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| Project Number:  | 1420-732-7230 |
| Project Title:  | Combining Integrated Pest Management with Climate Change, Mitigation, and Adaptation in Soybean-Corn Cropping Systems |
| Organization:  | Iowa State University, Michigan State University, University of Illinois Urbana-Champaign, and University of Wisconsin-Madison,  |
| Principal and Co-Principal Investigators Name: | ISU - Dr. Daren Mueller, Dr. Leonor Leandro, Dr. Mike Castellano MSU- Dr. Andrey Guber, Dr. Alexandra KravchenkoUIUC- Dr Darin Eastburn, UW – Dr. Vince Davis, Dr. Shawn Conley |
| 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.  |
| **Project activities:****Performance Measure: Effect of cover crop management on water, nitrogen, carbon, and soybean biomass**Iowa State Dr. Mike Castellano, Iowa State University***Effect of cover crops before soybean on soybean health and productivity.*** Rye cover crops was planted after corn and soybean in 2014 and 2015 and terminated at different times intervals before planting next season crop in 2015 and 2016. Cover crops before soybeans produce 300% more biomass than cover crops before corn in 2015. This extra biomass increases nitrogen retention by 100% and speeds soil health improvement without negatively affecting soybean yield. Soybean yield was similar in early and late terminated cover crop plots. Cover crops before soybeans are easier to manage and more successful than cover crops before corn because they have more time to grow. Cover crops produce more biomass before soybeans for two reasons: 1) soybeans are planted on average three weeks after corn and; 2) cover crops can be terminated as little as one day before soybean planting without impacting soybean yield whereas, cover crops must killed at least10 days before corn planting to avoid corn yield loss. In fact, our results show no difference in soybean yield following a cover crop killed three weeks prior to soybean planting vs. a cover crop that was killed one day before soybean planting. In 2016, late terminated cover crops plots yielded slightly more yield than bare and early terminate cover crop. Early terminated cover crop produced more corn yield than bare plots. Michigan StateDr. Andrey Guber and Dr. Alexandra Kravchenko, Michigan State University ***Field experiments. Effect of cover crop and termination date on corn and soybean***The effect of cover crops and termination time was studied at two experimental sites (Mason and LTER KBS) at several topographical positions with contrasting soil and hydrological characteristics during three growing seasons (2014-2016). Specifically, we looked at terrain summit (SU), slope (SL), low areas not subject to flooding (DNF) and a low area subject to flooding (DF). The experimental sites were in corn-soybean rotation with both phases of the rotation present every year. Cereal rye was the cover crop used in the study, planted in fall after corn and/or soybean harvests. When followed by corn as the main crop, the rye cover was terminated in spring two weeks before planting. When followed by soybean as the main crop, the rye was terminated at two different time points - two weeks before corn planting, i.e., at the same time as in the corn plots, referred to as "early termination", and immediately before the soybean planting, referred to as "late termination". A detailed monitoring of soil moisture, total N and C, soil nitrates and ammonium, plant biomass and N content, and corn and soybean yield was conducted at 20 experimental plots in Mason and 18 experimental plots in LTER KBS. Also we measured kinetics of N and C release from rye residue combined with soil temperature and water content monitoring in Spring 2016 at both experimental sites and all topographical positions. Precipitation, solar radiation, wind speed, air humidity and temperature were monitored at both sites. Basic soil properties and soil hydraulic properties were measured at four depths at all monitoring locations. We also used soil properties collected for USDA CSCAP project at the plots not monitored in this project. Surface topography was surveyed at 0.5 m resolution to obtain high resolution DEM. *Findings from the field experiments:*Yields of rye, corn and soybeans varied spatially and temporally due to soil topography and year-to-year variation in the weather. Generally, the correlation between the cash crop yields and cover crop biomass at termination was weak or statistically not significant. The yields of cash crops did not correlate with rye biomass, except for corn at Mason site in 2016. Corn yield reduction at a rate of 9 kg ha-1 per 1 kg rye ha-1 in rye biomass at termination was observed in 2016. This reduction was not associated with the surface topography and was not observed for corn or soybean yields in 2012-2015.The effect of topography on the crop yield was examined using the analysis of frequencies and deviation of crop yields and rye biomass from average values across the fields. The results demonstrated that:* Rye biomass was consistently the highest at topographical summits and the lowest at the flooded depression. Intermediate biomass values were observed at terrain slopes, which were somewhat lower than the biomass at the not flooded depression. On average, the rye biomass values were of 78% above the field-averaged values at summit, while of 18%, 42% and 48% below the field-averaged values at the not flooded depression, the flooded depression and the slope, respectively.
* The deviation of rye biomass from field-average values was also different for different topographical elements. The rye biomass at summit was above the average at 92% probability, while was below the average at 63%, 74% and 85% probability at not flooded depression, slope and flooded depression respectively.
* The highest values of corn yields were observed in not flooded depressions, while yield values were the lowest in the flooded depression. On average, the corn yield was 19% above the field-averaged corn yield in the not flood depression, close to field-averaged yield at the summits and the slopes, while 14% below the field-averaged values in the flooded depression.
* The highest values of soybean yields were observed at not flooded depression, while yield values were the lowest at the flooded depression. On average, the soybean yield was of 37% above the field-averaged yield at the not flood depression, close to field-averaged yield at the slope, while of 7% and 12% below the field-averaged values at the summit and flooded depression, respectively.

Nitrogen uptake by cover crops during fall, winter and spring seasons reduced NO3 contents in soil profiles. These reductions are not consistent due to year-to-year variations in weather but were observed more frequently on slopes and less in the not flooded depression. The analysis of frequencies and deviation of NO3 contents in soil profiles from the average values across the field conducted for the three years at Mason site revealed that: * Before planting cash crops, levels of NO3 on the plots allocated for corn production were higher compared to the plots allocated for soybeans. This probably reflected extra nitrogen provided by the soybean crop preceding corn, as well as the greater nitrogen uptake by the corn crop preceding soybean. Probabilities of NO3 levels smaller than average values across the field were 43% and 82% for corn and soybeans, respectively;
* Before planting soybeans, levels of NO3 in the soil were lower at the rye cover crop plots compared to the fallow plots. Probabilities of NO3 levels smaller than the average values across the field were 91% and 63% for cover crops and fallow plots, respectively;
* In the corn plots, the above-field average NO3 values were more frequent in not flooded depressions and less frequent on the slopes. Probabilities of NO3 levels smaller than the average values across the field were 11%, 26%, 45% and 60%, in not flooded depression, summit, flooded depression and slope, respectively;
* In the soybean plots, elevated NO3 values were observed more frequently in spring in not flooded depression and less frequently on the slopes. Probabilities of NO3 levels smaller than the average values across the field were 80%, 87%, 100% and 100%, in not flooded depression, summit, flooded depression and slope, respectively.

Changes in the total C and N storage in the soil profile at plots with and without rye cover crop during the studied period were smaller than the natural spatial variability in C and N contents, and therefore statistically insignificant. However, analysis of particulate organic matter and decomposition of rye residue revealed positive trends in soil organic matter related processes due to cover crop presence. Specifically:* Across all topographical positions rye residue decomposition was ~5% greater in the treatment with than without cover crop. Faster and more efficient decomposition of freshly added plant inputs by microbial decomposers in soil is known to lead to greater protection of soil organic matter.
* In slopes and summits the particulate organic carbon in the treatment with cover crop was significantly (~0.7 mg/g soil) greater than in the treatment without the cover crop, however the difference was not statistically significant in depressions. Particulate organic carbon is a labile fraction of soil organic matter that rapidly responds to changes in agricultural management. Thus, positive changes in particulate organic matter due to cover crop presence are likely the precursors of coming positive changes in total soil organic C levels. Our results indicate that in topographically diverse fields greater benefits from cover crops in terms of improvement in soil organic matter and soil carbon accrual can be achieved in summit and slope positions.

***Modeling:*** A raster-based overland water flow model was developed and coupled with DSSAT-CSM to simulate different hydrological conditions caused by runoff on the studied topographical positions. The model was calibrated and validated on the data obtained in the field experiments. The model was used to evaluate the effect of cover crops on nitrate losses and crop yields in soybean-corn rotation at a field scale for current and future weather scenarios. The future weather data included daily values of solar radiation, temperature and precipitation obtained from an ensemble prediction of 17 climate models for scenarios RCP 2.6 and RCP 6.0 for next 50 years, and downscaled for the central part of Michigan. Unfortunately, DSSAT-CSM cannot model the presence of cereal rye as a cover crop, therefore the rye biomass with C and N contents in rye measured at the monitored plots were used as the initial conditions in the simulations. *Results from Modeling*Modeling soil water and nitrogen contents in soil at different topographical locations showed that non-uniform distributions of precipitation during summer months resulted in overland water fluxes from summits and slopes toward depressions. These fluxes increased nonlinearly with increasing frequency and intensity of rainfall during summer months. The overland water fluxes decreased fractions of rainfall water infiltrated into the soil and thus caused a deficits of plant available water at summits and slopes. On the other hand, they resulted in high losses of nitrate from the root zone for deep infiltration at depressions where the run-on water added to the rainfall water. Therefore, corn and soybeans were often stressed at summits and slopes by water deficit, while corn at depressions was stressed by nitrate deficit. Despite relatively high total nitrogen contents in depressions compared to the summits and slopes, the N mineralization rates in the depressions were much lower than N leaching from the root zone, thus the nitrate losses in the depressions were not compensated by the mineralized N. The effect of rye termination time on soil C and N dynamics was not pronounced in simulations due to overall small differences in the amounts of C and N gained by rye between early and late terminations.While the studied sites did not have tile drainage, using model simulations we explored how installing such drainage would affect nitrate losses. Introducing tile drains at depressions resulted in an increasing N loses from the root zone due to increasing water discharge from the soil profiles after heavy rainfalls. Presence of cover crops at summit and slope positions is expected to reduce run-off. We hypothesized that cover crop use will result in improvements in soil structure and will increase soil water permeability, the hypothesis that was partially supported by the field observations. Thus, we simulated such potential benefit from the cover crop on reducing run-off in summits and slopes by increasing the surface water permeability via reducing the curve numbers in model experiments. The simulation results indicate that such improvements in soil structure will result in greater corn and soybean yields, however the magnitude of the yield gains varied in different weather scenarios. Specifically, the increases in infiltration did not eliminate water stress in dry years. When modeling the effect of future weather scenarios for next 50 years in the Central Michigan obtained by downscaling an ensemble prediction of 17 climate models for scenarios RCP 2.6 and RCP 6.0, we did not detect marked differences in soybean and corn yield trends from what was already observed in the studied sites. It appears that the weather extremes observed at the sites in 2011-2016 exceeded the downscaled predictions generated by the climate models. For example, the projected precipitations were distributed more uniformly across the growing season compared to the precipitation measured in 2011-2016, and did not reflect extreme drought and flooding conditions experienced at the sites during the study period. For simulation modeling at field-farm scale, more accurate weather downscaling approaches are needed to properly reflect local weather variations and to generate more reliable future yield projections.**Performance Measure: Evaluate the impacts of the suite of crop management practices tested in the USDA NIFA CSCAP project on pests**Iowa State Dr. Leonor Leandro and Dr. Daren Mueller, Iowa State University***Influence of drainage on soybean seedling health.*** A master’s student working on this project, Gang Han, graduated in May 2016. He is now working for his graduate degree in Statistics department. A Manuscript entitled “ influence of drainage on seedling health” was accepted in in the Journal of Soil and Water Conservation. In this study, Field and greenhouse studies were conducted to study the effect of drainage on seedling health. A field experiment was conducted at the Iowa State University research farm near Crawfordsville, Iowa, in 2012 and 2013. Four treatments were compared: conventional drainage (CvD, subsurface drains installed 1.2 m [3.9 ft] deep with 18.0 m [59.0 ft] spacing), shallow drainage (SD, 0.76 m [2.5 ft] deep with 12.2 m [40.0 ft] spacing), controlled drainage (CtD, 1.2 m [3.9 ft] deep and 18.0 m [59.0 ft] spacing with a water table control structure located at the outlet), and no drainage (ND, no artificial drainage). A greenhouse experiment was conducted three times to compare two soil sources (ND and CvD soil from the field experiment), two soybean cultivars (Ripley and Williams 82), and three watering intensities (low, moderate and saturated). Plants were sampled at the second trifoliate stage to assess root rot severity, root dry weight, root size, and *Fusarium* spp. incidence in roots. ***Susceptibility of cover crops* to Fusarium virguliforme *and Soybean cyst nematode:*** A master’s student working on this project, Renan Kobayashi-Leonel defended his thesis in November 2016. A Manuscript entitled “Susceptibility of cover crop plants to *Fusarium virguliforme*, causal agent of soybean sudden death syndrome, and *Heterodera glycines*, the soybean cyst nematode” was accepted in the Journal of Soil and Water Conservation. In this study, Greenhouse studies were conducted to evaluate the susceptibility of cover crop species to infection by *Fusarium virguliforme* (Fv), a soilborne fungus that causes sudden death syndrome (SDS) of soybean, and the soybean cyst nematode (SCN, Heterodera glycines), an important soybean pathogen. In the SDS experiments, cover crops were Fv-infested soil and plants were assessed for fresh biomass, root rot severity, foliar symptoms, and amount of Fv DNA in roots. In the SCN experiment, selected leguminous and non-leguminous cover crop plants were grown in soil naturally infested with SCN, and the number of females formed per root after 30 days was determined. In the SDS experiment, inoculated alfalfa, crimson clover, red clover and pea had more root necrosis than the non-inoculated controls, and Fv DNA quantities in roots did not differ from those found in soybean roots. Inoculated alfalfa, corn, crimson clover, oat, red clover, sorghum and turnip plants had lower biomass compared to non-inoculated controls, although corn, oat and turnip had no root necrosis. Biomass reduction and root necrosis were not observed in inoculated hairy vetch, false flax, millet, mustard, rye, ryegrass, triticale and wheat, and Fv DNA quantity in the roots of these species was lower than in soybean. In the SCN experiment, there were very few (zero to five) SCN females on the roots of multiple varieties of leguminous cover crop species studied. No females were recovered from the roots of any of the non-leguminous species studied, except for a single female on four plants from three different species. None of the cover crop plants studied were susceptible hosts for SCN. With the increasing interest in using cover crops as a soil conservation practice in corn-soybean production systems, it is important to understand how this practice would impact major soybean diseases. Knowing the impact that cover crops may have on SDS and SCN is important to help farmers make better decisions when planting cover crops in areas with history of these diseases.Grazieli Araldi da Silva, graduate student, working on the following projects for her PhD degree with Dr. Leonor Leandro and Dr. Daren Mueller at Iowa State University.***Identification of most appropriate grain-based inoculum substrates:*** In order to choose the most appropriate grain-based inoculum substrate to conduct field and greenhouse trials with soilborne pathogens of soybean, four different substrates (millet grain, perlite cornmeal, white rice and sorghum grain) were tested in greenhouse experiments. Substrates were very well colonized with *Fusarium oxysporum*, *Pythium sylvaticum* and *Rhizoctonia solani*; indicating that the substrates are suitable for these pathogens. Non-infested substrates cause root rot-like symptoms that can be mistaken for disease. Millet grain-based substrate was less likely to cause root discoloration and was an effective inoculum carrier for F. oxysporum, P. sylvaticum and R. solani; thus millet grain has been for the subsequent experiments.***Susceptibility of cover crop to* Fusarium graminearum *and* Pythium sylvaticum*:*** * *Petri dish assay:* A petri dish experiment was conducted to test the cover crop host range for *Fusarium graminearum* and *Pythium sylvaticum*. Seeds of seventeen cover crop species of Fabaceae, Poaceae and Brassicaceae families, corn and soybean (resistant and susceptible), were placed on petri dishes with a colony of *F. graminearum* or *P. sylvaticum*, and evaluated for germination loss, root length reduction, and root rot severity. All cover crop species tested were susceptible to *F. graminearum* and *P. sylvaticum*. The least susceptible cover crop to *F. graminearum* was hairy-vetch; and to *P. sylvaticum*, was winter pea. The most susceptible cover crops to *F. graminearum* were winter pea, rye, wheat, and false-flax; and to *P. sylvaticum*, were millet, ryegrass, sorghum, false-flax, and radish.
* *Greenhouse trial:* The same cover crops tested in the petri dish assay were also used in a greenhouse trial to identify the cover crop host range for *Fusarium graminearum* and *Pythium sylvaticum*. Seed of all species were planted in sand:soil amended with 5% (v:v) of millet grain-based inoculum infested with *F. graminearum* or *P. sylvaticum*. Only sand:soil was used as control. The experiment was conducted two times for each pathogen. Root rot severity and dry plant biomass were recorded. For all runs and pathogens tested, there was a small and no significant difference between inoculated and non-inoculated plants. This experiment is going to be repeated, using different methods.
* *Microplot study:* In 2015, a new cover crop microplot trial was established in the Agronomy farm located in Boone, IA. The purpose of this trial is to test the impact of eight cover crops on soybean seedling and root diseases caused by *F. graminearum* and *P. sylvaticum*. The cover crops used are cereal rye, oat, triticale, hairy vetch, red clover, brown mustard, rapeseed and radish. In 2015, field was artificially infested or not with *F. graminearum* or *P. sylvaticum*, and planted to soybean. In the fall of the same year, cover crops were hand broadcasted. In 2016, soybean was planted in the same area, and data for plant stand, root rot severity, *F. graminearum* and *P. sylvaticum* incidence, root and shoot weight, shoot height, healthy green leaf area, and yield were collected and analyzed. There were no significant differences in the variables analyzed over the cover crop treatments for the infested plots with *F. graminearum* and *P. sylvaticum*. No differences were observed even in the F. graminearum infested plots. However, differences were observed in the *P. sylvaticum* infested plots, excluding soybean shoot weight. Soybean stand, shoot height at V4 and R4 growth stages, healthy green leaf area, and yield were significantly greater in non-infested plots. Pythium root rot severity was significantly lower in non-infested plots. This study will be repeated in 2017.

*Effect of cereal rye on soybean seedling disease and yield:* An experiment testing the long-term effect of rye cover crop on soybean seedling and root diseases was completed at two locations, Boyd Farm and USB-Agronomy Farm in Boone, IA, in 2015 and 2016. None of the locations were artificially infested with the soilborne pathogens of interest. The treatments evaluated at Boyd Farm were no-rye and rye, and at USB-Agronomy Farm were no-rye, early-kill rye (approximately 3 weeks before planting soybean), and late-kill rye (approximately 1 week before planting soybean). Data for soybean stand, root rot severity, Fusarium spp. and *Pythium* spp. incidence, root and shoot weight, shoot height, healthy green leaf area, and yield were collected and analyzed. At Boyd Farm, no significant effects of rye cover crop was observed on the variables measured in 2015, except for healthy green leaf area measurements that showed a significant higher soybean canopy reflectance in the rye cover crop treatment compared to no-rye in both years. In 2016, soybean stand and yield were greater in no-rye than rye cover crop treatment. There was no significant difference in *Fusarium* spp. and *Pythium* spp. incidence between treatments in both years. At USB-Agronomy farm there were no significant effects of rye cover crop on the variables measured in both years, with the only exception for soybean yield in 2016, in which late-kill rye treatment resulted in higher yield than no-rye, but it was not significant different from early-kill rye. Rye cover crop did not affect seedling and root diseases in soybeans at Boyd farm and USB-Agronomy farm.*Effect Corn residue on SDS:* A field trial to test the effect of corn residue on SDS was established in 2015 in Indiana, Iowa, Michigan, South Dakota and Wisconsin. In 2015, all the plots were planted to corn. In May 6, 2016, corn was planted in half of the plots, and soybean in the other half. Corn residue and soil samples were collected prior planting soybean to determine whether corn residue harbors *Fusarium virgulifome*, and whether *F. virgulifome* is built up in soil with and without corn residue. Sudden death syndrome foliar disease and yield were also recorded. Foliar disease index was higher in residue not removed treatment than in residue removed for both tilled and no-tilled trials in Iowa. No difference was observed in Indiana and Michigan. Wisconsin did not have the data. Soybean yield was significantly lower in residue not removed treatment in no-tilled trial in Iowa, on the other hand, in Indiana, soybean yield was greater in residue not removed treatment. However, there was no significant difference between treatments in the tilled trial in both locations. Michigan and Wisconsin did not detect significant difference between treatments in the no-tilled and tilled trials. The study will be repeated in 2017.***Effect of root rot due to* Fusarium virguliforme *on soybean yield.*** A graduate student, Daniel Sjarpe*,* is working on this project for his master’s degree with Dr. Daren Mueller and Leonor Leandro at Iowa State University. *Fusarium virguliforme* O’ Donnell and T. Aoki, the soilborne fungus causes root rot and produces toxins, primarily the FvTox1, which causes foliar symptoms of sudden death syndrome. Since first reported in Arkansas in 1971, sudden death syndrome (SDS) has become economically important and widespread throughout the most soybean producing states. Several studies have been done to understand disease mechanism and it management since the discovery of the disease, however the contribution of root rot phase in the yield loss has not been studied very well. We initiated field studies in 2014 at multiple locations, Ames, Roland and Muscatine Iowa. Two seed treatment, a standard commercial base seed treatment and base seed treatment + IleVO, a commercial seed treatment fungicide released for SDS management in 2014 by Bayer crop science were applied in multiple varieties with different genetic background and level of SDS tolerance. Root rot was scored four times of the season at R2, R4, R5 and R6 on 0-100 scale based on area of root with necrotic lesions. *F. virguliforme* population in root was also quantified using a quantitative polymerase chain reaction (qPCR) technique. Foliar disease symptoms were recorded between the R5 and R7 growth stages using a standard SDS rating scale on 0-9 scale. Yield was obtained from the central two rows for the plots. Results suggested that IleVO seed treatment reduced root rot and foliar disease significantly that resulted in greater yield compared to the base treatment. Root rot and yield was negatively correlated. Contribution of the root rot to yield loss has not been clear yet we are still analyzing data however preliminary analysis showed that there was a significant contribution of root rot phase, up to 22%, in the yield loss. Illinois State Darin Eastburn, University of Illinois* Cover crop plots were established in the fall of 2014. These plots were set up using a split plot design, with tillage treatments (ridge till vs. chisel plow) as the main plot effects and cover crops, (rye, vetch, rye+vetch, mustard, and fallow as the sub-plot treatment effects.
* Tillage operations (ridge-till and chisel plow) were conducted in early May, 2015, and soybeans were planted in the plots in late May.
* Analysis of the DNA sequence data, resulting from DNA extraction of 2014 soybean and soil samples, is continuing. The data resulting from Fluidigm and Illumina HiSeq 2500 analyses are now being evaluated to see if there are differences in the microbial populations of each treatment (tillage and cover crop). We are using the web-based program Phinch for data analysis of the DNA sequencing results and the program Qiime to look for differences in microbial diversity resulting from the treatments.

Wisconsin State Vince Davis (now Shawn Conley) – University of Wisconsin***Weed Management and Nitrous Oxide Emissions***Becky Redline Bailey defended her master’s thesis in January 2015 and graduated in May 2015. “Effect of Weed Management Strategy and Row Width on Nitrous Oxide (N2O) Emissions from Soybean” (Weed Science) was accepted and is currently available online. Two manuscripts are in review: 1. “Weed management has a negligible effect on N2O emissions in Upper Midwest soils” (Journal of Environmental Quality) and 2. “Does herbicide management strategy influence N2O emissions from Midwest corn production?” (Agriculture, Ecosystems, and Environment). Becky presented two papers at the North Central Weed Science Society annual meeting in December 2014 and at the Weed Science Society of America meeting in February 2015. She also presented a poster at the 2014 North Central Weed Science Society meeting.S***oybean Genetic Gain under Different Weed Competition Levels***Research was conducted in 2014, 2015, and 2016 at the Agricultural Research Station near Arlington, WI. The experimental design was a randomized complete block in a split-plot arrangement with three replications. The whole plot factor was seeding rate (0, 2.8, and 11.2 seeds m-2) of our model weed species, volunteer corn, chosen for its high level of competitiveness and regular occurrence in Midwestern soybean fields. The sub-plot factor consisted of 40 maturity group (MG) II soybean varieties with 30 distinct years of release ranging from 1928 to 2013. In all three years soybean seed yield data were collected from each plot. Because soybean samples contained both volunteer corn and soybean seed, subsamples were collected and sorted to quantify the percentage of soybean yield by mass for each plot. In 2015 and 2016 data were collected in-season to characterize plant growth. Height and width measurements were recorded at V4 and R1 soybean for 3 marked corn and soybean plants plot-1. At R8 soybean, above-ground biomass was collected on the marked corn plants. The corn shoots were chipped and dried before recording dry biomass. Results show that when grown in the weed-free plots soybean yields were higher than those grown with the lower volunteer corn densities. More recently released varieties yielded higher than older ones. In the weed-free plots, soybean yield gain was estimated similar to previous reports of genetic gain. These slopes decreased with increasing volunteer corn densities. Comparing these to the control, the genetic gain of soybeans grown with a lower density of volunteer corn was not significantly different, but it was significant at the higher density. Corn biomass was not significantly different across years of release or between the two-planted densities. These results show that even under significant weed competition more recently released varieties of soybeans are still able to consistently yield higher than older ones. The data does not seem to suggest that soybeans have an increased competitive ability indirectly due to breeding efforts, as the regression line across release year is flat. However, this also shows that there has been no decrease in competitive ability as a trade-off for yield gain.***Response of broad spectrum and target specific seed treatments and seeding rate.*** A manuscript entitled “Response of broad spectrum and target specific seed treatments and seeding rate on soybean seed yield, profitability, and economic risk across diverse environments” is in review in crop science. In this study, field experiments were conducted in multiple locations in Indiana, Iowa, Michigan, Wisconsin and Ontario to quantify the effects of various seed treatment packages and seeding rate on soybean yield in 2015 and 2016. Economic risk and profitability of seed treatments and seeding rate for each seed treatment was also estimated. Three seed treatments with different components and relative cost were used. The three seed treatments consisted of untreated control (UTC), a commercial base fungicide + Insecticide + nematistat seed treatment (CB), and CB treatment + IleVO (fluopyram). Soybean yield was evaluated with and without history of SDS. It was apparent that sites with a history of SDS and visible SDS symptoms benefit the most from the ILeVO treatment. The CB and ILeVO seed treatments increased profit at each grain sale price and across all seeding rates compared to the UTC. Profit was calculated as follows: (Yield x Grain Sale Price) – (Seed Price + Seed Treatment Price). Economic risk analysis was applied to the profit curves to quantify the uncertainty of a seed treatment increasing profit when selected in January with no knowledge of spring disease and insect levels. Risk was measured as the break-even probability (the probability of breaking even relative to the base case of UTC at 140,000 seeds/a). At a grain sale price of $8/bu, a seeding rate reduction of the untreated seed to 120,000 seeds/a provided substantial risk benefits (99%), but profit was only increased on average $4/a. In comparison, the same seeding rate reduction for the CB maintained similar risk benefits (93%) but also provided a larger average profit increase ($9/a) with limited downside potential (-$3/a) only 7% of the time. Furthermore, the addition of fluopyram at 120,000 seeds/a improved the risk benefits of CB to an almost identical level as the UTC (98%) and provided considerably greater average profit increases for all outcomes ($14/a). Across all seeding rates and seed treatments, however, the lowest risk (99%) and largest average profit increase for all outcomes ($16/a) was ILeVO at its economically optimal seeding rate of 103,000 seeds/a. When the grain sale price increased to $11/bu, reducing the seeding rate below 120,000 seeds/a for the UTC resulting in profit losses across all outcomes of increasing magnitude as the seeding rate was lowered further. In contrast, CB was able to maintain high break-even probabilities and profit margins down to 100,000 seeds/a, while ILeVO did so down to 80,000 seeds/a. The economically optimal seeding rate, where the maximum average profit can be achieved, was approximately 112,000 seeds/a for the $11/bu grain sale price for both CB and ILeVO.  |
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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.  |
| Iowa StateKey Performance Indicator: Cover crops before soybean improve soil health. Cover crops before soybean crop produces 300% more biomass than cover crops before corn. The extra biomass increases nitrogen retention by 100% and speeds soil health improvement without negatively affecting soybean yield. High cover crop biomass may suppress weed growth and may impact certain insects and pathogens.The more cover crop biomass production, the greater the benefits to farmers and the environment. Cover crop biomass production is positively associated with nutrient retention, soil health and pest/weed management. However, these benefits are rarely observed because cover crops have not been optimized to the corn-soybean system. Cover crops produce more biomass before soybeans for two reasons: 1) soybeans are planted on average three weeks after corn and; 2) cover crops can be terminated as little as one day before soybean planting without impacting soybean yield whereas, cover crops must killed at least10 days before corn planting to avoid corn yield loss. In fact, our results show no difference in soybean yield following a cover crop killed three weeks prior to soybean planting vs. a cover crop that was killed one day before soybean planting. Key performance indicator: Drainage influences soybean seedling health.In the field experiment, root rot severity was significantly greater in the no drainage and shallow drainage treatments than in the conventional drainage treatment in 2013. *Fusarium* spp. were isolated less frequently from roots grown in ND soil than all other drainage treatments, in both years. In the greenhouse study, watering intensity significantly affected root rot on Ripley, with more water causing more root rot. Despite greater rot, roots showed increased root weight, root length, root diameter and number of root tips with increasing soil water up to saturation for both varieties. *Fusarium* incidence decreased as water amount increased. In summary, fields with high moisture are more prone to root rot but well-drained soil favors infection of soybean roots by *Fusarium* spp. Michigan StateKey Performance Indicator: Cover crop effects on soybean yield and environmental sustainability metrics.Soybean yield: presence of rye cover crop in the rotation and the timing of its termination (early vs. late) did not affect soybean yieldsEnvironmental sustainability metrics: 1) Carbon. Presence of rye cover crop increased soil particulate organic carbon, increased the rate of plant residue decomposition, and increased the amount of CO2 emissions from soil. All three metrics are early indicators of soil carbon accrual and improvements in soil organic matter. 2) Nitrogen. Presence of rye cover crop decreased levels of soil nitrates. Wisconsin StateKey performance indicator: Soybean yields were higher in weed free plots than plots with weed infestation and more recently released varieties of soybeans are able to consistently yield higher than older ones even in high weed infestation. More recently released varieties yielded higher than older ones (p<0.001). When soybean grown in weed free plots they produced more yield than those grown with the lower (p<0.001) and higher (p<0.001) volunteer corn densities by an average of 686 and 1575 kg ha-1, respectively, pooled across all varieties. In the weed-free plots, soybean yield gain was estimated at 15.6 kg ha-1 yr-1, which is similar to previous reports of genetic gain. These slopes decreased with increasing volunteer corn densities. In soybeans grown with low and high rates of volunteer corn, estimated yield gains were 13.0 and 5.4 kg ha-1 yr-1, respectively. Comparing these to the control, the genetic gain of soybeans grown with a lower density of volunteer corn was not significantly different, but it was significant at the higher density (p<0.001). Corn biomass was not significantly different across years of release or between the two planted densities. Key performance indicator: Yield response to IleVO seed treatment is better in field with SDS than without. The ILeVO seed treatment yielded only 2.1% over the CB in the sites that included fields with and without SDS compared to 5.3% in the sites with SDS data set and 6.1% in IA, which had SDS.Key performance indicator: The commercial Base and ILeVO seed treatments increased profit at each grain sale price and across all seeding rates compared to the untreated control. ILeVO at 140,000 seeds/a had an 87% chance of breaking even over the base case and on average for all outcomes (all environments) increased profit by $7/a. At a grain sale price of $8/bu, a seeding rate reduction of the untreated seed to 120,000 seeds/a provided substantial risk benefits (99%), but profit was only increased on average $4/a. In comparison, the same seeding rate reduction for the CB maintained similar risk benefits (93%) but also provided a larger average profit increase ($9/a) with limited downside potential (-$3/a) only 7% of the time. Furthermore, the addition of fluopyram at 120,000 seeds/a improved the risk benefits of CB to an almost identical level as the UTC (98%) and provided considerably greater average profit increases for all outcomes ($14/a). Not only were the benefits of CB and ILeVO present at slightly reduced seeding rates (120,000 seeds/a) but across a wide range of seeding rates from 80,000 –140,000 seeds/a. The opposite was true for the UTC, in which seed-ing rates below 100,000 seeds/a and approaching 80,000 seeds/a were risk adverse (4%) and resulted in profit loss. Across all seeding rates and seed treatments, however, the lowest risk (99%) and largest average profit increase for all outcomes ($16/a) was ILeVO at its economically optimal seeding rate of 103,000 seeds/aKey performance indicator: As grain sales prices increase, so should seeding rates to reduce economic risk and maximize profit When the grain sale price set to $11/bu, reducing the seeding rate below 120,000 seeds/a for the UTC decreased the break-even probabilities well below 50%, resulting in profit losses across all outcomes of increasing magnitude as the seeding rate was lowered further. In contrast, Commercial base was able to maintain high break-even probabilities and profit margins down to 100,000 seeds/a, while ILeVO did so down to 80,000 seeds/a when grain price is $11. One key finding is that as grain sales prices increase, so should seeding rates to reduce economic risk and maximize profit, especially for untreated seed; whereas CB and ILeVO treated seed could still maintain higher break-even probabilities and profit margins at reduced seeding rates. Yet, seeding rate adjustments were still warranted with the CB and ILeVO seed treatments to maximize profit and reduce risk as grain sale price changed. For instance, CB at 80,000 seeds/a with a grain sale price of $8/bu had a break-even probability of 76% compared to 50% when the grain sale price increased to $11/bu. The average profit increase for all outcomes also declined from $4 to $0/a. Like the lower grain sale price ($8/bu), simply adjusting the seeding rate for CB and ILeVO to the highest seeding rate (140,000 seeds/a) at the higher grain sale price did not maximize the average profit increase across all outcomes nor did it provide the greatest risk benefit. This was again achieved at the economically optimal seeding rate, which was approximately 112,000 seeds/a for the $11/bu grain sale price for both CB and ILeVO. |
| 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. |
| The following key results and subsequent recommendations for soybean and corn growers were generated by the project:Iowa State Cover corps improve soil health without negatively affecting soybean yield. Our results show no difference in soybean yield following a cover crop killed three weeks prior to soybean planting vs. a cover crop that was killed one day before soybean planting. Cover crops before soybeans are easier to manage and more successful than cover crops before corn because they have more time to grow.Cover crops especially the leguminous, for example alfalfa, crimson clover, red clover and pea, may harbor *F. virguliforme*, SDS pathogen but not the SCN. Cover crop species that are susceptible to *F. virguliforme* pathogens should be avoided when selecting cover crop especially in the locations where SDS is a major problem. Fields with high moisture are more prone to root rot but dry soil may favor infection of soybean roots by Fusarium spp.Root rot due to F. virguliforme significantly contributed in yield loss, seed treatment with fluopyram can be considered to minimize the loss due to root rot and foliar SDS symptoms. Michigan State1. Presence of a cereal rye cover crop did not have negative effects on soybean yields, regardless of the termination time.

**Recommendation:** rye cover crop presence can be extended in spring all the way to soybean planting, and then terminated immediately preceding the soybean planting. 1. A decrease of corn yield associated with cover crops was observed only in 2016, the year with particularly wet later-spring-early summer. Thus result reflects the known tendency for greater negative impact of rye cover crop on subsequent corn in the years when springs had lower temperatures and greater precipitations.

**Recommendation:** in cold and wet springs it might be beneficial to increase the window between rye termination and corn planting from recommended 10-14 days to 15-20 days.1. Presence of cover crops lead to positive trends in protection and accrual of new soil carbon. Markedly, the topographical positions that typically have lower levels of soil organic matter, e.g., summits and slopes, were found to be the ones where presence of cover crops produced greatest benefits in terms of soil carbon.

**Recommendation:** when time and labor constrains are an issue for planting cover crops across entire land, planting cover crops on slopes and summits can be an alternative option for maximizing soil organic matter benefits. 1. Modeling soybean and corn yield for the current and future weather scenarios supported the field observations that the presence of cereal rye cover crop will not have negative effect on soybean yields, regardless of the cover crop termination time. Moreover, presence of cover crops in summits and slopes will reduce run-off fluxes into topographical depressions, thus lead to decreases in nitrate losses.

**Recommendation:** when time and labor constrains are an issue for planting cover crops across entire land, planting cover crops on slopes and summits can be an alternative option for minimizing run-off and maximizing nitrate loss benefits.Wisconsin StateMore recently released varieties of soybeans are able to consistently yield higher than older ones regardless of weed pressure. In the weed-free plots, soybean yield gain was similar to previous reports of genetic gain. These slopes decreased with increasing volunteer corn densities. In soybeans grown with low and high rates of volunteer corn, estimated yield gains were 13.0 and 5.4 kg ha-1 yr-1, respectively.The CB and ILeVO seed treatments were able to decrease risk and substantially increase profit across a wide range of seeding rates. At current seed and seed treatment costs, CB and ILeVO at 140,000 seeds/a reduced economic risk by at least 70% and increased average profit ($4 –19/a) across environments and grain sale prices. However, to realize the lowest risk and highest average profit increase with CB or ILeVO, farmers should consider lowering their seeding rate to the economically optimal seeding rate of 103,000 – 112,000 seeds/a according to their expected grain sale price. In addition, fields with a history of SDS and damage from early season insects and pathogens should particularly be targeted to maximize the economic return.  |
| Describe any unforeseen events or circumstances that may have affected project timeline, costs, or deliverables (if applicable.) |
| 1. The downscaling techniques currently used to project future climate scenarios are not detailed enough to provide a reliable information for decision making on a spatial scale of individual agricultural fields or farms.
2. The duration of the project was not sufficient to see a long term effect of the cover crops on soil properties.
3. Some of the greenhouse results are not verified in field conditions because the duration of the project is not sufficient.
 |
| 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. |
| High cover crop biomass production can reduce or eliminate cover crop costs by: 1) retaining nutrients in the soil; 2) improving soil health; and 3) reducing the need for pest/weed management. Our current work has shown that a short period of extra growth can increase nitrogen retention by 30-60 lbs per acre. Cereal Rye cover crop use is also credited with reducing the loss of soil phosphorous in row crop fields to water bodies by 50% (Iowa Nutrient Reduction Strategy). The value of these nutrients is substantial. Moreover, high cover crop biomass may suppress weed growth and may impact certain insects and pathogens. We will develop web-based decision support systems that allow soybean growers to maximize cover crop benefits through interactions between corn genetics and cover crop management before soybeans.Results of this project indicated that certain actions can be undertaken by farmers to reduce nitrogen losses in depressions and reduce water stress on plants in summits and slopes, thus providing better conditions for sustainable crop production. Among such actions are: (i) improving infiltration and water retention by soil in slopes and summits; (ii) intercepting runoff fluxes from slopes and summits and redirecting these fluxes away from flooded depressions; (iii) supporting further long term studies aimed on better control of soil moisture and nutrients at different topographical elements be beneficial for development a sustainable crop production. We need to understand how management strategies and stem and root diseases interact. These studies show some important findings, but further research is needed to fully outline how soybean management decisions may affect root health and all stem diseases. |
| **List any relevant performance metrics not captured in KPI’s.** |
| N/A |