

ANNUAL RESEARCH REPORT



LETTER FROM THE EXECUTIVE DIRECTOR

In the following pages, we share details on the research projects currently receiving checkoff funding from Missouri's soybean farmers through the Missouri Soybean Merchandising Council.

The Missouri Soybean Merchandising Council is truly a farmer-run organization, led by 13 farmer-directors from across the state. Each director is elected by their peers and is instrumental in carrying out the responsibility of investing soybean checkoff dollars for Missouri soybean growers. In Missouri, those farmers ensure soy checkoff dollars go toward research and education programs, and growing demand for beans.

We appreciate your continued attention to the research process and this annual report, as well as your participation in field days and research seminars throughout the year.

Each project showcased in this report has been and continues to be evaluated by Missouri farmers, our professional staff, and independent reviewers. Some of these are short term projects with immediate applications on the farm and in industry, while others have a longer timeline before comparable results are published. All have a direct connection to the challenges facing Missouri farmers today.

Please don't hesitate to let any member of the Missouri Soybean team know how we can better serve you through your soybean checkoff. We're proud to work for you, Missouri farmers.



Gary Wheeler, MSA/MSMC Executive Director / CEO

A handwritten signature of Gary Wheeler in black ink.

Gary Wheeler - MSA / MSMC Executive Director / CEO



MSA Board Members

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LETTER FROM THE MSMC BOARD CHAIR

When we survey farmers about their priorities for the soybean checkoff and the Missouri Soybean Merchandising Council, the responses are clear: solve the problems we're facing now, and head off the big challenges coming at us as best we can.

This Annual Research Report highlights research and demonstration projects working toward those two objectives. And when we're considering new project proposals, the feedback we receive throughout the year is top of mind.

Research is a top priority for your Missouri Soybean Merchandising Council and one of three strategic priorities we've set (the other two are growing demand for soy and providing educational programs). In all three of our strategic areas, we're encouraging collaboration and partnership. It's important that we build upon previous work, and get the results into your hands – we know there's a bright future ahead for soy in Missouri and around the world. It's up to us to capture those opportunities, from raising yields and soybean quality to protecting our land and water resources.

Thank you for your continued support in this important work.



Robert Alpers - MSMC Board Chair



Robert Alpers, MSMC Board Chair

MSMC Board Members

Robert Alpers, Prairie Home
Kevin Mainord, East Prairie
Cecil DeMott, Rock Port
Kyle Durham, Norborne

Harold Gloe, Hermann
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Research Project Review Process



2020 ANNUAL RESEARCH REPORT

This annual report summarizes all of the current research projects supported with checkoff funding for 2019-2020. The projects are divided among three areas of emphasis: **Research, Demand and Education/Outreach.**

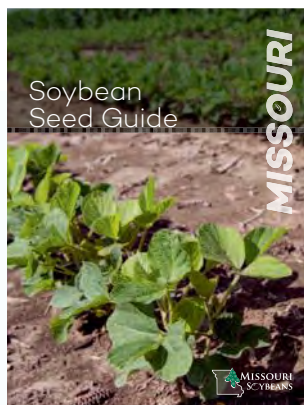
Research Projects include soybean breeding, solving specialized problems and multi-state partnerships.

Demand Projects focus on new uses, feed and food production that have the potential to increase soybean use.

Education/Outreach Projects help to answer agronomic questions and concerns and provide for student development.



-Research Projects-



Soybean Breeding – Several soybean breeding projects are funded by the checkoff at both the Fisher Delta Center and the Bay Farm Research Facility. The fruits of the labor in variety development takes years to accomplish and can be found in Missouri Soybean Seed Guide. This seed resource guide may be found online at: mosoy.org

frogeye leaf spot resistance and, of course, yield. This is the core funding for Dr. Chen's soybean breeding program.



Delta Center Crossing Block

DELTA CENTER SOYBEAN BREEDING PROGRAM

Pengyin Chen & Andrew Scaboo, UMC Budgeted: \$330,000

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,



Soybean Root suffering damage from Root Knot Nematode – A major pest of Soybean in the Delta Region

NORTH MISSOURI SOYBEAN BREEDING PROGRAM

Andrew Scaboo & Pengyin Chen, UMC Budgeted: \$300,000

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. This project funding is the base for the MU Northern Missouri Breeding Program.



Advanced yield trials growing in Atchison County, MO during the summer of 2019

WINTER NURSERY TO SUPPORT SOYBEAN BREEDING

Pengyin Chen & Andrew Scaboo, UMC Budgeted: \$115,000

Winter nurseries are an essential component of a successful soybean breeding and genetic program. Nurseries in Costa Rica, Puerto Rico and Hawaii are used so crosses can be made in off-season for Missouri and year-round, which greatly enhances the efficiency and timeliness of the Missouri soybean breeding program. These winter nurseries greatly support our breeding programs and are crucial to compete in variety performance and provide productive genetics for Missouri farmers.



Puerto Rico Winter Nursery

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

Kristen Bilyeu, ARS, Andrew Scaboo, UMC Budgeted: \$90,000

The goal is to create competitive soybean lines with the high oleic and low linolenic traits plus additional seed composition traits to enhance the value of the soybean to producers, processors, and end users alike. Establishing a HOLL plus soybean breeding and molecular selection program dedicated to developing high yielding maturity group III and IV soybean varieties for Missouri farmers is the specific objective of this proposal. The plus traits have each been characterized and molecular markers have been developed for selection.



Project Status for 2020:

- Progeny row field tests of first four finished HOLL Plus lines
- Final selection of HOLL Plus genotypes from 12,000 individual plants for 14 new lines
- Continued communication efforts to encourage testing and utilization
- Yield tests of HOLL Plus lines expected in 2021

The result of this research project will be high yielding soybean varieties that contain a combination of traits that will benefit Missouri soybean farmers, as well as the processor, and the end user.

SCN SCREENING FOR MISSOURI BREEDING PROGRAMS

Andrew Scaboo, Pengyin Chen & Melissa Mitchum, UMC Budgeted: \$110,000

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.



SCN bioassay for the southern breeding program growing in the greenhouse during evaluation for resistance to soybean cyst nematode, April 2019.

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 the delta region producers and ensure SCN resistance for the other portions of Missouri.

UTILIZING MOLECULAR MARKERS FOR SOYBEAN VARIETY DEVELOPMENT

Andrew Scaboo & Pengyin Chen, UMC Budgeted: \$100,000

Currently, there is a major investment by public and private company breeding programs to use molecular marker data for predicting the performance and breeding value, or usefulness, of experimental lines within the breeding populations, as well as for parental selection. 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.

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 over the last years from MSMC and MSA into the Bay Farm Research Facility, we now have access to much of what is needed to create a centralized applied molecular breeding lab for the soybean breeding program at MU.

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

Andrew Scaboo, UMC, Jason Gillman, ARS Budgeted: \$65,000

Project Objectives:

- 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.

- c) initiate backcrossing efforts to move value-added genetics from wild soybean into adapted soybean germplasm and varieties.



Experimental lines from crosses with wild soybean types.

A number of lines from the University of Missouri's northern soybean breeding program contain 25-50% genetic material from wild soybean. These lines are promising entries in both early and advanced yield trials. Although wild soybean has currently shown 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.

INVESTIGATING DICAMBA AND 2,4-D HERBICIDE OFF-TARGET MOVEMENT

Kevin Bradley & Mandy Bish, UMC Budgeted: \$40,000

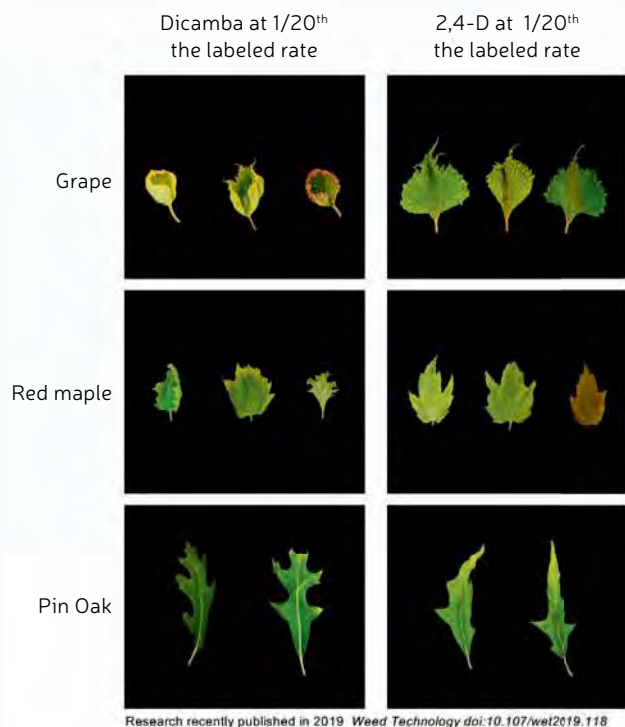
The primary objectives of this research are to determine the effects of time of application, weather conditions and new formulations on the concentration of dicamba detected in the air following application. Also, a primary goal is to assess weather and environmental factors surrounding dicamba applications in order to identify any consistencies that may explain off-site dicamba movement.

Off-target movement is typically grouped into one of three categories:

- a) tank contamination or improper cleaning of equipment
- b) physical drift, which is caused by factors that contribute to droplets being moved by wind at the time of application

- c) secondary drift, which is caused by factors that result in the herbicide moving some time after the application. The factors that contribute to secondary drift are not well understood.

The objectives of this study, which began in 2017, have focused on understanding factors that affect secondary drift, mostly as they pertain to dicamba movement. Starting in 2019 both dicamba and 2,4-D were evaluated.



Malformed leaves of grape, red maple, and pin oak due to synthetic auxin herbicide injury.

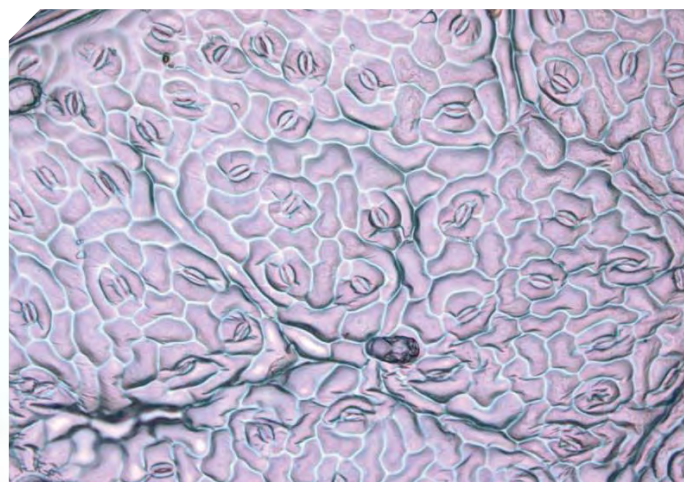
LEVERAGING STABLE ISOTOPE TRAITS TO IMPROVE SOYBEAN WATER USE EFFICIENCY

Felix Fritschi & Andrew Scaboo, UMC Budgeted: \$70,000

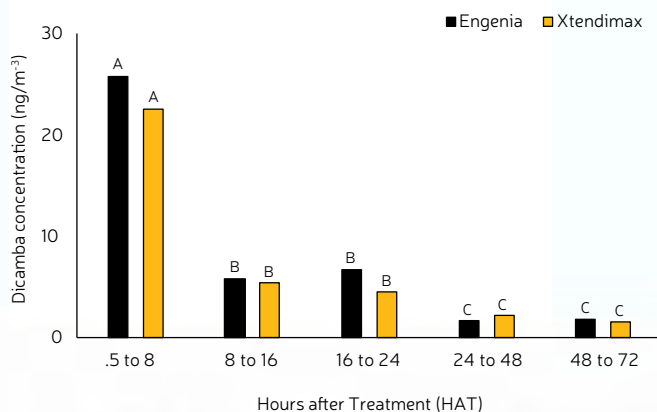
Water use efficiency (WUE) in crop species is defined as the amount of plant tissue and/or seed yield produced per unit of water used by the crop. Developing soybean varieties with improved drought tolerance can be achieved by increasing WUE. Soybean lines have been identified that differ in WUE and we are using these 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, and
- 4) develop soybean populations that can be used to identify molecular markers specific for different strategies that use water more efficiently.

In 2019 we examined physiological and morphological characteristics of soybean lines that contrast in WUE efficiency. We measured a range of physiological characteristics and measured stomatal numbers on the upper and lower surfaces of leaves of different lines. We are currently analyzing the data and processing the samples collected during the season to dissect mechanisms associated with greater WUE.



An epidermal print of a soybean leaf that was acquired with a microscope and shows the outlines of individual epidermal cells as well as stomata. Stomata are a main control point for water loss from the leaf and CO₂ uptake into the leaf and thus play a critical role in the regulation of soybean water use efficiency.



Engenia and Xtendimax were detected at similar levels in the air for more than three days following application. Research published in 2019 in *Journal of Environmental Quality* volume 48:1675-1682

As part of our breeding effort we have made crosses between elite germplasm and lines selected for WUE traits. We advanced offspring from these crosses and conducted yield tests of the most promising lines in 2019. We harvested the seed and submitted samples for analysis to obtain information about the WUE of these lines. Based on yield and WUE data the most promising lines will be planted in multi-location yield tests in 2020.

PARTNERSHIPS:

MID-SOUTH SOYBEAN BOARD

The Mid-South Soybean Board was organized 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



ENHANCED PEST CONTROL SYSTEMS FOR MID-SOUTH PRODUCTION

Trey Price, MSSB Project- MO Share Budgeted: \$40,000

Missouri partners on the pest project which is focused on varietal tolerance for cercospora leaf blight, frogeye leaf spot and stinkbug. All of these diseases/insects are important pests in the mid-south and in the delta region of Missouri. Pat Hobbs has served the MSSB for several years and now MSMC Director Baughn Merideth serves as the MSSB Director for Missouri.

SCREENING SOYBEAN GERmplasm AND BREEDING SOYBEANS FOR FLOOD TOLERANCE

Pengyin Chen, MSSB Project- MO Share Budgeted: \$60,000

The potential for flooding in the Delta is certainly much greater than is typical in the Midwest. Dr. Chen leads this study which is a collaboration between several states in the MSSB. The project focuses on flood tolerance at both mid-season and early season stages of soybean development.



Dr. Chen and other researchers in the Mid-South have made significant progress identifying soybean lines with superior tolerance to flooding conditions.

NORTH CENTRAL SOYBEAN RESEARCH PROGRAM

Ed Anderson Budgeted: \$150,000

The North Central Soybean Research Program, a collaboration of 13 state soybean associations, invests soybean checkoff funds to improve yields and profitability via university research and extension. The NCSRP funds many research projects and is involved with major initiatives such as:

- Soybean Cyst Nematode Coalition
- Soybean Research & Information Network
- National Soybean Checkoff Research Database



The NCSRP evaluates projects that have a regional impact and involve both basic and applied research. The QSSBs contribute to the funding pool and studies are decided upon by the farmer board. The current President of the NCSRP is MSMC Director, Cecil DeMott.

-Demand Projects-

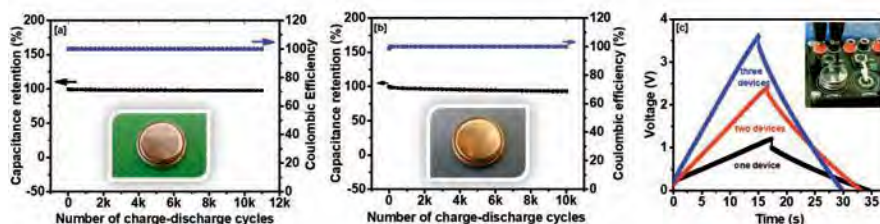
COMMERCIAL APPLICATION OF SOYBEAN HULLS/STOVER FOR ELECTRONIC INDUSTRIES

Ram Gupta, Karthik Ghosh & Pawan Kahol, Pitt. State

Budgeted: \$47,802

This project is designed to synthesize and characterize active carbons from various parts of the soybean plant. Then fabricate energy storage devices using the carbon from soybean plant. To date, tests show a 20 times better charge storage capacity as compared to commercial carbon.

This research has shown that soybean hulls/stover can be converted to high-performance carbon for batteries and supercapacitors. The value-added application of soybean hulls/stover will provide financial benefits to Missouri Soybean growers. The next year funding is dedicated to improving the performance and capacity of the devices so that soybean-based devices could be competitive with current commercial batteries and supercapacitors.



Comparison of device performance fabricated using carbons synthesized using soybean stem in (a) two-step process, (b) one-step process, and (c) devices in series configuration showing improved voltage.

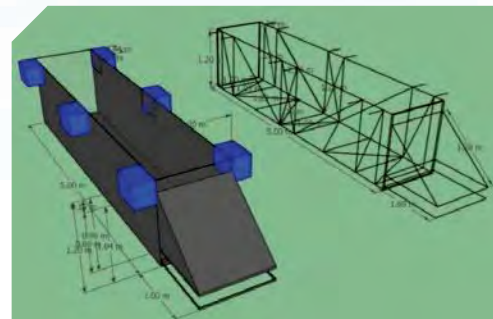
IN-POND RACEWAY SYSTEM DEVELOPMENT TO ENHANCE AQUACULTURE FEED SECTOR INTENSIFICATION IN CAMBODIA

Alan Pooch & Marypat Corbett, WISHH Budgeted: \$50,000

Project goal is to develop Cambodia's aquaculture feed sector to enhance opportunity for US soybean meal exports for use in aquaculture feed thru a demonstration "in-pond raceway system" technology.

The ASA/WISHH Asia Division Director travelled to Cambodia in September 2019 to discuss this project with

the WISHH In-Country Representative. Two possible aquaculture farms were identified. Discussions continued in October and November to finalize the aquaculture farmer, construction timeline and needed materials with WISHH In-Country Representative and the proposed technical consultant.



In-pond raceway blueprints for Rathada Hatchery.

Dr. Len Rodgers was selected as the technical consultant due to his aquaculture professional background, time at Auburn University and relationships with progressive Cambodian aquaculture farmers. AgriMaster, a Cambodian owned feed mill, opened their new aquaculture feed mill in 2019 and uses U.S. soybean meal.

Rathada Hatchery, is the aquaculture farmer and material sourcing and construction started in late December. In January 2020, a ribbon-cutting ceremony was held at Rathada Hatchery. Matt Amick, MSMC Director of Renewable Fuels and New Uses and David Lueck, a WISHH Committee Member, attended this ceremony. A Farmer Field Day will be scheduled to educate area aquaculture farmers on the economic advantages of using in-pond raceway (IPR) over

traditional production methods, how to construct their own IPR and the many benefits of using commercial aquaculture feed containing U.S. soybean meal.

VIETNAM IN-POND RACEWAY SYSTEM (IPRS) PROGRAM

Will McNair, USSEC Budgeted: \$35,050

Add an additional "in-pond raceway system" in the South of Vietnam to be used as an educational tool for area aquaculture producers and to enhance opportunity for US soybean meal exports.

COMPREHENSIVE APPROACH FOR HIGH OLEIC SOYBEAN OIL INCLUSION IN BROILERS, LAYERS, AND MARKET HOGS: (YEAR TWO LAYING HEN PERFORMANCE AND EGG QUALITY)

Bryon Wiegand, Ty Peckman and Zach Callahan, UMC

Budgeted: \$61,069

The FDA ban on the use of partially hydrogenated oils in food processing has led to a search for a stable alternative oil source. With its increased proportion of oleic acid, high oleic soybean oil has the ability to serve as a stable oil source for in human food processing. With the possibility of overflow of this oil into the livestock feed sector, it is necessary to understand the effect of this novel oil and meal source on livestock growth and performance, along with the parameters surrounding the meats products from those animals.

Feed sources that contain increased levels of oleic acid have shown improvements in quality traits of meats by altering the fatty acid profile. Oleic content has been positively correlated with properties such as flavor, tenderness, juiciness, etc. Another objective is to measure the uptake of high dietary oleic acid on the performance of non-ruminants.

Laying Hen Study: Laying hens started full egg production in December and we collected data on hen body condition and laying rates. Additionally, hens went on treatment diets in January. Periodic sampling for egg quality, composition, and shelf life will continue for 44 weeks of production.

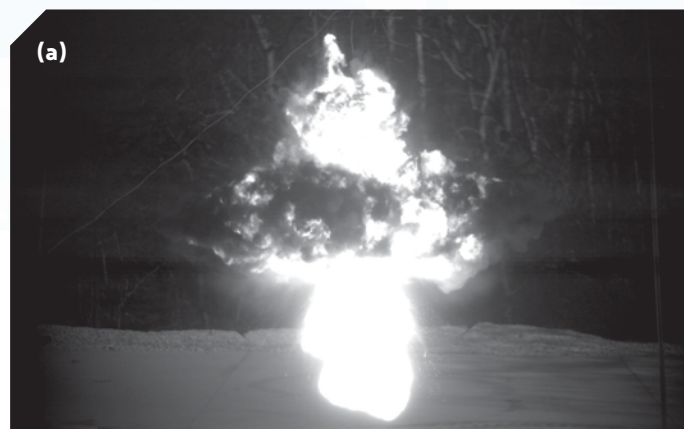
EXPLOSIVES AND SOYBEANS: MEETING THE NEED FOR A MORE ENVIRONMENTALLY FRIENDLY EXPLOSIVE

Phillip Mulligan & Philip Whitefield, MST Budgeted: \$94,511

Two primary tasks are being undertaken.

1. Complete a market study to understand why soy-based ammonium nitrate and fuel oil (ANFO) has not been widely used in the explosives industry.
2. Compare the relative energy and toxic gas production of biodiesel, soy oil, and traditional diesel based ANFO.

Overall, soybean oil presents itself as a viable substitute for diesel fuel, as it is packed full of energy, more environmentally friendly, and just as easy to use. The results of this study indicate a substantial domestic market for soybean farmers and significant cost savings for explosive manufacturers.



Fireball from a Controlled Explosion Examined at Missouri S&T's Test Facility (a), Plate Dent Results for ANFO (b), and Plate Dent Results for Soybean based ANFO (c).

Year one of the project has focused on conducting a market study to determine what factors have prevented Soybean oil from being used in Ammonium Nitrate and Fuel Oil (ANFO) bulk explosives and what factors need to be addressed to show the industry Soybean oil is a viable substitute for petroleum diesel. The market study provided an insight into what the primary concerns these companies had

about soybean oil breaking into the market. Year two of the proposed effort will focus on providing the MSMC with the information to address the mining and explosive companies' concerns and start marketing ANSOY with US explosive manufacturers.

ONE STEP SYNTHESIS OF SOYBEAN OIL-BASED POLYOLS FOR FLAME RETARDANT POLYURETHANES

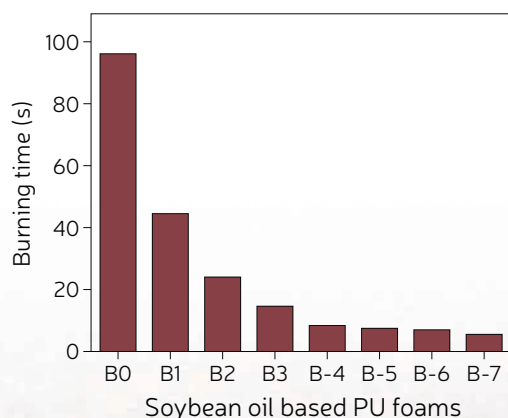
Ram Gupta & Pawan Kahol, Pitt. State Budgeted: \$51,268

The main disadvantage of the polyurethane foams is their high flammability which is due to the predominant presence of carbon and hydrogen in their structure. Highly porous and combustible nature of polyurethane foams further facilitates the flame spread rate. High flammability of polyurethane foams restricts some of their valuable applications.

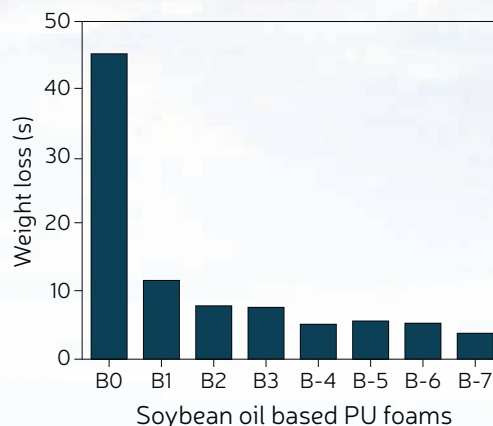


Photo of two foams before and after burning. B0 is a control foam and B4 is an experimental, soy-based foam with flame retardant.

In this project, we synthesize soybean oil based polyols for polyurethane industries using a cost effective method which will provide polyurethane foams with improved



Burning time of B0 (control) and multiple soy-based foams with retardant.



Weight loss of B0 (control) and multiple soy-based foams with retardant.

physicomechanical properties and significantly reduced flammability. Our method for the synthesis of soybean oil based polyols does not require any solvents, high temperature, multistep reactions or expensive chemicals making this process very suitable for commercialization. Research continues on this important project.

HIGH OLEIC SOY-BASED INSTANT POWDER THROUGH SPRAY DRYING: VALUE-ADDED PRODUCT

Kiruba Krishnaswamy, UMC Budgeted: \$32,134

Develop a novel food product from HO soybean. Ready-to-use HO soy instant powder from HO soybeans and mechanically defatted soybean meal using spray drying technology. Spray drying masks the beany flavor and allows the incorporation of new flavors to increase consumer acceptability.



Spray dried HO soymilk powder

High oleic soybean has up to 85% oleic acid and provides good nutrition for human consumption. The proposed project aims to address this nutritional challenge by developing a food product from High Oleic (HO) Soybean. Ready-to-Use High Oleic soy instant powder from HO soybean and mechanically defatted HO soy meal developed using spray drying technology. Spray drying is a technique used in the food industry for flavor encapsulation/ masking. Using this technique helps to mask the beany flavor of soy, and provides the



Buchi-Spray Dryer B-290 with soy milk powder

possibility of incorporating flavors (Chocolate & Vanilla) to increase consumer acceptability. Response surface methodology will be employed for statistical optimization of spray drying conditions. We are in the process of optimizing the time, temperature, flow rate, color, wetting time, flowability of the Ready-to-Use High Oleic soy instant powder.

in cattle diets. Ultimately, greater inclusion of soybeans in cattle diets could allow for greater demand and value of harvested soybeans when markets are congested.



Dairy cow fitted with Ruminant Cannula

A COLLABORATIVE FIELD EVALUATION OF HIGH OLEIC SOYBEAN OIL AS DIELECTRIC LIQUID IN TRANSFORMERS

Racha Seemamahannop, MST; Kristin Bilyeu, ARS; & Kevin Rapp, Cargill Budgeted: \$36,366

Real world testing of high oleic soybean oil as a highly stable dielectric liquid in transformers based on the laboratory studies conducted to date is the purpose of this project.

Fatty acid composition of neutralized Soyleic oil was determined with a gas chromatograph – mass spectrometer (GC-MS) after esterification to methyl esters. The average percent fatty acid composition of the Soyleic oil was determined to be Palmitic 5.4%; Stearic 3.2%; Oleic 79.5%, Linoleic 9.5% and Linolenic 2.4%. Low Linoleic and Linolenic content make Soyleic more resistant to oxidation than the generic soybean oil and desired applications require high oxidation stability as the dielectric oil in transformers. Further experiments are planned for this spring to confirm the positive attributes of Soyleic oil for use as dielectric liquid in operating transformers.

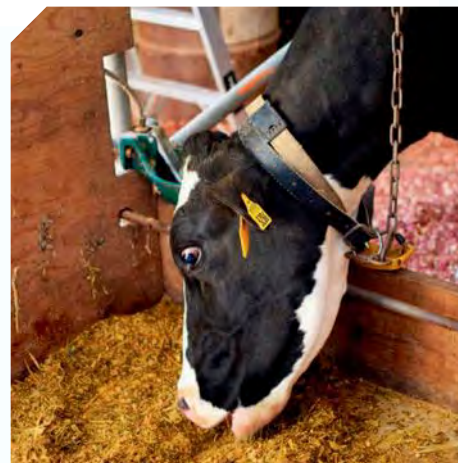
INCREASING SOYBEAN USE IN CATTLE DIETS: GROWING BEEF CALVES AND LACTATING DAIRY COWS

Derek Blake Budgeted: \$51,295

Gaining a greater understanding of the benefits provided from feeding growing cattle soybeans and feeding strategies that limit concerns of feeding unroasted soybeans to dairy cattle could allow for expanded use of soybeans

The Missouri Soybean Merchandising Council has helped to fund this work using lactating dairy cows fitted with ruminal cannulas that will help determine the direct impacts feeding whole soybeans on protein digestion in cows and to determine if feeding lysine able to bypass ruminal fermentation in combination with whole soybeans can increase milk production by dairy cattle. A greater understanding the impacts of feeding whole soybeans on milk production, and ration formulation strategies able to increase milk production among cows fed whole soybeans will

be able to help dairy producers take greater advantage of soybeans as a feed ingredient. Ultimately, improving the ability of dairy producers to use soybeans as an economically viable ingredient will help to increase the uses and market demand for whole soybeans that can allow improvements in economic returns to dairy and soybean producers. This work is ongoing at the University of Missouri's Foremost Dairy and is on schedule to conclude by June 2020.



Dairy cow in soybean feeding study



EMISSIONS AND DURABILITY FOR BLENDS OVER B20 IN CALIFORNIA

Scott Fenwick & Brad Shimmens, NBB Budgeted: \$25,000

The goal is to address technical concerns with blends over B20 as public policies are being considered to reduce carbon more than the 16% provided by B20 and which could provide favorable market conditions for blends over B20.

The California Air Resources Board (CARB) has announced their next regulatory proposal which will be a Low Emissions Diesel fuel requirement. The goal of the National Biodiesel Board is to help demonstrate that higher blends of biodiesel and blends with renewable hydrocarbon diesel fuels can help answer their thirst for low-carbon transportation fuels.

This Emissions and Durability project will work with OEMs and regulators to conduct technical efforts to answer initial questions regarding the next phase of significant biodiesel growth as we seek to move beyond B20 blends. NBB has now assisted in acquiring the fuels for CARB to initiate testing at the Univ. of California in Riverside (CeCERT) as well as the volumes needed at facilities duplicating the testing for the NBB. In order to demonstrate emissions and criteria performance, CARB is requiring dynamometer testing with three types of engines. The John Deere engine has been installed at CeCERT and is currently undergoing evaluation. The Cummins engine was installed at Southwest Research Institute and that analysis has been completed for the NBB. This engine will now be dismantled and shipped to CARB at CeCERT to be installed and tested at their facility. The last engine has been difficult, and we have been unsuccessful with obtaining in-kind OEM help. CARB has since purchased their own CAT engine and the NBB has found an identical one available. Arrangements are being made to obtain this engine for our duplicative testing.

STATE ENERGY INITIATIVES (SEI) - STATE REGULATORY AND ENVIRONMENTAL SUPPORT

Shelby Neal & Brad Shimmens, NBB Budgeted: \$25,000

Focus on regulatory activities at the state level. Monitor every state regulatory and legislative proceedings in the

nation. Ensure decision-makers fully understand technical issues associated with biodiesel and related industries.

We made significant progress on our ongoing project designed to summarize the most frequently asked technical questions that NBB receives. We finalized development of one-page infographics for the following issues: biodiesel's cold flow properties, biodiesel/renewable diesel greenhouse gas emissions benefits, food versus fuel, and performance issues associated with electric heating systems.

We continue to work closely with staff at the California Air Resources Board (CARB) on several programs designed to increase blends of biodiesel sold in the state. Specifically, we are engaged in testing to determine if combinations of biodiesel and renewable diesel offer unique emission benefits (NOx and PM) that the state might wish to incentivize. The first set of tests started in late December on an off-road John Deere engine. We expect CARB's testing to be finalized in the late spring timeframe.

We continue to work with New York State regulators to determine biodiesel's role in the recently passed Climate Leadership and Community Protection Act, which requires an economy wide greenhouse gas reduction of 40% by 2030. We engaged in a series of meetings with administrative agencies and other stakeholders during the week of December 2nd in Albany and New York City. The purpose of these meetings was to answer questions about biodiesel, its feedstocks, and its numerous applications. These meetings went very well.

We have started a project to summarize much of our most requested technical information in the form of one-page infographics. Examples of issues include cold flow properties, compatibility in engines and heating oil appliances, greenhouse gas benefits, and economic benefits.

EMISSIONS AND DURABILITY FOR BLENDS OVER B20 WITH ADM AND OPTIMUS

NBB Budgeted: \$25,000

Optimus Technologies produces vehicle technologies which include the ability to install secondary heated fuel tanks and fuel lines that enable the use of B100 as a fuel without blending the biodiesel with petroleum diesel fuel first. Optimus has partnered with ADM to install their systems on 5 vehicles. ADM will be supplying a similar 5 additional vehicles that will operate on petroleum diesel fuel for comparison. This fleet of 10 trucks is preparing to

be involved in the same routes between Decatur, IL and St. Louis. These 10 trucks are being equipped with new diesel particulate filters and fuel injectors to enable a baseline and for comparison over the life of the study. Over the last quarter, new fuel tanks have been purchased that will be used specifically for these fleets. Oil changes and filter changes at the recommended intervals, along with used oil monitoring analysis, has been arranged with a laboratory in-state. New fuel injectors and particulate filters have been analyzed for baseline comparisons. At the completion of the

study, the fuel injectors and diesel particulate filters will all be removed and re-analyzed to determine comparative fuel effects. The results are expected to yield durability impacts, differences in maintenance between the two fleets, and fuel economy differences between the two fuels.

The engineering and design calculations for these specific trucks is completed and the Optimus systems have been constructed for these trucks. The 12-month driving comparison commenced mid-February.

Education Projects

"MU CERTIFIED" STRIP TRIAL INITIATIVE: COVER CROP TRIALS

John Lory, UMC Budgeted: \$73,150

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 are the center of this project and it also serves as the core funding from MSMC for the strip trial program. Since the program inception we have completed 194 strip trials on Missouri fields, 25% of them focused on cover crops. The table summarizes strip trials completed by the strip trial program since the initial 2016 growing season. Various Cover Crop options and studying cover crop termination are examined. Over the past four years the Missouri strip trial program has implemented almost 200 trials on Missouri farmer fields.

A strip trial is a partnership with the farmer and a local Extension professional. We work with the farmer to layout the trial and a local contact is available to answer questions

and address problems. Over the course of the trial we 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. Over time we have learned some of the critical features of a successful trial.



Cover crop vs no cover crop strip trial. Soybean was planted into green cereal rye and winter wheat.

Trial Type	2016	2017	2018	2019	Total
Cover Crop Comparison	7	12	10	9	38
Cover Crop Termination date	8	3	5	0	16
Cover Crop Before Corn	-	-	-	3	3
Soybean R3 Fungicide	-	-	10	11	21
Soybean Seed Treatment	-	-	-	8	8
Nitrogen Management	5	1	11	12	28
ILEVO®	-	20	10	-	30
Phosphorus Response	25	20	2	-	47
Other trials	-	-	-	1	1
Totals	45	56	48	45	194

The strip trial program relies on our farmer advisory panel to help prioritize trials available each year and includes: Robert Alpers (Prairie Home), Neal Bredehoeft (Alma), Matt Lambert (Brookfield), Mark Lehenbauer (Hannibal), Brian Lehman (Versailles), Aaron Porter (Dexter), Linus Rothermich (Auxvasse), Doug Thomas (Brashear), Jules Willot (Ladonia), and Industry rep: Scott Wilburn (MFA, Ladonia).

We look forward to continuing our work with Missouri farmers implementing strip trials on their farm!

MONSANTO-EDUCATION CENTER FOR SUSTAINABLE SOLUTIONS (MECSS) PROJECT COORDINATOR/RESEARCH ASSISTANT

Darrin Peters, Shane McDuffie & Mihira Wijeweera; Rockwood School District Budgeted: \$19,440

We participated in the St. Louis Air Show and STEM Expo, we host field trips to the MECSS building, our students present biodiesel potential to our area schools, we provide biodiesel programs to Ranken Technical College and other



Ranken students working with biodiesel

schools that request our services. Our kids have built a super mileage car that competes in an annual competition and runs on student produced biodiesel. Ranken Tech has partnered with us to build an educational biodiesel trailer that can travel to schools and other educational facilities to help teach the public on the potential of soybean produced biodiesel. The trailer was used in Missouri and Illinois in the spring and fall of 2019. Saint Louis University contacted MECSS due to their interest in starting an educational biodiesel program. When they are ready, Ranken Tech's trailer will be delivered to them so they can produce around

40 gallons of biodiesel and prove their concept. During the last year, we have educated many people on the potential of biodiesel as renewable fuel

FOLIAR FUNGICIDES AND DISEASE MANAGEMENT: A STRIP-TRIAL STUDY

Kaitlyn Bissonnette, UMC Budgeted: \$50,550

The two major goals of this project are:

1. Test the effectiveness of current, farmer-implemented fungicide applications in managing foliar fungal diseases and for increasing soybean yield.
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.

Fourteen field sites were selected representing the diversity of the soybean growing regions of Missouri. Five paired strips (with a fungicide and no fungicide) were laid out across each field with the fungicide chosen by the cooperating farmer. Prior to and approximately two weeks following a fungicide application, each strip was scouted for disease to document differences in disease between treatment strips. Each scouting point also was visually assessed with aerial imagery to document differences. The primary diseases observed in the 2019 growing season were Septoria brown spot and frog-eye leaf spot at low levels. At most locations, differences in disease were not observed between the fungicide treated and no fungicide strips for disease level. Additionally, a yield benefit was only observed at 3 locations.



Scouting School July 2019. Presentations were given by experts in entomology, plant pathology & drone technology.

Scouting schools focusing on current and emerging disease threats and their management which are specific to a region allows for the development and implementation of improved disease management practices and the tools to minimize crop losses due to disease. The 2019 Scouting Schools were conducted at 4 locations in the four quadrants of Missouri for hands-on training in the areas of disease, insect and weed management. The schools drew in nearly 100 interested growers, industry professionals, extension personnel, and other stakeholders. Participants indicated that they intended to integrate the practices learned at the schools into their respective farms, with their clients, and business practices.

"MU CERTIFIED" STRIP TRIAL EVALUATING IMPACTS OF SEED TREATMENT FUNGICIDES AND INSECTICIDES ON EARLY SEASON DISEASES AND PESTS

Kaitlyn Bissonnette, UMC Budgeted: \$44,472



Graduate student, Bruna, sweeps for insects in a seed treatment trial planted into a cereal rye cover crop.

In the 2019 growing season, the Strip Trial program implemented eight fungicide-insecticide seed treatment trials at multiple locations across the state. At each location, five paired treatment strips of seed treated with fungicide + insecticide and naked seed were laid out across the field with some locations also including a fungicide only treatment comparison. Fungicides and

insecticides used for the seed treatment were the choice of the cooperating farmer and varied by location. To document difference in early season insect abundance, each strip was swept for insects once per week for 6 weeks starting one week after soybean emergence. The total number of target insects were counted for each strip every week.

In weeks 3 and 6, the percent stand loss was evaluated in the field at set scouting points which was paired with aerial imagery to visually document potential differences among the seed treatments.



Aerial imagery taken at 6 weeks after soybean emergence to assess percent stand loss due to early season disease.

Overall, the addition of an insecticide seed treatment did not reduce early season insect pest pressure at any location as compared to fungicide only or naked (untreated) seed. It was observed that insect pests increased over time with the highest levels of insects observed at 6 weeks after emergence. This is often well after the insecticide has lost its effectiveness as a seed treatment. The evaluation of percent of soybean stand also had no differences among treatments at either location with minimal stand observed in any treatment.

PROTECTING SOIL AFTER SOYBEAN

Peter Scharf, UMC Budgeted: \$25,000

The goals of the project are to use a farmer board to brainstorm ways to protect soil after soybean without hurting a following corn crop, with the expectation that cover crops will be a key component. Test 20 to 30 of the brainstormed ideas in small plots on the University of



Barley, as an alternative to cereal rye.

Missouri research farm to see how well soil is protected and how they affect yield of a following corn crop.

The farmer board met to brainstorm ideas for the project, coming up with 20 different ideas for how to protect soil after soybean. The main ideas we're testing are:

- Use species other than rye as cover crops to protect soil after soybean.
- Use rye to protect soil after soybean, but plant rye in strips and plant the next year's corn between those strips.
- Use rye to protect soil after soybean; apply most nitrogen fertilizer on with the planter so that rye's negative effects on the soil nitrogen supply do not hurt the corn.
- Plant soybean into tall rye, kill the rye, and count on it protecting soil for a whole year.

All of these ideas were implemented in 2019. In spring 2020 we'll plant corn to see whether they hurt yield. Monthly photos will be taken to assess how well each one protects the soil. The best ideas in the research plots will be added to the Missouri Strip Trial program for on-farm testing.

OFF-SETTING HERBICIDE-RESISTANCE: FUTURE WEED CONTROL OPTIONS FOR MISSOURI SOYBEAN PRODUCTION

Kevin Bradley & Mandy Bish, UMC Budgeted: \$31,500

This project aims to better understand the herbicide resistant waterhemp and to look ahead at non-chemical weed control options for Missouri soybean producers. The objectives include:

1. Test 6-way resistant waterhemp population to confirm or negate resistance to the 7th type of herbicide, which has not been applied.
2. Demonstrate waterhemp control when multiple tactics are used.
3. Investigate what cereal rye seeding rate is necessary to reduce waterhemp emergence.
4. Study the effectiveness of the Case IH integrated weed seed destructor by taking the implement to Missouri soybean farms for testing.

The Seed Terminator is a weed seed destruction implement that can be installed in current commercial combines and has become one of the common methods of at-harvest

resistant weed seed destruction in Australia. The Seed Terminator was installed on a Case IH 8250 combine and the Mizzou weed science program valued the efficacy of this implement in 4 soybean fields in central Missouri in 2019.



In the first season of research with the Seed Terminator, our initial impressions and observations are that a high percentage of waterhemp seed that enter the combine are successfully ground up and eliminated by this implement. Currently, our group is working to quantify and determine the viability of weed seed that passed through the Seed Terminator for more than 500 samples collected from the 4 soybean fields. An initial analysis of some of the combine engineering data suggests that engine load and fuel consumption of the combine will likely be slightly higher when the Seed Terminator is engaged compared to when it is not. Thus far the data is inconclusive as to the effects of this implement on the speed of harvest.

All research will be repeated in 2020 and demonstrations of some of this equipment will occur at the 2020 Pest Management Field Day at the Bradford Research Center this summer.

MONITORING SYSTEM USING STICKY TRAPS FOR MULTIPLE STINK BUG SPECIES

Kevin Rice, UMC Budgeted: \$8,775



Clear sticky trap with stink bug lures and captured stink bugs.

Objective: Development of stink bug management decision using clear stink traps deployed outside of field area. We are determining the relationship between stink bug captures on clear sticky traps placed outside the soybean field with in-field sweep net samples.

Clear sticky traps and sweep net samples were collected from 7 soybean fields on the Bradford Research Farm from August 15, 2019

through September 28, 2019. A single clear sticky trap was deployed on the center edge of each field border (4 traps per field). Traps were baited with stink bug aggregation lures. Stink bug species and abundance were recorded weekly. Twenty-five sweep samples were collected each week among each field edge (adjacent to each trap) and approximately 10 rows in from trap. An additional 25 sweep samples were collected from another 7 random points in the field interior (175 sweeps per field). Stink bug abundance and species identification were recorded.

In order to access, if traps created a spillover effect (attracted more stink bugs and caused increased damage), we collected five soybean plants adjacent to each trap and five from the interior of the field (25 soybean plants per field, total plants = 175). Plants were transported to laboratory and stored in freezers. Each soybean seed on all plants was removed and quantified for stink bug damage.

We have collected all field data and are currently still assessing soybean seed damage. We estimate that we will finish seed assessment by the end of February.

UNDERSTANDING THE IMPACTS OF SOYBEAN CYST NEMATODE SEED TREATMENTS ON SCN AND SUDDEN DEATH SYNDROME IN MISSOURI

Kaitlyn Bissonnette & Bill Wiebold, UMC Budgeted: \$37,537

Soybean cyst nematode (SCN) and soybean sudden death syndrome (SDS) are the two most damaging diseases of soybean production in the United States. Though caused by distinctly different organisms, the presence of one is known to impact the severity of the symptoms of the other. In Missouri, these two diseases are the primary diseases effecting soybean production, making their management of critical importance. Nematode-protectant seed treatments have been developed by multiple companies in the past decade, all varying in their mode of activity on the nematode. Unbiased data regarding how these nematode-protectant seed treatments perform in Missouri is largely unavailable. SCN also is known to increase the severity of SDS foliar symptoms, another disease that can be difficult to manage and whose management tools are currently quite limited.



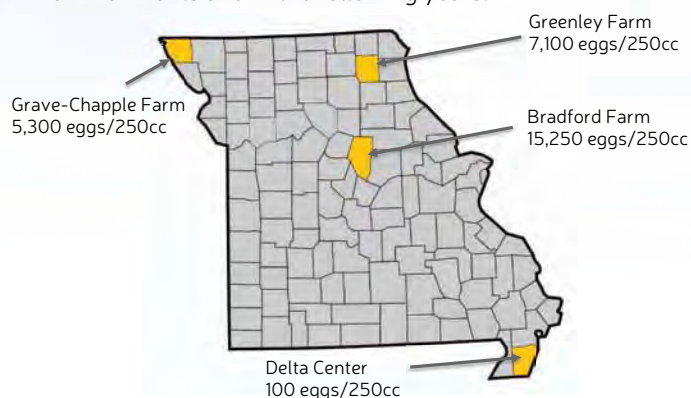
Graduate student Morgan Bruhn along with Research Specialist Daniel Sjarpe inspecting roots of soybean plants for signs of soybean cyst nematode and soybean sudden death syndrome late in the late reproductive growth stages.

This study has four primary goals:

1. Evaluate SCN seed treatments for their ability to control and manage SCN in Missouri.
2. Determine if SCN seed treatments reduce SDS foliar symptoms.
3. Explore how aerial imagery can be used to evaluate SDS foliar symptoms.
4. Assess how well SCN seed treatments perform across environments.

Statistically significant differences in SCN reproduction and SDS foliar disease severity was only observed among the treatments at the Graves-Chapple research station. No significant differences were observed among treatment at any other location or for yield at any location. This research supports the findings of other small plot research that has been conducted in other states for some nematode-protectant seed treatments with the base-treatment

associated with the company. By standardizing the base treatment to the same fungicide + insecticide across all products in this study, the nematode-protectant products can more easily be compared for their efficacy across environments and in the following years.



Locations where small plot field trials were conducted and initial soybean cyst nematode populations in number of eggs per 250cc.

PROMOTING BIODIESEL PERFORMANCE TO CONSUMERS AND OEMS

Don Scott & Brad Shimmens, NBB Budgeted: \$8,550

MSMC's support helped NBB participate in the 100 year anniversary of the founding of Cummins, Inc. The first truck documented to run on biodiesel in the US and the first to run on soy biodiesel in the world was displayed at Cummins global headquarters with the Missouri Soybeans logo. It joined a select handful of historic vehicles invited to participate at this event with a guest list approaching 9,000 people. It was a proud moment where the world's leading diesel engine developer and manufacturer celebrated the history of biodiesel as part of their own history, as well as part of their future. As Cummins displayed their static, prototypical hybrid-electric bus, biodiesel was also on display, but as a working unit with three decades of history behind it and another century of history ahead. This event led to media coverage including photos of the biodiesel exhibit in two consecutive issues of the Turbo Diesel Register magazine. This event also strengthened relationships with Cummins staff culminating with a pending meeting with the Cummins corporate sustainability director. Cummins announced their sustainability strategy in November including 25 percent reduction in emission from use of their engines. NBB's Director of Sustainability, Don Scott will be meeting with Cummins this spring to reinforce how biodiesel will help Cummins meet and exceed those goals and how biodiesel can help Cummins customers decrease the cost of ownership by using biodiesel. This should encourage Cummins to maintain and increase support for B20 and higher biodiesel blends.

Activity for the social media account dedicated to biodiesel vehicles is averaging a reach of over 30,000 accounts per week. These numbers peaked to over 170,000 account in the week of past special event. Upcoming events include the Work Truck Show in Indianapolis, Indiana. NBB has also been invited to present at the Advancing Renewables in the Midwest Conference in April and the American Trucking Association's national historical society show in Springfield, Illinois in May. NBB has submitted material that will be published in a pending article by Diesel Army magazine.

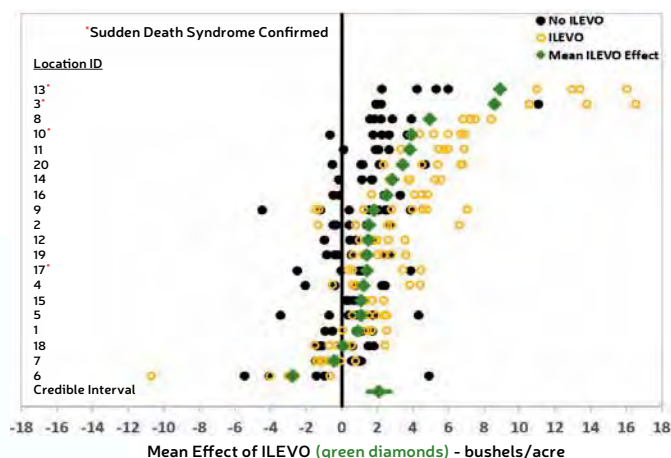
YOUNG LEADER PROGRAM 2019

Christine Luelf, ASA Budgeted: \$8,280

The Young Leader program provides newly identified and upcoming soybean leaders with critical leadership training. Through sessions on communications, organizational leadership and soybean industry updates, participants are better prepared to address state level issues while understanding their national implication. This is especially important as growers assume seats on regional, state and national checkoff and association boards. In addition, the Young Leader program provides each participant with a peer group of other innovative and progressive farmers.

STRIP TRIAL EXTRA:

Missouri ILeVO™ strip trial data set (20 Locations)



ILeVO increased yield in the Missouri trials.

- On these 20 farms, there was a >50% chance that ILeVO increased yield 2.0 bushels per acre
- On farms with SDS confirmed in the field (n=4) there was a 50% chance of yield >3.5 bushels per acre.
- For fields where SDS was not confirmed, it was unlikely the benefit of SDS exceeded 1.0 bushel per acre.

ILeVO rate reduced the SCN reproductive factor.

- The effect of ILeVO was greater at locations with higher SCN reproduction.



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