INDIANA CORN Marketing Council

INDIANA SOYBEAN ALLIANCE®

2018-2019

PRODUCTION & ENVIRONMENT RESEARCH HIGHLIGHTS

Funded by the Indiana Soybean Alliance and Indiana Corn Marketing Council

CHECKOFF INVESTMENT

Research Investments Funded by Your Checkoff

In farming, return on investment is everything. At the Indiana Soybean Alliance (ISA) and Indiana Corn Marketing Council (ICMC) it's no different. As the Indiana state soybean and corn checkoff organizations, we define ROI a little differently. Our ROI measures successes on investments that provide a *Return on Indiana.*

One way we bring ROI to Hoosier farmers is through investments in production research. We fund studies that help farmers bring ROI to their operations and take care of the land. That's good for Indiana farmers and the entire state.

Each year, soybean and corn farmer leaders invest checkoff dollars in carefully selected research studies that help farmers meet their goals. ISA and ICMC select projects based on potential impact to farmers in the near- and long-term. Research proposals must include project objectives, hypothesis and an explanation of benefits to Indiana farmers. ISA and ICMC monitor progress of funded projects and review end results. This summary publication highlights research projects funded in 2019.

Using checkoff dollars to invest in the productivity and longevity of Indiana soybean and corn farms is truly a farmer-funded, farmer-led initiative.

INDIANA CORN Marketing Council

INDIANA SOYBEAN ALLIANCE®

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Understanding the Checkoff

CHECKOFF INVESTMENT

A checkoff is a small percentage or dollar amount typically collected at the first point of sale of an agriculture commodity. Each soybean farmer contributes 0.5% of the net market price for each bushel of soybeans sold to a fund supporting increased demand in expanded markets and finding new uses for soybeans. Half of the collected funds is administered by the United Soybean Board (USB) and the other half is distributed to, and managed by, the Indiana Soybean Alliance board of directors.

The Indiana corn checkoff collects a ½-cent on each bushel of corn marketed in Indiana. The Indiana corn checkoff is administered by the Indiana Corn Marketing Council, a 17-member, elected farmer board.

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Joint-Funded Research Projects

Funded with Indiana corn and soybean checkoff dollars.

Discovering ways to push Indiana's ag industry further.

Thanks to your checkoff dollars, the Indiana Soybean Alliance (ISA) and Indiana Corn Marketing Council (ICMC) can partner with top universities to fund research programs that help improve conservation practices that benefit farmers while nurturing soil health and water quality. Moreover, checkoff research investments help address farmer challenges such as pest management, weed control and production efficiencies. Most notably, checkoff dollars helped to develop the new automated plant phenotyping facility at the Purdue Agronomy Center for Research and Education (ACRE). Inside the state-of-the-art facility, researchers measure, analyze and observe various plant characteristics. It's just one of the many ways ISA and ICMC are invested in Indiana.

Visit **incorn.org** or **indianasoybean.com** to learn more.

INDIANA SOYBEAN ALLIANCE®

INDIANA CORN Marketing Council

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A MESSAGE FROM THE PRESIDENT

Research Dollars for Yields Down the Road

As a farmer, I'm always looking for ways to improve practices on my operation to increase yield, manage pests and keep the land productive for years to come. Your checkoff board does the same when investing in research to ensure Indiana corn farmers are as efficient and productive as possible. From input utilization research to weed control and cover crops, we fund studies in a variety of areas.

We do this because every dollar invested brings dividends–read a few of this year's research projects to see that. We take your checkoff dollars seriously and your elected board chooses projects that will drive our industry and Indiana corn farmers forward.

Research is a pillar of the Indiana Corn Marketing Council's mission to serve Indiana corn farmers and a fundamentally critical component to building supply and meeting demand.

Do you have an idea for a research area you'd like to see in the future? Head to incorn.org/icmc/about/contact-icmc to share your thoughts.

Mike Beard
President
Indiana Corn Marketing Council

CHECKOFF INVESTMENT

FARMERS FUNDING THEIR FUTURE

Checkoff investments in production research ensure a long-term future for every Indiana corn farmer.

Research focuses on:

- Increasing and maintaining corn yields
- Input optimization and utilization
- 4R-focused management and education
- Developing and updating best management practices
- Sustainability practices
- Improved water quality and quantity
- Weed control and herbicide resistance
- Cover cropping systems
- Soil health

Control of Herbicide-Resistant Weeds With Cover Crops and Herbicides in Corn Production Systems – Year 2.

By Bill Johnson, PhD, Purdue University
Bryan Young, PhD, Purdue University

Weed populations that are resistant to glyphosate and other herbicides continue to increase in frequency across Indiana and in infestation severity within individual fields. The study was initiated to evaluate the performance of cover crops to contribute to control of herbicide-resistant weed populations in programs that would be used by medium-to-large scale corn growers. This will also enable most traditional farmers to implement best management practices to control herbicide-resistant weeds or delay the selection of these weeds on their farms.

RESEARCH FOCUS

Evaluation of impact of cover crops; diversified herbicide use on weed control, corn yields and economic returns; increase knowledge of proper management techniques for herbicide-resistant weeds in corn.

OBJECTIVE

1. Evaluate weed management practices in corn that incorporates the use of cover crops and diversified herbicide programs in fields with herbicide-resistant populations of waterhemp, marestail and giant ragweed.
2. Evaluate weediness of cover crops if preplant termination efforts fail, as well as the impact of heavy cover crop residues on preemergence herbicide efficacy.

PROTOCOL

1. Field experiments were conducted in Indiana at Purdue and farmer-owned sites that contained herbicide-resistant weed species. Utilized established blocks of bare ground, cereal rye and at least two mixtures commonly used in Indiana that contain a legume species for nitrogen fixation.
2. Cover crops were terminated at 2-3 weeks prior to corn planting using herbicide programs designed to give complete termination.
3. Field studies were also conducted at sites with established blocks of various cover crops, including cereal rye and other commonly used mixtures. Established a variety of termination timings to determine the impact of cover crop residues and in-season competition on corn yield.
4. Data from both objectives were subjected to statistical analysis.

RESULTS

- Cover crops were planted at three sites in 2018 and crop establishment and fall seeding were good at two of the three sites. Yield data will be collected in the fall.
- A healthy cover crop stand in the spring can provide early season suppression of marestail and giant ragweed. However, control is incomplete and follow-up herbicide treatments are needed to bring weed control levels up to commercially acceptable levels.
- More fine-tuning is needed on termination timings to determine the amount of biomass needed to provide suppression of the most significant weed issues.

WHY IS THIS IMPORTANT?

- Wide-scale adoption of glyphosate-resistant corn and soybeans have transformed the way growers manage weeds. Rapid development of additional herbicide-resistant weed species severely limits our weed control choices in both corn and soybeans.
- Three issues will heavily influence Indiana farmers about weed control: increased prevalence of herbicide-resistant weeds, increased popularity of cover crops and declining crop prices.

Funded with Indiana corn checkoff dollars.

Practical Placement Strategies for Potassium in Corn – Year 2

By Tony Vyn, PhD, Purdue University
Lauren Schwarck, MS, Purdue University

With an emphasis in corn fertility management previously focused on Nitrogen (N) and Phosphorous (P), farmers and consulting agronomists have hardly focused any attention on Potassium (K). Though K is not yet an environmental concern, there exists a new urgency in how to best manage K fertilizers from timing and placement perspectives. This study looks at the consequences of placement, timing and rate of Aspire™, a potassium fertilizer source.

RESEARCH FOCUS

Increase and maintain corn yields in Indiana above the national average; nutrient efficiency and utilization; and 4R-focused management and education for Indiana.

OBJECTIVES

1. To determine the corn yield and soil K consequences of alternate K fertilizer timings and/or placements associated with different tillage systems, ranging from no-till to conventional tillage in corn-soybean and continuous corn rotations.
2. To study the influence of corn plant K uptake (earleaf K, total K and grain K removal) and K nutrient efficiencies when applying the same K rate per acre via different placement and timing options.
3. To study practical strategies for K fertilizer application placements and timings in on-farm situations with varying intensities of soil-test K stratification when farmers broadcast versus band-apply K, when farmers combine N and K fertilizer in strip-till bands, when farmers combine tillage and K fertilizer applications, and/or when farmers seek to boost yield with in-season K applications.

PROTOCOL

1. We conducted research station trials in 2017 and 2018 and examined a range of K fertilizer placement and timing treatments. These field experiments had 4-6 replications and were intensively sampled for both plant and soil responses. We also conducted detailed experiments on two soil textures.
2. We started three on-farm trials to compare 2-3 K placement or timing treatments side-by-side, in a minimum of 4 replications, using field-length strips and with the intention of using GPS-guided and calibrated yield monitors.
3. We measured air temperature, rainfall, soil measurements (soil P, K, and organic matter in 0-2", 2-4" and 4-8" increments) and plant measurements.
4. We conducted data analysis that included mapping of the as-applied K rates for on-farm trials with variable K application capability and the grain yield monitor data, in addition to the leaf and whole-plant nutrient concentration data taken from representative biomass harvest areas at both research station and on-farm locations.

WHY IS THIS IMPORTANT?

- K frequently tests low in Indiana fields, often below the critical level.
- Almost every corn field in Indiana is highly stratified for exchangeable K concentrations, whether in no-till or in other conservation tillage systems.
- Too much K can lead to growth suppression and stand loss.

RESULTS

- Overall soil-test K concentrations were moderate. Despite excessive rain in both 2017 and 2018, corn yield result was rated excellent. Both years saw yield gains from Aspire™ applications for all tillage treatments. 2017 yield ranged from 239 to 269 bu/acre with an average increase of 5.9 percent following an application of Aspire™ across all tillage systems. In 2018, yields ranged from 232 to 252 bu/acre, with an average increase of 4.4 percent following an application of Aspire™.

Funded with Indiana corn checkoff dollars.

Profitable and Environmentally Sustainable Corn Production in Indiana 2018

By Dr. RL Bob Nielsen, Professor of Agronomy, College of Agriculture, Purdue University
Dr. James Camberato, Professor of Agronomy, College of Agriculture, Purdue University

Sound agronomic advice and recommendations are crucial for today's corn growers as they strive for improved yields, profits and sustainability. Seemingly simple agronomic decisions like choice of nitrogen (N) fertilizer rate or seeding rate are, in fact, quite complicated because of their interactions with soil properties, landscape features, hybrids and variable annual weather patterns. Collaboration between growers and university Extension specialists in on-farm research projects offers the means to not only generate independent data on agronomic management options, but also the means to aggregate such research data over regions of the state to develop reliable crop management recommendations.

RESEARCH FOCUS

Spatial analysis of corn response to N fertilizer and plant population. Analysis of corn response to starter fertilizer and in-furrow biological treatments.

OBJECTIVES

1. To analyze the years of spatial yield response data to N rates and plant population collected from Indiana Corn Marketing Council-sponsored research trials conducted on Purdue and cooperator farms during the past 11 growing seasons.

2. To evaluate the yield response of corn to in-furrow (aka "Pop-up") and traditional 2x2 row starter fertilizers, as well as response to several in-furrow biological plant stimulants purported to enhance nutrient efficiency and crop yield.

PROTOCOL

1. We were fortunate to collaborate with Mac Bean, a PhD student at the Univ. of Missouri who was advised by Dr. Newell Kitchen. Mac modeled corn N response to soil and weather variables. Our field scale data collected since 2006, along with that from additional Corn Belt states, was utilized in his research. Mac collected additional soil information from our sites as part of his project and we were involved in the interpretation of the data and will be included in the ensuing publications from his PhD research. Mac graduated in May, 2019.

2. Evaluation of the yield response of corn to starter fertilizers, in-furrow biological plant stimulants and sulfur (S) fertilizers; including the initial evaluation of the use of UAV-based aerial imagery as a means of 'sampling' large-scale research trials. Twenty-three experiments were established at seven Purdue farms and with four farmer cooperators on their fields.

3. We also began to explore the use of unmanned aerial vehicles (UAVs) to collect imagery which could potentially be used to document phenotypic responses of corn to experimental treatments in these large-scale research experiments. Nearly 290 autonomous, planned flight missions were conducted during the 2018 growing season with our two UAVs over 25 of our field scale trials around the state.

RESULTS

- Over all locations, the nitrogen recommendation based on the PhD student's model was within 30 lb N/acre of the true Economic Optimum N Rate 43 percent of the time. The model was particularly accurate for the Pinney Purdue Ag Center in northwest Indiana, but consistently overestimated the nitrogen need at the Agronomy Center for Research and Education in west central Indiana and underestimated the nitrogen requirement at the Davis Purdue Ag Center in east central Indiana.

- Sulfur fertilization increased corn yield in 4 of 7 trials conducted in 2018. Yield increases were 4, 18, 20 and 22 bu/A and occurred in northeast, central, southeast and southwest Indiana. In 2017, sulfur fertilizer increased yield in 2 of 4 locations. Sulfur rates differed some from trial to trial, but, in general, less than 5 lb S/acre as a starter fertilizer had little effect on yield, while the lowest rate of sidedress-applied sulfur (10-20 lb S/acre) in each location gave the maximum response. The number of S trials to date are still insufficient to make recommendations for the inclusion of sulfur for all corn production systems across the state.

- Corn responses to several biological and plant growth regulator treatments applied in-furrow at planting were negligible and inconsistent in 14 field scale trials conducted from 2016–2018.

- We successfully correlated several UAV-derived spectral vegetative indices to yield from 2 fields showing a strong response to S fertilization. Work will continue to explore ways to use UAV imagery in research and in crop production to quantify treatment effects using spectral reflectance data and identify nutrient deficiencies so corrective measures can be applied.

WHY IS THIS IMPORTANT?

- This research has resulted in improved and more profitable recommendations for seeding rates, nitrogen rates, starter fertilizer, biological stimulants and sulfur fertilizer.
- Corn farmers will increase their profits and reduce the loss of nitrogen to the environment.
- To provide 4R-focused management and education.
- To develop and update best management practices.
- To practice environmental sustainability and secure the most optimal water quality for the community while maintaining crop profitability.

Funded with Indiana corn checkoff dollars.

Investigation of Corn Yield Improvement Following Cereal Rye Using Starter Nitrogen Fertilizer – Year 2

By Shalamar Armstrong, PhD, Purdue Agronomy, Soil Conservation and Management
James Camberato, PhD, Purdue Agronomy, Professor and Extension Specialist

Although cover crops have been identified as one of the most efficient in-field conservation practices that can be employed on a larger scale to reduce nutrient loading, the adoption of cover crops in the Corn Belt is minimal. One of the leading adoption barriers is the fear of corn yield reduction following cereal rye, the most common and viable cover crop option in the Midwest, due to its winter hardiness and Nitrogen (N) scavenging ability. Thus, there is a critical need to investigate the adjustment of current N management of farmers in the Corn Belt to improve corn yield following a cereal rye stand.

RESEARCH FOCUS

- Investigate the adjustment of current N management of farmers in the Corn Belt to improve corn yield, following a cereal rye stand.
- Optimize rate of starter N fertilizer to offset N fertilizer and to offset the apparent N immobilization, due to cereal rye before corn.

OBJECTIVES

1. Determine the impact of cereal rye inclusion and starter fertilizer on soil N availability and the use N efficiency of the corn plant.
2. Optimize the starter N needed to improve corn yield following the termination of a cereal rye cover crop stand.

PROTOCOL

1. Four sites established with the state of Indiana –northeastern, west central and two sites in the southeastern portion of the state–and cover crops successfully established at each site.
2. Following cereal rye termination, corn was planted and samples at V2, V4, V6, V8, V9-V11, R1-R3 and R6 growth stages.
3. Plant population was determined and aboveground plant biomass analyzed for N uptake at each sampling date.
4. Corn yield was commercially analyzed for statistical differences.
5. Treatments for each site were four starter N levels (0, 28, 56, 84 kg ha^{1}) and two cover crop levels (cereal rye and no cereal rye).

RESULTS

- Cereal rye significantly decreased soil inorganic nitrogen at all three locations.
- Starter N rate significantly increased corn development at varying growth stages within both cereal rye and non-cereal rye plots at all sites.

WHY IS THIS IMPORTANT?

- Adopting the use of cereal rye and then adjusting N management will likely positively affect corn yield following the use of cereal rye. Thus, allowing farmers to maintain corn yield while significantly reducing the potential for nitrate loss through tile-drainage.

- In fields where cereal rye-limited spring soil N availability, cereal rye significantly reduced total corn N uptake at growth stage V6 by 29.1 percent, and at R6 by 23.5 percent, NRE by 27.5 percent and corn grain yield by 8.4 percent after terminating cereal rye at least two weeks before planting.
- In fields where cereal rye did not reduce soil N availability, a starter N rate of 84 kg N ha^{1} significantly increased R6 total N uptake, relative to the cereal rye control. Starter N rate of 56N, 56NP and 84N significantly increased corn grain yield, in cereal rye plots, relative to the CR control (CR-0N). Starter N application of 56NP increased corn grain yield, in non-cereal rye plots, relative to the conventional control (non-CR 0N).

Funded with Indiana corn checkoff dollars.

Indiana soybean fields are full of opportunity.

Indiana Soybean Alliance (ISA) is the state soybean checkoff organization. ISA ensures there are strong, viable markets for soybeans through the discovery and development of innovative new uses that have major commercial value. Through partnerships with development companies, entrepreneurs and universities, ISA's new use innovation efforts have led to the creation of popular commercialized products, including: soy candles, soy crayons and soy-based concrete sealants.

To learn more about Indiana soybean checkoff investments, visit **indianasoybean.com**.

CHECKOFF INVESTMENT

Funded with Indiana soybean checkoff dollars.

INDIANA SOYBEAN ALLIANCE®

A MESSAGE FROM THE CHAIRMAN

A Successful Future for Soybean Farmers

Like you, I measure success on my farm in more ways than just a good harvest. The soybean checkoff helps facilitate future market growth in multiple ways, including funding research projects important to soybean farmers.

Your soybean checkoff is proud to conduct production research with state and university partners. Through these partnerships, the soybean checkoff is able to invest dollars to identify best management practices that Indiana's soybean farmers can then translate onto their farms.

ISA is excited to share the projects that have been funded with your soybean checkoff dollars and their results. Projects included in this support our goal of developing tools that:

- Increase and maintain soybean yield
- Provide weed control and manage herbicide resistance
- Provide pest and disease control
- Improve production and management technologies

By investing in new ideas, the soybean checkoff helps ensure a strong and profitable future for all Indiana soybean farmers.

Joe Tuholski
Chairman
Indiana Soybean Alliance

CHECKOFF INVESTMENT

FARMERS FUNDING THEIR FUTURE

Checkoff investments in production research ensure a long-term future for every Indiana soybean farmer.

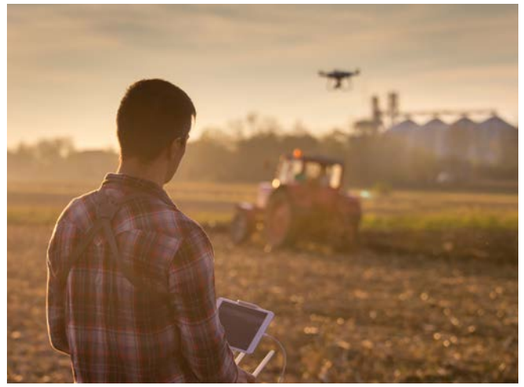
Research focuses on:

- Increasing and maintaining soybean yields
- Input optimization and utilization
- 4R-focused management and education
- Developing and updating best management practices
- Sustainability practices
- Improved water quality and quantity
- Weed control and herbicide resistance
- Cover cropping systems
- Soil health

A Public-Private Partnership to Use Drone-Acquired Metrics to Increase Accuracy of Yield Estimation in Multi-Environment Yield Trials of Soybeans

By Katherine Rainey, PhD, Purdue University
Keith Cherkauer, PhD, Purdue University

There is currently a great need throughout the seed industry to advance analytical capabilities to use sensor data, drone data and to develop new analytical techniques to describe temporal variation. While farmers and agronomists are well aware that canopy development is critical to yield in soybeans, it has never before been quantified for selection of new soybean varieties. This is because it is difficult to measure canopy development on thousands of soybean plots. However, quantifying canopy is now possible with drones. This research is conducted in cooperation with Beck's Hybrids.



RESEARCH FOCUS

Improve rate-of-gain for yield potential in soybean breeding and introduce higher-yielding varieties to inform commercial seed operations.

OBJECTIVES

1. Test the efficacy of image-based parameters acquired with UAS (Unmanned Aerial Systems) to increase the accuracy of yield estimation in multi-environment yield trials of soybeans.
2. Develop methods to determine custom plant populations for all soybean varieties using UAS imagery.

PROTOCOL

1. We conducted 17 flights over two of Beck's on-farm research trials in Remington and Lafayette, Indiana. Hundreds of high-resolution RBG images were captured for each flight, and multispectral images were captured on three of those flights.
2. We conducted a calibration experiment at ACRE (Agronomy Center for Research and Education), in which seeds were planted and surveyed over 40 times for development of methods for quantifying row length.
3. Forty-eight plots were planted in May 2017, with a second planting following in June of 2017. Three seeding rate treatments ranging from 60-120,000 per acre for four varieties were used, and we conducted stand counts on the inner two rows.
4. More than 40 flights were conducted at ACRE, encompassing this experiment and images processed to obtain canopy coverage (CC) values.

RESULTS

- Our results showed that there is potential to make drone RGB images a standard procedure in breeding trials, as it can be used to improve yield estimates. Further studies are necessary to narrow down to one or two parameters that are consistently improving yield estimations in any given trial.
- Seeding rate and planting date influence the CC regardless of the selected cultivar.

WHY IS THIS IMPORTANT?

- Canopy development has a strong association with yield potential and tracking canopy parameters may predict yield potential in a plot that may be disadvantaged due to other factors.
- Drones can reduce error and improve efficiency so that better products may come to market more quickly.

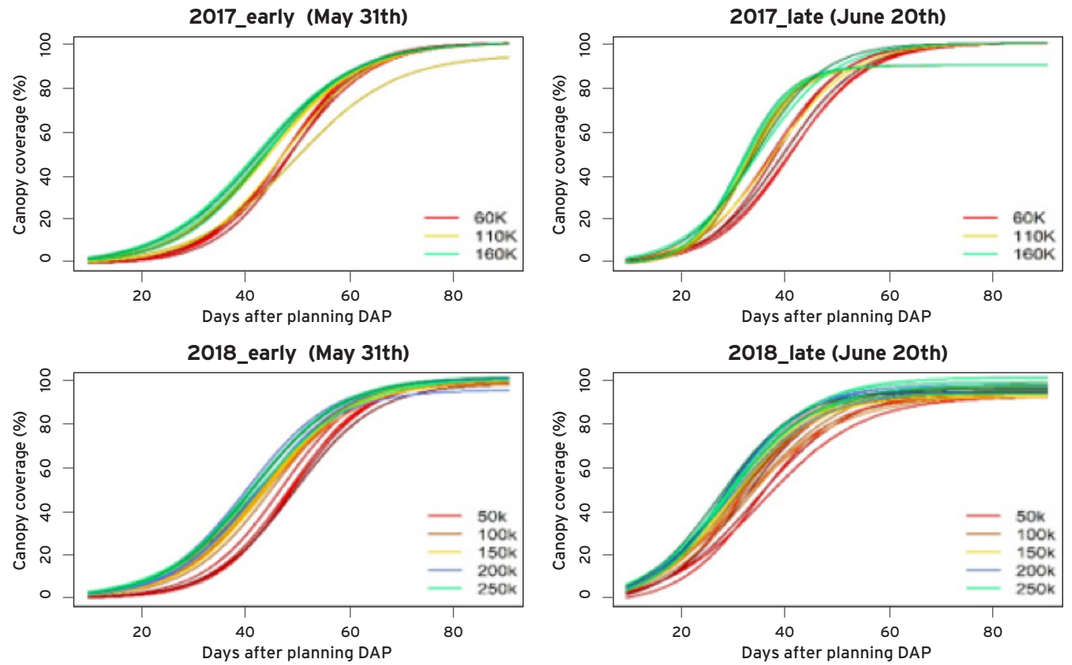


Figure 1: Canopy coverage (CC) dynamic in soybean as a function of seeding rate and planting date

Funded with Indiana soybean checkoff dollars.

Genetic Dissection of Yield-Related Traits For Soybean Breeding

By Jianxin Ma, PhD, Purdue University

Increases in soybean yield through breeding in the past few decades have been slower than growers expect, due to the overall low level of genetic diversity in soybeans and the narrow genetic base of ancestral soybean lines used in soybean breeding programs. The main objective of this project was to identify genes and/or genomic regions associated with these yield-related traits and to develop molecular markers for implementing marker-assisted selection for yield-related traits in breeding programs.

RESEARCH FOCUS

Best-performing RILS, Williams 82, high-yielding cultivars and F_2 individuals advanced to F_3 families.

OBJECTIVES

1. Identify genes and/or genomic regions underlying yield component traits, such as pod numbers per node, node numbers per plant, seed sizes and plant architecture traits, such as branching angles and leaf shapes.
2. Develop molecular markers for implementing marker-assisted selection for yield-related traits in breeding programs.
3. Select and evaluate experimental lines with enhanced yield potential.

PROTOCOL

1. Evaluated F_2 and F_3 populations and parental lines for phenotypes in two replicates each at two locations.
2. Defined genes and genomic regions underlying specific traits, and then designed and tested SSR markers and single nucleotide polymorphism (SNP)-type markers within defined genes/regions and tested them for effectiveness for marker-assisted selection.
3. Used the SSR and SNP markers to examine high-yielding experimental lines from this project and from a North Central Soybean Research Program-sponsored soybean yield project. The best-performing lines were then genotyped via a genotyping-by-sequencing approach for precise identification of introgressed genomic regions and alleles.

RESULTS

- A set of genomic regions/genes underlying the investigated traits have been identified and are in the process of functional validation.

WHY IS THIS IMPORTANT?

- Increases in soybean yield through breeding have been modest in past decades due to limited genetic variability and a result of minimal number of Asian soybean landraces introduced that form its genetic base, but remain a long-term goal.
- Addresses the challenge of dissecting yield component traits and plant architecture traits, which affect canopy coverage, photosynthetic efficiency and yield potential.

Funded with Indiana soybean checkoff dollars.

INDIANA WATERSHED INITIATIVE (IWI):

Continued Quantification of Water Quality and Economic Benefits From the Watershed-Scale Pairing of Cover Crops and the Two-Stage Ditch

By Jennifer Tank, PhD, University of Notre Dame
Todd Royer, PhD, Indiana University – Bloomington
John Tyndall, PhD, Iowa State University

Indiana croplands play a crucial role in feeding the country and the world, but runoff of excess nitrogen (N), phosphorus (P) and sediments can impact both local and downstream water quality by causing harmful algal blooms and degrading freshwater habitat. Additionally, water quality problems and the loss of fertilizer nutrients in fields can reduce farmer productivity by compromising soil quality, which must be replenished with fertilizer additions and risks reducing both crop yields and profitability.

This results in a need for best management practices to support the economic needs of the agricultural community.

RESEARCH FOCUS

Development and updates of best management practices; cover cropping systems; two-stage ditch; water quantity/quality; soil health and nutrient reduction cost analysis of benefits; maintaining yields in Indiana above national average.

Figure 1. Stream nutrient measurements are collected every two weeks throughout the year.

Figure 2. A graduate student analyzes water chemistry in the laboratory, measuring ammonium, nitrate, and soluble reactive phosphorus in both the stream and tile drain samples.

OBJECTIVES

1. Quantify the water quality and quantity benefits of pairing cover crops and the two-stage ditch implemented at the watershed scale, through monitoring of the Shatto Ditch Watershed (SDW) and Kirkpatrick Ditch Watershed (KDW).

2. Quantify the benefits of winter cover crops on improving soil health via increased nutrient retention as well as expected improvements in soil organic matter over the four years of the Indiana Watershed Initiative (IWI) through the USDA Resource Conservation Partnership Program.

3. Use the process-based Soil Water Assessment Tool (SWAT) model developed by the USDA Agricultural Research Service, as well as the Agricultural Conservation Planning Framework tool for conservation scenario planning.

PROTOCOL

1. In both the SDW and KDW, quantified dissolved N and P losses from tile drains and from the watershed outlet every two weeks to document the impact of cover crops and the two-stage ditch on nutrient reductions.

2. Quantified soil N, P and organic matter content in SDW and KDW during fall and spring of each year and calculated changes associated with cover crop implementation.

3. Developed SWAT model for SDW and KDW, validated model using field samples to quantify the effect of cover crop planting implemented in larger watersheds.

RESULTS

- As of the end of 2018, good progress was made on quantifying the effect of the watershed scale and cover crop planting on water quality, using high frequency sampling in both watersheds.
- Farmers continue to plant cover crops on 67 percent of row-crop acres in the SDW and about 35 percent in the KDW.
- Construction on two new segments of floodplain is complete for the SDW and now totals 4.1 miles, which is the longest two-stage ditch in the nation.

Additional results still to be published.

WHY IS THIS IMPORTANT?

- Generalizable information about the net private economic benefits of cover crops is decidedly scarce, making survey data that has been collected and SWAT modeling scenarios valuable.
- Pairing winter cover crops and the two-stage ditch in two Indiana watersheds to improve soil health and reduce nutrient loss from fields.
- Cover crops and the two-stage ditch could circumvent costly, and perhaps burdensome, future regulatory actions to reduce agricultural nutrient loading to local or downstream surface waters.

Funded with Indiana soybean checkoff dollars.

Monitoring Herbicide-Resistant Weeds and Improving Management of Roundup Ready 2 Xtend® Soybeans

By Bryan Young, PhD, Purdue University
Bill Johnson, PhD, Purdue University

This research study from May 2018 through April 2019 was conducted to observe and ascertain the level of herbicide resistance in weeds. Furthermore, it looked at best management practices of Roundup Ready 2 Xtend® soybeans in the context of dicamba stewardship.

RESEARCH FOCUS

Confirmation of herbicide resistance in weed samples to various herbicides and mode of action groups; analysis of weather conditions and label restrictions for performing dicamba applications.

OBJECTIVES

1. Analysis of various weed samples to confirm resistance to various herbicides and to explore current management strategies. Weeds included waterhemp, Palmer amaranth, horseweed (Marestail) and giant ragweed. Explore specific resistance: PPO-inhibiting herbicides (e.g. Cobra®, Flexstar®), glyphosate (e.g. Roundup®), ALS-inhibiting herbicides (e.g. Firstrate®, Classic®), as well as the correlation of both PPO and glyphosate resistance.
2. Demonstrate best management practices for Roundup Ready 2 Xtend soybeans for Indiana.

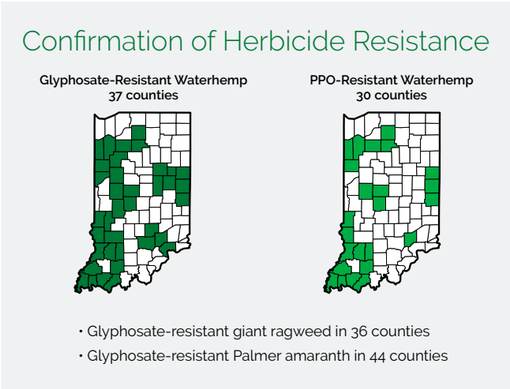


Figure 1. Maps of Glyphosate- and PPO-Resistant Waterhemp in Indiana (Jan. 2019)

PROTOCOL

1. Conduct DNA assays and whole plant greenhouse screens on weed populations with suspected herbicide resistance. Molecular DNA assays will be performed on leaf tissue collection during the growing season or from plants grown from seed in the greenhouse. The molecular assays will include those for confirmation of waterhemp resistance (glyphosate, ALS herbicides and PPO herbicides), Palmer amaranth resistance (glyphosate, and ALS herbicides) and giant ragweed (ALS). Traditional greenhouse screens will be performed for any herbicide-resistance mechanisms for which we don't have a molecular assay.
2. Determine classifications and regions of potential resistance.
3. Field demonstration trials on weed management with Roundup Ready 2 Xtend soybeans compared to other soybean traits/varieties at four Purdue Agricultural Centers.
4. Separate field research will be conducted in Xtend soybeans where dicamba is excluded as an option for weed management to identify potential solutions for achieving successful weed management in buffer zones where dicamba will be prohibited.

RESULTS

- Documented the presence and spread of key herbicide-resistance traits in weeds across Indiana (Figure 1).
- Summarized the accuracy of phone apps for predicting temperature inversions that would restrict the safe application of dicamba in Roundup Ready 2 Xtend soybeans (Figure 2).
- Weed management field days held in Summer 2018 to review herbicide strategies, programs and newer weed management technologies.
- Follow-up field days to present research, data and recommendations for growers for 2019 field season. Total of over 1,000 people attended field days.
- Data analysis of weather conditions for performing legal dicamba applications in Xtend soybean were shared at regional/national meetings with peer weed scientists in Extension and with regulatory groups, such as the Indiana State Chemists and the U.S. EPA.
- Weather/dicamba application analysis has also been supplied to several Extension bulletins, newsletter articles and the Weed Control Guide for Ohio, Indiana and Illinois.

The study concluded in Spring 2019 and final results have not yet been published.

WHY IS THIS IMPORTANT?

- This research emphasizes the need to enhance soybean weed management throughout Indiana. As herbicide-resistant weeds are becoming more commonplace, increased education and successful implementation of Xtend is necessary to provide the greatest benefits to Indiana producers. The tools to effectively manage weeds, even those with multiple herbicide resistance, are available, but implementing the proper strategy with these tools is the key to success.

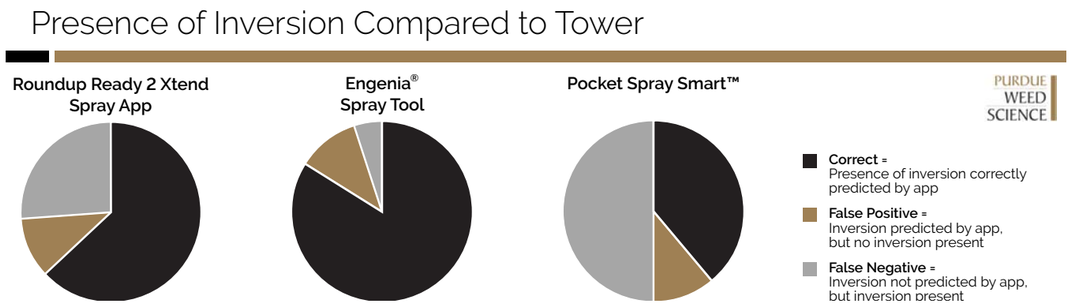


Figure 2. Prediction of weather conditions for applying dicamba in Xtend soybeans using different phone apps versus actual weather measurements at the field site in 2018.

Funded with Indiana soybean checkoff dollars.

Sulfur Synergies in Soybean Management

By Shaun Casteel, PhD, Purdue University

Sulfur (S) deposition from the atmosphere has been on the decline over the last few decades, due to improvements in air quality. As it pertains to agriculture, S is a macronutrient that is needed in large quantities for all crops including soybeans. Organic matter in the soil can help make up the difference in crop needs and deposition from the atmosphere, but evidence is mounting that more S is needed in some fields. As a result, our research aims to determine the best options to manage S for soybeans and determine opportunities for synergies in management to optimize yield and quality.

RESEARCH FOCUS

Synergies in soybean management, optimize S applications, yield and quality responses.

OBJECTIVES

1. Determine management practices to alleviate S deficiency of soybean in the most responsive and cost-effective manner.
2. Characterize the physiological changes that have improved soybean grain yield and quality in response to S applications.

PROTOCOL

1. Prior to planting, we broadcasted or sprayed sulfur sources, depending on the material: AMS, AMS:ES, Elemental Sulfur, MES10, Sul-Po-Mag and Gypsum. An untreated control was also included. We did this for nine treatments and replicated it five times near LaCrosse, Indiana. We also monitored canopy development through digital imagery from the ground and in the air.
2. Over 13 treatments, we applied foliar treatments at V4, R2 and R4 with spray-grade AMS dissolved in water. These treatments were replicated five times near LaCrosse, Indiana. We also monitored canopy development through digital imagery from the ground and in the air.
3. We conducted 24 treatments at two broadcast, three seed treatment and four foliar. These treatments were replicated five times near West Lafayette. We also monitored canopy development through digital imagery from the ground and in the air.
4. For all treatments, grain subsamples were collected to determine seed size, nutritional content, protein and oil.

RESULTS

- First-year results of this project have documented 10+ bu responses to ammonium sulfate, MES10 and pelletized Gypsum, followed by ~6bu responses to the other sulfur sources at LaCrosse in 2018.
- At the same location, optimal foliar S application rate was ~4 lb S/acre regardless of growth stage applied (V4 or R3) with 8 bu yield improvement. These yield improvements are also coupled with improvements of protein concentration.
- Synergies in management seem to align more with combined applications of AMS prior to emergence and foliar protection at R4 than seed-applied inoculant and AMS application prior to emergence.

Figure 1. Soybean plant on the left is well nodulated due to the application of 20 lb S/acre prior to planting; whereas, the plant on the right is poorly nodulated (i.e., no S applied). Picture taken Sept. 11, 2017 near LaCrosse, Indiana.

Figure 2. Soybean on the left were not treated with S. The leaves contained 0.27 percent S with N:S ratio of 18: 1. Soybeans on the right were treated with 20 lb S/acre from AMS at PRE. Their leaves contained 0.38 percent S with N:S ratio of 15: 1. Pictures were July 15. 2016 near LaCrosse, Indiana.

Figure 3. Subset of sulfur sources applied to soybean in 2018 near LaCrosse, Indiana. UTC is untreated. The remaining treatments were AMS, MES10, Gypsum, K-Mag and ATS applied at 20 lb S/acre prior to soybean emergence. Notice the plant height and root systems of AMS and MES10 in particular. Picture taken on July 11, 2018.

WHY IS THIS IMPORTANT?

- We aim to determine the most effective method of correcting S deficiencies of soybean, both agronomically and economically.
- We are teasing out the field situations where S is warranted. Preliminary studies have indicated the protein concentration is improved with S applications.
- Management strategies are a foundation to maintain yield and improve quality.

Funded with Indiana soybean checkoff dollars.

Utilizing Novel Sources of Resistance to Phytophthora Root and Stem Rot of Soybean —Year 3

By Jianxin Ma, PhD, Purdue University
Guohong Cai, PhD, Purdue University

Soybean root and stem rot caused by the soil-borne oomycete pathogen Phytophthora (P.) sojae is one of the most destructive diseases of soybean. A few genes/alleles conferring resistance to P. sojae (designated as RPS genes) were used to develop resistant soybean cultivars–an economical and effective approach to protect soybeans from this disease. However, resistance contributed by individual Rps genes is usually non-durable and effective for a limited amount of time. As a result, most of the known Rps genes used for soybean protection in the past decades have become partially effective or completely ineffective to many emerging new races/isolates of the pathogen and have brought an immediate threat to soybean production. Therefore, it is important to identify and deploy novel genes for soybean protection.

RESEARCH FOCUS

Identify soybean landraces resistant to a set of diverse P. sojae races/isolates used for evaluation. Identify new genes that confer excellent resistance to the pathogen races/isolates, introgress novel sources of Rps genes into elite varieties.

OBJECTIVES

1. Introgress the genomic regions carrying Rps11, Rps1-f, Rps1-das, and Rps2-das into the elite cultivars, including two Purdue cultivars and two Illinois cultivars.
2. Develop Rps11, Rps1-f, Rps1-das, and Rps2-das isogenic lines using Williams as recurrent parental lines in backcrosses with the donor lines of these four genes.
3. Determine if Rps1-k, RpsUN1, and Rps1-das, Rps2, RpsUN2 and Rps2-das are different genes.
4. Pyramid more than one of the four novel genes and the two known genes into the same elite cultivars.

PROTOCOL

1. Crossing and backcrossing of the Rps gene donor lines with the Purdue and Illinois elite cultivars were done in the greenhouse and agronomy farm of Purdue University.
2. Rps gene donor lines were crossed and backcrossed with Williams in the greenhouse and agronomy farm of Purdue University. Rps genes in the progeny lines were tracked by molecular markers closely linked to these Rps genes to obtain BC6F2 generation isogenic lines, which have the Williams background, but different Rps genes.
3. Rps1-das and Rps1-k lines were crossed to generate F2 populations and F3 families. Similarly, the Rps2-das and Rps2 lines were crossed to generate F2 populations and F3 families.
4. Introgression of two different Rps genes into the same elite cultivars.

WHY IS THIS IMPORTANT?

- The impact of this project will move to soybean producers and the soybean industry, as new soybean lines with novel and more durable resistance are developed and deployed.
- This will further strengthen soybean translational genetics, breeding and will foster collaboration among soybean breeders, pathologists and geneticists.

RESULTS

- Successfully initiated the crosses and backcrosses as proposed and continued advancing the backcrossing lines.
- Examined some of the progeny seeds and lines with molecular markers for effective and accurate selection for the Rps genes during the introgression process.
- Started converting the current CAPS- and KASP-based Single Nucleotide Polymorphism (SNP) markers to high efficient semi-thermal asymmetric reverse PCR (STARP) markers.

Funded with Indiana soybean checkoff dollars.

Tracking Cereal Rye Nitrogen Release Through Soil Pools and Cash Crop Uptake – Year Two

By Shalamar Armstrong, PhD, Purdue University
Shaun Casteel, PhD, Purdue University
Corey Lacey, PhD Candidate, Purdue University

Cover crops have re-emerged nationally as a possible solution to reduce nitrogen (N) loading from agricultural fields. The integration of cover crops into a farmer's existing N management system requires three considerations before full voluntary adoption and N management can be adopted: can cover crops reduce the amount of fertilizer N lost; what percentage of cover crop scavenged N will be available to the next crop; and how does the timing of cover crop residue N release correlate with the N demand of corn and soybeans?

RESEARCH FOCUS

- Knowledge gaps surrounding timing and release of cover crop N following termination.
- Understanding how cover crops can be managed to provide both economic and environmental benefits.

OBJECTIVES

1. Use ^{15}N techniques to quantify the amount of cover crop N that is released to the soil in inorganic and organic pools.
2. Measure the amount of cover crop residue N that is utilized by the subsequent corn and soybean crop.

PROTOCOL

1. The study was conducted at the Purdue Agronomy Center for Research and Education, near West Lafayette, Indiana
2. A randomized, complete block design was established, consisting of six macro plots: cereal rye grown before corn and cereal rye grown before soybeans, replicated 3 times. Each plot was broken down into six micro plots.
3. Cereal rye N with a high amount of ^{15}N was grown in the micro plot "High Label Nursery." Cereal rye N with a low amount of ^{15}N was grown in the "Low Label Nursery" micro plot.
4. Corn and soybean samples were sampled at an early vegetative growth stage, early reproductive stage and physiological maturity.
5. Soil samples were collected from the "Low Label" micro plots, at cover crop termination, at two weeks after termination and at each plant sampling date.

RESULTS

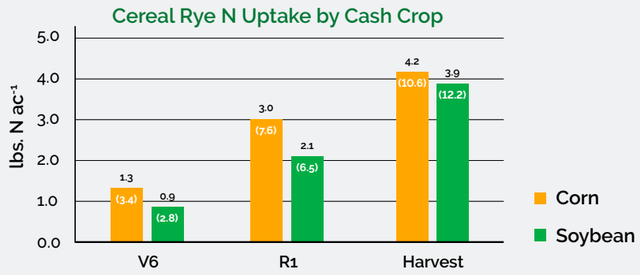
- The percent of cereal rye scavenged N (cereal biomass N) recovered by the subsequent corn and soybean plants increased as the plants matured. At the V6, Vt-R1, and harvest corn recovered 3.4, 7.6, and 10.6 percent of cereal rye biomass N. A similar trend was found for soybean, where at V6, R1, and harvest soybean recovered 2.8, 6.5 and 12.2 percent of cereal rye biomass N.
- On average, 88.6 percent of cereal rye biomass nitrogen remains in the soil where it may be utilized by future crops. Thus, we will continue to investigate the fate of the cereal rye biomass N after it decomposes.
- On average, only 11 percent (4 lbs/A) of cereal rye N released after decomposition is utilized by the following cash crop (corn or soybean).

WHY IS THIS IMPORTANT?

- Results from this study allow farmers to estimate the release of nitrogen from the cover crop biomass as the corn plant grows and matures.
- The study also demonstrates that only a small portion of cereal rye nitrogen is available to the subsequent corn plant, demonstrating the need for starter N and other adaptive nitrogen management practices to replenish soil nitrogen used by cereal rye.

15 N Results

What amount of the N within cash crop is N from cereal rye?



- Numbers in black at top of each column are the amounts of N uptake.
- Numbers in parentheses inside each column are the percent of CR N applied taken up by the cash crop.

Funded with Indiana corn and soybean checkoff dollars.

The Efficacy of Fall Cover Crops As They Relate to Stream Water Quality: a Paired Watershed Approach

By Jerry Sweeten, PhD, Manchester University, and Herb Manifold, MS, University of Minnesota

Landscape level changes have facilitated the development of a strong agricultural industry in Indiana and one of the best areas in the world to produce food and fiber. Unfortunately, there are external costs of the system as it now exists. Some challenges include excessive loss of soil and nutrients from upland fields, along with major upland and instream modified habitats. The loss of this "natural capital" is not particularly good for long-term agricultural profitability, sustainability, soil health or water quality.

Over the recent past, there has been increased interest across natural resource agencies, agriculture producers and the scientific community to examine the efficacy of soil and water conversation practices as they relate to nutrient loss, soil erosion, soil health and stream ecological integrity. Though not entirely understood, it's clear that the ecological effects of excess nutrients have a dramatic effect on water quality.

The purpose of this study is to maintain or advance agricultural productivity, measure export of nutrients and soil, and examine stream biota in two small agricultural watersheds less than 3,000 acres.

RESEARCH FOCUS

Economic and ecological benefits of fall cover crops; maintain or advance agricultural productivity; measure export of nutrients and soil; examine stream biota in two small watersheds (not to exceed 3,000 acres); effectiveness of cover crops as they relate to nutrient and sediment export.

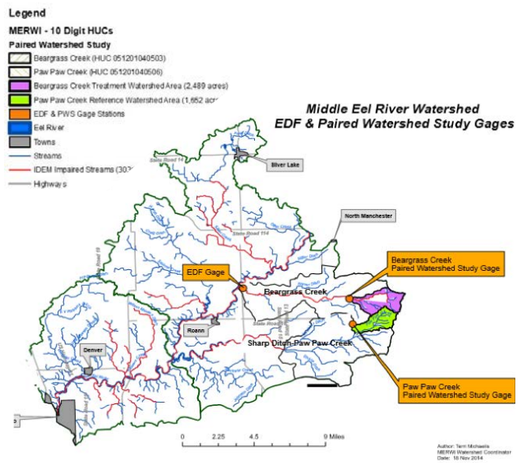


Figure I. Beargrass Creek in Wabash County, Indiana encompasses 2,489 acres (purple). The most downstream portion of the watershed is at County Road 100 East. This is the watershed that v,-i..11 be treated with fall cover crops and other conservation practices. Pawpaw Creek watershed (green) will be the untreated watershed and is located just south of Beargrass Creek. Pawpaw Creek in Wabash County, Indiana encompasses 1,652 acres. The most downstream portion of the watershed is at County Road 500 North.

OBJECTIVES

1. The focus and intent is to promote and fund the application of fall cover crops and other conservation practices in Beargrass Creek watershed over a five-year period.
2. The second watershed, Pawpaw Creek, is a reference watershed left under "normal" agricultural practices, as determined by the individual operator.
3. This experimental design provides valuable data in regard to the current ecological condition of both watersheds and may provide sufficient data to illuminate the effectiveness of fall cover crops as they relate to nutrient and sediment export and to document changes in the biotic community.

PROTOCOL

1. There are two watersheds and both are tributaries of the Eel River in Northern Indiana. Their landscape position, along with interest from producers, makes them suitable for experimental design.
2. Data includes water chemistry (grab samples), stream habitat and fish community structure.
3. Six water samples are collected daily for analysis between May-June; from July-April, the first rain event that increases stream discharge is to be analyzed, unless it is below freezing.
4. Water samples are to be analyzed for total phosphorus, soluble-reactive phosphorus, total nitrogen, nitrate-nitrogen, Kjeldahl nitrogen, total nitrogen and total-suspended sediment (turbidity and gravimetrically).
5. Additionally, stream discharge has been calculated to determine nutrient and sediment loads.

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WHY IS THIS IMPORTANT?

- This has provided an opportunity to examine stream habitat, fish communities and upland wildlife before and after construction.
- Each year, we continue to add to our scientific understanding and nudge the agricultural conservation needle in a positive direction.

RESULTS

- With a large movement of phosphorous and sediment across all years of monitoring and consistent high levels of nutrient and sediment in Beargrass Creek, there was no indication of change in stream habitat and dish community structure/function. Externally of the Beargrass Creek watershed in the Eel River, a 95 percent survival rate is documented for federally endangered freshwater mussel reintroduction.

Funded with Indiana corn and soybean checkoff dollars.

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