2017
PRODUCTION & ENVIRONMENT RESEARCH HIGHLIGHTS

Funded by the Indiana Soybean Alliance and Indiana Corn Marketing Council
With improved technology and new available data, soybean and corn farmers continue to learn, adapt and improve practices to yield the greatest potential from every acre while managing the land as good stewards. The Indiana Soybean Alliance (ISA) and Indiana Corn Marketing Council (ICMC) are dedicated to helping achieve these goals. Each year, soybean and corn farmer leaders invest checkoff dollars in carefully selected research studies to help optimize farm operations. This summary publication highlights research projects funded in 2017.

ISA and ICMC select projects based on potential impact to corn and soybean 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.

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

Understanding the Checkoff

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 are 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 1/2-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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In 2016/2017, U.S. grain exports set a new record of 114 million metric tons. More than 95% of the world’s consumers live outside the U.S. (OUS), meaning export markets are critical to the success of those that grow our commodities. With growing populations and an increasing middle-class in previously developing countries, demand for consistent, quality food products will also continue to rise. Meeting that demand will be U.S. farmers.

Over the course of the next 30-50 years, U.S. farmers will continue to innovate and increase production. That innovation will be needed to meet increased OUS demand and be necessary to support current farm outputs, as well as future innovation. Export markets, current and burgeoning, are a critical component for Indiana corn and soybean farmers and the U.S. ag economy as a whole.


**Why Exports Matter**

32% of U.S. gross farm income comes directly from exports.

US Ag exports in 2016, equivalent to building 34 skyscrapers.

1 of every 3 planted corn acres is exported, making corn exports = $9 billion

Grain exports account for $55.5 billion in economic output and 262,000 jobs.

* Accounts for exports of grains in all forms: feed grains, and feed grain equivalent of U.S. ethanol, distiller’s dried grains with solubles, and meat exports.

1 Export data provided by U.S. Grains Council.

Funded with Indiana soybean and corn checkoff dollars.
The Indiana Corn Marketing Council invests corn checkoff dollars in production research to ensure Indiana corn farmers are as efficient and productive as possible. Why do we do this? Your checkoff board invests your corn dollars to develop methods and tools that enhance yield, find new ways to control pests and manage diseases, fight against resistant weeds, and seek sustainable practices that keep our land productive for years to come.

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.

**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

**Research by the Numbers**
ICMC production and environmental research, 2008-2018:
- 60 grants funded
- Equaling a nearly $3,000,000 investment
- Working with more than 150 researchers

**Mike Beard,**
President
Indiana Corn Marketing Council
CONTROL OF HERBICIDE-RESISTANT WEEDS WITH COVER CROPS AND HERBICIDES IN CORN PRODUCTION SYSTEMS

By Dr. William Johnson and Dr. Bryan Young, Purdue University

This field project was designed with the long-term objectives of reducing the impact of herbicide-resistant weeds on corn production and profitability; as well as best management practices for herbicide-resistant weed species while increasing and maintaining corn yields and cover cropping systems.

Marestail, giant ragweed, common waterhemp, and Palmer amaranth are all significant weeds that have developed a resistance to glyphosate and at least one other herbicide mode of action. This has created a challenge to farmers when looking at production levels in corn and soybean systems. With the emergence of these resistant weeds brings difficulty in finding an effective postemergence herbicide. Thus, more work is needed to evaluate the usage of cover crops and more diverse herbicide programs to manage resistant weeds.

OBJECTIVES

1. Evaluate weed management practices in corn that incorporate the use of cover crops and diverse herbicide programs with herbicide-resistant populations of waterhemp, Palmer amaranth, marestail and giant ragweed.

2. Evaluate the “weediness” of cover crops if preplant termination efforts fail, and the impact of heavy cover crop residues on preemergence herbicide efficacy.

Research Focus: Increase and maintain corn yields, Weed control and herbicide resistance, Sustainability, Cover cropping systems
PROTOCOL
The field trials were established at Indiana sites with known infestations of herbicide-resistant weeds such as marestail, waterhemp, palmer, and giant ragweed.

- Blocks of the following cover crop species were established:
  - None (bareground)
  - Cereal rye
  - Two common legume mixtures
- Cover crops were terminated around two to three weeks prior to corn planting
- Pre- and post-herbicide programs were designed for dominate weed species at each site using at least two modes of action
- Data collected was based on cover crop residue cover, weed control efficacy by species, and end of season crop yield data

RESULTS
- Increased the data set to help make more informed management recommendations regarding cover crops and herbicide resistant weeds.
- Cover crops were effective at suppressing winter annual weeds.

WHY IS THIS IMPORTANT?
- Driving down populations in the weed seed bank in corn benefits both sides of typical crop rotations
- Utilizing cultural weed management tools including cover crops and tillage increases weed control

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PRACTICAL SYSTEMS OPTIONS FOR SUPPLEMENTAL N APPLICATION TO LATE-VEGETATIVE CORN: YEAR 3

By Dr. Tony Vyn and Sarah M Mueller, Ph.D. Candidate, Purdue University

This ongoing research study will provide practical and economically viable production management recommendations about late-season nitrogen applications for corn farmers in Indiana and the entire eastern Corn Belt.

OBJECTIVES

1. Determine influence of various supplemental nitrogen rates and timings on corn yields when up to 75-percent of the intended nitrogen rate has been pre-plant and/or side-dress applied using conventional nitrogen fertility systems.

2. Determine impact of supplemental nitrogen application timing when the last 25-percent of the total nitrogen applied is delayed to late-vegetative or early reproductive stages.

3. Develop research based Extension office recommendations regarding practical supplemental nitrogen approaches for Indiana corn farmers.

Research Focus: Increase and maintain corn yields, Input optimization and utilization, 4R focused management and education, Sustainability

PROTOCOL

On-farm trials were located in three different areas. Lack of a positive yield response to late-split N timing in 2015 and 2016 when corn followed soybeans prompted 2017 adjustments to increase the level of N stress at two sites. For the 2017 experiments, both on-farm sites were continuous corn and the late-split application represented 50-percent of the total N rate instead of only about 20-percent. The third site was also in...

Grain yield at Frankton and Middletown in 2017. Bars represent standard error. Means assigned different letters are significantly different within each experiment. N treatments represent the N rate and an “S*” denotes that the last 50% of the total N rate was delayed until V16 (Frankton) or R2 (Middletown).
continuous corn, but the late-split treatment involved a 50-pound N application at the V12 stage.

- Population counts were conducted after planting to determine the emerged population
- Researchers measured plants during the second nitrogen application, mid-grain filling and late-grain filling
- Earleaf tissue samples were collected to analyze for plant nitrogen status and other nutrients
- At maturity, researchers collected ears from each plot to estimate grain yield and determine kernel number and kernel weight

Researchers also measured soil mineral nitrogen just prior to the second side-dress application and at maturity. These soil samples were taken at depths of one to 12 inches and 12 to 24 inches.

**Location 1: Frankton**

At Frankton, the first and second side-dress timings were applied at VE and V16. Only the lowest N rate (110 lbs) resulted in a significant reduction in grain yield (reduction of 16 bu/acre) and there was no increase in grain yield with late-split N applications at either total N rate of 150 or 190 lbs of N per acre.

**Location 2: Middletown**

At Middletown, the N applications were later (because of rain delays) and occurred when the corn was V7 and R2, respectively. The 170 split (170S) was significantly lower than the single N application of 170 lbs applied at V7, and not different from a single N application of 120 lbs/acre. There was no difference in grain yield between 190 lb single or split N applications. Although yields were lowest with the single 120 lb rate, there was no yield gain from the single-time 190 lb rate versus the single-time 170 lb rate.

**Location 3: LaCrosse**

At LaCrosse, the field experiment was performed using the same N rates and timing applications as in 2016. Again, grain yields responded positively to N rate, but this time significant differences were found between 150 N and 200 N treatments. The application timing (V5 side-dress alone versus V5 plus V12) did not affect grain yield, but there was a tendency to lower yields in all N rates when the last 50 lbs were applied at V12 stage.

**RESULTS**

The primary conclusion from this research was that there was little yield advantage for a late-split N application when N management involves an early side-dress application. Soil sampling could only detect large differences in soil-applied N (greater than 100 lbs N/acre). Ear leaf N concentrations at flowering could only detect N deficiency severe enough to lower yields by more than 30-percent relative to the maximum yield in a given experiment. Therefore, a more robust in-season indicator of N stress still needs to be developed before the optimum late-split N rate can be determined.

**WHY IS THIS IMPORTANT?**

- Helps farmers decide when late-season N applications are warranted and/or a good investment
- Late-split N is a good practice from an environmental perspective in that fertilizer N recovery by corn increases
PROFITABLE MANAGEMENT OF SEED AND FERTILIZER IN CORN THROUGHOUT INDIANA

By Dr. Robert Nielsen and Dr. Jim Camberato, Purdue University

Research Focus: Increase and maintain corn yields, Input optimization and utilization, 4R focused management and education, Development and updates of BMPs, Sustainability, Improved water quality

Field-scale and on-farm research offers the opportunity to evaluate real-world scenarios and generate independent data across multiple locations, soil types, and growing conditions.

These ongoing field trials aim to improve yield, profitability and sustainability for Indiana corn farmers while reducing nutrient losses to water and the atmosphere. The trials address simple but economically meaningful crop input decisions that every grower makes each growing season.

OBJECTIVES

Researchers established field-scale trials at agricultural research centers and on-farm trials with Indiana corn farmers. Extension educators and local advisers to:

1. Identify region- or soil-specific nitrogen (N) fertilizer rates for optimum and sustainable yields.
2. Determine impact of long-term nitrogen fertilization rate and corn grain nitrogen removal on soil organic matter and nitrogen supplying capacity.
3. Evaluate yield response of continuous corn to in-furrow and traditional 2x2 row starter fertilizers.
4. Identify region- or site-specific plant populations for optimum and sustainable corn yields.
PROTOCOL

Researchers conducted nitrogen trials and collected data to develop soil-specific N rate guidelines. In current trials, researchers looked closely at soil properties to explain potential spatially variable yield responses to nitrogen among, and within, fields to make regional recommendations.

In past trials, corn was grown in rotation with soybeans and fertilized with various nitrogen rates. Researchers worked to determine whether they should adjust fertilizer rates for corn to influence maintenance of organic N and carbon. In addition, researchers worked to fine tune recommendations that reflect soil properties, and whether the mining of soil nitrogen decreased soil organic matter over time, damaged soil structure or reduced water-holding capacity.

Continuous corn often yielded less than rotation corn. Research determined how starter fertilizer could aid struggling young corn plants’ transition from reliance on kernel reserves to nodal roots and provide necessary nitrogen to the young plants while stover decomposition temporarily immobilized soil nitrogen.

Our study suggested that the optimum plant population for corn grown under typical yield levels and growing conditions was approximately 31,000 plants per acre (ppa) or about 34,000 seeds per acre (spa) if the crops weren’t in challenging conditions. In this study, researchers evaluated whether yield response to seeding rate was influenced by the rate of nitrogen fertilizer and whether variable rate seeding by spatial field zones was economically justified.

RESULTS

Maximum yield response to plant populations for corn grown under minimal to moderate stress conditions occurred at about 31,600 ppa, equal to seeding rates of about 33,250 spa.

Corn grown under extremely challenging conditions performed best at plant populations no higher than 22,800 ppa and perhaps as low as 21,000 ppa under truly severe growing conditions (e.g., actual drought, non-irrigated center pivot corners, non-irrigated sandy fields with minimal rainfall).

Economic optimum populations were several thousand lower than the agronomic optimum.

Identification of soil properties and terrain attributes to support variable rate seeding and N application was started and will be continued until results are seen.

WHY IS THIS IMPORTANT?

Identifies management and weather factors resulting in excessive and insufficient N application and establishes the frequency of over- and under-application.

Allows farmers to make better economic and environmentally sound decisions by determining the best methods for making variable seeding and N rate decisions.

4R: Right source, at the right rate, at the right time and in the right place.
**PRACTICAL PLACEMENT STRATEGIES FOR POTASSIUM (K) IN CORN**

By Dr. Tony Vyn, Purdue University

With most of the emphasis in fertility management for corn having been focused on nitrogen and phosphorus, farmers and consulting agronomists have hardly focused on potassium management. Understanding how best to manage potassium fertilizer timing and placement is necessary.

**Research Focus:** Increase and maintain corn yields, Input optimization and utilization, 4R focused management and education, Soil health

**OBJECTIVES**

1. Determine corn yield and soil consequences of varied K fertilizer timings and/or placements associated with different tillage systems: no-till or conventional tillage in corn-soybean and continuous corn.

2. Study influence of corn 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. Study practical strategies for K fertilizer application placements and timings in on-farm situations with varying intensities of soil-testing when farmers:
   - Broadcast versus band-apply K
   - Combine N and K fertilizers in strip-till bands
   - Combine tillage and K fertilizer applications (i.e. with fall or spring strip-till)
   - Seek to boost yield with in-season K applications
PROTOCOL

Two plots, located in West Lafayette, were used in field trials. Three different potash application rates (from 0 to 200 pounds/acre) compared in no-till, fall strip-till, spring strip-till and fall chisel plowed systems for corn following soybeans were trialed.

Plant measurements in all trials included:
- Plant populations, plant heights and leaf stages during vegetative growth
- Ear-leaf K concentrations at R1 stage
- Grain moistures and proportions of barren and logged plants at harvest
- Total-plant K uptake from each plot before and after grain harvest

RESULTS

- Corn yields (treatment means) in the 2017 trial in West Lafayette ranged from 236 to 260 bushels/acre in the no-till, strip-till and fall chisel plow treatments that were compared with and without a 200 pound potash (Aspire™) application where the original soil-test K averaged 110 ppm.
- Yields were raised 7-percent in fall strip-till and 10-percent in spring strip-till systems with coulter-banded K application, but yields were not significantly raised in the chisel and no-till systems that involved broadcast K application.
- None of the tillage systems overcame the potential challenge of vertical stratification of K; concentrations from either fall or spring K application typically enriched the top 2” of soil, but not the soil at the 4-8” depth.

WHY IS THIS IMPORTANT?

- Ability to make better K fertilizer placement and timing recommendations when farmers:
  - Vary intensities of soil-test K stratification
  - Broadcast versus band-apply (deep or shallow) K₂O
  - Combine pre-plant N and K fertilizers in strip-till bands
  - Seek to boost yield with in-season K applications
- Ability to determine whether the present leaf tissue K recommendation is still valid
- Ability to increase Indiana corn over-saturation and drought stress tolerance during vegetative and early reproductive growth
- Ability to determine how K placement for corn every second year affects the narrow-row soybeans that typically follow
CORN YIELD IMPROVEMENTS FOLLOWING CEREAL RYE USING STARTER NITROGEN FERTILIZER

By Dr. Shalamar Armstrong and Dr. Jim Camberato, Purdue University

Research Focus: Increase and maintain corn yields, Input optimization and utilization, 4R focused management and education, Development of adaptive nitrogen management practices, Sustainability, Cover cropping systems, Soil health

This ongoing research study is designed to optimize starter nitrogen application rates for productive, sustainable, and economically viable corn production following the adoption of cereal rye for Indiana and the entire eastern Corn Belt.

OBJECTIVES

1. Determine the impact of cereal rye inclusion and starter fertilizer on soil N availability and N use 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

The research project was conducted at three different experimental sites across the state of Indiana to account for different growing conditions. Treatments for each site were based upon five starter N levels (0, 25, 50, 75 lb A⁻¹) and two cover crop levels (cereal rye and no cereal rye).

- Sites were arranged in a randomized block with four replications
- Crops were sampled in the spring to determine biomass production and N uptake
- Cover crop plant samples were collected from three random locations
- Cover crops were terminated two to three weeks before corn planting and soil samples were collected
- Samples from each plot were analyzed for total nitrogen and total carbon, ammonium, and nitrate

RESULTS

First year research study, results are still pending.

WHY IS THIS IMPORTANT?

- Understand how to adapt existing N fertilizer management in the presence of cereal rye to maintain or increase yield
- Potentially decrease the economic risk of cover crop adoption by maintaining or increasing crop yield
- Increase long-term sustainability of corn production due to greater environmental stewardship, soil health, and corn production

Funded with Indiana corn checkoff dollars.
INfield Advantage combines locally sourced data, innovative ag technologies and farmer-to-farmer discussions so participants can make personalized best management decisions for their farms. Farmers have the opportunity to increase yields, adapt management practices, protect natural resources and benefit their surrounding communities.

Want to participate? For more information about INfield Advantage visit www.infieldadvantage.org or contact your local Soil and Water Conservation District.

INfield Advantage is available to Indiana crop farmers thanks to:

- Indiana Soybean Alliance
- Indiana Corn Marketing Council
- Indiana State Department of Agriculture
- Indiana Association of Soil and Water Conservation Districts
- Purdue Extension
- Indiana Conservation Partnership
- USDA Natural Resources Conservation Service

Funded with Indiana soybean and corn checkoff dollars.
INTRODUCING THE INDIANA AGRICULTURE NUTRIENT ALLIANCE

The Indiana Agriculture Nutrient Alliance (IANA) is dedicated to keeping Indiana at the forefront of proactive nutrient management and soil health practices that improve farm viability and, ultimately, reduce nutrient loss to water.

OUR GOALS

IANA will work alongside partners, utilizing each organization’s individual strengths to identify and overcome barriers, encouraging Indiana farmers to:
- Regularly perform soil sampling
- Implement nutrient management plans
- Apply nutrients to frozen and snow-covered ground only as a last resort
- Apply nutrients at-planting or in-season
- Implement living cover on cropland acres year round
- Implement minimum tillage, strip-tillage or no-till practices

OUR APPROACH

IANA will focus on bridging the multi-partner efforts to create practical, cohesive and significant effect across Indiana through:
- Shared goals
- Shared information
- Shared opportunities
- Shared outcomes

LEARN MORE

IANA PARTNERS
- Agribusiness Council of Indiana
- Indiana Farm Bureau
- USDA Natural Resources Conservation Service
- Indiana Soybean Alliance
- American Dairy Association of Indiana
- Indiana Association of SWCDs
- Indiana Beef Cattle Association
- Indiana Corn Marketing Council
- Indiana Dairy Producers
- Indiana Pork
- Indiana State Department of Agriculture
- Indiana State Poultry Association
- Purdue University
- The Nature Conservancy of Indiana

Ben Wicker, Executive Director
bwicker@inagnutrients.org
www.inagnutrients.org

This piece funded with Indiana Corn and Soybean checkoff dollars. IANA funded through joint-partnership dollars and USDA Natural Resources Conservation Service matching funds.
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

RESEARCH BY THE NUMBERS

ISA production and environmental research, 2008-2018:
- 90 grants funded
- Nearly $5,000,000 total investment
- Working with more than 150 researchers

A MESSAGE FROM THE CHAIRMAN

A SUCCESSFUL FUTURE FOR SOYBEAN FARMERS

Success for soybean farmers in today’s market takes more than just a good harvest. The soybean checkoff helps facilitate future market growth by 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. The projects included in this magazine 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.

TOM GRIFFITHS,
Chairman
Indiana Soybean Alliance
INCREASING SOYBEAN YIELD BY ENHANCING SEED FILL

By Dr. Shaun Casteel, Purdue University

Research Focus: Increase and maintain soybean yield, Production and management technologies

This research determined the duration and rate of seed fill during late soybean development. Based off previous research, a better understanding of late season development in soybeans, especially pod retention (R4 to R6) and seed fill (R4 to R8), is necessary to exploit the potential management synergies in fertility and foliar protection of modern varieties.

OBJECTIVES

Enhance seed fill and therefore increase yield by:

1. Determining duration and rate of seed fill during late soybean development, especially after R6 (full seed) until harvest.
2. Determining opportunities to enhance seed fill (e.g., higher daily gain, extended seed fill duration) and thus, improve grain yield through synergies in nutrient supply and foliar protection.
**PROTOCOL**

Cultivars were grown in west-central Indiana under conventional herbicide programs. Nutrient analysis included soil samples at planting and harvest, and plant partitions at full pod, full seed, and full maturity.

- Two cultivars from each decade for each maturity group (MG) II and III were selected to represent breeding efforts from the 1970s, 1990s, and 2010s.
- Six fertilizer plus foliar protection programs were crossed with these cultivars:
  1. Untreated control (UTC)
  2. MAP (monoammonium phosphate)
  3. MES10 (MicroEssentials)
  4. TSP (triple superphosphate) and AMS (ammonium sulfate)
  5. UTC and foliar
  6. TSP and AMS mixed with foliar

Targets were 80 lb P2O5 / acre and 20 lbs / acre. Fertilizers were applied prior to planting and incorporated.

- Foliar protection was applied at R4 (full pod) using Priaxor™ and Warrior II™
- The 36 treatments were replicated three times to total 108 plots per MG creating a total of 216 plots.
- Pods and seed samples were taken every 7-10 days after R4 through maturity to measure seed fill rate.

**RESULTS**

Preliminary yield results provided exciting and interesting interactions with nutrient supply and foliar protection. Cultivars were grown in a field south of Lafayette that was nutrient-rich and had optimal soil pH in 2016. Additional supply of P and S did not appear to provide major yield differences compared to the untreated areas. Foliar protection did not demonstrate a strong yield response across these cultivars. However, the combination of P and S nutrition with foliar protection resulted in the highest yields.

**WHY IS THIS IMPORTANT?**

- Alters scouting strategies and management when it comes to last season diseases and insects
- Impacts the growers’ profitability in terms of money invested in:
  - Fertilizers
  - Variety selection
  - In-season management
  - Yield response

**Maturity Group II Yield Effects (bu/ac) in 2016**

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Priaxor is a registered trademark of BASF.
Warrior II with Zeon Technology, is a trademark of a Syngenta Group Company.
This research project investigated how to reduce the impact of herbicide-resistant weeds on soybean production and profitability, and how to develop best management practices for herbicide-resistant weed species.

**OBJECTIVES**

1. Survey and screen for herbicide-resistant weeds
2. Manage Roundup Ready Xtend™ soybeans

### Research Focus: Increase and maintain soybean yield, Weed control and herbicide resistance, Production and management technologies

**Which of the following are you most concerned about with dicamba applications in 2017?**

<table>
<thead>
<tr>
<th>Concern</th>
<th>% of Respondents (n = 762)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical (spray particle) drift</td>
<td>4%</td>
</tr>
<tr>
<td>Vapor drift</td>
<td>9%</td>
</tr>
<tr>
<td>Tank contamination</td>
<td>4%</td>
</tr>
<tr>
<td>Interpreting the label’s buffer requirements</td>
<td>4%</td>
</tr>
<tr>
<td>Available days to make a labeled application</td>
<td>3%</td>
</tr>
<tr>
<td>All of the above</td>
<td>66%</td>
</tr>
<tr>
<td>Some other concern</td>
<td>1%</td>
</tr>
<tr>
<td>Doesn’t apply to me</td>
<td>9%</td>
</tr>
</tbody>
</table>
As seen in the graph on page 20, many farmers are concerned about applying dicamba. Label restrictions for dicamba formulations Xtendimax™, Engenia™, and Fexapan™ severely limited the number of available spray hours to make timely applications of dicamba for proper weed management. New dicamba label restrictions will further reduce the viable application window in 2018.

**RESULTS**

- Tracked the development and spread of PPO* (Group 14) herbicide resistance in waterhemp, as growers are relying extensively on Group 14 herbicides to control waterhemp with glyphosate (Group 9) and ALS** (Group 2) resistance.
- As a result of control failures, waterhemp resistance spread was tracked to 24 counties. More than one Group 14 herbicide resistance mechanism was identified bringing long-term Group 14 viability into question.
- Demonstration trials† with additional control tactics have been implemented at several Purdue agricultural centers.

**WHY IS THIS IMPORTANT?**

- Provides soybean growers with sound management strategies to minimize the cost of weed control and maximize soybean yield
- Limits off-target plant injury from herbicide applications, reducing the financial risk associated with making effective herbicide applications

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*Protoporphyrinogen oxidase
**Acetolactate synthase
†Demonstration trials will be shown at Purdue fall field days.
Xtendimax is a trademark of Monsanto Technology LLC. Engenia is a registered trademark of BASF. Fexapan is a registered trademark of The Dow Chemical Company.
GENETIC DISSECTION OF YIELD-RELATED TRAITS FOR SOYBEAN BREEDING

By Dr. Jianxin Ma, Purdue University

Research Focus: Increase and maintain soybean yield, Production and management technologies

This project will identify genes and genomic regions associated with soybean yield, to ultimately lead to higher yielding varieties for producers in Indiana and other North Central regions.

OBJECTIVES

1. Identify genes and/or genomic regions underlying yield related traits such as pod numbers per node, node numbers per plant, and 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 and make these lines and related information available to soybean breeders.

PROTOCOL

Highest performing recombinant inbred lines (RILs) with desirable traits were selected from the large population based on traits observed over multiple growing seasons at Purdue ACRE and University of Illinois Research Farm. RILs were crossed with Williams 82 and four high-yielding cultivars.

Phase 1

F2 and F3 populations and parental lines were evaluated for phenotypes and replicated at each of the two locations. Only the highest segregating population for each trait was phenotyped.
Phase 2

Once the genes and/or genomic regions underlying specific traits were identified, molecular markers within the defined regions were tested for effectiveness for marker-assisted selection.

Phase 3

The markers from Phase 2 were used to examine the high-yielding experimental lines selected from this project and high-yielding experimental lines selected by the North Central soybean breeders in the NCSRP* yield project. The best-performing experimental lines were genotyped by genome re-sequencing for precise identification of introgressed genomic regions and alleles from wild soybean parents.

RESULTS

- Mapped major genes underlying branching angle/canopy coverage, leaf shapes, and seed numbers per pod to small genomic regions of each soybean.
- Identified genomic regions associated with high soybean yields.
- Produced F2 and F3 derived from crosses between selected RILs and elite soybean varieties. These progeny lines will be further advanced and evaluated for yield-related traits.
- Developed molecular markers that are useful for more accurate germplasm evaluation and enhancement.

WHY IS THIS IMPORTANT?

Previous research by our collaborators and our own program indicate that very useful genes exist in the wild relatives of soybeans that are not being used in commercial soybean breeding today.

Commercial soybean breeding companies are making major investments in producing new transgenic varieties. They have produced new varieties using the limited genetic diversities available. New seed genes would provide additional opportunities for further soybean advancement.

Soybean created with the Williams 82 line

*North Central Soybean Research Program
A PUBLIC-PRIVATE PARTNERSHIP TO USE DRONE-ACQUIRED METRICS TO INCREASE ACCURACY OF YIELD ESTIMATION IN MULTI-ENVIRONMENT YIELD TRIALS OF SOYBEANS

By Dr. Katy M. Rainey and Dr. Keith Cherkauer, Purdue University

This research utilized drone technology to reduce errors and improve efficiency to bring products to market more quickly by testing the methodology in elite commercial germplasm.

While farmers and agronomists are well aware that canopy development is critical to yield in soybeans, it had never been quantified for selection of new soybean varieties until 2015 with recent advances in drone technology (or unmanned aerial systems; UAS).

To accelerate the impact of precision phenotyping technology, a public-private partnership with Beck’s Hybrids was established. Starting in 2017 and continuing into 2018, two seasons of data to test the efficacy of image-based parameters from UAS will be available.

OBJECTIVES

1. Test the efficacy of image-based parameters acquired with drones 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.

To accomplish these objectives, the following must be done:

- Efficient testing of image-based parameters acquired with unmanned aerial systems (UAS) to increase the accuracy of yield estimation in multi-environment soybean yield trials.
- UAS imagery method development to determine custom plant populations for all soybean varieties.

Research Focus: Increase and maintain soybean yield, Production and management technologies
PROTOCOL

- In 2017 and 2018, we conducted 28 flights over Beck’s on-farm research trials (MG 2-4.2) in Remington and Lafayette, IN, and acquired hundreds of RBG images each flight.
- We completed automatic extraction of plot images of equal pixel dimensions from drone imagery of each plot, including quantification of canopy coverage and row length.
- Purdue will implement different statistical models that will include yield covariates, canopy coverage and estimated row length from UAS, and spatial statistics to calculate yield predictions.
- We compared Purdue rankings from two years and two locations to Beck’s overall yield rankings from multiple environments.
- Different seeding rates will be evaluated using canopy coverage as a response variable. Purdue planted plots of Beck’s-provided seeds at various seeding rates at the ACRE farm in 2017 and at ACRE and Romney, IN in 2018 and surveyed canopy development with UAS imagery as described above.
- Testing will be done at recommended custom seeding rates.

RESULTS

- For the first objective, preliminary results show that there were changes in the lines rankings between the different models in all the trials.
- For the second objective, fast canopy development promoted by medium (110,000 seeds/acre) and high (160,000 seeds/acre) seeding rates planted early in the season, increased the yield in around 14% compared with the low seeding rate (60,000 seeds/acre).
- Increased seeding rates in late planting did not show any advantage on final yield even when canopy differences were determined.
- Improving the canopy development through seeding rates increased the yield when the planting date occurred early in the season but had limited effect in late planting.
- Seeding rates greater than approximately 110,000 seeds/acre may not imply important yield increases in early season while late season could be managed with seeding rates around 60,000-100,000 seeds/acre.

WHY IS THIS IMPORTANT?

Critical outcomes of this efficiency research are:

- Development of new precision metrics for selection and marketing of soybean varieties
- Improved seed company yield trial ROI
- Cost-saving, seeding rates for soybean varieties
- Enhanced precision agriculture capabilities and incorporation of new technologies into breeding and agronomy
Soybean root and stem rot is one of the major diseases responsible for severe soybean production loss in Indiana. It is estimated that annual yield loss from diseases in the U.S. is valued at approximately $200 million. However, the resistance contributed by an individual Rps gene usually is effective only for about ten years due to the rapid evolution of *Phytophthora sojae* races. As a result, most of the known Rps genes have become partially effective or completely ineffective.

**Research Focus:** Increase and maintain soybean yield, Pests and diseases, Production and management technologies

**OBJECTIVES**

1. Introgress the genomic regions carrying the Rps gene into the elite cultivars.
2. Develop Rps isogenic lines using Williams’ as recurrent parental lines.
3. Determine if Rps1-k, RpsUN1, and Rps1-das, and RpsUN2, Rps2 and Rps2-das in the two resistance gene clusters are different genes.
4. Pyramid more than one of the four novel genes and/or the known genes in the same genomic regions into same elite cultivars.
PROTOCOL

- Crosses and back crosses of the Rps gene donor lines with the Purdue and Illinois elite cultivars were done in the greenhouse and agronomy farm of Purdue University. Researchers looked to obtain the BC6F2 generation elite lines, each with an introgressed novel Rps gene. The introgressed regions were defined by SNP genotyping-by-sequencing approach.

- The Rps gene donor lines were crossed and backcrossed with Williams in the greenhouse and agronomy farm at Purdue University. The 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. The introgressed regions were then defined by SNP genotyping or the genotyping-by-sequencing approach.

- The Rps1-das and Rps1-k lines were crossed to generate F2 populations and F3 families, and, similarly, the Rps2-das and Rps2 lines were crossed to generate F2 populations and F3 families. Molecular markers linked to these genes will be used to track the presence or absence of these genes in the F2 and F3 progeny lines.

- Researchers introgressed at least two different Rps genes into the same elite cultivars at the late stage of introgression of the novel Rps genes and into individual elite varieties by crossing two different introgression lines. Molecular markers closely linked to these genes were used for marker-assisted selection to facilitate the process of pyramidining different Rps genes. The progeny lines with pyramided Rps genes are genotyped by SNP genotyping or the genotyping-by-sequencing approach.

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 current CAPS- and KASP-based Single Nucleotide Polymorphism (SNP) markers to high efficient semi-thermal asymmetric reverse PCR (STARPM) markers.

WHY IS THIS IMPORTANT?

- Creates new soybean elite lines or experimental lines with more durable resistance
- Reduces time and cost needed for developing new soybean varieties with more durable resistance
- Increases the annual production of soybeans regardless of improvements in yield and will also reduce the use of chemicals

*Williams is a line susceptible to all races of Phytophthora sojae, and researchers are putting different Rps genes into Williams to obtain a set of lines (which are called isogenic lines). These lines are extremely useful for discovering new pathogen isolates and for evaluating existing isolates, and from the host side, for identifying new Rps genes in soybean. Thus, once new Rps genes in soybean are found, it’s a community need to integrate new Rps genes to Williams.
Due to the re-emergence of cover crops as a potential solution to mitigate nitrate loading to the Gulf of Mexico, scientists have focused extensively on the cover crop’s ability to scavenge and conserve N. Recently, new questions concerning cover crops and N scavenging have surfaced and have exposed a critical knowledge gap: What percentage of cover crop scavenged N will be available to my next crop? How does the timing of cover crop residue N release correlate with the N demand of corn and soybeans?

**OBJECTIVES**

1. Use 15N techniques to quantify the amount of cover crop N that is released into the soil.
2. Measure the amount of cover crop residue N that is utilized by the subsequent corn and soybean crop.
PROTOCOL
This study was conducted at the Purdue Agronomy Center for Research and Education in West Lafayette.

■ To prevent 15N contamination enrichment. 15N cereal rye was done in nurseries located in the same field but separated from the micro plot areas
■ Enriched (15N) cereal rye shoot biomass was removed from nursery plots, subsampled, then applied on a fresh weight basis to micro plots
■ Each micro plot was 8 feet (2.5m) x 8 feet and spanned 4 corn and soybean rows
■ All corn and soybean sampling was conducted in the center rows to minimize edge-effects
■ Both soil and plant samples were analyzed for 15N concentration, allowing for a determination of the fate cereal rye 15N

RESULTS
Crop rotation (corn residue or soybean residue) resulted in differences in cereal rye growth. The research suggested that there was better cover crop planting and growth conditions in soybean residue. Additionally, cereal rye following corn responded to a fertilizer response to the added spring N. This response to applied N was not evident in the cereal rye following soybean plots. This data suggests that cereal following corn was potentially N limited in the spring in 2016.

WHY IS THIS IMPORTANT?
■ The addition of cover crops has the potential to reduce soil erosion and stabilize the fertile and valuable topsoil. In tile drainage studies, cover crops have also demonstrated the ability to drastically reduce N loading from residual or soil mineralized N
■ The adoption of cover crops results in increased soil health such as aggregate stability, increased infiltration and air movement, greater biodiversity, and potential long-term increase in soil organic matter
■ This study provides farmers with insight and understanding of how cover crop adoption affects N availability, which allows for N fertilizer adjustments for optimum cash crop production
THE EFFICACY OF FALL COVER CROPS AS THEY RELATE TO STREAM WATER QUALITY: A PAIRED WATERSHED APPROACH

By Dr. Jerry Sweeten, Manchester University and Herb Manifold, Ecosystems Connections Institute, LLC

This joint study benefits corn and soybean farmers by providing relevant water quality data as it relates to sediment and nutrients and through acquisition of conservation cost-share dollars. The data evaluates the efficacy of fall cover crops as they relate to water quality and the biological integrity of agricultural streams.

OBJECTIVE
The study compares two watersheds that are tributaries of the Eel River in Wabash County, Indiana. One watershed is treated with fall cover crops and other conservation practices, while the second watershed is left under “normal” agricultural practices as determined by the individual operator. The watersheds are part of a larger Eel River watershed study that began in 2009.

Research Focus: Sustainability, Cover cropping systems, Water quality, Soil health

PROTOCOL
The streams within each watershed are being carefully monitored.

- Six water samples were collected daily during the May-June period
- The first rain event that increased the stream discharge was analyzed in each month from July through April
- Samples were collected weekly and analyzed
- Rainfall along with air and water temperatures were recorded once every 30-minutes, each day
- Stream discharge was calculated to determine nutrient and sediment loads
- Stream fish communities were examined and stream habitat measured once each year
**Watershed #1: Treated with fall cover crops**

Cover crops were planted across as much of the upper portions of Beargrass Creek as possible. At the end of the 2017 growing season about 1,200 acres of cover crops had been planted in the Beargrass watershed. Data was collected at six different sites.

**Watershed #2: Left under “normal” practices**

The upper portions of Pawpaw Creek were left in a conventional production strategy with few, if any, cover crops applied. Data was collected at nine different sites.

**RESULTS**

Four years of watershed research and monitoring has been concluded.

- Analyzed over 3,000 water samples
- Completed biological surveys at 15 stations
- Installed a prototype fish passageway project (fish ladder) around the dam at Stockdale in the Eel River. This ladder is unique in the United States
- Reintroduced the federally endangered clubshell freshwater mussel in the Eel River during the summer of 2016. During the survey in 2017, over 95% survival was documented

**WHY IS THIS IMPORTANT?**

Watershed restoration requires innovative water and soil health partnerships across all stakeholders, including:

- Voluntary conservation management
- Mitigating off-site movement of soil and nutrients
- Conserving stream ecological integrity
- Efficient use of nutrients
- Drainage management
- Providing education and outreach
INDIANA WATERSHED INITIATIVE (IWI):
QUANTIFYING WATER QUALITY RESPONSES FROM THE WATERSHED-SCALE PAIRING OF COVER CROPS AND A TWO-STAGE DITCH

By Dr. Jennifer Tank, University of Notre Dame; Dr. Todd Royer, Indiana University, and Dr. John Tyndall, Iowa State University

This ongoing project will quantify water quality and soil health benefits of pairing winter cover crop implementation and a two-stage ditch in two Indiana watersheds. The project will document the effect of these practices on nutrient loss rates from fields and estimate full benefits and cost of implementation.

RESEARCH GOALS

- Help Indiana farmers implement best management practices that reduce nutrient runoff while maintaining productive and profitable agriculture operations at the watershed scale
- Pair cover crops and a two-stage ditch to determine if they improve soil health and reduce nutrient loss from fields
- Determine whether cover crops and a two-stage ditch could circumvent costly, and perhaps burdensome, future regulatory actions for reducing agricultural nutrient loading to downstream surface water
**OBJECTIVES**

1. Quantify water quality and quantity benefits
2. Quantify benefits of cover crop implementations on soil health
3. Use SWAT to predict cover crop and two-stage ditch effects on water quantity and quality
4. Analysis of economic impact
5. Build long-term data sets on soil health and water quality outcomes that will serve as a baseline for future studies

**PROTOCOL**

- Researchers used watershed budget approach to determine how paired practices influence nitrogen and phosphorus across the two watersheds
- Researchers qualified benefits of cover crops in improving soil health through increased nutrient retention and improvements in soil organic matter, as well as soil health metrics during fall and spring
- Researchers used the process-based Soil Water Assessment Tool (SWAT) model to predict the benefits of watershed-scale cover crops and the two-stage ditch implemented across other watersheds in the region
- Quantified the economic benefits for farmers and the environment of watershed-scale implementation pairing cover crops with the two-stage ditch. The economic analysis will provide much-needed information about the actual costs and benefits to farmers

**RESULTS**

- Sustained/new enrollment in cover crops and two-stage ditches
- Collected year-round water sampling of tile drains and streams
- Collected spring and fall soil sampling in both watersheds

With these results the research is showing that the adoption of pairing winter cover crops and the two-stage ditch will benefit water quality and quantity at the watershed and improve soil health.

**WHY IS THIS IMPORTANT?**

- **Cover crops help to reduce annual nutrient loss from tile drains.** Fields with cover crops lose less nitrate through tile drains than fields without cover crops. Understanding how, and to what extent, cover crops contribute to improved soil health is useful when adopting cover crops.
- **Reduces uncertainty for producers regarding the outcomes/benefits of cover crops.** The nutrients that are retained on the fields by cover crops are then available for use by the cash crop. At the same time, keeping the nutrients in the fields reduces detrimental impacts on water quality.
- **Cover crops have the potential to improve yields, reduce fertilizer inputs, and protect water quality.**
MANAGEMENT PRACTICES CONTRIBUTING TO STALK NITRATE CONCENTRATION

By Meg Leader, Indiana State Department of Agriculture; Dr. Hans Kok, INfield Advantage Lead Agronomist; Dr. Ashley L. Kissick, Dr. James Camberato and Dr. Robert Nielsen, Purdue University Department of Agronomy

INfield Advantage is an opportunity for farmers to collect and understand personalized, on-farm data to optimize their management practices to ultimately improve their bottom line and benefit the environment. On-farm data, over a five year period (2011-2016) from over 340 farmers across the state of Indiana has been collected and analyzed.

GOALS
- Identify management practices contributing to stalk nitrate concentration i.e. previous crop planted, cover crop, tillage, soil composition, and fertilizer (N form, timing and total N applied)
- Identify management practices contributing to stalk nitrate testing in categories “Low” (< 450 ppm), “Optimal” (≥ 450 ppm, < 2000 ppm), or “Excessive” (≥ 2000)

PROTOCOL
Farmers’ fields that are enrolled in the INfield Advantage program have corn stalk samples collected for stalk nitrate testing. To accomplish this, local Indiana Conservation Partnership staff were provided with pre-selected sample locations.

- Eight-inch segments were collected for testing (starting six-inches above ground level)
- Corn stalks were sampled after physiological maturity (black layer)
- Three locations were selected as “typical” based on aerial imagery
- A fourth location was selected based on “stressed” appearance

Once stalks were collected, they were sent to a laboratory for testing. On-farm, field-specific data, including soil type, weather patterns, field conditions, etc. were also shared for analysis and comparison.

RESULTS
Fertilizer (Total N, N form and timing)
- Form and timing of fertilizer contributed to higher nitrate values
- Ammonia in-season resulted in higher stalk nitrate in four of six seasons, confirming

INfield Advantage Program Growth

<table>
<thead>
<tr>
<th>Year</th>
<th>Groups</th>
<th>Producers</th>
<th>Fields</th>
<th>Acres</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>1 Group</td>
<td>15 Producers</td>
<td>39 Fields</td>
<td>2,700 Acres</td>
</tr>
<tr>
<td>2011</td>
<td>9 Groups</td>
<td>114 Producers</td>
<td>271 Fields</td>
<td>19,000 Acres</td>
</tr>
<tr>
<td>2012</td>
<td>12 Groups</td>
<td>162 Producers</td>
<td>430 Fields</td>
<td>31,000 Acres</td>
</tr>
<tr>
<td>2013</td>
<td>17 Groups</td>
<td>217 Producers</td>
<td>609 Fields</td>
<td>42,000 Acres</td>
</tr>
<tr>
<td>2014</td>
<td>24 Groups</td>
<td>264 Producers</td>
<td>722 Fields</td>
<td>50,000 Acres</td>
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<tr>
<td>2015</td>
<td>29 Groups</td>
<td>346 Producers</td>
<td>828 Fields</td>
<td>57,960 Acres</td>
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<tr>
<td>2016</td>
<td>34 Groups</td>
<td>403 Producers</td>
<td>1,015 Fields</td>
<td>72,100 Acres</td>
</tr>
</tbody>
</table>
this form and timing as the most efficient commonly-used fertilizer practice
■ High nitrate with urea in the excessively wet 2015 season was reflected in the application of urea as a ‘rescue-N’ mid- to late-season; loss of N would be diminished the later the application

Tillage
■ No-till decreased soil N mineralization. All other factors held constant (especially N rate), lower stalk nitrate would be expected
■ Higher rates of N fertilizer application to achieve optimum yield may be expected in no-till fields, especially when relatively newly established
■ Farmers using no-till applied on average 10-25 pounds/acre less N than those employing fall, spring, or fall and spring tillage

Precipitation
■ Within a season, there was not a very large increase or decrease in either stalk nitrate value or the odds of stalk nitrate due to precipitation

Composite Soil Variable
■ In seasons with normal rainfall, corn grown on poorly- and well-drained soils had similar stalk nitrate values suggesting little difference in N availability to corn crop on soils differing in drainage with average rainfall conditions
■ With excessive drought, stalk nitrate values were elevated in poorly-drained soils, suggesting greater moisture availability resulted in continued N uptake by the crop on these soils

Previous Crop
■ Previous crop was a significant predictor of stalk nitrate during 2011, 2012 and 2013 years; values were lower in corn planted after soybeans than in corn planted after corn
■ Farmers in this study applied an average of 22 pounds more N per acre to corn after corn than corn after soybean; research found 40-50 pounds more N per acre is typically needed for corn after corn

Cover Crops
■ Cover crops were generally not as important for predicting stalk nitrate value
■ Whether stalk nitrate was higher or lower in corn planted after a grass cover crop may be related to weather. Grass cover crop was a significant predictor of stalk nitrate values and for testing in a higher stalk nitrate test category only during 2013 and 2015

WHY IS THIS IMPORTANT?
Each year the INFA program is focused on bringing together regional farmer groups and allowing them to have apples-to-apples comparable data so they can have a discussion on how their different management practices affected their crop within similar soil and environmental conditions. By doing this, we help growers in these ways:
■ Understand the year’s crop and create a better understanding of nitrogen application
■ Understand how different management of applications respond to Indiana climates
■ Allow growers to increase yields, reduce expenses and keep more of their applied nitrogen in the fields and out of waterways

Learn more about INfield Advantage at www.INfieldAdvantage.org.
Funded with Indiana soybean and corn checkoff dollars.

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