ANNUAL RESEARCH REPORT

MISSOURI SOYBEANS

LETTER FROM THE EXECUTIVE DIRECTOR

Gary Wheeler, MSA/MSMC Executive Director / CEO

In the following pages, we share details on research projects that received checkoff funding from Missouri's soybean farmers through the Missouri Soybean Merchandising Council. 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 will be published. All have a direct connection to the challenges facing Missouri farmers on the farm and in the marketplace.

The Missouri Soybean Merchandising Council is a truly 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.

Additional information on these projects is posted online at **mosoy.org** and through our research partnership, the Soy Research Information Network (SRIN). Learn more about SRIN online at **soybeanresearchinfo.com**.

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

MISSOURI SOYBEANS

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LETTER FROM THE MSMC BOARD CHAIR

"Research is creating new knowledge."

These words from Neil Armstrong outline the value your Missouri Soybean Merchandising Council places in the investigative work we fund on your behalf. At your soybean checkoff, research is a cornerstone of our pursuit of innovative solutions to the challenges we face as farmers.

While these challenges may be immediate and short-term or yet to be realized, farmers' support of this research remains focused on addressing barriers and strengthening our state's soybean farmers to weather any storms on the horizon.

When we survey farmers, increasing yields, pest management, soybean quality, new uses, and protection of our natural resources are the goals you have outlined for us. The MSMC board of farmer-leaders is accountable to you in all aspects, and this Annual Research Report is presented so that you, the farmers of our state, can share in the new knowledge supported by your checkoff.

Collaboration and partnerships are vital to maximizing the effectiveness of our research dollars. These collaborators range from colleges and universities to other commodity groups to agribusiness and private industry, with the shared goal of empowering Missouri soybean growers. We know the future is strong for soy not only in Missouri, but around the world.

Kyle Durham, MSMC Board Chair

We welcome your input moving forward in identifying and addressing the challenges that you face, and truly value you as our partner. Your feedback throughout the year guides our work. On behalf of the MSMC board of directors, thank you for your continued support in this important work.

MSMC Board Members

Robert Alpers, Prairie Home
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Aaron Porter, Dexter
Justin Rone, Portageville

Research Project Review Process

RFP Development by staff under the direction of MSMC board of directors → Proposal → **Review by staff, MSMC board members and key industry and academic partners** → Project Scoring → **Review by MSMC Committees** → Review and Vote by Board of Directors

2021 ANNUAL RESEARCH REPORT

This annual report summarizes all of the research projects supported with soybean checkoff funding in 2020-2021. The projects are divided between 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

The University of Missouri (MU) soybean breeding programs receive a large portion of Missouri's soybean checkoff funding for both the Fisher Delta Research Center and the Missouri Soybean Association's (MSA) Bay Farm Research Facility.

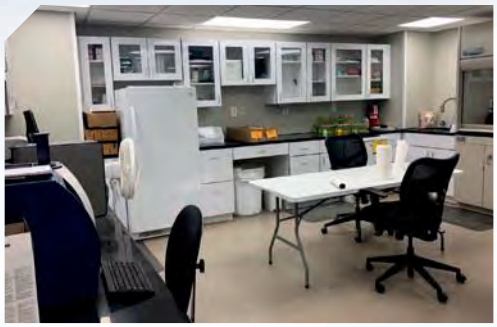
THE DELTA CENTER SOYBEAN BREEDING PROGRAM IMPROVEMENTS PROJECT

As a partner with MU and seeing the tremendous need for improvements, the Missouri Soybean Merchandising Council (MSMC) supplied a total of **$375,000** in funding over nearly four years, toward improvements that were made to the soybean breeding program located at the Fisher Delta Center Research facitlity in southeast Missouri. The MSMC funding was matched by MU at $225,000 to add to this significant contribution. The soybean breeding facility was in desperate need of repair and upgrading and through the total efforts of the combined project, the soybean breeding building got a complete transformation. Improvements included a new roof, a new cold storage unit, lab upgrades, supplies, an automatic overhead door, warehouse lights, storage space, building insulation, remodeled offices, breakroom/meeting area and new kitchen. Equipment and supply upgrades included new computers, a Kawasaki mule, storage racks, as well as new office, lab and breakroom furniture. All the major work was completed in the fall of 2020. A new security system was installed for the protection of valuable equipment and seed resources in February 2021. This project fully demonstrates the ongoing

Breakroom and Kitchen

Seed Work Space

Seed Cold Storage Room



Remodeled Lab Room

partnership and support that MSMC has for the MU College of Agriculture research programs. Because of this investment at the Delta Center, this soybean breeding program has a tremendous facility that helps it compete nationally and maintain its place as a renowned plant breeding facility.

DELTA CENTER SOYBEAN BREEDING COMBINE PURCHASE

The MSMC helped to fund the purchase of a low hour, 2012 model ALMACO SPC 40 Combine. A collaborative effort between MSMC, a generous gift from MSA, and Dr. Chen's MU research program all contributed to this purchase.

MSMC paid $108,500 and the **Missouri Soybean Association contributed $25,000** and Dr. Chen's program covered the remaining portion. This purchase was done because there was a huge need for a reliable combine and to avoid the costly repairs needed to keep the other, much older, combines operating for the soybean breeding program.

With this purchase, the Delta Center soybean breeding team will have a very effective combine that should help the program for years to come.

DELTA CENTER SOYBEAN BREEDING PROGRAM

Pengyin Chen & Andrew Scaboo, UMC Budgeted: $450,000

Despite the challenge of COVID-19 throughout the crop season in 2020, we were able to have a full-scale breeding program and things were pretty much on track. We got hit, as expected, multiple times throughout the growing season by dicamba off-target movement. Fortunately, we had both Xtend and RR2 checks in every test so that we were able make meaningful comparisons and selections. Overall, we had approximately 160 acres of research for breeder seed increases, demonstrations, purifications, 36 UT lines, 250 AYT lines, 2,500 PYT lines, 30,000 progeny rows, 300 winter nursery populations, and 300 crossing block. The RR2 check averaged 70-90% of the Xtend checks across the farm and planting dates. We selected our lines using the threshold of >100% RR2 check and >80-90% of the Xtend checks depending on the maturity groups.

Dr. Chen & Delta Center Soybean Breeding Team

In 2020, we released 5 conventional—1 RR1, 1 RR2, and 1 high oleic (HO)— lines as cultivars. Foundation Seed program grew two released MG-4 lines for increase. We grew other released lines for breeder seed increase and produced 8-20 units of seed each for commercialization in 2021. We entered 18 released and to-be released lines in state variety trials across 15 different states in 2020. Yields of these lines were comparable to the popular commercial varieties and several lines did well in several states. We entered 36 lines in the USDA Uniform Tests and our lines ranked well on top in all maturity groups.

We have approximately 300 breeding populations being advanced in Costa Rica and Puerto Rico. We made approximately 300 new crosses and they were sent to winter nurseries for generation advancement, and breeding lines will come back in 2022. We are also in the process of converting eight high-yielding lines to E3 and three other lines to Xtend. This is done by alternating greenhouse, field, and winter nursery backcrossing and may take two years to complete.

NORTH MISSOURI SOYBEAN BREEDING PROGRAM

Andrew Scaboo, Pengyin Chen, & Mariola Usovsky, UMC
Budgeted: $450,000

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.

Liz Prenger and Elizabeth De Meyer harvest yield trials at the Bay Farm Research Facility

During 2020, approximately 100 unique cross combinations with conventional and Enlist E3 were made at the Bay Farm Research Facility. The hybrid F1 seeds were harvested and immediately planted in Kekaha, HI, during October 2020. The F1 plants were harvested during February 2021 and the F2 seed was planted within a day or two of harvest. The F2 plants will be harvested in May 2021 and the seed will be shipped back to Bay Farm. The F3 plants will be grown at the Bay Farm during summer 2021 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 2022. We will also have a crossing block in Puerto Rico during spring 2021 to enable more efficient and timely germplasm and variety development.

Each year, approximately 1,000 progeny rows are visually selected, 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 these 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.

HOLL PLUS SOYBEAN VARIETY DEVELOPMENT

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

This project is designed to investigate soybean quality traits that may be added to increase the value of the high oleic, low linolenic (HOLL) trait.

HOLL Plus OIL traits:

SATS = *low in saturated fats nutrient content claim (<7% saturated fat)*

VITE = *enhanced bioavailable vitamin E content for human health*

HOLL Plus MEAL traits:

LIPOX = *lipoxygenase null seeds for improved stability and flavor*

CARB = *high energy meal for livestock rations*

PROTEIN = *higher protein content meal*

SOYLEIC™

Lines for Yield Tests	Plus Trait	Palmitic	Stearic	Oleic	Linoleic	Linolenic	SATS
77	SATS	3.3	2.5	89.0	3.1	2.1	5.8
15	LIPOX	6.3	3.2	84.4	2.9	3.2	9.5
24	CARB*	6.8	3.2	84.4	2.6	3.1	10.0
12	VITE	7.0	3.3	83.6	3.7	2.4	10.4

We have completed the 2020 harvest, some of the seed composition analyses, and winter nursery seed generation for 2021 yield tests and progeny row evaluations for our HOLL Plus stacks corresponding to the five or six targeted genes. From the 571 plant rows with the four HOLL Plus combinations, we selected 174 for further analysis. We completed fatty acid analyses and NIR assessments of protein, oil, and other seed qualities. The table on page 6 lists the summary number of lines for 2021 yield tests and the mean 2020 fatty acid results by Plus category.

The HOLL Plus SATS lines achieved both very high oleic acid and low linolenic acid levels and met the threshold of <7.3% saturated fatty acids that enables labeling the oil consistent with FDA rules for "low in saturated fats" and the qualified health claim for high oleic acid oils. The HOLL Plus LIPOX and HOLL Plus VITE lines were HOLL, but their Plus seed composition traits were not evaluated. We used the fatty acid analysis to select HOLL Plus VITE lines that contained all of the targeted genes for the HOLL trait from those that were noted to still be segregating for one gene. The CARB Plus lines had high oleic acid levels. We discovered a genotyping error during line selection that resulted in only one of the two genes for low linolenic acid being present in this germplasm, and the slightly elevated linolenic acid results reflect the impact of missing the second gene. Fatty acid analyses were conducted on all HOLL Plus lines targeted for progeny rows for 2021.

SCN SCREENING FOR MO BREEDING PROGRAMS

Andrew Scaboo & Pengyin Chen, 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. The primary goal of this project is to develop productive soybean germplasm and varieties for Missouri with resistance to soybean cyst nematode. The work performed under this project will ensure the continued development of high yielding soybean cultivars with multi-nematode resistance for Missouri producers.

Dr. Chen's lines in the greenhouse evaluation for resistance to SCN.

During 2020, 339 advanced soybean breeding lines from Missouri's Southern and Northern breeding 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 5,169 plants from the breeding programs were evaluated.

Graduate student, Pawan Basnet, inoculating his experiment with SCN eggs.

This year we continued to evaluate material for Pawan Basnet's research project involving the mapping of SCN resistance genes in a particular plant introduction (PI) line. In this project, we screened 218 lines to evaluate the interaction of SCN resistance genes for response to four different nematode populations, Races 1, 2, 3, and 5. We also screened 126 lines for fine-mapping of SCN resistance genes in that PI line. Approximately 5,390 plants were evaluated for this part of the project. This project will allow us to identify the genetic architecture of Race 2 resistance in the unique PI line.

UTILIZING MOLECULAR MARKERS FOR SOYBEAN VARIETY DEVELOPMENT

Andrew Scaboo, Pengyin Chen, & Mariola Usovsky, 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.

Mariola Usovsky gives a pre-Covid tour of the Bay Farm soybean composition lab to high school students

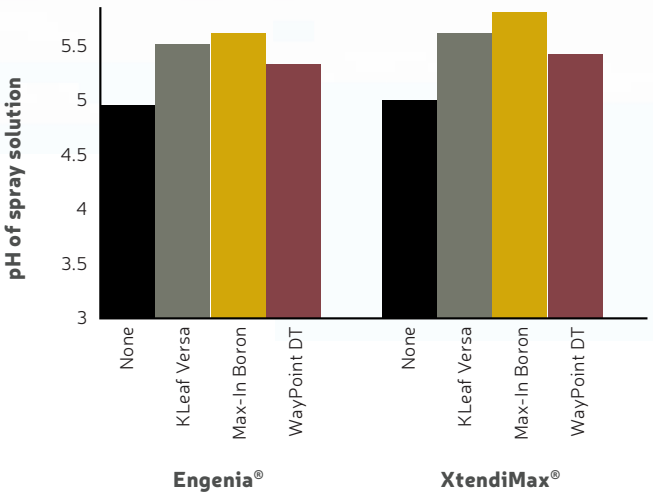
Modern plant breeding utilizes molecular biology techniques and data to improve efficiency during the breeding process and to assure quality control. In the past, the soybean breeding program at MU did not fully utilize molecular data for parental selection or for prediction of breeding value during 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.

ADDRESSING NEW QUESTIONS ON MANAGING DICAMBA AND 2,4-D USE IN SOYBEAN

Kevin Bradley & Mandy Bish, UMC Budgeted: $20,000

The Roundup Ready® Xtend®, XtendFlex®, and Enlist E3® soybean traits offer options for the control of some of our most problematic herbicide-resistant weed species in soybean. Adoption of these systems is anticipated to continue to increase along with the post-emergent applications of dicamba and 2,4-D. However, questions remain regarding weed control and off-target movement of the herbicides.

Applications of XtendiMax® with VaporGrip® and Engenia® require the addition of a volatility reduction agent (VRA). It is presumed that FeXapan® with VaporGrip® will also require a VRA once the label is approved. Dicamba is more likely to volatilize at a pH below 5, and these VRAs, which are also known as pH modifiers, reduce volatility by increasing the pH of the spray solution. We evaluated pH and waterhemp control of spray solutions that included one of three approved VRAs in combination with either XtendiMax® with VaporGrip® or Engenia®. Each mixture included a drift-reduction adjuvant, water conditioner, and glyphosate, and was applied at 15 and 20 gallons per acre (GPA). All three pH modifiers increased pH of the spray solution and each spray solution resulted in greater than 90% waterhemp control by 4 weeks after application. However, it remains unknown how effective the VRAs will be in reducing dicamba volatility when applications are made on a large scale.



Gray, gold, and red bars represent one of three approved pH modifiers added to a spray solution of dicamba plus glyphosate, Intact, and Class Act Ridion. Black bars represent spray solution that lacked a pH modifier.

Another question is whether the newest formulation of 2,4-D, which is used in the Enlist™ products, is less volatile than the newer dicamba formulations. In a series of experiments funded by MSMC and the United Soybean Board, we have found Enlist™ products to be less volatile overall. However, it is important to note that we can still detect 2,4-D in the air and it is unknown whether this amount of 2,4-D detected in the air could increase as the Enlist™ technology is adopted on a higher percentage of acreage.

Missouri producers are urged to use these products with care and remember to incorporate best management practices that prevent off-target movement and also the development of herbicide-resistant weeds.

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. We previously identified soybean lines that differ in WUE and have been using these lines to improve soybean drought tolerance. Building on our previous efforts we are now pursuing the following objectives:

1) conduct multi-environment yield tests to determine stability and potential tradeoffs associated with WUE traits;
2) dissect the physiological traits associated with WUE and identify putative genes associated with carbon isotope discrimination and oxygen isotope discrimination;
3) continue development of mapping populations by advancing the Multi-parent Advanced Generation Inter-Cross (MAGIC) population and inbred line populations that can then be used to identify molecular markers to accelerate breeding; and
4) continue selection and breeding with genotypes with proven isotope signatures (WUE traits) and elite varieties background to develop soybean cultivars that produce more yield per unit of water used.

In 2020, we identified novel genetic markers and confirmed previously identified markers for WUE. We also examined the regions surrounding the markers and have identified a number of candidate genes that may be associated with soybean productivity per unit water.

Soybean plants of the MAGIC population are growing in the greenhouse to accelerate population advancement.

As part of our breeding effort we have continued to make crosses between elite germplasm and lines selected for WUE traits. Seeds resulting from eight unique crosses have been sent to the winter nursery for generation advancement. Further, we conducted yield tests on the three most promising breeding lines, one of which ranked 5th for yield among all tested lines. Unfortunately, due to travel restrictions associated with COVID-19, we were not able to test yield stability of the three lines across multiple locations.

This project delivers a better understanding of the mechanisms that can be employed to improve soybean yields under drought, germplasm with enhanced WUE, and genetic markers that can be used to accelerate improvement of drought tolerance.

REGIONAL PARTNERSHIPS:

MID-SOUTH SOYBEAN BOARD

The Mid-South Soybean Board was organized to promote soybeans, soybean products, soybean research and development. Originally formed in 2009, other members include the soybean checkoff organizations of Arkansas, Louisiana, Mississippi, and Texas. The Missouri Soybean Merchandising Council joined the MSSB in 2012. The goals are to eliminate duplicate research spending and to develop and fund research of importance to our producers.

Baughn Merideth, Caruthersville

District 7 MSMC Director Baughn Merideth serves as the MSSB Director for Missouri. MSMC has partnered on the following MSSB projects:

ENHANCED PEST CONTROL SYSTEMS FOR MID-SOUTH PRODUCTION

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

This pest project 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.

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 region 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 tolerance to flooded conditions.

SCREENING AND SELECTING NON-XTEND SOYBEANS FOR DICAMBA TOLERANCE

Pengyin Chen, MSSB Project- MO Share Budgeted: $16,375

Testing is being conducted to compare non-Xtend soybean varieties for natural tolerance to dicamba. This could be used to identify genetic natural tolerance to dicamba to develop lines that would not experience as much damage if subjected to off-target movement. Observation and yield testing show strong and consistent negative correlation between off-target dicamba damage and yield performance in 2019 and 2020. Results were obtained across 4,841 yield plots in two years.

The research led by Dr. Chen clearly demonstrates there is significant differences in naturally occurring genetic tolerance to dicamba.

Many advanced breeding lines with superior tolerance to off-target dicamba damage have been identified, of which several will be entered in the 2021 USDA uniform trials for more extensive testing.

NORTH CENTRAL SOYBEAN RESEARCH PROGRAM

Ed Anderson Budgeted: $150,000

The North Central Soybean Research Program, a collaboration of 13 state soybean organizations, invests soybean checkoff funds to improve yields and profitability via university research and extension. Collaborative soybean research objectives and priorities include:

1. Soybean yield and quality enhancement through genetic improvement and biotic and abiotic stress mitigation for soybean maturity groups 0-IV, clearly focused on the North Central region.
    - Classical and molecular soybean breeding efforts that will enhance yield potential and yield stability.
    - Research that addresses the control of insects and diseases (defensive traits) with consistent or potentially significant economic impacts.
    - Research that addresses weed resistance to herbicides for species of common occurrence and threat.
    - Research that addresses soybean response to water, nutrients, soil, and environmental conditions.

2. Soybean production practices that will increase yield, profitability, and environmental stewardship issues, specific to the North Central region.
    - Soybean–corn rotations
    - Plant populations, row spacing, and input management
    - Water quality and watershed planning
    - Cover crops and other conservation agronomy
    - Soybean production sustainability and life cycle assessment.

NCSRP serves as a bridge between state and national soybean organizations and will be 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.

The NCSRP evaluates projects that have a regional impact and involve both basic and applied research. The qualified state soybean boards (QSSBs) contribute to the funding pool and studies are decided upon by the NCSRP farmer board. District 1 MSMC Director Cecil Demott has provided extraordinary service on the NCSRP board. Cecil is the immediate past President of the NCSRP and his leadership will be sorely missed when he terms off the MSMC board.

Cecil Demott, Rock Port

Demand Projects

COMMERCIAL APPLICATION OF SOYBEAN HULLS/STOVER FOR ELECTRONIC INDUSTRIES

Ram Gupta & Pawan Kahol, Pittsburg State & Kartik Ghosh, Missouri State Budgeted: $47,802

The global battery market was valued at $108.4 billion in 2019 and is expected to grow at a compound annual growth rate of 14.1% from 2020 to 2027. Soy hulls/meals derived carbons can be used as active materials in energy storage devices such as batteries and supercapacitors. These batteries have the potential to be used in items such as cell phones, computers, and electric vehicles.

The performance of soy-derived energy devices can be tuned by chemical modifications of the soy-derived carbons and the use of different electrolytes. Our research has shown that the energy and power densities of these devices could be significantly enhanced by using different electrolytes. These energy devices have the potential to meet the current and future demand for energy due to their high energy density, low cost, and fast charging time. The soy-derived carbon for these devices is prepared using our patent-pending technology. The research has the potential to create new demand for soybean hulls/meals for battery/supercapacitor industries.

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

Phillip Mulligan, Missouri S&T Budgeted: $87,706

Throughout 2020 a study at Missouri University of Science and Technology has shown soybean oil can be mixed with ammonium nitrate to produce an explosive. The new explosive may be suitable for mining applications and

serve as a low-cost alternative to the traditional ammonium nitrate and diesel fuel mixture (ANFO). The results of the study indicate an explosive that uses soybean oil (ANSOY) produces lower concentrations of toxic gasses after the explosive detonates. The particle size of the gasses is large, which means they do not travel as far. Additionally, the ANSOY produces equivalent power to ANFO. ANSOY could be a low-cost alternative for ANFO, be better for the environment, and result in a need for 21.4 million bushels of soybeans to support the mining industry's demand

Soybean Based Explosive Graphic (Right) And ANSOY (Left)

Before explosive companies will support the production of ANSOY, they have requested a small-scale test showing ANSOY will work. The number of test holes suggested by the explosive companies was beyond the capacity the Missouri S&T Experimental Mine could support. Therefore, a new test site was developed. The new site was identified in Crawford County, about 40 minutes east of Rolla. The new site was selected to support the project but also to aid some local farmers in Missouri. The drilling and blasting performed at the site will produce fill material and riprap (large boulders) for the farmer.

Blasting for the Test Site Preparation

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

Ram Gupta & Pawan Kahol, Pittsburg State Budgeted: $51,268

Polyurethanes are prominent sorts of polymeric materials that can be found within a plethora of commercial and industrial applications ranging from furniture, sound insulation, automotive, and coatings. The widespread use of polyurethanes can be attributed to the diverse range of synthetic feedstocks and preparatory methods used to manufacture both rigid and flexible foam derivatives, elastomers, and adhesives. Depending on the starting materials, the physical and mechanical properties of polyurethanes, e.g. density, flexibility, rigidity, etc., can be varied. The primary drawback of polyurethane foams is that they are overtly flammable.

In this project, we have shown that eco-friendly polyurethane foams using soybean oil can be prepared, and its flammability can be significantly reduced by adding cheap and green flame-retardants. Soybean oil was converted into polyol, a starting chemical for polyurethane, using a one-step process that does not require high temperature, high pressure, and solvents.

As seen in the figure below, the weight loss of the foams and burning time was significantly reduced even after adding only 0.93 % phosphorous in the foam. Additionally, no dripping was observed during the burn test, suggesting the high quality of the flame-retardant foams using soybean oil.

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

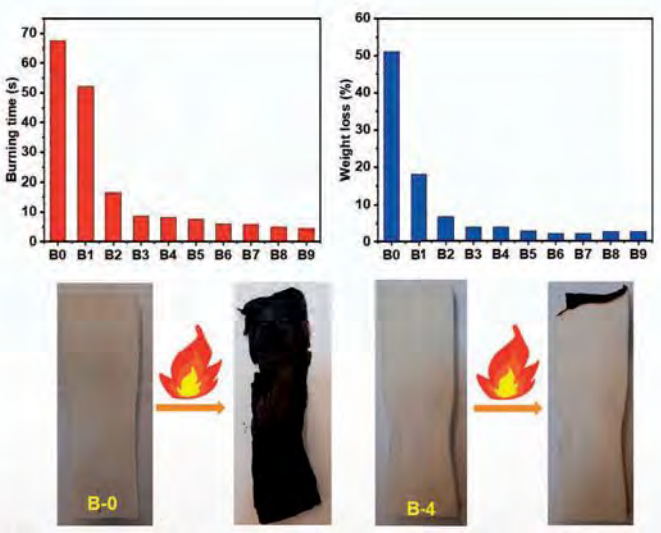


Photo of two foams before and after burning. B-0 is a control foam and B-4 is an experimental, soy-based foam with flame retardant.

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

Alan Poock & Marypat Corbett, World Initiative for Soy in Human Health (WISHH) Budgeted: $50,000

During FY21, MSMC approved funding for WISHH to implement three activities in Cambodia to increase the inclusion of U.S. soybean meal in aquaculture feed and introduce In-Pond Raceway System (IPRS) technology:

- Provide technical assistance on raceway technology and management to the aquaculture farmer who built the pond in FY20.
- Demonstrate the value of using commercial aquaculture feed containing U.S. soybean meal through a feeding demonstration at the IPRS to improve feed use efficiencies and producer net incomes using soy-based pelleted feeds.
- Disseminate the feeding demonstration results from Phase I and II through farmer field days and other events.

Rathada Raceway with Farmer Leaders

Two feeding demonstrations starting in late January 2021 using aquaculture feed from Agrimaster, a Cambodian feed miller that uses U.S. soybean meal in its aquaculture and animal feed formulations.

A non-profit training organization operating a welding shop in Siem Reap built cages for the second location. The welding shop is receptive to building and selling cages to aquaculture farmers; this will help make IPRS technology more accessible and affordable. This activity continues to be high profile in the Cambodian aquaculture industry, with strong interest from Cambodian government officials.

The overall project goal is to demonstrate the efficacy of IPRS technology to increase commercial U.S. soy exports to animal feed millers in Cambodia.

OPTIMIZATION OF FOOD PROCESS ENGINEERING PROCESS PARAMETERS FOR SHELF STABLE SOYLEIC™ MILK, SOYLEIC™ YOGURT, SOYLEIC™ TOFU AND SOYLEIC™ EXTRUDED OKARA PRODUCTS FORTIFIED WITH VITAMIN B12

Kiruba Krishnaswamy & Azlin Mustapha, UMC Budgeted: $57,076

Balanced human diets require the intake of many different vitamins and nutrients, some of which are not included in the fast-paced lifestyle food options. These vitamins play an extremely important role in healthy development and maintaining of bodily systems, so they are important for people of all ages.

Vitamin B12 deficiency is characterized by fatigue, weakness, constipation, loss of appetite, weight loss, megaloblastic anemia, and permanent neurological damage. Vitamin B12 deficiency affects a wide range of risk groups from lactating and pregnant women, adolescents, children, vegetarians, individuals with gastrointestinal disorders, pernicious anemia, and older adults. Atrophic gastritis affects 10-30% of older adults, and adults above 50 years old are recommended to obtain vitamin B12 from fortified foods.

During our initial study, we have found that using SOYLEIC™ milk could be an ideal carrier for vitamin B12. We aim to develop and optimize processing parameters for developing value added products from SOYLEIC™ (non-GMO High Oleic Soybean), namely shelf stable SOYLEIC™ milk, SOYLEIC™ yogurt, SOYLEIC™ tofu and SOYLEIC™ extruded okara products fortified with Vitamin B12. The formulations and technology could be scaled up for industrial processing with licensing to food industries.

CREATING DEMAND FOR U.S. POULTRY IN THE PHILIPPINES' FOODSERVICE SECTOR

Shelby Watson, USA Poultry & Egg Export Council
Budgeted: $36,000

The Philippines is an emerging market with a service-based economy, backed by an estimated population of 109.5

million inhabitants, on pace to reach 125 million by 2030. It is the ninth largest export market for U.S. agricultural products and its largest market for consumer-oriented products in Southeast Asia, reaching $3.1 billion in 2020 despite disruptions caused by the coronavirus pandemic. According to USDA/FAS, this is up 7% from the 2019 level amid the health crisis that forced many countries to close their borders. This demand is driven mainly by higher domestic consumption, a shift in consumer habits to buy fresh and frozen products from supermarkets, and growth of e-commerce and online grocery shopping. The food service sector, however, continues to grapple with mounting concerns over food safety, including lack of knowledge in product handling, poor logistics infrastructure, inadequate storage facilities, and frequent power outages.

Due to the global COVID health crisis, food retailers were suddenly inundated with click-and-collect orders and home deliveries. This unexpected high order volume not only placed pressures on e-fulfillment infrastructures, but also required renewed adherence to food safety best practices. Food retailers/grocers not only had to maintain proper temperature ranges during storage, picking, staging and delivery, but also follow proper sanitation and hygiene protocols for in-store customers and employees alike.

The planned food safety seminar aims to provide training on the proper handling and storage of frozen, ready-to-eat, and chilled U.S. poultry products to maintain consumer confidence, by ensuring that the products stay safe—from entering the country to reaching the dining table. The two-day seminar will target influential supermarkets and food service operators, procurement supervisors, and other personnel in the frozen handling chain, as well as those in culinary institutions, with the intent to develop more opportunities in this market. The seminar will be conducted onsite in May 2021, possibly a virtual seminar due to the COVID situation.

EVALUATING AND OPTIMIZING THE USE OF HIGH OLEIC LOW LINOLENIC (HOLL) SOYBEAN OIL IN ICE CREAM

Bongkosh Vardhanabhuti & Andrew Scaboo; UMC
Budgeted: $31,609

The global plant-based ice cream market was valued at $1.7 billion in 2017 and is expected to reach $3.4 billion by 2026 with an annual growth rate of 9.5%. Replacing dairy fat and protein with plant-based ingredients, however, has been a challenge for the industry. Milkfat plays important roles in ice cream properties and quality by increasing the richness of flavor, producing smooth texture, giving body to ice cream, and aiding in melting. Nondairy fat sources used in ice cream are palm oil, palm kernel oil, coconut oil or hydrogenated oil. With increasing awareness of health risk associated with trans-fat and saturated fat, the use of these oils has been in decline or prohibited.

In dairy ice cream, milkfat plays an essential role in the formation and stability of the structure of ice cream. Ice cream made with liquid oil has low overrun, fast melting rate, and large ice crystals which result in icy texture and poor eating quality. High oleic, low linolenic (HOLL) soybean oil has great potential to produce healthier ice cream without hindering the physical properties responsible for their final attributes. Commercial soybean oil is produced by solvent extraction followed by refining process. However, unrefined oil contains components such as phospholipids and fibers that could contribute to the desirable properties of ice cream. In addition, with increasing awareness on sustainability, we may see an increase in the utilization of unrefined cold-pressed oil especially if its benefits are clearly established. The overall goal of this project is to evaluate the use of HOLL soybean oil in ice cream. Both refined and unrefined oil will be investigated and compared to milkfat and coconut oil. Finally, various methods will be used to improve the properties of ice cream made with HOLL oil.

In 2020, two HOLL soybean varieties were planted and harvested. The seed will be processed, and its cold-pressed oil will be used in ice cream. We are currently in the process of training sensory panelists and will conduct the descriptive sensory analysis to determine the ice cream properties made with cold-pressed HOLL soybean oil in early 2021.

DEVELOPMENT OF BIFUNCTIONAL ACID-BASED ORGANOCATALYSTS AND PROCESS FOR ISOMERIZATION OF HIGH OLEIC ACID

Ali Rownaghi, Shubhen Kapila & Racha Seemamahannop, Missouri S&T Budgeted: $46,765

This project is designed to extract cellulose nanocrystals (CNCs) from soybean hulls and formulate into a material which can be used for sustainable conversion of fine chemical applications. These CNCs can be used as a catalyst

for sustainable and economically attractive transformations into chemicals, pharmaceuticals, agrochemicals and water treatment.

Most are done using homogeneous catalysts and batch process that typically have short lifetimes and require further separation from reaction mixtures. The CNCs will be used to immobilize cheap chemicals and utilize them as active sites to catalyze reactions under mild conditions while invoking cooperative catalytic pathways, whereby two or more active sites work together to activate the reactant(s). The use of cooperative (bifunctional) catalysts, rather than homogeneous catalyst, and continuous flow chemistry, rather than a batch process, are commonplace in sustainable chemical transformation and attract a great deal of interest with respect to economic and environmentally sustainable production of fine chemicals. This process is a new and novel approach to the role of CNCs from soybean hulls in catalysis and continuous-flow systems. Continuous flow systems allow for more efficiency, quality, safety and conservation of resources than a batch system.

The pharmaceutical industry has been the main market for fine chemicals for many years. Their technology is based on batch processes. Top chemical and pharmaceutical industries include Sigma-Aldrich, Cargill, Monsanto (Bayer now), DOW Chemicals, Phillips 66, BASF, Evonik, Lonza, DSM, Albemarle, etc.

Global Fine Chemicals Market, researchandmarket.com

3D-PRINTED ACTIVATED CARBON ADSORBENTS DERIVED FROM SOYBEAN HULLS FOR USE IN SEPARATION AND PURIFICATION PROCESSES

Fateme Rezaei, Missouri S&T Budgeted: $21,782

The overall goal of this proposal is to convert soybean hulls into valuable carbon-based adsorbents and then formulate them into practical configurations such as monoliths using 3D printing technique.

Activated carbons are essential materials with versatile use in a wide range of applications. The carbon produced from soybean hulls can be used in various fields including:

- Wastewater treatment – removing chemicals from water
- Gas separation – oxygen production from air for medical devices
- Pharmaceutical industry – separation of drug compounds
- Energy storage – development of electrodes in supercapacitors

Conversion of Missouri soybean hull into activated carbon monoliths using 3D printing technique.

The carbon produced from soy hulls in its raw form is not practical for the industry. Thus, researchers turn it into powder and shape the powder using 3D printing to make it into a more practical, scalable application for industry. Soybean hulls are also an economically attractive alternative for use in these applications.

Given the versatility of activated carbon in a wide variety of applications, the soybean farmers can significantly benefit from this profitable by-product.

BEYOND BIODIESEL – COMPUTATIONAL EXPLORATION OF GASOLINE PRODUCTION FROM SOYBEANS

Matthew Siebert, Missouri State Budgeted: $28,628

Gasoline and diesel fuels make up the backbone of transportation in the U.S. Finding alternatives to petroleum will extend our finite supply, providing more choices at the pump and more opportunities for farmers.

Soybean oil can be used to produce biodiesel, an alternative fuel source for diesel engines.

There is a chemical process, termed "cracking", that can convert soybean oil and soybean-based biodiesel into gasoline. The cracking process involves heating the raw

input in an oxygen-deprived environment. The cracking process takes time and quite a lot of heating. We used quantum chemistry to simulate the cracking process – including the time required, the heat required, and even the identity of the raw input compounds. These simulations will help determine the patterns in the resulting product to optimize gasoline production from soybeans.

Our simulations match experimental works quite well in our comparisons (carbon monoxide and carbon dioxide are critical components used to monitor the cracking). They showed varied ways that gasoline components can be created from soybean oil in all its chemical detail. Amazingly we also see products critical to creating plastics.

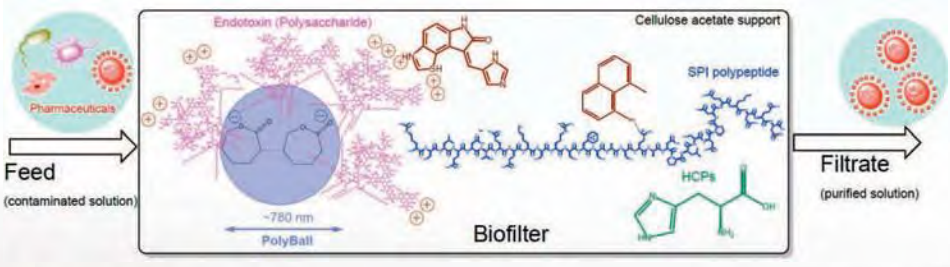
Much more work is required to determine optimal temperature and pressure as well as ideal input material. This data will come fast as we push from our current realm of quantum chemistry into our future realm of artificial intelligence. We do all this with our focus on gasoline production from a carbon-neutral source like soybean oil so that we may continue use of gasoline and diesel engines.

ENGINEERING BIOFILTERS FOR PHARMACEUTICAL PURIFICATION

Sutapa Barua, Missouri S&T Budgeted: $19,966

Biopharmaceuticals such as monoclonal antibodies, proteins, vaccines, etc., are one of the most effective public health medicinal products with an excellent safety record by inducing potent and long-lasting immune responses against infectious agents. These would likely be prioritized for health-care workers and people at greatest risk of severe illness and death. There is a need to safeguard the vaccine product against potential contamination with adventitious agents that include bacterial endotoxins that may have been unintentionally introduced into the production and manufacturing processes.

My research team at Missouri S&T has synthesized a novel composite biofilter modified with cellulose acetate, soy protein isolates (SPI), and PolyBall nanoparticles to remove endotoxins for the purification of therapeutic protein solutions and water. The permeability, porosity, selectivity, and toxin removal were studied. The ability of endotoxin removal using PolyBall nanoparticle powder and biofilters was investigated for protein and water purification. Protein solutions and water were spiked with E. coli O111:B4 endotoxins and passed through the biofilter. The amount of endotoxins in filtrate and retentate were measured using an EndoDye assay. To control the accuracy of the spikes, an equal amount of endotoxins was spiked into depyrogenated water (positive control). The kinetics of endotoxin removal efficiency were determined as a function of PolyBall loading (concentration), filter composition, pore structure, and additional factors (pH, ionic strength, etc.). The percent endotoxin removal was measured in the filtrate and retentate solutions. The Biofilter exhibited all around capability of targeting and removing endotoxins from vaccine solutions without the need for any external pressure or any special equipment. The exceptional selectivity combined with high permeability for the target compound makes an ideal mode of operation for highly selective biopharmaceutical purification membranes.



Schematic showing biopharmaceutical solution purification using PolyBall particles in cellulose acetate and SPI Biofilters.

DATA NEEDED TO ADDRESS PIPELINE BARRIERS

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

A growing criticism from biodiesel's detractors and regulatory agencies is the potential inability to transport and distribute greater quantities of biodiesel where needed, particularly in places such as the Northeast to meet the growing demands for the heating oil market. The fuel distribution system would be unable to handle the total number of trucks and railcars that would be needed as the heating oil industry moves towards B100 to reduce their carbon footprint. Pipeline movements would allow for higher volumes to be moved and at a lower cost than is currently possible. However, to do so pipeline companies would need to ensure and prevent cross contamination from biodiesel into batches of jet fuel moved along the pipe.

Previously, the National Biodiesel Board worked with the airline industry to prove that 400-ppm "contamination" is not a flight safety risk. According to industry protocols, airlines are unwilling and unable to approve levels more than 25% of the tested levels. Being

conservative, the industry initially placed a limit of 50-ppm allowance of biodiesel in jet fuel batches to determine feasibility of pipeline movements. While there have been some trial runs, pipeline companies are concerned over this tight limit, and are unwilling to jeopardize jet fuel shipments now that one engine manufacturer has expressed additional concerns over this lower limit.

The current work is toward designing one last project to help alleviate any concerns at 100-ppm allowances, that would lead to an ASTM specification and a comfort level for pipeline companies to begin commercial B5 and potentially B20 shipments.

SUSTAINABILITY ANALYSIS

Brad Shimmens & Don Scott, National Biodiesel Board (NBB)
Budgeted: $25,000

As part of the Sustainability Analysis project, efforts recently have been toward combating claims of indirect emissions and lack of feedstock. As new policy and corporate emission reduction targets are driving increased demand for sustainable solutions, biodiesel and renewable diesel have become a preferred commercial solution for immediate, low-cost carbon reductions in heavy duty applications.

However, as the industry's success has grown—now consuming over 22 billion pounds of fats and oils, of which approximately 50% is soy oil—the opposition to our industry continues to claim that we are sourcing vegetable oils and animal fats in an unsustainable manner. While these arguments have traditionally focused on potential "Indirect Land Use Change" associated with crop-based feedstocks, more recently these lines of reasoning have expanded and now arguing that increased demand for biodiesel is limiting the ability of waste fats, like yellow grease and used cooking oil, to be included in animal rations. In response, NBB is undertaking an animal ration supply and demand study, focusing specifically on the source of energy calories used in the state of Iowa. Preliminary estimates show that while intentional lipid inclusion from waste fats and oils in the animal ration has declined since 2000, the data and timeline seem to suggest this resulted from a consumer preference for animals fed with vegetable diets, regulations like the Food Safety Modernization Act, and in particular the increased use of distiller's grains, which often contain a significant fraction of corn oil. We believe these changes in supply, coupled with the limited amount of fats certain animals can consume, has shifted the demand for energy calories from waste lipids to corn-based commodities. The completion and subsequent peer review of this research will lead to a more robust and accurate displacement methodologies when attempting to assign indirect penalties to biodiesel and other biofuels.

Education Projects

"MU CERTIFIED" STRIP TRIAL INITIATIVE: COVER CROP TRIALS

John Lory, Kaitlyn Bissonnette & Kent Shannon, UMC
Budgeted: $65,947

The "MU Certified" Strip Trial Program is a signature program helping farmers validate management decisions on their farm and document efficiency and environmental stewardship. The program is a collaboration between Missouri farmers, MU Extension, Missouri Soybean Merchandising Council, Missouri Corn Growers Association, and the Missouri Fertilizer Board.

The strip trial program relies on our farmer advisory panel to help prioritize trials available each year. Advisory members are Robert Alpers (Prairie Home), Neal Bredehoeft (Alma), Matt Lambert (Brookfield), Mark Lehenbauer (Hannibal), Brian Lehman (Versailles), Aaron Porter (Dexter), Dylan Rosier (Mound City), Linus Rothermich (Auxvasse), Doug Thomas (Brashear), and Jules Willot (Laddonia) who are joined by industry representative Scott Wilburn (MFA, Laddonia).

Cover crops have many benefits including providing soil cover and increasing water infiltration and water holding capacity. Soybeans have a dynamic role in the cover crop story. On one hand, soybean yield can increase following a cover crop (Bar Chart, green bars). But when cover crop follows soybean ahead of corn, corn yields can suffer (Bar Chart, gold bars).

The farmer panel overseeing strip trial options has emphasized the importance of finding solutions to low yield when a cover crop follows soybean ahead of corn. In fall 2020, we initiated a new trial option that builds residue ahead of soybean by planting soybean "into the green". In this trial we track a field two years: first year tracking soybean yield after planting into the green, and in the second year, tracking corn planted into the resulting higher residue. The treatment is compared to a no-cover control. Three of these trials were initiated this fall. The "MU Certified" Strip Trial program remains committed to helping soybean farmers find the best management strategies for using cover crops with soybeans.

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

Darrin Peters, Rockwood School District Budgeted: $17,280

The year 2020 has certainly been different for us at MECSS as it has been for everyone throughout the world. The year started fairly normal. The Organic Chemistry Classes started their semester making biodiesel as their laboratory project. Corey Meyer (Research Assistant) and I recruited some Organic Chem Students and went to a STEM (Science Technology Education Math) night at one of our local middle schools in mid-February. My students talked with many children about renewable fuels and biodiesel. In March, Corey and I were invited to a New City School for a biodiesel presentation. We pulled Ranken's Trailer and talked with the students in their classroom and then led them out to the trailer. We visited with 3 different classes, all of whom did a wonderful job asking questions and participating in discussion.

Our biodiesel presentations for the school year were limited due to COVID.

We were invited to the Coding School in St. Charles where we met with a very small group of students in late June. Corey gave a short presentation on how coding can be used to program a computer which controls the biodiesel processor. He also taught the students how computer programing could be used to monitor things like gas mileage, speed, and distance travelled in our student's diesel-powered super mileage car. The Coding kids really enjoyed seeing the biodiesel go-kart that our students had designed and assembled. We had no more opportunities during 2020 to interact with our community on the benefits of biodiesel.

FOLIAR FUNGICIDES AND DISEASE MANAGEMENT: A STRIP-TRIAL STUDY

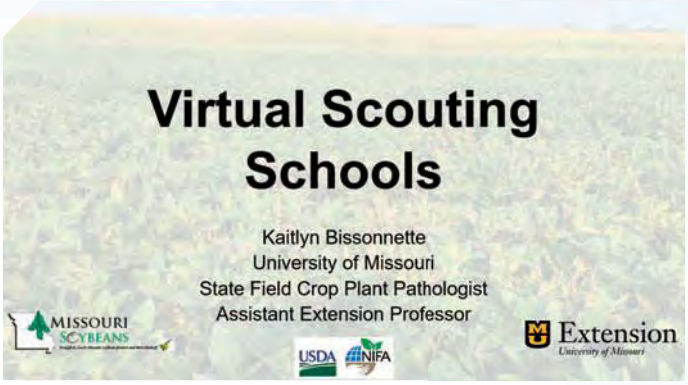
Kaitlyn Bissonnette & John Lory, UMC Budgeted: $42,527

Fungicide applications can be an essential part of an integrated management plan if timed and applied appropriately. The question of whether fungicide applications provide added value to current crop production practices is of exceeding importance.

In the 2020 season, ten field sites were selected throughout the state of Missouri representing a diversity of cropping systems. At each site, five paired strips (no fungicide and with a cooperator-chosen fungicide) were laid out across the field. To assess and document disease differences, each strip was scouted prior to and approximately two weeks following the fungicide application. Visual assessments also were conducted utilizing aerial imagery at each scouting point. Environmental conditions during the growing season at many locations were not ideal for the development of most foliar diseases of soybean. In the 2020 growing season, the primary diseases observed were Septoria brown spot and sudden death syndrome. Differences in Septoria brown spot control with the application of a fungicide were noted at a single location. At this same location and two additional locations, yield increases of greater than 1 bushel per acre were observed.

Aerial imagery showing severe SDS symptoms.

An additional and vital component of this project is the implementation of soybean Scouting Schools. Due to limitations imposed by the Covid-19 pandemic, the 2020 Scouting Schools were held both in-person at 3 locations and in a virtual format 2 times. Despite these limitations, attendees gained valuable insight about diseases impacting soybean production in Missouri. Each Scouting School focused on the principles of disease management, emerging pathogens of field crops, and how to utilize tools to minimize yield losses due to disease.



Virtual Scouting Schools were held twice during the month of August focusing on disease management, emerging pathogens of field crops, and how to utilize tools to minimize yield losses due to disease.

"MU CERTIFIED" STRIP TRIAL – EVALUATING IMPACTS OF SEED TREATMENT FUNGICIDES ON EARLY SEASON DISEASES

Kaitlyn Bissonnette & John Lory, UMC Budgeted: $35,597

Soybean seed treatments have become an integral part of a commercial soybean production system as protection against early season diseases. These include the damping off diseases which are responsible for upwards of $30 million/yr in yield losses in the state of Missouri. Understanding how they fit into the production agriculture system is the key to their continued use.

A total of nine fungicide seed treatment trials were implemented throughout the state with two trials lost due to replant. Five paired treatment strips of fungicide + insecticide vs. naked seed were laid out across each field site. All fungicide + insecticide seed treatment chemicals were chosen by the cooperating partner. Each strip was scouted for early season disease at three and six weeks after soybean emergence. Stand counts were conducted to evaluate losses attributed to these early season "damping off" diseases. In addition to ground scouting, aerial imagery was collected for the same scouting point where stand counts were conducted to document potential differences between treatments.

With a wet spring and early summer, early season disease pressure was high in many fields with conditions being ideal for disease development. As a result, high levels of early season disease in two fields resulted in trial loss. Of the seven remaining sites, the addition of a fungicide +

Stand loss observed using aerial imagery at six weeks after planting in a seed treatment trial.

insecticide seed treatment increased total plant population between 2,000 and 10,000 plants per acre. Positive differences in yield response with and without a seed treatment ranged from 1 to 12 bushels per acre. In more than one field, the addition of a seed treatment did not result in a statistically significant increase in yield.

This season was ideal for the development of early season disease, and this study showed the importance of using fungicide + insecticide seed treatments to protect against early season diseases in fields where stand loss was observed. This early season protection can also help to reduce weed pressure by reducing bare spots in fields and promoting timely row closure.

PROTECTING SOIL AFTER SOYBEAN

Peter Scharf, UMC Budgeted: $19,792

The objectives of this project are first to evaluate which cover crops can we plant after soybean that provide effective soil protection without hurting the yield of a following corn crop. And secondly, to determine how best to manage the cover crop or the corn to make the system work best.

Winter oat cover crop protected soil well into the growth of the following corn crop.

Results:

Objective 1: Which cover crops protect soil after soybean without hurting corn yield?

Winter oats worked best, among the species tested, to protect soil without hurting corn yield, giving a yield of 188 bu/acre. There may have been a small (4 bu, 38% probability) yield penalty but less than other cover species. Soil protection was excellent with winter oats. Annual ryegrass also gave excellent soil protection but caused by far the largest yield penalty of any species: 86 bushels. Corn was stunted early in the season following ryegrass.

Objective 2: How can we best manage the cover crop or the corn?

Planting soybean green into tall rye or wheat looked promising for soil protection with minimal corn yield loss (3 bu/ac, 39% probability). This relies on the rye/wheat residue to protect soil all the way through until the following corn crop canopies. Soil protection was good in January after soybean harvest; however, it deteriorated considerably by late March when erosion potential is higher.

Soil cover from soybean planted green into rye in 2019 on January 10, 2020 (left) and March 26, 2020 (right).

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: $34,208

This project involves the evaluation of non-chemical control methods for integration into an overall weed management program. Emphasis is on waterhemp, and a subset of the work was conducted on Missouri soybean fields. In 2020, the

team concluded a 3-year evaluation of fall-seeded cereal rye, which was sown at 30, 50, 70, 90, or 110 lbs/acre, to suppress early-season waterhemp emergence. Soybean was planted into the non-terminated cereal rye. Findings include:

Planting soybean into green cereal rye.

- Cereal rye planted at 50 lbs/acre resulted in comparable levels of early season waterhemp suppression to the higher seeding rates.
- Cereal rye seeded at 30 lbs/acre resulted in less consistent suppression.
- Soybean stand and yield were similar regardless of the cereal rye seeding rate.

Seed Terminator™ on Case combine

Additional ongoing objectives of this project focus on minimizing the amount of viable waterhemp seed that returns to the soil. The Seed Terminator™ was tested in four mid-Missouri soybean fields in 2019 and three in 2020. The machine is a multi-stage hammer mill that is integrated into a commercial combine. The mills rotate at 2,500 rotations per minute to grind weed seed. Questions being addressed include:

- What percentage of waterhemp seed passes into the Seed Terminator™?
- How effective is the machine at rendering seed non-viable?
- How does the implement affect fuel usage and engine load of the combine?

Preliminary results indicate that during soybean harvest approximately one third of waterhemp seed returned to the soil due to header loss. Of waterhemp seed that successfully passed through to the thresher, 72% made it into the Seed Terminator™. Approximately 92% of waterhemp seed that entered the Seed Terminator™ was damaged. On average, combine fuel consumption was 4.1 gal/hour greater and engine load was 17.6% higher when the Seed Terminator™ was engaged. Data analysis of the 2020 samples continues.

Finally, a side-by-side comparison is being conducted to evaluate the effects of different non-chemical control options on a dense stand of multi-resistant waterhemp in soybean. At soybean harvest in 2019, the Seed Terminator™ and narrow windrow burning were implemented, and cereal rye was planted in a subset of those treated plots. Waterhemp density counts were conducted in the spring of 2020. Plots with cereal rye and the Seed Terminator™ treatment had the least waterhemp emerge in the spring. This objective is being repeated with the addition of weed electrocution as another non-chemical treatment. Waterhemp density counts will be conducted in the spring of 2021.

EVALUATING ELECTROCUTION AS A VIABLE METHOD OF PREVENTING WEED SEED PRODUCTION IN MISSOURI SOYBEAN SYSTEMS

Kevin Bradley & Mandy Bish, UMC Budgeted: $46,968

This project involves evaluating the effectiveness of the Weed Zapper™ on common weeds in Missouri soybean production systems. The Weed Zapper™ is a Missouri-made product that consists of a front-mounted electrocution boom and rear-mounted PTO-powered generator. The boom must contact the plant for electrocution to occur, and up to 15 kV of electricity can be translocated through contacted plants.

In 2020, our Mizzou Weed Science team evaluated the efficacy of weed electrocution on marestail (horseweed), common and giant ragweed, waterhemp, and a mix of common weedy grasses like giant and yellow foxtail and barnyardgrass. Soybean injury and yield response were evaluated following contact with the electrocution boom.

Preliminary findings include:

- Better weed control was obtained when weeds were higher above the soybean canopy.

- Waterhemp control was greater than 80% if electrocution occurred at R5 or R6 soybean growth stages.
- Electrocution was effective on marestail (horseweed) and common and giant ragweed, with general trend that the taller the plants, the more effective the control.
- Control of grassy weeds was less effective than broadleaf weeds. The growing point of grasses is below the boom, and these species tended to produce new growth after electrocution.
- Weed electrocution at the R1 or R2 soybean growth stage may not be an effective timing as in most cases, few escaped weeds have emerged above the soybean canopy at that time of the season.

Waterhemp electrocuted 3 days prior to photo.

In a deliberate, "worst case scenario" where the electrocution boom maintained constant contact with the upper 2 to 3 inches of the soybean canopy, up to 17% visual soybean injury was observed. In some instances, this injury resulted in soybean yield loss when compared to the controls. These results indicate the importance of having a height differential between the weed escapes that are being electrocuted and the soybean canopy, and in keeping the boom as high as possible with this implement.

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

Kaitlyn Bissonnette, UMC Budgeted: $21,950

Seed treatments for the protection and control of soybean sudden death syndrome (SDS) and soybean cyst nematode (SCN) have become more widely available through numerous companies. As these two diseases are the most damaging diseases of soybeans and begin early in the growing season, treatment must begin early in the season. Often, the presence of SCN in a field increases the foliar disease severity of SDS symptoms. This research study was specifically developed to better understand how nematode-protectant seed treatments can be used to control and manage these two important diseases of Missouri soybeans.

SDS appearing in late reproductive stages.

Trials were conducted at four MU research centers spanning the state. Continuing the nematode-protectant seed treatment trials that were initiated in the 2019 growing season, the 2020 trials were expanded to include 3 additional products for a total of 8 seed treatment products. All nematode-protectant seed treatments were compared to a base fungicide + insecticide and naked seed. Additionally, each field site represented a range of SCN egg levels and SDS risk levels. Nematode reproduction, sudden death syndrome foliar symptom severity, and soybean yield were measured for each plot, and comparisons were made among treatments.

Much like was observed in the 2019 season, results of the 2020 trials indicated differences among treatments at the Graves-Chapple research station. Differences among SDS foliar disease severity, SDS root rot, and soybean yield were observed at this location. Overall, lower SDS foliar disease severity and SDS root rot were observed in the ILeVO® and Saltro® containing treatments as compared to the non-treated control. Significantly higher yield also was observed in these same treatments as compared to the non-treated control and the Clariva® treatment at this single location. At no other location in Missouri and for no other treatments was there a significant difference as compared to the non-treated control

or among treatments. Overall, environment, SCN initial egg counts, and SDS field history are the biggest factors driving the effectiveness of nematode-protectant seed treatments.

BIODIESEL MARKET EXPANSION DRIVE

Brad Shimmens & Kaleb Little, National Biodiesel Board (NBB)
Budgeted: $25,000

The growing adoption of state and regional carbon policies, net zero carbon commitments from the heating oil industry, corporate sustainability commitments from Fortune 100 businesses, stable federal policy, and other successes are all driving factors behind potentially doubling our industry to a more than six-billion-gallon market annually even sooner than the industry's vision of 2030.

Biodiesel, renewable diesel, and renewable jet fuel will be recognized as mainstream low-carbon fuel options with superior performance and emission characteristics. In on road, off road, air transportation, electricity generation, and home heating applications, use will exceed six billion gallons by 2030, eliminating over 35 million metric tons of CO2 equivalent greenhouse gas emissions annually. With advancements in feedstock, use will reach 15 billion gallons by 2050.

Leading key tactics for success in this program include highly targeted, regional paid-advertising campaigns, outreach to key stakeholder groups like environmental organizations, soybean farmers, and animal agriculture audiences, and coordination among key influencer groups. This strategic advertising campaign aids in amplifying our vision for growth from 3-billion-gallons to six-billion and conveys our message that biodiesel and renewable diesel is "Better, Cleaner, Now!" Uniting agriculture top to bottom behind biodiesel and renewable diesel is the ultimate goal.

Increased emphasis of this project is on farmer engagement and education. Reaching this key influencer audience "energizes the base" of biodiesel and renewable diesel supporters but provides important information to those on the leading edge of influence. This proactive, targeted, branding and education initiative will be critical in seizing the opportunity in front of us today.

SEI STATE REGULATORY AND ENVIRONMENTAL SUPPORT

Brad Shimmens & Shelby Neal, NBB Budgeted: $20,000

Goals of this project are:

- Focus on regulatory activities at the state level, both for established and emerging markets.
- Monitor every state regulatory and legislative proceedings in the nation.
- Ensure decision-makers fully understand technical issues associated with biodiesel and related industries.

We continue to work closely with staff at the California Air Resources Board (CARB) to increase biodiesel blends sold in the state. We remain engaged with CARB on the test program they are conducting to determine if combinations of biodiesel and renewable diesel (RD) offer unique emission benefits (NOx and PM) that the state may wish to incentivize in future rulemakings or through other policy mechanisms. Technical feedback to CARB by NBB and member companies have helped clarify and resolve issues so that the testing can continue as planned.

We continue to work with New York regulators to determine biodiesel's role under the recently passed Climate Leadership and Community Protection Act, which requires an economy-wide reduction in greenhouse gas emissions of 40% by 2030. Those discussions have focused on biodiesel's immediate environmental and public health benefits that accrue when biodiesel is used to displace more carbon-intensive liquid fuels in transportation and space heating applications.

On the Bioheat front, NBB has been engaged with and provided substantial comments to the Connecticut Department of Environmental Protection (DEEP) to address various points DEEP staff raised in a recent report with regard to NOx emissions. We provided combustion chemistry and other technical information to rebut the erroneous conclusions contained in the report and continue discussions with DEEP staff on how to best address their NOx concerns moving forward.

NBB staff continues to work closely with several other regulatory agencies regarding development and implementation of programs designed to reduce GHG emissions. Besides California, New York, and Connecticut, we have been working with regulators in Washington state, Oregon, Colorado, Massachusetts, and Rhode Island. Biodiesel continues to be of interest in these states since it offers a GHG benefit of at least 50% relative to fossil fuel.

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