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| Project Number:  | 2020-172-0151 |
| Project Title:  | Seedling Diseases of Soybean: Characterization and Education |
| Organization:  | Southern Illinois University |
| Principal Investigator Name: | Jason P Bond |
| **National Soybean Checkoff Research Database** [**https://www.soybeanresearchdata.com/**](https://www.soybeanresearchdata.com/) **(public website funded by USB). Please include a non-technical summary along with your project status. The non-technical summary will be published to the website. If a non-technical summary is not provided, the contents of this entire report will be published.** |
| Project Status - What key activities were undertaken and what were the key accomplishments during the life of this project? Please use this field to clearly and concisely report on project progress. The information included should reflect quantifiable results (expand upon the KPIs) that can be used to evaluate and measure project success. Technical reports, no longer than 4 pages, may be included in this section.  |
| Objectives:1. Impact of environmental conditions, cover crops and other production practices on early season pathogens and the soil/root microbiome
2. Interaction of seedling and seed pathogens with seed quality affecting soybean emergence and seedling vigor
3. The relationship between Iron deficiency chlorosis and Fusarium diseases in soybean
4. Extension and Outreach

**North Dakota State University – Berlin Nelson**We continued our research on environmental factors, such as temperature, soil type, moisture, and interactions between these factors, on Fusarium root rot caused by *F. solani* and *F. tricinctum.* We published a paper on the effect of temperature on growth and disease development by these two *Fusarium* pathogens. Temperature had a significant effect on disease development in cotyledons and roots after 1-week incubation. The most favorable temperature for disease in cotyledons was 30°C for *F. solani* and 25°C for *F. tricinctum*. For roots, the optimal temperature for *F. solani* was also 30°C, but root disease by *F. tricinctum* was highest at 15°C. In infested soil after 4 weeks, lesion lengths on roots were longer and disease incidence was greater for *F. solani* at 30°C versus lower temperatures, whereas for *F. tricinctum* the optimum temperature for root disease was 15°C. The thermal specific characteristics of these pathogens implied disease development by *F. solani* is favored by warmer temperatures, while in *F. tricinctum* it is favored by cooler temperatures.To assess the effect of soil type on infection of soybean, three types of soil (Glyndon sandy loam, La prairie silt loam and Fargo silty clay) which represent soils of the soybean production regions in the Red River Valley were examined in greenhouse and field studies. Soil type significantly affected disease development, with higher severity in light soils of Glyndon sandy loam and La Prairie silt loam compared to heavy soil of Fargo silty clay. Soil type also interacted with *Fusarium* species, in which the maximum severity was observed in Glyndon sandy loam for *F. solani*, and in La Prairie silt loam for *F.* *tricinctum.* The cumulative effects of soil type, temperature and soil moisture were tested in growth chamber. Emergence and disease of seedling were evaluated at 3 weeks after inoculation. Significant reductions in emergence occurred at 10°C in treatments with *F. solani* and *F.* *tricinctum*, but there was no significant difference among the three soil types. Infection was visible at temperatures of 10-20°C for *F. solani* and 15-20°C for *F. tricinctum*. *F. solani* caused the greatest infection at 20°C in Glyndon sandy loam, while it was at 15°C in La Prairie silt loam for *F. tricinctum*. The two *Fusarium* species were able to cause root rot in soil moisture ranging from 20% to 100% water holding capacity (WHC) in soil. The biggest reduction of emergence was observed at 80% WHC in silt loam and silty clay soils and 40% WHC in sandy loam soil. The range of soil moisture causing infection was negatively correlated with temperature. At lower compared to higher temperatures there was a broader range of soil moistures resulting in infection. At 18°C, the greatest infection occurred at soil moistures of 20-80% WHC, while it was 40-80% WHC at 28°C. There were differences between *F. tricinctum* and *F. solani* in their sensitivity to environmental changes and the subsequent amount of disease development in plants. We continued our investigation on the effects of the macroconidia concentration and the additive effects of soybean cyst nematode, *Heterodera glycines*, on the severity of Fusarium root rot. The percentage of root discoloration and the length of lesions on taproots increased as spore numbers increased, with significant effects of spore concentrations starting at 104 and 105 macroconidia/ml soil for *F. solani* and *F. tricinctum*, respectively. Root rot severity caused by *F. solani* and *F. tricinctum* showed similar trends when *H. glycines* was added to the soil. In the greenhouse, root discoloration and lesion length were significantly greater in plants inoculated with *Fusarium* spp. and *H. glycines* at 10 eggs/ml soil or greater, compared to *Fusarium* spp. alone. In the field trials, co-inoculation of the two Fusarium spp. with *H. glycines* significantly increased root rot severity at a nematode population of 16.7 eggs/ml soil. The results indicated that the presence of soybean cyst nematode can increase severity of root rot caused by *F. solani* and *F. tricinctum* and egg level in the soil is an important factor in the interaction of *H. glycines* with these Fusarium root rot pathogens. We conducted multiple greenhouse experiments using eight different soybean varieties and several isolates of *F. virguliforme* from North Dakota, and measured emergence, pre and post-emergence damping-off, plant height, leaf development, and general plant health. In 2020 we had a field experiment that also examined the effect of the pathogen on seedlings. The results showed significant negative effects of the pathogen on emergence and seedling development, an area that has not received a lot of research attention. In addition, cultivars with reported resistance to SDS foliar symptoms, in general, showed greater resistance to pre-emergence damping off by the pathogen. For example, the moderately resistant variety MN 0302, had significantly greater emergence (85%) at 9 days after planting than the susceptible variety Spencer (3.5%). Furthermore, seedling development and the production of trifoliate leaves were more rapid in varieties with some level of resistance. **Iowa State University - Leonor Leandro** At ISU, our work has focused on testing the effects of soil amendments with green manures on seedling rot caused by *Fusarium acuminatum* and *Pythium sylvaticum*. In the earlier quarters, we developed and optimized greenhouse protocols with Fusarium species. In last two quarters we conducted three greenhouse experiments, two with *P. sylvaticum* and one with *F. acuminatum*. Effect of green manure amendments on seeding disease caused by *Pythium sylvaticum*In the first run of the experiment, root rot severity ranged from 5-40%, with the inoculated control showing average of 30%. The green manure amendments with oat did not affect root rot but rye significantly reduced root rot to 7%. Oat amendment caused in non-inoculated plants caused discoloration of the roots which might have confounded the results. Shoot and root dry weights were not affected by green manure amendments in plants infected by *P. sylvaticum*. In the second experimental run, root rot severity caused by *P. sylvaticum* was low ranging from 5-13%. The green manure amendment did not have a significant effect on root rot compared to *Pythium* alone. There were also no effects on dry or shoot dry weight. Therefore, the results from the two experimental runs are inconclusive and the experiments need to be repeated with a higher disease pressure to verify the results.Effect of green manure amendments on seeding disease caused by *Fusarium acuminatum*The first run of an experiment to test the effect of green manures of oat, alfalfa and rye on seedling disease caused by *Fusarium acuminatum* was conducted in July-August. In this experiment, root rot severity was low and ranged from 5-20%. Green manure amendments did not affect soybean root rot severity compared to control infected plants not amended with green manures. However, the green manures alone tended to cause some root discoloration or rot that was more severe than in infected plants. In summary, to date we did not obtain clear evidence to state if green manure amendments with rye, oat or alfalfa affect seedling disease caused by *P. sylvaticum* and *F. acuminatum*. This is in contrast with our work on *F. virguliforme* (funded by other sources), where we have seen a consistent suppression of SDS due to amendments with oat green manures. It is possible that the low severity observed in the experiments conducted so far may have reduced our ability to detect any effects. In the next year of funding we plan to continue to conduct greenhouse experiments to clarify if green manures with different crops affect seedling disease caused by *P. sylvaticum* and *F. acuminatum*. We found no difference in Fusarium species' frequency on roots of plants with and without IDC, suggesting that infection by Fusarium is not a key driver in the development of this syndrome.**Kansas State University – Chris Little**Cultural management of *Brassica juncea* and impacts on soil and seedling *Fusarium* pathogen populations.* Total *Fusarium* spp. were measured in soil samples acquired prior to mustard planting and after mustard cultural treatments. Treatments were as follows: (1) No mustard (control), (2) mustard left standing, (3) mustard rolled, (4) mustard mowed, (5) mustard disked in. It appears that the rolled mustard treatment showed lower *Fusarium* spp. soil populations. More data will be forthcoming concerning the impact of these management approaches on soybean seedling root colonization.

Controlled, microscale studies with *B. juncea* ("mustard") cover crops and *Fusarium proliferatum* (FPR).* The first experiment has been to test the direct interaction between *Brassica juncea* extracts and the pathogen in *in vitro* studies. Mustard plants were grown in the greenhouse, harvested at mid-vegetative, flowering, or senescence stage. Plant tissues were dried, ground, and diluted in sterile-distilled water. Extracts were applied to filter paper disks and placed on one edge of a quarter-strength plate, and an *F. proliferatum* isolate placed on the other side of the plate. Colony growth and colony distance from the filter disk were measured over three days after plating. Results of the preliminary experiment have shown a significant interaction between FPR isolate and plant extract stage (vegetative, flowering, senescent tissue, or control [no extract] for colony growth slop).

**Martin Chilvers – Michigan State University**The Chilvers lab completed a study evaluating the influence of the fungicides metalaxyl and ethaboxam on isolation probability of oomycetes (*Pythium* spp.) from soybean taproot or lateral root sections. In some site-years, the probability of isolating an oomycete from a taproot or lateral root section was significantly different. Seed treatments containing a combination of ethaboxam and metalaxyl significantly reduced the probability of oomycete isolation from lateral roots in one site-year, but not others, which may have been related to the heavy soil type (clay loam) combined with approximately 10 cm (~4”) of rain two weeks after planting. Among the 439 oomycete isolates collected from the two years sampled, 24 oomycete species were identified, and community compositions were different depending on location and year. The five most abundant species were *Pythium sylvaticum* (28.9%), *Pythium heterothallicum* (14.3%), *Pythium ultimum* var. *ultimum* (11.8%), *Pythium attrantheridium* (7.9%), and *Pythium irregulare* (6.6%) which accounted for 61.7% of the isolates collected. There were large differences in ethaboxam sensitivity by oomycete species with EC50 ranging from < 0.01 to > 100 μg ml-1. Isolates with insensitivity to ethaboxam (> 12 μg ml-1) belonged to the species *Pythium torulosum* and *Pythium rostratifingens* but were sensitive to mefenoxam. Sensitivity to mefenoxam ranged from < 0.01 to 0.62 μg ml-1. The mean EC50 of the five most abundant species to ethaboxam ranged from 0.35 to 0.97 μg ml-1 of ethaboxam or from 0.02 to 0.04 μg ml-1 of mefenoxam. No shift in sensitivity to mefenoxam or ethaboxam was observed due to soybean seed treatment or year relative to the non-treated seed controls. In summary, this study demonstrated that isolation of oomycetes from soybean can depend on the tissue, location, year, and seed treatment. Additionally, seed treatments containing mefenoxam or metalaxyl and ethaboxam can be effective to reduce the probability of oomycete isolation from soybean roots. In a related study we explored the sensitivity of oomycete species to ethaboxam and found particular oomycete groups to be sensitive to the fungicide and others insensitive (resistant), indicating the importance of combination seed treatments. The Chilvers lab also worked with MSU soybean breeders to identify QTL’s for resistance to *Pythium sylvaticum*. We also developed a transformation system for the soybean sudden death syndrome pathogens *Fusarium virguliforme* and *Fusarium brasiliense*. The information from these studies will improve seedling disease management, through the selection and use of the appropriate fungicide. Two extension articles describing advancements in our understanding of oomycete seedling disease and were published on the Crop Protection Network. **University of Arkansas – John Rupe and Alejandro Rojas**Cover crop. The second year of the cereal rye cover crop termination test was planted at the Lon Mann Cotton Research Station, Marianna, AR. The cover crop treatments were different termination dates for the cereal rye. Termination was in February, March, and at planting. Weather prevented the January termination. Within each cover crop termination plot, six seed treatments were established. The greatest biomass occurred with CC4 but was less than last year. Very few plant pathogenic nematodes were found in the planting and mid-season samplings. Harvest samples are being processed. There were no differences in stands between seed treatments or cover corps. There were differences in soil nutrients. This was the second year of the cover crop. There were no differences in yield. The above seed treatments except the treatment containing Avicta were incorporated into an existing cover crop test at the Vegetable Research Station, Kibler, AR. The cover crop treatments were cereal rye, black oats, barley, Austrian winter pea, blue lupin, a mix of black oats and Austrian winter pea, a mix of cereal rye, crimson clover, and Seven-Top turnip, and a fallow control. This test was planted May 29. There were no significant differences in stand or yields between treatments. Stands averaged 77,023 plants/a and yields averaged 61.9 bu/a.Cover crop interaction with soilborne pathogens. Taproot decline, caused by *Xylaria* sp. is an emergent disease of soybean in the southern United States. The hypothesis is that cover crops could serve as potential hosts for this pathogen or the increase of organic matter will favor the prevalence of *Xylaria*. A field trial was established at Milo Shult Research & Extension center at Fayetteville. The test had a randomized block design with four cultivars inoculated or non-inoculated and each treatment combination had four replications. The cultivars with the lowest stand were ‘Archer’ and ‘Sloan’ with 50.1 and 43.5 plants per row at 15 days and 50.8 and 48.7 plants per row at 30 days. The cultivar with the higher stands was foundation cultivar ‘UA5715GT’ followed by ‘Hutchenson’. Soil samples and roots were collected for each inoculated plot and those are being processed for DNA extraction. In addition, aerial imagery was collected in September 15th with multispectral sensor to evaluate plant performance. The plots will be harvested, and cereal rye will be seeded in half of the plot in a split design for the following season. In growth chamber experiments, we continue looking at the interaction of TRD with these cultivars and helping to develop methods to detect TRD using DNA based techniques.**University of Arkansas – John Rupe and Alejandro Rojas.** Seed Treatments. The seed treatment test was planted at two locations (Southeast Research Station, Rowher, AR, on 3 June and the Vegetable Research Station, Kibler, AR, on 11 June). Each test consisted of an early cultivar (3901C a MG 3.9 cultivar from Missouri) and the late cultivar (UA5715GT, a MG 5.7 cultivar from Arkansas). The two cultivars were included to determine if an early maturing cultivar is more likely to experience yield loss from seedling disease than a late maturing cultivar since it has less time to compensate for stand loss than the later maturing cultivar. High and low vigor seed lots were generated for each cultivar by subjecting the high vigor seed to high temperature and relative humidity. This resulted in lower germination and lower seed vigor. At Kibler, there was a significant cultivar by seed vigor by seed treatment interaction on stand. With high vigor seed there were no significant differences between seed treatments or cultivars. Low vigor seed there were no differences between seed treatments with UA5715GT. However, stands of all seed treatments were greater with high vigor than low vigor seed of 3901C. The greatest stands within each cultivar and vigor group occurred with seed treated with CruiserMaxx Vibrance Beans. The results with 3901C showed the importance of treating low vigor seed with a seed treatment. There were significantyield differences with both high and low vigor seed of 3901C. With high vigor seed, CruiserMaxx\_Vibrance\_Beans, Avicta\_Complete\_Beans, EverGol\_Energy, and Trillex had yields that were significantly greater than the control. With the low vigor seed, all seed treatments resulted in yields greater than the low vigor control. Yields of UA5715GT are being processed. These results show the importance of using a seed treatment with low vigor seed. There were no treatment effects at Rohwer with stands averaging 66 seedlings/200 planted seed and yields averaging 23.9 bu/a across both cultivars. Heavy weed pressure significantly lowered yields.Low quality seed and interaction with soilborne pathogens. Advance aging (AA) was used to generate batches of seed with reduced quality for cv. Hutcheson. Seed batches of low-quality seed (AA induced) and high-quality seed (untreated) of soybean cv. Hutchenson were used to setup a growth chamber experiment with the soilborne pathogens *Pythium sylvaticum* and *Xylaria* sp. At planting Hutchenson had a gemination rate 84% (high quality) vs 54% (low quality). Overall, low quality seeds yield lower plant biomass but the effect was exacerbated by soilborne pathogens. The biomass reduction was greater for *Pythium* than for *Xylaria*. The same pattern was observed for root mass for all treatments.Soil samples were collected in two locations (Chico county and Lincoln county) that exhibited different levels of TRD, a grid sampling was conducted on both locations collecting 40 samples and 70 samples respectively. **Southern Illinois University – Ahmad Fakhoury and Jason Bond**We completed cover crop and long-term no-tillage (40 years) research and the impact on pathogens and microbial communities. **University of Kentucky – Kiersten Wise; University of Tennessee – Heather Kelly; Ontario Ministry of Agriculture, Food and Rural Affairs – Albert Tenuta**Improved information on seedling disease management was developed in this project. Videos, fact sheets, guides, in person trainings and webinars will lead to better management of disease leading to increased economic returns, improved yields and quality of the U.S. soybean crop.

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| Did this project meet the intended Key Performance Indicators (KPIs)? List each KPI and describe progress made (or not made) toward addressing it, including metrics where appropriate.  |
| **Specific proposed outcomes:**1. Determine how soil moisture affects disease development in soybean seedling roots caused by *Fusarium solani* and *F. tricinctum*.

Substantial progress was made in understanding the effects of environmental factors on root rot caused by *Fusarium solani* and *F. tricinctum*. In depth studies on temperature, soil type, soil moisture and the interactions among these factors were completed. Models were created to show the relationship between temperature and pathogen activity in plants. Differences in the effects of soil type on disease development for the two pathogens were demonstrated. Interactions between soil type, temperature and soil moisture were shown for the two pathogens. The range of soil moisture favoring infection was negatively correlated with temperature. There were differences in the sensitivity of the two pathogens to environmental changes and the subsequent amount of disease development in plants. In addition, studies on conidial concentration and the additive effects of soybean cyst nematode were completed. Models were developed for root discoloration against inoculum concentration and root lesion length against inoculum concentration. These studies showed the presence of soybean cyst nematode can increase the severity of root rot caused by F. solani and *F. tricinctum* and egg level is an important factor in the level of severity. One other study showed a relationship of inoculum level to damping off of soybean by *F. virguliforme* and how resistance to SDS foliar symptoms can also result in less pre-emergence damping-off.1. Validate the usefulness of FSSC 11 primers for determining the extent of infection of soybean roots in North Dakota soybean production.

Research has shown that the FSSC 11 primers can be used as a tool to assess infection and subsequent frequency of infected soybean plants in the field. Thus far, there is no evidence that the primers are identifying other species within the general Fusarium population on roots. The primers are also useful for general greenhouse studies when presence of the pathogen in host tissue is in question. The pathogen can be detected in both root and above ground tissue, but accuracy is improved if plant tissue is not in advanced stages of decay as secondary microorganisms can rapidly colonize such tissue.1. Determine the importance of seed treatments in soybean planted into a variety of cover crops.

Work was completed. Yields and disease severity were not different across treatments when planted following cover crops. Future work may focus on how disease severity was impacted by the cover crops. 1. Determine if cover crops increase or decrease seedling disease and which pathogens are most affected.

Work is still ongoing. In this project the cultivars of cover crops tested have not proven to be significant hosts to soybean pathogens.1. Determine the effect of cover crop and seed treatment on soil health parameters.

Work is still ongoing.1. Determine the effect of cover crop incorporation into soil as green manures on seedling disease caused by *Fusarium acuminatum* and *Pythium sylvaticum*

Work is still ongoing. We did not obtain clear evidence to state if green manure amendments affect seedling disease caused by *P. sylvaticum* and *F. acuminatum*. 1. The diversity of seedborne fungi at different seed quality levels will be determined in two environments.

Work is still ongoing.1. Determine which seed treatments are beneficial or detrimental to low quality seed.

This work was completed. 1. Determine how seed treatments can alter interactions between low-quality seed and seedling and seed-borne pathogens.

This work was completed. 1. Evaluate the impact of seed quality on plant resilience and the interaction with soil microbial community.

Work is still ongoing.1. Determine the impact of seed treatments and root type (lateral vs. tap) on the recovery of oomycete species

This work was completed. 1. Determine the fungicide sensitivity of Pythium species to mefenoxam (metalaxyl) and ethaboxam

This work was completed.  |
| Expected Outputs/Deliverables - List each deliverable identified in the project, indicate whether or not it was supplied and if not supplied, please provide an explanation as to why. |
| 1. Information about soybean seedling diseases was distributed at a booth at the Farm Machinery Show in Louisville, February 12-15, 2020. Over 80,000 people attended the Farm Machinery Show, and over 3,000 publications were distributed to attendees, making them aware of the resources available for soybean seedling disease management through the soybean checkoff.
2. Hosted a webinar with the Crop Protection Network, “Seedling Disease of Soybean and Using Seed Treatments to Reduce Losses” <https://youtu.be/0Skpq1P7peU>, which was viewed live by over 70 attendees.
3. Research summaries with CPN to highlight take home messages from seedling disease research. Released these through SRII and CPN.
4. The CPN publication Seedling Diseases of soybean was also updated: doi.org/10.31274/cpn-20190620-023
5. The soybean seed treatment fungicide efficacy guide was updated: doi.org/10.31274/cpn-20190620-015
6. Two research updates were created through CPN to highlight the results of key research on oomycete and fungicide sensitivity results.

1. Detection and prevalence of oomycete seedling diseases on soybean. Chilvers, M.I., McCoy, A., Noel, Z., Rojas, A., Faske, T., Mueller, D., Smith, D., Tenuta, A., Wise, K. https://cropprotectionnetwork.org/resources/publications/detection-and-prevalence-of-oomycete-seedling-diseases-on-soybean Crop Protection Network doi.org/10.31274/20200918-2. Soybean seed treatment and oomycete fungicide resistance testing. Chilvers, M.I., McCoy, A., Noel, Z., Rojas, A., Robertson, A., Faske, T., Mueller, D., Smith, D., Tenuta, A., Wise, K. https://cropprotectionnetwork.org/resources/publications/soybean-seed-treatments-and-oomycete-fungicide-resistance-testing Crop Protection Network doi.org/10.31274/20200918-0  |
| Describe any unforeseen events or circumstances that may have affected project timeline, costs, or deliverables (if applicable.) |
| Covid-19 impacted all research groups and many projects were delayed for several months. Several projects are now being completed.  |
| What, if any, follow-up steps are required to capture benefits for all US soybean farmers?Describe in a few sentences how the results of this project will be or should be used. |
| Many of the results have already been released to farmers by extension publications, field day presentations and other large meetings. Additionally, efforts are needed to multiple this effort by releasing the information through new avenues and also at high profile events. |
| **List any relevant performance metrics not captured in KPI’s.** |
| **Publications:** 1. Cochran, K., Steger, A., Holland, R., & Rupe, J. C. (2020). Effects of soybean cultivar, foliar application of azoxystrobin, and year on seed vigor and microflora under delayed harvest conditions. *Plant Disease*, Phttp://doi.org/10.1094/PDIS-04-20-0843-RE.]
2. Lin, F., Wani, S.H., Collins, P.J., Wen, Z., Li, W., Zhang, N., McCoy, A.G., Bi, Y., Tan, R., Zhang, S., Gu, C., Chilvers, M.I., Wang, D. 2020. QTL mapping and GWAS for identification of loci conferring partial resistance to *Pythium sylvaticum* in soybean (Glycine max (L.) Merr). Molecular Breeding 40, 54 https://doi.org/10.1007/s11032-020-01133-9
3. Nelson Jr., B., Wilkinson, A., Markell, S. and Langseth, C. 2019. First Report of sudden death syndrome of soybean caused by *Fusarium virguliforme* in North Dakota. Plant Disease. Published Online:25 Sep 2019 <https://doi.org/10.1094/PDIS-08-19-1737-PDN>
4. Noel, Z.A., McDuffee, D., Chilvers, M.I. 2020. Influence of soybean tissue and oomicide seed treatments on oomycete isolation. Plant Disease <https://doi.org/10.1094/PDIS-03-20-0642-RE>
5. Noel, Z.A., Chang, H.-X., Chilvers, M.I. 2020. Variation in soybean rhizosphere oomycete communities from Michigan fields with contrasting disease pressures. Applied Soil Ecology 150:103435 <https://doi.org/10.1016/j.apsoil.2019.103435>
6. Noel Z.A., Sang, H., Roth, M.G., Chilvers, M.I. 2019*.* Convergent evolution of C239S mutation in *Pythium* spp. B-tubulin coincides with inherent insensitivity to ethaboxam and implications for other Peronosporalean oomycetes. Phytopathology <https://doi.org/10.1094/PHYTO-01-19-0022-R>
7. Noel, Z.A., Rojas, A.J., Jacobs, J.L., Chilvers, M.I. 2019. A high-throughput microtiter fungicide phenotyping platform for oomycetes using Z’-factor. Phytopathology 109:1628-1637 <https://doi.org/10.1094/PHYTO-01-19-0018-R>
8. Roth, M.G., Chilvers, M.I. 2019. Protoplast Generation and Transformation Methods for Soybean Sudden Death Syndrome Causal Agents *Fusarium virguliforme* and *F. brasiliense*. Fungal Biology and Biotechnology https://rdcu.be/bCnE6
9. Srour, A. Y., Ammar, H. A., Subedi, A., Pimentel, M., Cook, R. L., Bond, J., & Fakhoury, A. M. (2020). Microbial Communities Associated With Long-Term Tillage and Fertility Treatments in a Corn-Soybean Cropping System. *Frontiers in microbiology*, *11*, 1363
10. Hui Yan & Berlin Nelson JR (2020): Effect of temperature on *Fusarium*

*solani* and *F. tricinctum* growth and disease development in soybean, Canadian Journal of Plant Pathology, DOI: 10.1080/07060661.2020.17458931. Hui Yan & Berlin Nelson JR (2020): Effects of Spore Concentration and Interaction with *Heterodera* *glycines* on Soybean Root Rot caused by *Fusarium solani* and *F. tricinctum.*

Plant Dis.104. (accepted for publication with revision on 10-26-20)**Extension publications:**1. Detection and prevalence of oomycete seedling diseases on soybean. Chilvers, M.I., McCoy, A., Noel, Z., Rojas, A., Faske, T., Mueller, D., Smith, D., Tenuta, A., Wise, K. https://cropprotectionnetwork.org/resources/publications/detection-and-prevalence-of-oomycete-seedling-diseases-on-soybean Crop Protection Network doi.org/10.31274/20200918-1
2. Soybean seed treatment and oomycete fungicide resistance testing. Chilvers, M.I., McCoy, A., Noel, Z., Rojas, A., Robertson, A., Faske, T., Mueller, D., Smith, D., Tenuta, A., Wise, K. <https://cropprotectionnetwork.org/resources/publications/soybean-seed-treatments-and-oomycete-fungicide-resistance-testing> Crop Protection Network doi.org/10.31274/20200918-0
3. Rupe, J. Holland, R. and Rojas A. Effect of Termination Dates of Cereal Rye Cover Crop on Soybean Seedling Disease and Yield. Pest Management: Disease Control. 2019 Soybean Research Series.
4. Detection and prevalence of oomycete seedling diseases on soybean. Chilvers, M.I., McCoy, A., Noel, Z., Rojas, A., Faske, T., Mueller, D., Smith, D., Tenuta, A., Wise, K. https://cropprotectionnetwork.org/resources/publications/detection-and-prevalence-of-oomycete-seedling-diseases-on-soybean Crop Protection Network doi.org/10.31274/20200918-
5. Soybean seed treatment and oomycete fungicide resistance testing. Chilvers, M.I., McCoy, A., Noel, Z., Rojas, A., Robertson, A., Faske, T., Mueller, D., Smith, D., Tenuta, A., Wise, K. https://cropprotectionnetwork.org/resources/publications/soybean-seed-treatments-and-oomycete-fungicide-resistance-testing Crop Protection Network doi.org/10.31274/20200918-0

**Abstracts:**1. Yan, H. and Nelson Jr., B. 2019. Effects of macroconidial concentration and *Heterodera glycines* on Fusarium root rot of soybean caused by *Fusarium solani* and *F. tricinctum*. Phytopathology 109: S2.191. https://doi.org/10.1094/PHYTO-109-10-S2.1
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| **Non-technical summary:** |
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