ANNUAL RESEARCH REPORT

MISSOURI SOYBEANS

LETTER FROM THE EXECUTIVE DIRECTOR

The Missouri Soybean Merchandising Council is the entity authorized by the USDA to oversee soybean checkoff dollars for Missouri soybean growers. With that comes the responsibility for investing the half of farmers' soybean checkoff dollars that stay in Missouri for state-specific programs and projects. In Missouri, those dollars go toward research, promotion and education programs – never lobbying.

The Missouri Soybean Merchandising Council (MSMC) is truly a farmer-run organization, with 13 farmer-directors from across the state elected by their peers at the helm. They oversee investments into programs and projects, as well as distribution of results – all focused on fulfilling the Merchandising Council's mission for maximizing Missouri soybean farmer profitability.

In the following pages, we share details on the research projects currently receiving checkoff funding. Each project has been and continues to be evaluated by Missouri farmers, as well as independent reviewers. Some of these are short term projects with immediate applications on the farm and in industry, others have a longer timeline. We appreciate your attention to the research process – including the progress updates and results in this annual report.

Don't hesitate to contact your farmer-directors and staff with questions, ideas and challenges. We appreciate the opportunity to work for you.

Gary Wheeler - MSA / MSMC Executive Director / CEO

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MISSOURI SOYBEANS

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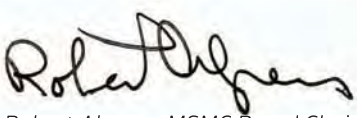
LETTER FROM THE MSMC BOARD CHAIR

Technology helps our research go farther – from sharing data and findings online to putting drones to work for scouting, aerial imagery and other assessments. It helps us know what is in our seed without destroying the genetics, and to engage the next generation in the science of agriculture. Research is a top priority for your Missouri Soybean Merchandising Council and we continue to see a greater emphasis on technology each year.

It's exciting to see the marriage of technology with the hands-on, traditional research methods – including hand-pollination in soybean breeding, walking fields to determine disease and pest pressures, and making those side-by-side comparisons through strip trials. They're successfully building on previous work to move the needle for soybean farmers, from raising yields and quality to protecting our land and water resources.

Working with the Merchandising Council, along with the research committee and their teams has been a deeply educational experience for me, and I'm glad to share their work with you through the Annual Research Report. There's so much opportunity ahead, and it's invigorating to think of where we're headed. Thank you for helping make this possible, and for your continued support.



Robert Alpers - MSMC Board Chair

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MSMC Research Committee

Chairman Cecil DeMott, Kyle Durham, Tim Lichte, Lewis Rone and Robert Alpers make up the MSMC Research Committee. They work with their fellow board members to gather input from soybean farmers statewide to set priorities based on the needs of growers, sort through research proposals and guide the board of directors in funding research projects to provide the greatest benefit to farmers.

Research Project Review Process

RFP Development by staff under the direction of MSMC board of directors → Pre-Proposal → Review by staff, MSMC board members and key industry and academic partners → Full Proposal → Review by MSMC Research Committee → In-Person Presentations to Board of Directors → Review and Vote by Board of Directors

RESEARCH PROJECTS FOR 2018–2019 ANNUAL REPORT

Current projects supported by checkoff funds distributed by the Missouri Soybean Merchandising Council are listed below, divided by type of research – Agronomic, Soybean Breeding, SCN and Crop Physiology, Feed, Food and New Uses, Research Educational Opportunities and Regional Affiliations.

Agronomic

"MU CERTIFIED" STRIP TRIAL PROGRAM WORKS WITH MISSOURI FARMERS TO UNDERSTAND COVER CROP MANAGEMENT BEFORE AND AFTER SOYBEAN

Budgeted: $73,150

John Lory, Peter Scharf, Greg Luce, Bill Wiebold, Kent Shannon, Wayne Flanary, Charles Ellis, Wyatt Miller; University of Missouri Extension

The primary goal of the "MU Certified" Strip Trial program is to work with Missouri farmers to validate management decisions and document efficiency and environmental stewardship. Cover crops can increase sustainability of cropping systems through reduced erosion, improved soil organic matter and reduced nutrient losses. Farmers are still learning the best way to integrate cover crops into their crop rotations.

Aerial image of strip trial taken April 27, 2018 at elevation of 75 meters. Strips are labeled with the cover crop termination date: April 24, 2018 and May 6, 2018. The field was planted to soybean May 17.

Strip trials are focused and easily implemented experimental tests that farmers can perform on their fields using their equipment. Over the past three years the strip trial worked with farmers to completed 45 cover crop strip trials.

The research team works with farmers to layout the trial and a local contact is available to answer questions and address problems. Over the course of the trial, researcher use UAV's (drones) to collect information about the trial. Ultimately, the goal of the partnership is to use the yield map from the field to compare treatment outcomes. The farmer receives reports throughout the growing season on comparisons of the treatments on their field.

In February 2019, the team initiated farmer meetings throughout Missouri to meet with farmers who had strip trials or were interested in strip trials to discuss outcomes of individual trials and review summary reports of trial outcomes.

High-resolution aerial images of a termination date strip trial taken June 6, 2018 at an elevation of approximately three meters. Strips are labeled with the cover crop termination date: April 24, 2018 and May 6, 2018.

INCORPORATING COVER CROPS INTO SOYBEAN CROPPING SYSTEMS

Budgeted: $13,823

Bill Wiebold, University of Missouri

This project focuses on the effects of a common cover crop mixture on soybean yield. The research site was first established in 2013. The experiment had three rotation systems and two cover crop treatments. The rotations were continuous soybean, soybean rotated with corn and continuous corn. The cover crop treatments were no cover crop and a mixture of cereal rye and forage radish. These treatment combinations have been planted in the same plots since the experiment begun.

Cover crops are planted each fall by broadcasting seed into standing soybean and corn plants. Planting is timed to occur just before soybean leaves mature and are shed. Fallen leaves holds moisture at the soil surface so cover crops seeds germinate. Cover crops and any emerged weeds are terminated before planting corn and soybean. Plots are larger than most research plots and are 8 rows wide and 40 feet long. This provided adequate border between corn and soybean.

Cereal rye and forage radish cover crop.

The cover crop mixture did not increase or decrease yield in any of the three years. There has been some concern that cereal rye could decrease yield. We have seen no evidence to support that concern. In 2018, continuous soybean yielded 16 percent less than soybean rotated with corn. The yield decrease was about the same with or without cover crop. We will determine SCN levels next spring to determine if some of the yield effect was from SCN build up in continuous soybean plots. The cover mixture did not decrease soybean yield in any of the three years.

"MU CERTIFIED" STRIP TRIAL PROGRAM WORKS WITH MISSOURI SOYBEAN FARMERS TO TEST THE EFFECT OF ILEVO© ON YIELD AND SOYBEAN CYST NEMATODE NUMBERS

Budgeted: $39,758

Kaitlyn Bissonnette, John Lory, Greg Luce, Bill Wiebold, Kent Shannon, Wayne Flanary, and Peter Scharf; University of Missouri Extension

Soybean sudden death syndrome (SDS) is the second most damaging disease of soybeans in the state of Missouri. This pathogen infects soybean seedlings early in the season through the roots and results in the yellowing and death of foliar tissue which can begin in the early flowering stages. These foliar symptoms can increase in severity in the presence of soybean cyst nematode (SCN). Ultimately, control and management of the SDS pathogen must begin early in the season with seed treatments. Some research has suggested that the use of the fungicide/nematode protectant seed treatment ILeVO could provide some benefit, especially in areas where SDS and SCN co-occur.

Strip trials are focused and easily implemented experimental tests that farmers can perform on their fields using their equipment. Strip trials are ideal for side by side comparisons like comparing the use of a seed treatment like ILeVO versus not using a seed treatment. The "MU Certified" Strip Trial program, with support from the Missouri Soybean Merchandizing Council, has worked with Missouri soybean producers at 29 locations to test ILeVO on their fields in 2017 and 2018.

Aerial survey image of soybean showing evidence of sudden death syndrome. The image was obtained with a drone August 16, 2018. Soybean was at R5 maturity.

Incidence of SDS was low in 2017 and 2018; significant levels of disease were only observed in five of the trials.

Across all locations, ILeVO had a small but significant positive impact yield. There was weak evidence that ILeVO reduced the reproductive success of SCN over the growing season. These results are in line with data from other states and emphasize how important understanding the expectation of an SDS outbreak during the growing season is to determining the economics of a product like ILeVO.

FOLIAR FUNGICIDES AND DISEASE MANAGEMENT: A STRIP TRIAL STUDY

Budgeted: $50,550

Kaitlyn Bissonnette, John A. Lory, Bill Wiebold, Greg Luce, Kent Shannon, Charles Ellis, Rusty Lee; University of Missouri Extension

Disease management decisions in soybean often require the question of whether a well-timed fungicide application will result in yield gains, especially in the absence of disease. These management decisions are often made quickly and do not always follow in field disease scouting to determine disease pressure. Understanding how and when to make disease management decisions is a critical first step to reducing the development of fungicide-resistant pathogens and to increasing yield potential.

The two major goals of this project are: 1) to test the effectiveness of current, farmer-implemented fungicide applications in managing foliar fungal diseases and for increasing soybean yield; and 2) execute disease scouting schools designed for farmers and extension specialists that provide hands-on training of how to scout, rate, and sample for foliar diseases of soybean.

For the first objective, eleven field sites in ten counties were selected representing the diversity of the soybean growing regions of Missouri. At each of these sites, five pairs of strips (with a fungicide application and no fungicide) were laid out across the field. The fungicide used varied by location and was determined by the individual farmer cooperator. Each strip was scouted for disease prior to and approximately two weeks following the fungicide application time to document differences in disease between the strips. In addition, aerial imagery was taken at each of the scouting points in each field to visually document the differences. Overall, the primary diseases observed were Septoria brown spot and Frogeye leaf spot. With the 2018 field season being extremely dry, conditions were not conducive to disease development, so little foliar disease was observed at many locations. Analysis of the yield data collected revealed no differences between treatments, unsurprising with such low levels of disease.

Five scouting schools were administered in the four quadrants of the state with a total of over 100 farmers, cooperators, Extension specialists, and other stakeholders reached. Participants were tested on their ability to identify a series of common soybean diseases impacting production in Missouri and their management. They were then trained in the basics of fungicide resistance management, the potential impacts of resistant fungal pathogens on production and which pathogens are at the highest risk of developing resistance. The scouting school participants then moved into the field where they were asked to identify the diseases that they observed and how best to manage them. When asked about the value of the scouting school, all those surveyed indicated they found the school useful and would be interested in attending future meetings.

Scouting schools in the four quadrants of the state attracted growers, Extension specialists, farmer cooperators, and other stakeholders.

INTERACTION OF COVER CROPS AND NEMATICIDES IN RELATION TO SOYBEAN CYST NEMATODE POPULATION DENSITIES ON SUSCEPTIBLE AND RESISTANT SOYBEAN VARIETIES

Budgeted: $30,717

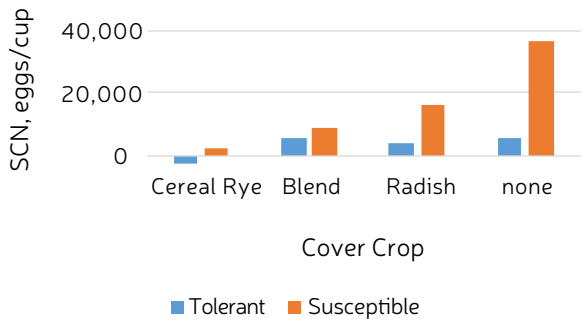
Tim Reinbott, Bruce Burdick, Melissa Mitchum, Andrew Scaboo and Jennifer Miller; University of Missouri

Soybean cyst nematode (SCN) has spread to 80 percent of soybean fields in the US with an annual loss of $1.2 billion and is widespread in Missouri. The conventional means of controlling SCN damage is through the use of genetic resistance in soybean. The use of cover crops such as cereal rye or radish could reduce numbers by promoting premature hatch, but they could also serve as hosts for SCN. Also, recent seed treatments such as ILeVO have shown

promise preventing soil borne diseases, including SCN. This study examined the interaction between SCN cultivar resistance, cover crops, and ILeVO seed treatment.

Soybean varieties were selected with SCN resistance and planted into cereal rye, radish, a cereal rye/radish blend or control plots in 2017 and 2018 at two locations in Missouri. Each soybean variety was either treated or untreated with ILeVO. Cover crops were overseeded into soybeans prior to harvest and terminated a week before soybean planting. Plots planted with cereal rye had a higher SCN density in the spring but decreased by fall, whereas those without cover crops continued to increase throughout the year and into the next year. SCN population density was less on SCN resistant cultivars following a cover crop (Figure 1).

Figure 1. SCN Change From Planting to Harvest



Cereal rye may promote SCN egg hatch but since a host is not present juveniles ultimately die resulting in a reduction in the SCN population. We were able to recover a very low number of cysts (some with eggs) when SCN was inoculated to cereal rye seedlings in the greenhouse (Figure 2). This indicates that cereal rye is a poor host, but may allow for limited reproduction of SCN. Soil SCN levels were three times greater after two years following the susceptible variety Williams 82 than the SCN tolerant variety. There was no change in SCN due to ILeVO seed treatment.

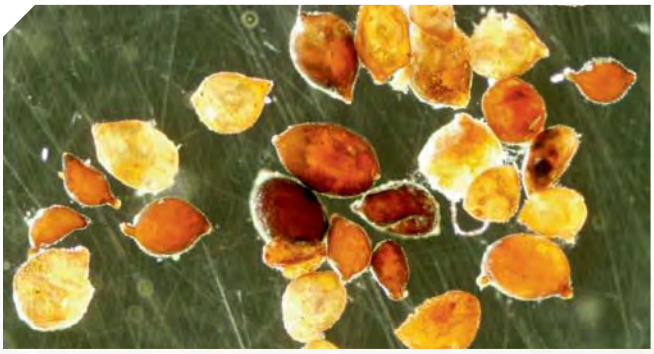
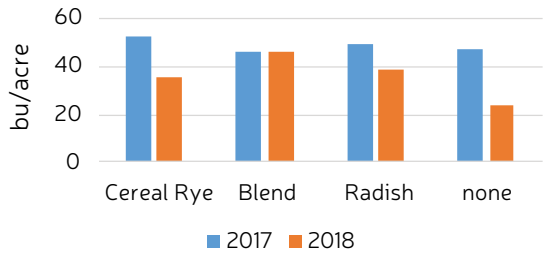


Figure 2. SCN cysts recovered from cereal rye and radish in the greenhouse.

Soybean yield was slightly higher (3 bu/acre) after cover crops in 2017 when soybean yields were in the 50 bu/acre range. However, in 2018 soybean suffered from a summer long drought at both locations and soybean yield was over 10 bu/acre greater following cover crops especially the SCN susceptible Williams 82 (Figure 3). This greater yield response during drought after cover crops corresponds to the reduction in SCN counts from the previous year.

Figure 3. Soybean Yield After Cover Crops in a Normal Year (2017) and a Dry Year (2018)



INVESTIGATING DICAMBA MOVEMENT AND INJURY TO SOYBEAN

Budgeted:$64,971

Kevin Bradley and Mandy Bish; University of Missouri

Several million acres of U.S. soybean were injured by off-target movement of dicamba in 2017 and 2018, and state departments of agriculture collectively investigated more than 4,000 dicamba-related soybean injury claims in the past two seasons alone. In many incidences, the cause(s) of dicamba movement have been identified as factors related to physical drift (wind speed, improper nozzles, boom height, etc.), but in other instances further investigations have revealed that label guidelines were followed yet off-target movement of dicamba still occurred. The primary objectives of this research were to 1) determine the effects of time of application, weather conditions and new formulations on the concentration of dicamba detected in the air following application, and 2) assess weather and environmental factors surrounding dicamba applications in order to identify any consistencies that may explain off-site dicamba movement.

Through this research, the team has been able to determine that dicamba can be detected in the air for as many as 96 hours following an application of either Xtendimax or Engenia, although highest dicamba air concentrations typically occur within the first 8 hours after application.

Air sampler used to detect dicamba air concentrations after applications of Engenia or Xtendimax.

Highest dicamba concentrations have consistently been detected during the night following an application made in either the evening or afternoon, however "peaks" in dicamba air concentrations have also been commonly detected in the afternoon following an evening application. Results from this research also indicate that the concentration of dicamba in the air is highly influenced by atmospheric stability (i.e., surface temperature inversions) and other variables such as temperature and relative humidity.

Our findings from this air sampling research led us towards the establishment of a real-time inversion monitoring network (mesonet.missouri.edu), and an additional project in which researchers conducted a statistical analysis of the weather conditions surrounding approximately 200 commercial, field-scale successful and unsuccessful dicamba applications. This analysis led to the identification of several environmental factors that are likely to increase the likelihood of off-target movement of dicamba, including:

1. lower soil pH
2. increase in maximum dew point temperature the day of application
3. increase in maximum wind speed the day after application
4. proximity to larger bodies of water.

As a result of this analysis, in 2018 the team conducted two field research experiments to confirm the results from the statistical weather analysis pertaining to the effects of soil pH on off-target movement of dicamba. Results from both experiments indicate that greater dicamba volatility occurred in response to lower soil pHs (<6.8), and that soybean injury as a result of dicamba volatility was similar from Engenia and Xtendimax.

"Low tunnel" hoop houses used to measure dicamba volatility in 2018 field research.

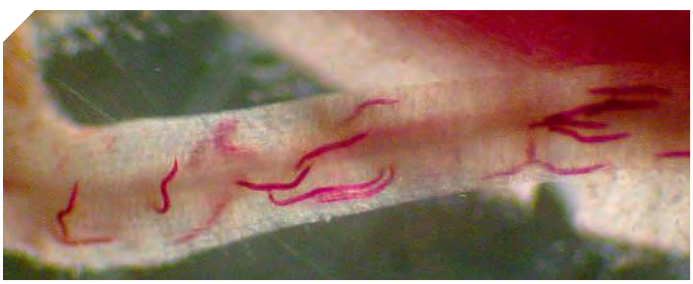
SCN and Crop Physiology

MICROGENOMICS TO IDENTIFY NEW SOURCES OF SOYBEAN CYST NEMATODE RESISTANCE IN SOYBEAN

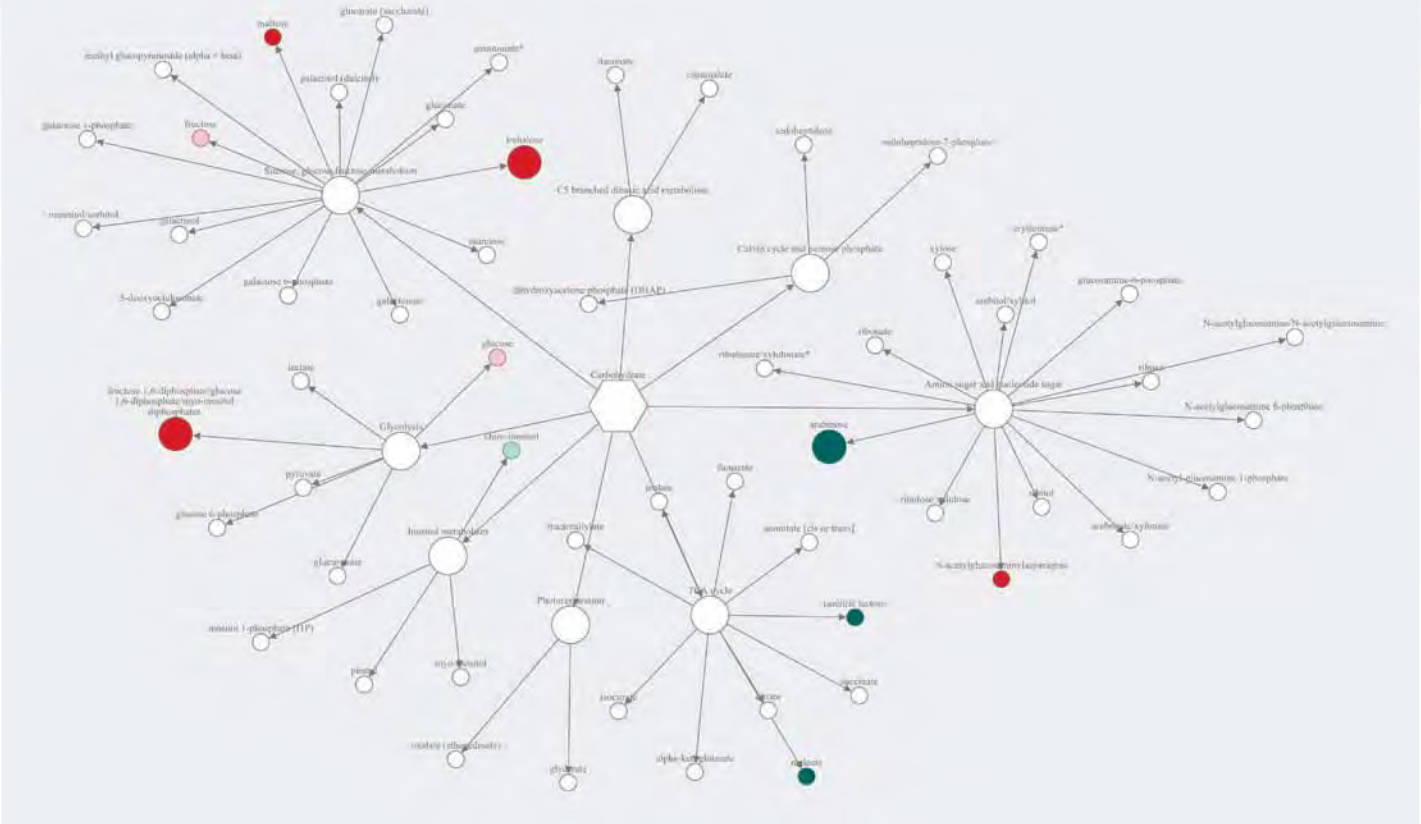
Budgeted: $117,533

Melissa G. Mitchum; University of Missouri

Soybean cyst nematode (SCN) continues to spread throughout soybean-producing regions of Missouri. Planting of soybean varieties with SCN resistance from the plant introduction (PI) is widespread in the state. The percentage of individuals within SCN field populations throughout Missouri that can reproduce on PI 88788 has



A soybean root infected with soybean cyst nematode, Heterodera glycines. Infective second-stage juvenile nematodes (stained pink) hatch from eggs in the soil and penetrate the roots of soybean plants where they feed and develop into adult females (cysts). Picture taken by Ph.D. student Vinavi Lakshman.



An example of a metabolic map of soybean compounds altered upon nematode infection. The bigger the circle the more abundant the compound. Blue = reduced; Pink = induced. Map generated by Postdoctoral Fellow Arati Poudel Nepal.

markedly increased. There is an urgency to develop soybean varieties with novel, more durable SCN resistance for Missouri farmers.

The aim of this project is to identify SCN disease-resistance genes and associated metabolites that can be used to develop improved SCN-resistant soybean varieties. Objectives of this study are to:

1. Profile the metabolome of SCN resistant and susceptible cultivars
2. Functionally validate a role for the identified genes and metabolites in soybean resistance to SCN.

A resistant and susceptible cultivar of soybean were either inoculated or not-inoculated with SCN. Root tissues were isolated and the ribonucleic acid and metabolites were extracted. Gene expression and metabolite analyses comparing uninoculated and SCN-inoculated plants were performed.

The research team identified 238 differentially expressed genes and 224 differentially abundant metabolites with a potential role in SCN resistance. Metabolites in secondary, amino acid, lipid, and nucleotide metabolism were enriched in resistant plants in response to nematode infection.

HIGH-THROUGHPUT PHENOTYPING TO ACCELERATE SOYBEAN IMPROVEMENT THROUGH AGRONOMY, BREEDING, AND GENETICS

Budgeted: $70,895

Felix B. Fritschi, Gary Stacey, Andrew Scaboo, Bill Wiebold, Guilherme DeSouza, Minviluz Stacey; University of Missouri

Yield measurements are a key measure of crop performance. In-season measurements are critical to understand why yield may differ, and what may change within the growing season to improve profitability. Because manual in-season assessments of plant growth, development, and physiology are very time consuming and therefore not suitable for large numbers of lines required for genetic studies and breeding, the team proposed to develop a tractor-mounted sensor platform that allows for rapid collection of such data.

The goals of this project are to:

1. assemble and deploy a highboy-based phenotyping platform for Missouri soybean researchers that will allow rapid and accurate assessment of a broad range of traits of field-grown soybean, and
2. deploy the phenotyping platform to study soybean traits in response to different management practices, genetic/breeding populations, and soybean mutants to accelerate agronomic and genetic advances.

The team designed and constructed a sensor platform that was deployed using a high-clearance tractor. The sensors included on this platform are used to measure plant height, canopy temperature, the light that is reflected by the canopy, and the shape of the plant. The collection of these data is coupled with a high-precision GPS system so that the data points can be assigned to specific locations in the field (e.g. treatments, entries).

Plant height and canopy coverage can differ between lines and are influenced by management practices such as planting date, seeding rate, fertilizer application, herbicide applications, and tillage system. Wavelengths of light reflected by the canopy differ depending on the health of the leaves (e.g. disease, nutrient status) and are influenced by management strategies (e.g. moisture, fertility) as well as developmental stage (e.g. senescence). Thus, the sensors installed on the platform can provide information that is useful for agronomic, physiological, and genetic studies.

Ongoing efforts include improving computational approaches to use data from depth images are acquired with Kinect sensors and using algorithms to provide more information about the morphology of soybean plants growing in the field.

The team has conducted several rounds of data acquisition to improve and optimize the sensor position and orientation, data logging, and algorithm development for the Kinect sensors.

LEVERAGING STABLE ISOTOPE TRAITS TO IMPROVE SOYBEAN WATER USE EFFICIENCY

Budgeted: $85,292

Felix B. Fritschi, Andrew Scaboo; University of Missouri

Water use efficiency (WUE) in crop species is defined as the amount of plant tissue and/or seed yield produced per unit of water used by the crop. Developing soybean varieties with improved drought tolerance can be achieved by increasing WUE. The team has successfully identified soybean lines that differ in WUE and are using those lines to pursue the following objectives:

1. determine the mechanisms that allow some soybean lines to produce more biomass and yield per unit of water than others
2. differentiate between soybean lines that use different strategies to produce more per unit of water used
3. breed for soybean germplasm that produce more per unit of water used
4. develop soybean populations that we can use to identify molecular markers that are specific for different strategies to produce more per unit of water used. In turn, molecular markers can be used to accelerate the rate of breeding.

In 2018, the research team examined the response of soybean lines that contrast in WUE efficiency to differences in water availability (drought stress) under field conditions. They measured a range of physiological characteristics and collected plant tissues for detailed analysis of the responses of the different lines. Measurements conducted include leaf- and canopy-level photosynthesis (see picture) as well as canopy temperature. We are currently analyzing the data and processing the samples collected during the season to dissect mechanisms associated with greater WUE. As part of the breeding effort, the team made six different crosses between elite germplasm and lines selected for WUE traits. They advanced offspring from those crosses to the F5 generation and identified 77 progeny rows based on promising agronomic characteristics. The team then harvested the seed and submitted samples for analysis to obtain information about the WUE of these lines. Of the 77 lines, those with desirable WUE will move forward in a multi-location yield test for 2019.

The research team is also developing a mapping population that combines traits of interest for WUE derived from plant

introductions in an elite germplasm background. For that purpose, they made a series of crosses and obtained F1 seed that will be crossed during the 2019 growing season to provide the founder parent for the mapping population.

This project delivers:

1. a better understanding of the mechanisms that can be employed to improve soybean yields under drought
2. germplasm with enhanced WUE
3. genetic markers that can be used to accelerate improvement of drought tolerance.

Soybean Breeding

BREEDING PRODUCTIVE, PEST RESISTANT, CONVENTIONAL AND HERBICIDE TOLERANT GROUP IV AND V SOYBEANS

Budgeted: $298,069

Pengyin Chen, Andrew Scaboo; University of Missouri

The objective of this research is to develop new soybean varieties for the Missouri Delta region and other Mid-South environments. Specific objectives are breeding for higher yields, quality traits, and disease and nematode resistance. This soybean breeding program is housed at the University of Missouri Delta Center in Portageville, Missouri. Key areas of focus include the development of varieties with SCN and Root Knot nematode resistance, frogeye leaf spot resistance and, of course, yield. The Fisher Delta Center Soybean breeding program has released multiple varieties over the last several years. An important aspect of the research program continues to be developing soybean varieties with higher oleic acid and linolenic acid content, as well as herbicide resistance and other traits.

2018 Foundation and Pre-Foundation Seed Production

The research team had twelve lines grown by Foundation Seed to increase seed supply for commercial sales as well as prepare for future release.

2018 Yield Trials

Researchers entered 15 high yielding advanced lines in the 2018 USDA uniform trials along with 22 high yielding preliminary entries in the uniform preliminary trials. They evaluated 136 high yielding lines in advanced yield trials, as well as 1,769 lines in our preliminary yield trials. The team also evaluated the advanced lines in a set of cooperative tests in five states across the mid-south. Over 150 lines have been selected from advanced and preliminary tests for the 2019 Missouri advanced tests.

2018 Progeny Rows

805 lines were selected from the 2018 progeny row nursery. Those will be screened for salt tolerance, STS resistance and analyze the FA profile of necessary lines before including in the 2019 Missouri preliminary tests.

Dr. Chen and his staff show and discuss the Fisher Delta Center soybean breeding program at the annual field day.

2018 Crossing Block

The research team made 346 new crosses in the 2018 Crossing Block. Crosses were made for high yielding conventional, RR1, R2Y, Liberty, high oleic, low linolenic, high stearic, high protein, high oil, high sugar, drought tolerance, flooding tolerance, nematode resistance, stink bug resistance, and other food grade commodities. The F1 seeds were sent to winter nurseries in Costa Rica and Puerto Rico for generation advancement.

Disease Screening

The 136 advanced yield test lines were screened for southern root knot, stem canker and frogeye leaf spot. The results of these screenings will be used to determine disease resistance for future releases. These lines were also evaluated at each of the four advanced test locations for presence of natural occurring diseases, such as: SDS, cercospora leaf blight, stem canker and frogeye leaf spot.

EVALUATION OF OLEIC ACID GERMPLASM FOR DEVELOPMENT OF SOYBEANS WITH HIGH OLEIC ACID

Budgeted: $81,016

Pengyin Chen and Andrew Scaboo; University of Missouri

Increasing oleic acid content in soybean seed will provide a healthier oil with improved oxidative stability for increased shelf life, flavor, extended cooking time and other applications such as for lubricants and biodiesel. High oleic soy oil will reduce the need for hydrogenation and eliminate trans-fats. A diet in which fat consumption from soybean high in oleic acid would mimic olive oil which is associated with reduced cholesterol, arteriosclerosis and heart disease. Several U.S. plant breeders are incorporating the non-GMO, high oleic trait into maturity groups 00 through VII soybeans for production throughout the USA and the first cultivars with these non-GMO genes are expected to be released in 2019.

2018 Advanced HOLL yield trials grown in Novelty, Missouri

During the 2018 growing season, the research team evaluated HOLL MG III through MG V lines (conventional/RR2) in advanced yield trials at five to seven locations in Missouri and four locations in Illinois, Nebraska, and Iowa. These lines were submitted to the 2018 USDA Northern and/or Southern Uniform Soybean Trials. The team had approximately 300 HOLL MG III and early MG IV lines (conventional/RR2) in preliminary yield trials at four locations in Missouri and three additional locations in Nebraska, Iowa, and Illinois during 2018. The team has HOLL plant material in various stages of early generation development throughout the breeding process. The best lines will be advanced through broader testing during 2019.

Development of non-GMO derived high oleic soybeans will allow a healthier, more functional seed oil desired by consumers and oil processors than oil from commodity soybeans. High oleic acid, low linolenic acid soybean oil is similar to olive oil but, it can be produced in large quantities and sold at a lower price than olive oil. High oleic soybeans will improve cold flow of biodiesel; stability at high temperatures in lubricants and cooking oil and demand for use in foods and other products.

NORTHERN MISSOURI SOYBEAN BREEDING PROGRAM

Budgeted: $446,536

Andrew Scaboo and Pengyin Chen; University of Missouri

The objective of this project is to develop commercially competitive conventional and herbicide resistant soybean varieties for northern Missouri. Variety development is focused on early maturity group III through early maturity group IV soybeans with high yield potential, resistance to major diseases, and improved value-added traits such as seed composition. During 2018, the research team finalized an agreement with Bayer Crop Science to begin working with the Liberty Link (LL55) herbicide resistance trait with hopes to release glufosinate resistant soybean germplasm and varieties within the next five years. The University of Missouri's northern soybean breeding program devotes a considerable amount of time and effort on all stages of variety development each year including crossing, inbreeding and generational advancement, plant row selection, preliminary and advanced yield trials, regional and national yield trials, and germplasm and variety release. During 2018, approximately 150 unique cross combinations with conventional, LL55, and RR2 material were made at the Bay Farm Research Facility in Columbia, Missouri. The hybrid F1 seeds were harvested and immediately planted in Kekaha, Hawaii during October 2018, and those F1 plants will be harvested in early 2019 with the F2 seed planted within a day or two of harvest. Ththe F2 plants will be harvested in May of 2019 and the seed will be shipped back to Columbia, Missouri. The F3 plants will be grown in Columbia at the Bay Farm Research Facility during the summer of 2019 and single pods from each plant will be harvested. The F4 plants will be grown for one generation in Ponce, Puerto Rico to develop progeny rows to be grown in 2020. The research team will also have a crossing block in Hawaii during the spring of 2019 to enable more efficient and timely germplasm and variety development. Each year, approximately 2000 progeny rows are visually selected

2018 Advanced yield trials grown in Rock Port Missouri

and the selected lines will go into preliminary yield trials across six locations in Missouri including Columbia, Novelty, Rock Port, Corning, Albany, and Portageville. Some of those lines (the MG III material) are also planted in replicated trials at three locations in Nebraska, Iowa, and Illinois in collaboration with the soybean breeders at the respective public institutions. The top five to ten percent of lines in preliminary yield trials are advanced to multiple replicate and locations advanced trials, and the best lines are also tested in the USDA northern and southern regional uniform trials which are grown at 15 locations across 20 states and Canada each year.

The University of Missouri Seed Committee released 5 soybean lines from our program during its November 2018 meeting.

WINTER PRODUCTION PROJECT

Budgeted: $114,000

Pengyin Chen and Andrew Scaboo, University of Missouri

The use of winter nurseries is critical to the success of a soybean breeding program. Multiple generations can be grown in winter nurseries which allows for more rapid development of superior soybean genetics. The University of Missouri soybean breeding programs utilize nurseries in Costa Rica, Puerto Rica and Hawaii. The use of these locations is essential so that there is no down time and crosses can made along with small increases conducted during the Missouri winter months. This year-round effort greatly enhances the efficiency and timeliness of the Missouri soybean breeding program.

The timeline for using winter nurseries begins as soon as seed is harvested in Missouri. Soon after harvest, seed is sent off to one of the winter nursery locations. This is typically late September or early October. We can typically grow two cycles in winter nurseries with the first cycle planted in October and harvested in January. A second cycle is planted in February and harvest in May. In May or June, the seed is sent back to Missouri for planting. There are times when the second generation has arrived very late in June or early July. This is one reason why irrigation is so important to the University of Missouri soybean breeding programs, to ensure winter produced seed can be properly established and grown upon return to Missouri.

The timely release of the best genetics and traits would not be possible without winter nurseries. The use of the winter nurseries is certainly a tremendous support to the University of Missouri breeding programs and key to the ability to provide productive genetics for Missouri farmers.

University of Missouri winter production site in Hawaii; April 2018

GWAS TO GENES: A SYSTEM TO UTILIZE ASSOCIATION ANALYSES TO CLONE GENES AND DEVELOP MARKERS TO IMPROVE SOYBEAN BREEDING FOR VARIETY DEVELOPMENT

Budgeted: $37,628

Kristin Bilyeu, USDA, ARS; Trupti Joshi and Dong Xu; University of Missouri

The goal of this project was to enhance existing bioinformatics tools and resources to enable broad and efficient identification of soybean genes that control phenotypes so that they can be directly and effectively utilized in soybean germplasm and variety development programs. The challenge the research team sought to address was the gap between the rapid generation of soybean genomic sequence information and the ability to utilize the "big data" in ways that could lead to improved

soybean varieties. This project accomplished the goal.

New analysis methods, collectively termed Genome Wide Association Studies, or GWAS, that take advantage of "big data" in both genotype and phenotype information hold the promise to ultimately identify hundreds of soybean genes that control phenotypes. However, these new methods of association analysis stop short of producing information that can be directly utilized in soybean breeding programs. The current methodologies available to generate GWAS results do not lead to the direct identification of genes that control the phenotypes. This project led to the development of a research pipeline and online tools to enable researchers and breeders to identify key alleles that control important soybean traits.

The research team designed and verified a strategy and developed bioinformatics tools to enable generalized "cloned" gene identification that can be immediately utilized in soybean germplasm and variety development programs. Identifying the genes that control key phenotypes leads to the development of molecular marker resources that allow perfect selection for the trait, a critical feature of the most effective soybean breeding programs.

The outcomes of this project are two manuscripts in preparation that fully describe the technical aspects of the work and present other researchers with the strategy (the GWAS to Genes pipeline) and online tools so it may be widely adopted. The key tool researchers developed, SNPViz2, facilitates the exploration of allelic variation and diversity by its visualization in a web-based haplotype viewer. Major improvements were made to an existing tool that was a single nucleotide polymorphism (SNP) similarity-based clustering tool. The key features of the new SNPViz2.0 tool include increasing the available datasets to over 600 re-sequenced soybean genomes, incorporation of additional gene-based annotation and variant impact information, improved filtering of phenotype and sequence information, and the ability to link GWAS output information for use with the tool.

BREEDING SOYBEANS RESISTANT TO MULTIPLE NEMATODE SPECIES

Budgeted: $211,987

Pengyin Chen, Melissa Mitchum, and Andrew Scaboo; University of Missouri

Plant-parasitic nematodes (PPN) are the cause of significant yield losses for Missouri soybean producers each year. Soybean cyst nematode (SCN) is the most economically important nematode species that infects soybeans, and it is found throughout the state of Missouri where soybeans are grown. Root-knot nematodes (RKN) cause major yield losses in southeast Missouri and often occur in the same field with SCN, particularly in sandy soils prevalent in the mid-south. Reniform nematode (RN) is also an increasing threat to soybean production in southeast Missouri when soybean is grown in rotation with cotton. The primary goal of this project is to develop productive soybean germplasm and varieties for Missouri with resistance to multiple nematode species. This will be accomplished using SCN, RKN, and RN resistant sources with genes that are most effective against the species prevalent in the state. The work performed under this project will ensure the continued development of high yielding soybean cultivars with multi-nematode resistance for Missouri producers.

During 2018, 280 experimental breeding lines and varieties from the University of Missouri northern and southern breeding programs were screened for SCN resistance. For the southern program, experimental lines were evaluated for Race 1 (HG 2.5.7), Race 2 (HG 1.2.5.7), Race 3 (HG 7), and Race 5 (HG 2.5.7) resistance. Forty-nine lines exhibited some level of SCN resistance. Many lines had resistance to more than one race (HG type) and nine lines exhibited resistance to all four SCN populations. For the northern program, lines were evaluated for Race 1 (HG 2.5.7), Race 2 (HG 1.2.5.7), and Race 3 (HG 7) resistance. Seventy-four lines exhibited some level of SCN resistance, mostly to race 3 (HG 7). The southern program additionally genotyped 136 lines tested in advanced yield trials in 2018 for SCN,

RKN, and RN resistance. Based on the molecular marker screening, 92 lines have resistance genes for SCN, 52 lines have resistance genes for RKN, and 64 have resistance genes for reniform nematode. During the fall of 2018, eight soybean lines from the MU breeding programs with confirmed resistance to SCN, RKN, or RN were approved for release by the University of Missouri Seed Committee. The Missouri Foundation Seed program produced high-quality

Foundation Seed (seed produced to maintain specific varietal purity and identity) of all of the newly released lines, and all lines were requested for commercialization purposes by several private companies during the recent bid request process. This is the final step in the process of research, development, and commercialization and shows the value and return on investment by this project for Missouri farmers, and the entire soybean industry.
In 2018, 280 advanced soybean breeding lines from the Southern and Northern programs were evaluated for resistance to four soybean cyst nematode populations including Race 1 (HG 2.5.7), Race 2 (HG 1.2.5.7), Race 3 (HG 7) and Race 5 (HG 2.5.7). Approximately 5,200 plants were evaluated for this project.

DEVELOPING HIGH-YIELDING, HIGH OLEIC ACID, LOW LINOLENIC ACID SOYBEAN VARIETIES WITH ADDITIONAL VALUE-ADDED COMPOSITION TRAITS (HOLL PLUS)

Budgeted: $97,856

Kristin Bilyeu, USDA, ARS; and Andrew Scaboo, University of Missouri

This project is designed for the development high yielding soybean cultivars having the high oleic and low linolenic trait (HOLL) with additional value traits (the *plus traits*) to benefit Missouri Farmers. The focus of soybean varieties with this combination of traits will be in maturity groups III and IV, which are widely grown in Missouri.

Soybean is essentially two products, vegetable oil and meal. The HOLL trait increases the oil value by offering improved functionality for oil used in heating and frying food applications. Other oil traits may also provide value to soybean oil. The HO trait, on its own, produces slight reductions in saturated fats in the oil. However, additional reductions in saturated fats are possible with the use of additional variant genes. Experimental soybean lines are currently being characterized with the HO and low saturated fats traits in combination.

If the HOLL soybeans are going to improve the oil fraction, it makes sense to couple it with a value-added meal trait. Finding the optimum balance between protein content and high yields is extremely important to soybean breeding programs. Multiple new high protein sources are continually being evaluated and incorporated into the soybean breeding program at the University of Missouri. Combining the high protein trait with the HOLL oil trait is one way to achieve additive producer value from single varieties when both the oil and the meal contain premium traits.

A second meal trait of interest is the altered carbohydrate trait. Soybean meal typically contains nutritionally useless carbohydrates that have either neutral or negative impacts in livestock rations. The altered carbohydrate trait shifts the negative carbohydrates into their more useful forms without changing other factors in the meal.

The initial phase of this on-going project focused on development of new populations with the best sources of all the *plus traits* as parent material. An intricate crossing, advancement, and selection strategy is the next phase to carry out the soybean breeding and variety development work. All the *plus traits* have been characterized individually and the research is working to perfect molecular markers available for selection. The result of this work will be high yielding soybean varieties having a combination of traits that will benefit Missouri soybean farmers, as well as the processor, and the end user.

UTILIZING MOLECULAR MARKERS FOR SOYBEAN VARIETY DEVELOPMENT

Budgeted: $112,794

Andrew Scaboo and Pengyin Chen; University of Missouri

Modern plant breeding utilizes molecular biology techniques and data to improve efficiency during the breeding process and to assure quality control. In the past, the soybean breeding program at the University of Missouri did not fully utilize molecular data for parental selection or for prediction of breeding value during the development of experimental lines. This was traditionally due to the lack of a centralized facility and appropriate equipment with experienced staff for collecting and analyzing molecular data. With the investment from the Missouri Soybean Merchandising Council and Missouri Soybean Association into the Bay

Farm Research Facility, the research team now has access to much of what is needed to create a centralized applied molecular breeding lab for the soybean breeding program at the University of Missouri.

The high oleic trait can be combined much more easily and efficiently into new high-yielding conventional varieties as they are identified, developed, and tested by the breeding program by using molecular markers, which improves the efficiently during variety development, assures quality control of introgressed traits, and ultimately reduces the time needed from research and development to products on the market. Prediction of performance and breeding value has allowed for increased genetic gain within breeding programs by increasing the selection intensity and eliminating breeding cycles, and thereby increasing efficiency during variety development.

During the past two years, DNA samples of the top breeding lines in the program were sent to UDSA-ARS in Beltsville, MD (Dr. Qijian Song) for 6K SNPChip analysis. Samples were carefully sampled and extracted with the highest quality methods for best results and all samples scored 92-100 percent of the 6,000 possible SNPS. The genetic distance between breeding lines was calculated and used for selection of parents for crossing. This is the first major step into utilizing molecular information to make more efficient decisions during all steps in the breeding process, and it's the foundation of molecular data for making parental selections for crossing, for genomic prediction of the breeding value, and performance of progeny for traits (such as yield). These data were used in both 2017 and 2018 for selection of parents for crossing.

BREEDING HIGH-YIELDING SOYBEANS WITH FUNCTIONAL TRAITS

Budgeted: $114,751

Pengyin Chen and Andrew Scaboo, University of Missouri

This research intends to provide a steady flow of new and improved soybean lines with desirable functional traits for food, feed, oil, and biodiesel production.

Specific Objectives:

- Develop high yielding lines with high protein content (>45 percent) for food, feed, and protein isolate
- Develop high yielding lines with high oil content (> 23 percent) for oil crushing and biodiesel production
- Develop high yielding lines with high sucrose (>8 percent) and low stachyose (<1 percent) for food and feed
- Incorporate high protein, high oil, high sucrose and low stachyose into high oleic lines.

The program is evaluating advanced high protein lines that are showing very promising protein levels. We will be analyzing selected lines from the 2018 Missouri preliminary test for the 2019 Missouri advanced tests based on yield and protein and oil content. High yielding lines with adequate protein and oil content will be entered in the 2019 Uniform and Protein Diversity tests. In addition, 822 progeny rows were selected in 2018 for the 2019 Missouri preliminary tests that we will analyze for protein and oil content. Nine of the selected lines are from two high protein pedigrees.

Similarly, seven high oil lines (including the three listed above) were entered in the USDA Uniform Trials, Missouri advanced tests, and cooperative tests in five additional states. The oil content ranged from 18.8 to 20.3 percent while the protein content ranged from 33.7 to 35.7 percent. In the Missouri advanced tests yields ranged from 90 to 108 percent of the average check yield. A release decision will be made based on their performance across the multi-state tests. The research team evaluated ~1800 lines in the 2018 Missouri preliminary tests at four locations. They selected 822 progeny rows in 2018 based on phenotypic appearance that will be evaluated for protein and oil content and included in the 2019 Missouri preliminary tests. Forty-four progeny rows were selected from three populations with high oil pedigrees. Researchers will have ~2,100 F5 progeny rows from 14 populations with high oil pedigrees in the 2019 progeny row nursery. Seventeen new high oil crosses were made in 2018 with high yielding conventional, RR1 and R2Y lines and sent to winter nursery for generation advancement.

A set of 29 Plant Introductions (PIs) previously identified to have varying combinations of sugar and stachyose were grown in 1-row plots to reconfirm the level of sugar and stachyose content in the seeds. These PIs are categorized as: i) high sucrose/normal stachyose, ii) high sucrose/reduced stachyose and iii) normal sucrose/reduced stachyose. Twenty-three crosses were made between elite high-yielding breeding lines and germplasm lines with high sucrose content and/or low/reduced stachyose in 2018. The F1 seeds of these crosses have been sent to the winter nursery in Costa Rica (CR) and Puerto Rica (PR) for generation advance.

DELTA CENTER BREEDING PROGRAM IMPROVEMENTS

Budgeted: $150,000

Pengyin Chen

The objective of this project is to make long overdue improvements to the Fisher Delta Research Center facilities used for soybean breeding work.

Purchases:

- **Barcom barcoding software and hardware** for upgrading seed cataloguing system in new cold room and seed storage warehouse. The barcoding upgrades were completed.
- **150 Wire Storage Crates for warehouse** - Received and partially assembled and installed.
- **Accufast P4 Mass Envelope Printer**
- **Cabinets and shelving for new GC lab and student work lab** - The expectation is to be complete by the end of April 2019.
- **Building Renovations** - A new blueprint for the lab renovation has been finalized. Plans to upgrade the HVAC system, windows, and data access ports are also underway.

CHARACTERIZING VALUE-ADDED QTL FROM WILD SOYBEAN FOR ENHANCEMENT OF GERMPLASM RESOURCES

Budgeted: $72,886

Andrew Scaboo, University of Missouri; and Jason Gillman, USDA ARS

Wild soybean has been demonstrated to contain substantially more genetic diversity than domesticated, and at least one study has demonstrated wild soybean has seed yield genes; one group reported that alleles from a single wild soybean contribute an approximately 9 percent yield advantage (Concibido, La Vallee et al. 2003). However, investigations to date have typically focused only a single wild soybean line at a time. This is in part due to the very poor agronomic traits and difficulty in working with such material. Despite this fact, a number of promising lines from the University of Missouri's northern soybean breeding program contain 25-50 percent genetic material from wild soybean, yet are promising entries in early or advanced yield trials. Although wild soybean has currently a very limited impact on soybean breeding as a whole, we have evidence that suggests that agronomic and value-added traits are controlled by novel genes in wild soybean which could have substantial utility and impact in the coming decades.

The objectives of this project are to a) utilize existing (domesticated x wild) soybean populations to further refine genomic positions containing genes responsible for elevated protein and improved amino acid profiles, b) collaborate to develop in-house capabilities to quantify amino acid composition of soybean seeds for improvement of breeding operations, and c) initiate backcrossing efforts to move value-added QTL from wild soybean into adapted soybean germplasm/varieties.

During 2018, the team completed two multi-year QTL mapping projects, which identified a number of highly significant QTL associated with (not a complete list): increased protein, increased oil, altered photoperiod response, altered amino acid and fatty acid levels, and even some genetic markers associated with improved agronomic performance. These studies also gave us substantial wet-chemical data, which they are leveraging to improve analytical capabilities at the Bay Farm Research Facility.

Dr. Xiaofan Niu analyzing seed samples via Perten NIR technology

Near-Infrared Spectroscopy (NIR) is a method to indirectly predict seed traits through complicated mathematical correlation of visual and near-infrared spectral signals with measured trait data. These methods can cheaply, non-destructively and rapidly evaluate seed, but the quality and quantity of data that make them up are critical. In collaboration with the University of Minnesota, the wealth of spectral data produced was leveraged to improve the Perten NIR calibrations, which directly led to improved NIR performance for a number of valuable seed traits (protein, oil, amino acids, fatty acids). These Perten calibrations have already been deployed across the world.

Feed, Food and New Uses

COMPREHENSIVE APPROACH FOR HIGH OLEIC SOYBEAN OIL INCLUSION IN BROILERS AND MARKET HOGS

Budget: $96,239

Bryon Wiegand, University of Missouri

Feed sources containing increased levels of oleic acid have shown the ability to improve quality traits of pork products by altering the fatty acid profile. Mono-unsaturated fats/oils not only can increase the firmness of pork fat when compared to PUFA, but oleic acid (C18:1) content has been positively correlated with organoleptic properties such as flavor, tenderness, juiciness, pork flavor, flavor liking, and overall acceptability. With the emergence of high oleic soybean, little is known of its effect on the lipid quality of non-ruminant products and the retention rate of oleic acid within these products. The overall objective of these studies is to measure the uptake of high dietary oleic acid into products from non-ruminants and to analyze the effects of the inclusion of high dietary oleic acid on the production performance of non-ruminants.

Broiler chicks (n=1440) were divided randomly into 2 treatment groups of 24 pens each. All birds were housed in the same barn and under the same lighting and ventilation conditions. The treatment groups consisted of a control diet (conventional soybean oil) and a diet containing high oleic soybean oil at 3.5 percent. The weights of both broilers and feed were recorded weekly and used to determine average daily gain, feed intake, and feed to gain ratio throughout. Broilers were slaughtered at 7 weeks of age at a USDA inspected processing plant. Internal fat was harvested from each bird for fat profile determination and whole carcasses were packaged for meat quality analysis. Following the laboratory analyses of the chicken meat samples, researchers anticipate a shift in the fat profile to reflect more oleic acid in the HO-fed birds and a lower rate of lipid oxidation in processed chicken products resulting from the fat profile shift.

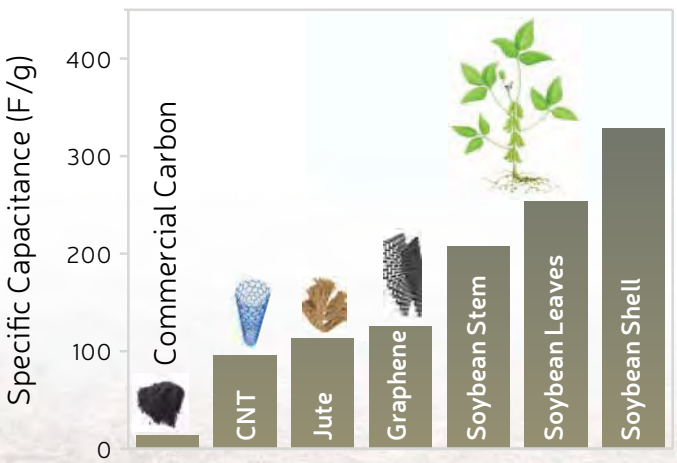
In the second phase of this study, grower pigs (n=80) weighing approximately 180 pounds will be randomly assigned to one of 8 treatment combinations containing high oleic soybean oil, conventional soybean oil, or choice white grease as well as varied sources of soybean meal. Pig weights and the amount of feed consumed by each will be recorded weekly and used to determine average daily gain, feed intake, and feed to gain ratio. Pigs will be slaughtered under USDA inspection at a target finished weight of 280 pounds. Carcasses will be weighed and chilled 24 hours, after which carcass measurements for fatness and muscling will be recorded. Carcasses will then be fabricated to obtain samples for fresh pork and fat quality evaluation. Fresh ground pork sausage will be obtained from the shoulder cuts and analyzed for color and oxidation (rancidity) as measures of fresh pork shelf-life. Fresh bellies will be removed from carcasses and evaluated for fat firmness. Pork bellies will be weighed and used to measure flexibility (a physical measure of fat firmness indicative of fat profile and future bacon quality). Bellies will be processed into bacon and sliced to analyze the quality and yield of the major categories of bacon slices, followed by changes in lipid oxidation. The research team predicts the inclusion of high oleic soybean oil in diets of non-ruminants will not negatively impact production performance, while at the same time products from these animals will possess fatty acid profiles higher in oleic acid.

COMMERCIAL APPLICATION OF SOYBEAN HULLS/STOVER FOR ELECTRONIC INDUSTRIES

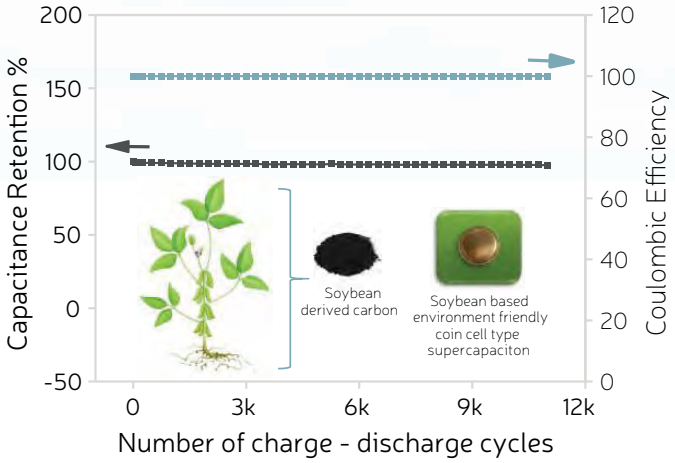
Budgeted: $50,000

Ram Gupta and Pawan Kahol Pittsburgh State University; Dr. Kartik Ghosh, Missouri State University

The USA is one of the largest producers of soybeans in the world. However, a huge quantity of by-products such as soybean hulls and stover remain largely unused for value-added industrial applications. This project utilizes soybean hulls and stover for electronic industries such as



batteries and supercapacitors providing better financial benefits to soybean growers. The batteries/supercapacitors industries have become rapidly growing industries with a global battery market of about $120 billion by 2019. Utilizing soybean hulls/stover for such industries will increase demand for soybean and thus will financially benefit soybean growers.



ENGINE PERFORMANCE TESTING WITH B21-B100

Budgeted: $25,000

National Biodiesel Board

California, under the Low Carbon Fuel Standard, has an increasing appetite for renewable fuels with low Carbon Intensity scores such as biodiesel and renewable diesel. However, CARB has had previous concerns for biodiesel due to increases in Nitrous Oxide (NOx) emissions that lead to the formation of smog. Numerous studies have been performed showing the effects of various biodiesel blends and the impacts of the feedstocks utilized on emissions. Without the results of previous studies validating the performance of NOx mitigating additives, biodiesel would have likely been limited to B5-B7 blends throughout California, particularly biodiesel made from soybean oil. Additive solutions have now increased the allowability to B20 blends. This project then set to move beyond B20 blends in legacy engines to determine how effective additive strategies are for blends above B20.

This project quickly evaluated the emissions from different blend levels and additive doses. As researchers pressed above B20 blends, small chemical differences in the fuels and biodiesel samples were found to have had varying impacts on the emissions. With the support of the funders of this project, the NBB was successful in proving that NOx mitigated B20 blends can be shown to be NOx neutral against CARB diesel fuels under the LCFS and ADF programs in California.

This was the first stage of higher biodiesel blend approval within California and the rest of the country. There currently do not exist any quality specifications for blends above B20 within ASTM that will certainly need to be developed for OEM approval. At this point, CARB has asked to see emissions studies for higher blends with different types of engines. These will include larger new technology diesel engines with emissions aftertreatment systems used in both on- and off-road applications. This next phase for Fiscal Year 2019 will involve looking at biodiesel emissions of various concentrations; in both EPA and CARB diesel fuels; and in various diesel engines to include both on-road / off-road / light-duty / medium-duty / and heavy-duty equipment. The biodiesel samples used may also need to include both low- and high saturation biodiesel fuels as considered by the LCFS and ADF regulations in California. With industry partners, those engines are currently being provided by their manufacturers and installed within emission testing cells at an approved emissions testing facility. Fuels are currently being acquired and shipped to the testing facility to begin the analysis.

MULTI-VISCOSITY BLENDS OF HIGH OLEIC SOYBEAN OIL (SOYLEIC©) AND ESTERS FOR INDUSTRIAL APPLICATIONS

Budgeted: $38,072

Racha Seemamahannop, Shubhen Kapila, Missouri University of Science & Technology

Results obtained to date show a clear difference in properties of Soyleic and generic soybean esters. Results clearly show that the Soyleic oil and its esters are more stable (less prone to oxidation) than generic soybean oil and its esters. In fact, Soyleic oil has been found to be more resistant to oxidation than other available high oleic soybean oils, such as the Vistive and Plenish. Results also show that relevant properties for lubricating applications such as viscosity, pour point, cloud point, lubricity easily varied through transesterification of the Soyleic oil, and Soyleic oil and its esters are the most suitable of the vegetable oils for these applications. A more comprehensive assessment should emerge once remaining experimental evaluations have been completed in July 2019. Results obtained with the project and a related project on dielectric application of Soyleic oil have been presented at an International Conference in Italy – Mytransfo 2018, December 18 – 20, Turin, Italy. Results will also be

presented at the International Conference - PittCon 2019. An invited manuscript for publication in the IEEE Journal is also being prepared.

Educational Opportunities

MONSANTO EDUCATION CENTER FOR SUSTAINABLE SOLUTIONS (MECSS)

Budgeted: $21,600

Darrin Peters, Rockwood Summit High School

2018 was a successful year for the MECSS building at Rockwood Summit High School. They installed all new equipment provided by a grant from the St. Louis-Jefferson County Solid Waste Management district and the Missouri Department of Natural resources, making processing biodiesel much more efficient. Since the arrival of the equipment they have collected gallons of waste glycerin from Washington Universities' cafeteria system. This amount converts to tons of waste not going into the landfill. The previous biodiesel produced has been used in Rockwood School District equipment, including two pick-up trucks, a school bus, a tractor and several lawn mowers. The next batch of fuel will be blended into B50 (50 percent biodiesel and 50 percent petroleum diesel) and sold back to Washington University. The team is excited to deliver their first batch of fuel to Washington University.

Old Brownie, the Ford pickup, won a grant for a vehicle wrap from the National Biodiesel Board. Its wrap was completed in the early fall and she looks amazing! LMC truck has donated many items to Brownie's restoration. With the help of a local Midas repair shop, students are installing new accessories and parts to Brownie's interior and exterior. Soon she will run, drive, and look brand new.

This fall, research assistant Shane McDuffie helped Ranken Technical students with their biodiesel production labs. Ranken's biodiesel education trailer accompanied Rockwood Summit High School students to the St. Louis County Air Show and STEM expo this past fall. Students used the opportunity to increase awareness of biodiesel as a homegrown renewable fuel to the patrons visiting our booth. The Rockwood School District has started hosting STEM nights at various elementary and secondary schools. Students are excited to explain the biodiesel process from field to fuel to other students and their parents. The ASR class is building a biodiesel go-cart that will compete in the state super-mileage challenge in 2019. Fulton High School and Webster High School have already scheduled time this spring to tour MECSS and make a small batch of biodiesel, purify it, and give it to Brownie. Both schools have visited the MECSS building before, and they want to come back.

Craig Poe of Ranken Technical College and Darrin Peters of Rockwood Summit High School plan to take the trailer to Columbia Missouri this summer to teach Ranken's Renewable Fuel Workshop to interested teachers in the central Missouri area.

Darrin Peters and students at Rockwood Summit High School

UNDERGRADUATE RESEARCH INTERNSHIPS

Budgeted $15,471

Bill Wiebold, University of Missouri

The objective of this project was to connect promising and highly motivated undergraduate students with scientists working with some aspect of the soybean industry. The goal was to demonstrate to students that soybean is a great topic for research and encourage them to continue in their education after they graduate.

In 2018, two undergraduate students were mentored by two faculty members in the Division of Plant Sciences at the University of Missouri. Chrisee Wheeler was mentored by Dr. Felix Fritschi. Dr. Fritschi is plant physiologist. He studies nearly every aspect of soybean growth and development. Chrisee's research focused on nitrogen

fixation – one of the most important set of reactions in plants. Through nitrogen fixation soybean plants can obtain all of their nitrogen requirements. Her project included sampling soybean plants and measuring multiple characteristics that can be used to select for improved nitrogen fixation. Data obtained by Chrisee will be added to information collected by Dr. Fritschi's other students and staff.

Jessica Vitale was mentored by Dr. Kaitlyn Bissonnette. Dr. Bissonnette is a plant pathologist. Dr. Bissonnette research and extension programs focuses on finding economical ways to manage multiple soybean diseases. Jessica conducted a survey of foliar soybean diseases in Missouri in conjunction with the Field Crop Pathology lab. Eleven fields were scouted representing each of the four distinct agricultural regions of the state. Leaf and plant samples showing signs of diseases were collected and the diseases were identified in the lab with the assistance of the MU Plant Clinic. Multiple diseases were identified and mapped for their occurrence and severity in production fields to provide valuable insight for implementing disease management solutions. In addition, Jessica participated in the MSMC sponsored Scouting Schools by demonstrating basic soybean scouting techniques and disease identification strategies.

Regional Affiliations

MID-SOUTH SOYBEAN BOARD (MSSB)

Budgeted: $100,000

Dawn Howe, Mid-South Soybean Board

The MSMC has been a member of the Mid-South Soybean Board (MSSB) since 2012. The other states associated with the MSSB include Arkansas, Louisiana, Mississippi, and Texas. Being a member of the MSSB is very important for our Missouri Bootheel producers that typically have more in common with the rest of the Delta region than they do with Midwest production.

The Mid-South Soybean Board was organized in 2009 to promote soybeans, soybean products, soybean research and development, to include but not limited to:

- promote industry information
- promote consumer information
- promote market development
- promote producer information
- promote research and development.

Projects funded by the MSMC through our affiliation with MSSB include:

Breeding and Genetic Mapping for Flooding Tolerance in Soybean
Led by Pengyin Chen, University of Missouri
$60,000

Enhanced Pest Control Systems for Mid-South Soybean Production
Led by Trey Price, Louisiana State University
$40,000

These two studies are great examples of research focused towards the issues faced in the Delta region. The potential for flooding in the Delta is much greater than is typical in the Midwest. And the pest project is focused on varietal tolerance for cercospora leaf blight, frogeye leaf spot and stinkbug. All of these are important pests in the mid-south. Pat Hobbs has proudly served as the MSSB Chair the last several years and is currently serving as one of our four Missouri USB Directors.

Pat Hobbs - Dudley, MO MSSB Board Chair

Dr. Chen & Pat Hobbs, MSSB Chair from Dudley, MO, observe and discuss flood project at the MU Delta Center

NORTH CENTRAL SOYBEAN RESEARCH PROGRAM (NCSRP)

Budgeted: $150,000

Ed Anderson, North Central Soybean Research Program

The North Central Soybean Research Program is a collaboration of 12 state soybean associations.
The farmer-led NCSRP invests soybean checkoff funds to improve yields and profitability via university research and extension. The focus of NCSRP is soybean production research and extension outreach. The states included in the NCSRP include: Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota and Wisconsin.

MSMC Director Cecil DeMott, Rock Port, MO, recently elected NCSRP President.

NCSRP collaborates to improve farmer profitability through research for over twenty-five years. Rock Port soybean farmer Cecil DeMott, President of the group, represents Missouri on NSCRP board of directors and executive committee.

NCSRP serves as a bridge between state and national soybean organizations and is the recognized leader in funding and communicating basic and applied soybean research programs that are highly collaborative and uniquely appropriate in addressing soybean production, profitability and environmental sustainability for growers across the North Central region.

NCSRP's emphasis on enhancing and protecting soybean yield and quality through genetics and agronomic practices contributes to soybean farmer success today and tomorrow.

THE SOYBEAN RESEARCH & INFORMATION INITIATIVE

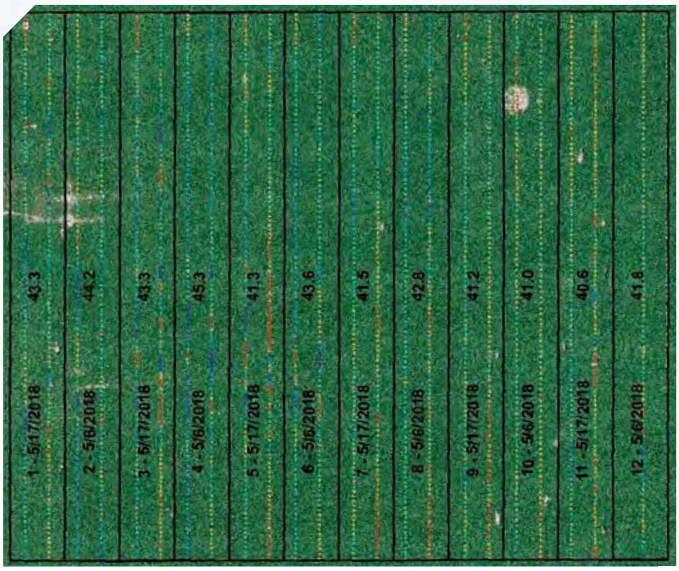
The Soybean Research and Information Initiative, funded by the North Central Soybean Research Program (NCSRP), launched in Spring of 2014 to make soybean research more accessible.

The site features research from 13 universities, grower-focused disease and pest information, and resources on other agronomic issues. Most beneficial is the overview of 24 of the most prolific soybean diseases throughout the region, which details disease life cycles, agronomic impact, and disease management solutions.

The Missouri Soybean Merchandising Council, a member of the NCSRP, supports this project.

Learn more online through the NCSRP or at ***www.soybeanresearchinfo.com***.

STRIP TRIAL EXTRAS



Yield map of strip trial showing soybean dry yield data reported as bushels per acre (bu/A). Strips are labeled with their mean yield and the date of termination. Delaying termination reduced yield by just over a bushel at this location.

- < 25 bu/A
- 25-30 bu/A
- 30-35 bu/A
- 35-40 bu/A
- 40-45 bu/A
- > 45 bu/A

Termination trial in Cooper County in 2018. A cereal rye cover crop was terminated 13 days before planting and on the same day as planting (May 8). Image was taken June 1.

Yield results from the termination date comparison trials planted to soybeans (2016-2018)

YEAR	COUNTY	COVER CROP	REPS	DELTA TERMINATION DATES (DAYS)	LATE TERMINATION DATE DAYS TO PLANTING 1	GRAIN YIELD (BUSHELS/ACRE)			P VALUE
						EARLY	LATE DATE	DELTA	
2016	Andrews	Cereal rye	4	33	18	62.6	60.2	-2.4	0.02
2016	Lafayette	Cereal rye	3	22	3	43	37.6	-5.4	0.14
2016	Perry	Cereal rye	5	21	-3	63.8	56.2	-7.6	0.02
2017	Ralls	Cereal rye mix	5	33	0	54.4	57.6	3.2	0.71
2018	Cooper	Cereal rye	5	13	0	39.1	36.1	-3	<0.01
2018	Franklin	Cereal rye	7	12	7	49.8	50.7	0.9	0.43
2018	Callaway	Cereal rye	6	11	0	43.1	41.8	-1.3	0.02
2018	Callaway	Cereal rye	8	18	-3	57.6	58.4	0.8	0.36
				MEANS		51.5	50	-1.4	0.11

[1] *Negative numbers mean late termination date was after planting.*

ver. March 5, 2019

MISSOURI SOYBEANS

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