs in horticulture and field crop production systems. Effect of cover crops with mustard, oilseed radish, cereals, and legumes on lesion nematode in vegetable production systems. Two Michigan locations; treatments were fallow control, oats, oats + 'defender radish;, radish and dwarf Essex rapeseed. Results varied between locations. Differences by time (4 sample periods) as well. Stunt nematode populations were also recorded. Carrot yield was similar, forked carrots varied. Yield varied from one site to another. Nematodes as an indicator of soil quality and nutrient cycling. Looked at enrichment index; site one had no differences between cover crop treatments. Site #2 had more variation among cover crops. We conclude nematodes are not a big factor on carrot yield, cover crops did not affect nematodes Impacts on nematode community time and site variable.

Rhode Island (N. Mitkowski) Stunt and lance mostly a problem in NE; some courses have rebuilt their courses. High populations of lance nematodes results in patches of dead turf in golf greens. Stunt nematodes more evenly dispersed often in a gradient. Dursban is being used to control stunt nematodes (off label rates?). Indemnify works against stunt nematode but $3200/A is 4x more expensive than the most expensive chemical available. Indemnify is a SDHI fungicide with a high risk of resistance development. Good results with 2x rate but that would be very expensive.

West Virginia (J. Kotcon) Alternative Management systems for plant parasitic nematodes in horticultural and field crops: effects of sixteen years of compost on nematode populations. Field trials of various "green" nematicides on *Xiphinema,* dagger nematode (stem pitting was a big problem in one plot). No significant differences in dagger or lesion populations but some variation in predatory nematodes (not statistically different). Possible adverse effect on predatory nematodes but very low numbers. Concluded that after 3 years, no effect on dagger nematodes. Incorporation of nematode reducing products would be difficult in perennial orchards. *Bacillus firmus* for biocontrol. Looked at direct toxicity, behavior, and reproduction. At 10^7 CFU's the *B.* firmus treatment resulted in some non-motile nematodes. Attraction assay with bacteria and seedling roots: Nemmatodes preferentially migrated to seedling treated with soil side extract of test but not to *B. firmus* treated tomato. More j2's infected the tomato in soil extract than in the *B. firmus* treatment. The experiment was repeated with the dagger nematode. Mortality of 10% at 10^7 CFU. Attraction assay on glass slides to *B. firmus* was small but significant. No difference occurred when tomato seedlings were used. Turned out that DNA testing showed the formulated product to be *Bacillus cereus*. Re-isolation showed that about 90% of formulated product was *B. cereus* and not *B. firmus*. *B. cereus* was more "active" than *B. firmus*

Tennessee (E. Bernard) Meta-analysis of the influence of agricultural intensification and urbanization on nematode diversity and abundance. Effects of plant community types on nematode diversity. Hypothesis was that nematode diversity and abundance are greater in forest and grassland ecosystems than in urban agricultural ecosystems. Of 579 papers, 72 met the criteria for the meta-analysis. Forest had the most genera, grassland, agriculture and urban were similar. Grassland had more than agriculture and urban. Trophic diversity was found to be highest in forest for all groups. Overall abundance was highest in agricultureal soils.

October 7

Minnesota (S. Chen) Impact of winter cover crops pennycress and camelina on soybean cyst nematode (SCN) in the field: SCN reproduction in greenhouse, plants inoculated with 20,000 eggs, 3 pennycress lines allowed a moderate amount of reproduction, 7,500-9,000 eggs, soybean about 24,000 eggs. About 90 varieties were tested in the field against SCN. New source of resistance, PI 567516C, did very well against SCN races 1, 2, 3, 14 but not so well on "14a". PI 88788 reproduced very well on SCN races 1 &2. Discussed a thesis published in 2010 describing Novel SCN-resistance QTLs in PI 567616C. 'Sheyenne' x P1567516 C (14MSC09-774074) yielded almost twice as much soybean as 'Sheyenne'. Fungal communities associated with SCN in Midwest soybean-corn production systems (long term project) 5 years soybean and 5 years corn, corn-soybean annual rotation, soybean monoculture and corn monoculture. Barcoding data of fungal communities of roots (only) shows separation of soybean and corn, while overlapping when you look at rhizosphere (soil left over after shaking). Soy rhizoplane separated out but not too far from rhizosphere group. Rotating corn with soybean separates the soybean when you look at 5 different years.

Connecticut (J. LaMondia) Strawberry black root rot complex. Discussed survey of 12 years ago on nematodes and black vine weevil. Black vine weevil and black root rot seem to have disappeared in the area. Several cycles of rotations can reduce nematode populations over several years; can it be accelerated? Various mixtures of covercrops were planted in spring, summer and fall; field plots and microplots. Black oats and 'Pacific Gold' oriental mustard looked good. Tobacco Cyst Nematode, *Globodera tabacum*, as a model system for *Globodera pallida*: Looking at microplots with susceptible tobacco, resistant tobacco, eastern black nightshade and litchi tomato. Litchi tomato best, followed by resistant tobacco, and an increase in population with susceptible tobacco. Diffusates from plants affects hatching of j2's. Also reported work on biological control using 4 species of fungi; not much mortality however. There was an increase in hatch in the presence of these fungi. So, you can force and then put in a trap crop. *Rudbekia herta* (prairie seed) good trap crop for lesion and root-knot nematodes.

Business Meeting

Approval of minutes: approved

Old business NE1040: need electronic report at earliest convenience.

New business NE1640: Just starting. (George) biologically based agriculture is new. Objective 3: short courses, Webinars and regional website. Mitkowski, Crow and Wick; turfgrass short course

in 2017. Wick will do vegetable crop short course in 2020. Webinars would include extension publications. George suggests that a grant proposal be written to help develop the Webinar. Regional website would be open to everyone; would require funding to put together and maintain.

Invitations for 2017: Rhode Island, E. Bernard will Chair. R. Wick will be secretary for next year

Resolutions: Thanks to Deb Neher very much for hosting our meeting 2016.

Adjourn: 11:10

Summary of Accomplishments:

Objective 1: Develop effective and economically-viable cultural management tactics for plant-parasitic nematodes based on host resistance, nematode antagonistic rotation or cover crops, soil amendments and biological agents. The most significant results are provided below.

Substantial advances were made toward management of nematodes by a range of non-pesticide approaches, including biological control, biofumigants, cover crops, trap crops, resistance, crop rotation, soil amendments, nematode-suppressive soils, as well as more basic work on nematode population dynamics and symptoms on plants. In addition, chemical management research was conducted on high-value crops and turf for which no alternative approaches are yet viable. In **biological control**, a significant advance was made by the ability to propagate the bacterial nematode pathogen *Pasteuria* in a bacteria-feeding nematode. These nematodes can be propagated limitlessly in agar culture, thereby providing a ready source of inoculum and the potential for h high-throughput sequencing systems to provide the first genome sequence to be obtained for *Pasteuria*. This sequence may in turn provide a template with which to decipher sequences from *Pasteuria* species with biocontrol potentials that are often contaminated with genes from other soil-borne bacteria. Application of a species of *Paenibacillus*, a soil-borne bacterium related to *Pasteuria*, to soybean cyst nematode (SCN) infested soil resulted in yield increase equivalents of up to 7 bu/acre. A proprietary product containing *Bacillus firmus* also gave good control of SCN in greenhouse tests. Biocontrol fungi were extensively investigated in terms of their specialization to particular nematode life stages and interactions with trap crops. Many tested fungi stimulated hatch of SCN, which would improve trap crop efficiency by disrupting the J2 infective stage. This work correlated well with similar results using Globodera pallida on potato.

Biofumigants were tested on a variety of cultivated plants, extending our concepts of how this approach can be used. For instance, while mustard seed meals are phytotoxic as well as nematotoxic, application rates can be manipulated so they can be applied close to transplant time in vegetable crops and still achieve suppression of Meloidogyne incognita (MI, southern root-knot nematode). Application of mustard seed meal in cherry orchards as an alternative to chemical fumigants reduced population densities of plant parasitic nematodes to below the pathogenicity threshold.

Continued retreat of the use of chemical nematicide treatments on many crops has led to extensive investigation of **cover crops** for nematode management. These crops, often planted as a winter cover, should be particularly suited for more northern states since they usually grow best in cooler climates where manufactured nematicides are more difficult to apply effectively. This approach is especially important in organic production systems. Several states cooperated in a multi-year project assessing a range of cover crops for their ability to suppress root pathogens. This project used four management systems (conventional, organic, present integrated pest management (IPM) and future IPM) and nine cover crops (rye grain/hairy vetch, oats, sudax, forage radish, red clover, rapeseed, buckwheat, and wheat). Results were consistent within treatments but pointed to the complexity of the soil biome. Nematode populations were influenced by cover crops: all of the grains and rapeseed reduced populations of root-knot; whereas, red clover, radish, and rye/vetch increased populations. All cover crops, however, increased lesion nematodes; especially sudax, oats, wheat, and rye/vetch as well as the weedy fallow treatment. A similar series of treatments using pearl millet before potato resulted in a decrease in lesion nematode (*Pratylenchus penetrans*) but a rye/vetch mixture and had reduced tuber yields. *Brassica* spp. produce a broad range of glucosinolates (GSLs) that decompose into toxic metabolites that can be utilized in biofumigation for nematode management Three processed biofumigation products derived from *Brassica* spp. were equal in efficacy to a standard *Brassica* cultivar, but were more expensive, and one of the products failed to suppress *Xiphinema* (dagger nematode). The type of glucosinolate was more important than the amount. However, one continuing problem in multi-year experiments was inconsistency of results. For instance, mustard seed meal from *Sinapis alba* showed some activity against MI on tomato but results were not consistent between years. Studies on the effects of oilseed radish and mustard as cover crops, and corn and soybeans as rotation crops, with sugar beet on nematodes and soil health suggest that the outcomes are soil type-specific. Further manipulation with cover crops in rotation may have a broader impact.

Cover crops can often double both as **trap crops** and as **soil amendments**. For instance, the lowest reproduction rates for *M. hapla* (MH, northern root-knot nematode) occurred on rapeseed cultivars. Dwarf Essex and Rangi, whereas the highest reproduction occurred on mustard cultivars Tilney, Ida Gold and Caliente 199. However, all of these crops suppressed MH when they were incorporated as green manures in comparison to soybean. Thus, cover crops can serve a function of soil conservation and suppression of some pests and serve as good hosts for nematodes that are then eliminated from soil due to planned incorporation of the plants as green manure, which then decomposes to a lethal natural fumigant to further reduce nematodes. Other plants have been examined for their ability to attract nematodes that are ultimately unable to develop on their roots, including sticky nightshade (*Solanum sisymbriifolium*) for cyst nematodes and epazote (*Dysphania ambrosioides*) for root-knot nematodes.

Resistance continues to be a cornerstone for nematode management since it is the most cost-effective way to manage plant-parasitic nematodes, if resistance exists in the plant's genome. This project yielded much significant research concerning applications of resistance to pest management. This research is an ongoing and permanent feature of nematology; as new crops and germplasm are introduced, some nematodes become more serious pests or more virulent genotypes are selected by the use of resistant hosts. Greenhouse, microplot and field research were applied to a wide range of commercial crops, including potato, lettuce, vegetables,

watermelon, strawberry, sugar beet, soybean, and several small-acreage, specialty fruits and vegetables.

Resistance is often combined with **crop rotation**, which itself can include cover crops and trap crops. Typical three-year rotations used in this project were oats and clover no till/soybeans no till/rye and vetch no till; or Pacific Gold brassica tilled/sudangrass tilled/millet-forage radish tilled. These schemes were designed to enrich soil, preserve beneficial soil biota, and keep nematode populations off-balance and below damaging levels by alternating susceptible and resistant crops. This project has been a leader in studying the manipulation of crop rotation schemes to develop suppressive soils against SCN. Rotation of non-hosts and soybean along with reduced tillage increased soil suppressiveness by enhancing the activity of SCN-parasitic fungi.

This project also yielded valuable information that may have applications in the future. Nematode egg masses and galling were visualized with non-destructive two-dimensional X-ray imaging of cotton and sunflower seedlings infected with *Rotylenchulus reniformis* (reniform nematode) and MI, respectively. Egg masses of *R. reniformis* were clearly differentiated from root irregularities and MI galls were obvious. Application of this method could provide insights into how host-parasite relationships are influenced by root architecture. In a very different study, SCN was introduced into virgin cropland and its population dynamics followed for eight years. SCN densities were correlated with total nematode, free-living nematode, and bacteria-feeding nematode abundance, suggesting that conditions favoring free-living nematodes can also favor SCN. Adjusting crop practices to enhance free-living nematodes, often considered desirable for healthy soils, may also enhance SCN.

Objective 2: Evaluate cultural management procedures for plant-parasitic nematodes in relation to their impacts on the sustainability of soil health: with special research to the utility of nematode community structure as an indicator of overall soil quality and their roles in plant nutrient cycling. The most significant results are provided below.

Soil Health Management Practices: Biochar, an engineered charcoal soil amendment that sequesters soil carbon and has been associated with increased plant growth and yield, was evaluated for potential to reduce the bioavailability of cyst nematode-specific hatch signaling compounds in soil. Hatch of juveniles of *Globodera tabacum* (GT, tobacco cyst nematode) from cysts exposed to diffusates leached through Biochar was reduced compared to diffusates leached through non-amended pasteurized sandy loam soil. Both biochar amendments were effective in reducing juvenile hatch from full-strength root diffusate to levels similar to water alone or the 100-fold dilution of the root diffusate control. Biochar may adsorb host-specific hatch signaling compounds, disrupting GT host recognition and subsequent hatch stimulation.

In collaboration with the University of Ghent (Belgium), three components of soil health were examined. 1) Nematode community indicators were validated as tools to quantify the successional maturity of compost; 2) high-throughput genetic sequencing was applied to compare soils that are naturally suppressive or conducive to soybean cyst nematodes in the Midwest; 3) a suite of biological indicators were compared for their ability to predict suppression of Rhizoctonia damping-off disease on radish in a bioassay. The best predictors of disease

suppression were respiration (immature compost) and an *in vitro* plate assay to quantify suppression of *R. solani* growth (mature compost).

Nematode Community Structure Analysis (NCSA) can provide answers to fundamental questions about sustainability and the suitability of soils to support a particular nematode assemblage that benefits the landscape. NCSA is used as a surrogate for soil food web health and quality, and has proven useful as a guide for urban blight reclamation and decision-making in relation to urban agriculture development. Soil food web health and quality varies tremendously in urban landscapes and the soil nematode food web appears to be highly enriched indicating abundance of nutrients, but is less structured indicating disturbance. Compared to the urban core, soil food webs are more disturbed on the urban fringe, indicating the effect of recent development activities. There is greater un-coupling of the soil food web and nutrient cycling process with proximity to the road indicating anthropogenic impact such as chemical contamination from road salts and vehicle emissions. Gravel roads were the least disturbed nematode community. The ditch and the forest were areas of increased trophic structure, while abundance of plant-parasites was greatest along the roadside. The results suggest that conscious design and management of the forest buffer and intentional inclusion of a ditch as a roadside feature may minimize pollutant movement and protect surrounding landscapes.

A meta-analysis project was developed to assess the influence of agricultural intensification and urbanization on nematode genus and trophic diversity compared to forest and prairie ecosystems through analysis of published literature. Meta-analysis of nematode communities in 539 published papers was conducted to compare the diversity and abundance of those communities according to trophic and colonizer-persister (CP) groups among urban, agricultural, and forest ecosystems. Agricultural intensification and urbanization negatively impacted nematode community diversity, which is critical for the maintenance of soil ecosystem services and resilience, although abundance was higher in agricultural ecosystems than in forest and urban ecosystems because of higher abundance of lower trophic and CP groups, indicating disturbance of the soil food web.

Nematode genera from 3 ecosystems (grassland, cropland, and forest) were analyzed to compare relative magnitude of energy pathways through the soil food web (67 data sets). The patterns of soil energy pathways were similar whether expressed as relative abundance or relative biomass. Relative abundance of bacterivorous nematodes was similar among ecosystems but mean values of biomass were greatest in grassland. In contrast, both relative abundance and biomass of fungivorous nematodes decreased progressively from forest to cropland and grassland ecosystems. The opposite pattern across ecosystems was observed for both relative abundance and biomass of herbivorous nematodes. Energy pathways are bacteria-dominated in all of the ecosystems and fungal and herbivorous pathways are second in dominance in forest and grassland ecosystems, respectively. The relative size of the fungal-based energy pathway suggests a gradient of resource quality among ecosystems, suggesting that herbivorous-based energy pathways are more important in grassland ecosystems than reported previously.

Studies with compost products were tested for their effects on soil chemistry, nematode community composition, and yield and quality of carrot cultivars. The Maturity index (MI) in

compost-treated plots was higher than in the controls, and the fertility index in compost-treated plots was lower, suggesting improved soil conditions. There was astrong correlation between c-p1 bacteriovores and NO3-N. Soil food web structure appears to mature with time. The results support the hypothesis that compost-based improvements in soil food web structure may lead to increases in ecosystem services provided by the soil food web.

Objective 3: Provide educational materials and programs on cultural management of plant-parasitic nematodes based on host resistance, nematode antagonistic rotation or cover crops, soil amendments and biological agents. The most significant results are provided below.

This objective focused on outreach activities to communicate results and conclusions to target audiences and stakeholders. Results were distributed to the agricultural community through a Short Course, workshops, meeting sessions, farm tours, demonstration trials, the release of preliminary data in handout format and a national webcast (http://agbioresearch.msu.edu/news/no_matter_how_you_slice_it_healthy_soil_is_important?utm_source=MSU+AgBioResearch+E-Newsletter&utm_campaign=d2b52059b8-Futures_Spring_Summer_2015&utm_medium=email&utm_term=0_766437723c-d2b52059b8-230134969). Project leaders in CT, NY, PA and VT provided a series of workshops on diagnosis, on-farm assessment and management of plant-parasitic nematodes; this series began with the prvious project and extended into NE-1040. Other collaborative efforts included a turf grass management conference for 300 attendees presented by project leaders from MA and RI. A Nematode Short Course for AgriBusiness was held at Michigan State University in 2015, with 70 participants and several presenters from the NE-1040 project.

Project leaders in individual states also presented information and recommendations developed whole or in part from project research efforts. For instance, a multi-year program on management of *Ditylenchus dipsaci* on garlic was prepared and executed in NY. A number of valuable publications synthesizing all of the available knowledge on management of nematodes in sugar beet, soybean and potato agriculture were distributed by an MI member of the project. Among these publications were Pocket Field Guides on Potato Nematodes and Soil Fumigant Reregistration Regulations. Many members gave presentations to grower, commodity and consumer groups that related directly to project objectives, such as nematode community structure analysis, cover crops, role of nematodes in nutrient mineralization and nature of soil health. This project also featured significant international interaction. Most notably, an MI member devoted extensive time to international soil quality education outreach in Montenegro and Central Asia (Kyrgyzstan and Tajikistan). The TN representative gave invited presentations to two groups of Chinese agricultural officials on plant-parasitic nematodes and the role of nematode communities in soil health.

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