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WHERE SCIENCE MEETS PRACTICE
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The quest for high-yield corn

Fred Below, Professor, Crop Sciences

Data collected over many years and locations in the state of Illinois led to the identification and ranking of seven categorical management factors that impact corn yield each year, known as ‘The Seven Wonders of the Corn Yield World’. These seven factors provide a framework for understanding the value of different agronomic management inputs to corn yield and include weather, nitrogen/fertility, hybrid selection, crop rotation, plant population, tillage, and growth regulators/biologicals. In addition to their individual impacts, these seven factors interact with each other in a myriad of combinations, with the general rule that the higher the ranking of a factor the more influence it exerts on the factors below it. These factors and their interactions form the basis of corn yield research in the Crop Physiology Laboratory.

Combining management factors
Recognizing the need to combine management factors to drive increased yield, we developed a systems approach of enhanced management practices and inputs that we compared to a standard management system similar to that used by most producers (Figure 1). Yield gain from the enhanced management system (all factors enhanced) was compared to a standard management system (using the baseline factors) and the value of an individual factor determined using an ‘Addition/Omission’ experimental design, where each factor is either enhanced in the standard management system, or diminished one at a time from the enhanced management system.

<table>
<thead>
<tr>
<th>Production Factor</th>
<th>Standard</th>
<th>Enhanced</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fertility</td>
<td>P &amp; K based on soil test</td>
<td>In lbs/acre 100 P₂O₅, 75 K₂O, 25 S, 2.5 Zn &amp; 0.6 B as banded MicroEssentials-SZ and broadcast Aspire</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>180 lbs/acre N preplant as UAN</td>
<td>180 lbs/acre UAN preplant + 60 lbs Sidedress (240 lbs total)</td>
</tr>
<tr>
<td>Population</td>
<td>32,000 plants/acre</td>
<td>44,000 plants/acre</td>
</tr>
<tr>
<td>Fungicide</td>
<td>No fungicide</td>
<td>Headline-AMP, Quilt-Xcel, or Trivapro at flowering</td>
</tr>
<tr>
<td>Row Space</td>
<td>30 inches</td>
<td>20 inches</td>
</tr>
</tbody>
</table>

The increase in growth and yield
Replicated trials conducted from 2013-2018 (16 site years) showed marked visual differences in plant growth and leaf health between the standard and the enhanced management plots (Figure 2), which on average was associated with a 51 bushel/acre difference in grain yield. Although the importance of an individual management factor varied for the different sites and years, in all cases the value of a given factor when combined with the other factors in the enhanced management system was greater than when that factor was provided alone. These trials show that single production factors cannot guarantee high yields, but rather it is the positive interaction among multiple factors that gives producers the greatest opportunity to achieve high corn yields.
Subsurface drip irrigation, more than just water

Ben Wiegmann, Graduate Research Assistant, Crop Sciences
Fred Below, Professor, Crop Sciences

The key to reaching the maximum yield potentials for corn and soybean is managing a higher population of plants by providing adequate mineral nutrition and limiting crop stress. Combining subsurface drip irrigation with mineral nutrients (i.e., fertigation) gives farmers the tools to mitigate environmental and nutrient stresses by supplying adequate amounts of water and fertility at the necessary growth stages all season long.

Research methodology
In order to understand the value of subsurface drip fertigation for corn and soybean yield, schedules were developed to supply nutrients to each crop based upon previously determined nutrient uptake curves of both crops. In addition to adequate amounts and placement of preplant fertility, additional nutrient applications were fertigated to both corn and soybean at multiple growth stages via a Netaflex 3g system (Netafim USA, Fresno, CA) (Figure 3). Fertigated trials in 2019 consisted of five corn hybrids or five soybean varieties, planted on 20-inch rows with corn planted at varying populations of 40,000, 50,000, and 60,000 plants/acre and soybean at 120,000, 180,000, and 240,000 plants/acre. These intensively managed systems were compared to a standard growers’ practice, with both crops planted on 30-inch row spacings and with corn receiving 160 pounds of nitrogen/acre and planted at 36,000 plants/acre and soybean planted at 160,000 plants/acre. Additional fertility was not provided with the standard practice to either crop based on adequate levels of available nutrients according to soil test values.

Management response
Striking visual differences in plant health and leaf area were observed between the intensively managed and the standard production systems (Figure 4). When higher plant populations of corn and soybean were intensively managed through subsurface drip fertigation, large yield increases were obtained. On average, intensively managed corn produced 117 bushels/acre more than the standard system, and at the highest population of 60,000 plants/acre yields were boosted by 133 bushels/acre. Soybean yields were increased on average by 25 bushels/acre, with the highest population of 240,000 plants/acre yielding the most. These results highlight the positive influence that higher planting populations have on increasing yield potential, but show that these extra plants must be provided with adequate mineral nutrition to mitigate plant-to-plant competition. Subsurface drip fertigation allows for the management of higher plant populations without nutrient or crowding stress, and thus maximizing the yield potential.
Need for narrow—the future of corn production

Eric Winans, Graduate Research Assistant, Crop Sciences
Fred Below, Professor, Crop Sciences

As U.S. corn yields have increased, average planting population has also increased. Studies have shown that tolerance to higher planting populations, rather than increased yield potential of individual plants, is the primary basis of the higher yields obtained with modern corn hybrids. Because the yield potential of individual corn plants has not increased, the use of higher plant populations will be important for continued yield increases in the U.S. However, as planting populations increase, competition for resources increases, leading to greater plant-to-plant variability and reduced yields. Narrowing row spacing (< 30 inches) is a potential strategy for managing higher corn populations while maintaining individual plant yield potential.

Why narrow rows work
The advantage of narrow-row corn (< 30 inches) is the reduction of crowding stress within the row and more efficient usage of resources such as light, nutrients, and water. Corn grown in narrow rows can intercept a greater percentage of solar radiation than in 30-inch rows by closing the space between the rows earlier in the season (Figure 5). Additionally, increased plant-to-plant spacing within the row allows for a larger and more evenly distributed root system, thereby increasing the interception of water and mineral nutrients. Better interception of soil resources gives narrow rows an advantage during drought periods or in areas of low soil fertility.

The yield advantage
Our research has consistently shown that increasing plant populations above 38,000 plants/acre will not increase yields in 30-inch rows, but will in 20-inch rows (Figure 6). While the advantage of 20 inch over 30 inch rows was only 7 bushels at 38,000 plants/acre, it increased to 13 bushels at 44,000 plants/acre. Contrary to the common belief that narrow rows will only work in the north, we have observed similar yield gains from narrow rows across the entire state. We have also observed a considerable range among current commercial hybrids in their yield response to narrow rows. Our research shows the potential for substantial increases in corn yield with narrow rows when planting higher populations and the correct hybrids.

<table>
<thead>
<tr>
<th>Row Spacing</th>
<th>Plant Population (plants/acre)</th>
<th>Avg</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>38,000</td>
<td>44,000</td>
</tr>
<tr>
<td>30”</td>
<td>279</td>
<td>281</td>
</tr>
<tr>
<td>20”</td>
<td>286</td>
<td>294</td>
</tr>
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Figure 6. Effects of row spacing and planting population on grain yield of corn. Values are the average of six hybrids and two locations in Illinois from 2017-2018.
Plant biologicals and plant biostimulants are becoming popular in the agricultural market as products to improve soil nutrient cycling in the rhizosphere, and/or to increase the growth, health, and yield of crop plants. As there is much confusion on how these products are defined and categorized, we developed a classification system, and then utilized this classification in experimentation to determine product efficacy under varying levels of crop management. Our goal was to evaluate in-furrow applications of select plant growth regulators (PGRs), and foliar applications of select plant biostimulants on corn grain yield, and to determine if they impact yield differently depending upon the agronomic management system.

How do we classify
Plant biologicals are diverse in nature, and come from many different sources with multiple target applications in cropping systems. We consider “Plant Biologicals” to be the overarching term, with three underlying categories of “Plant Growth Regulators,” “Plant Biostimulants,” and “Beneficial Microbes.” The growth regulators include hormone products most commonly composed of auxins, cytokinins, and gibberellic acids. Plant biostimulants contain humic acids, seaweed extracts, protein hydrolysates, enzymes, and sugars. Beneficial microbes include mycorrhizal fungi and N-fixing or P-solubilizing bacteria.

Where do they work
What are the production conditions that give the greatest response to biological and biostimulant products? Are they for all growers, or only for progressive growers trying to really push the envelope for high yields? To answer these questions, we evaluated two plant growth regulator (PGR) products applied in furrow at planting, and two biostimulant products applied to the foliage at V5. The PGRs (Ascend SL and Optify/Stretch) contained auxins, cytokinins, and gibberellins, while the biostimulants (Toggle and Voyagro) were a seaweed extract and a mixture of proline and glycine betaine. These products were evaluated under a standard and an intensive management system (Figure 7).

When did they increase yield
The intensive system yielded 14 bushels per acre more than the standard system, demonstrating that grain yield can be improved through more intensive agronomic management (Figure 8). While the PGR and biostimulant applications resulted in some early season vegetative growth differences, it was only when they were used in an intensive management system that yields tended to increase. These findings suggest that biologicals work best when other production factors are optimized.
**Precision management of soybean seedling diseases**

**Santiago Mideros,** Assistant Professor, Crop Sciences  
**Daniel Cerritos,** Graduate Research Assistant, Crop Sciences

**Diverse pathogens cause soybean seedling diseases**  
Over a dozen microbial species infect soybean seed and seedlings, causing a significant reduction of stand and yield. Some of the most damaging pathogens are oomycete species of the genera Phytophthora and Pythium (Figure 9). Precision management of plant diseases is the use of targeted practices to reduce the damaging effects of a pathogen. Soybean seedling diseases are traditionally managed using host resistance, seed treatments, and cultural practices. Host resistance, however, can be very specific to some races of each pathogen species; and pathogen strains can develop resistance to chemicals used in seed treatments. Since 2016, we have sampled soils and collected diseased plants in Illinois to very precisely identify the species and races of oomycetes affecting local soybean producers.

**Characteristics of the oomycete species in Illinois**  
Over 56% of the isolates we recovered were Pythium ultimum, followed by 26% Phytophthora sojae, and 7% Phytophthora sansomeana (Figure 10). Our results indicated that 18% of the Pythium isolates are insensitive to azoxystrobin; and 55% are insensitive to ethaboxam. Other chemicals (metalaxyl and mefenoxam) were very effective in controlling all tested isolates of both Pythium and Phytophthora species. Among the Phytophthora species, 20% of the isolates were able to cause disease on soybean plants with the Rps1c gene; and 60% of the isolates were able to cause disease on plants with the Rps1k gene.

**Management**  
We conducted two years of multi-location management field trials using INTEGOâ Suite (Valent, CA), which includes a mixture of various fungicides (clothianidin, ethaboxam, ipconazole, metalaxyl), and soybean plants with diverse resistance genes. Our results indicated that the use of the seed treatment increased the stand counts compared to untreated controls for all soybean lines except those with Rps1c. These results suggest that producers wishing to protect their soybean stands are well served by using a broad-spectrum seed treatment. Azoxystrobin and ethaboxam should be used in combination with other active ingredients to control Pythium species. In 2018, the resistance gene Rps1c still protects soybeans against 80% of the Phytophthora sojae isolates found in Illinois.
New field crop diseases in Illinois

Nathan Kleczewski, Research Assistant Professor, Crop Sciences

Plant diseases in Illinois
2018 was an interesting year for plant disease research in Illinois. In corn, an outbreak of a relatively new disease called tarspot occurred (Figure 11), resulting in significant yield losses throughout parts of Illinois and surrounding states. In addition, a new disease of soybean, known as red crown rot was detected for the first time in the west-central part of the state (Figure 12). This disease caused an estimated 25-30 bushel per acre loss for the fields where it was detected.

What you can expect
This talk will cover identification, management, and current research into these two diseases. Hands on samples as well as extension materials will be provided.
And the waterhemp challenges keep coming...

Seth Strom, Graduate Research Assistant, Crop Sciences
Aaron Hager, Associate Professor, Crop Sciences

Waterhemp challenges growers across the Midwest due to its propensity to evolve resistance to herbicides from various sites-of-action and stacking multiple resistances within populations. To date, waterhemp has developed resistance to inhibitors of ALS, PPO, HPPD, EPSPS, PSII, VLCFAs, and the plant growth regulator 2,4-D. Populations demonstrating up to 6-way combinations of resistances have been reported. Resistance to Group 15 VLCFA-inhibitors is the first case of resistance to herbicides in this class in a broadleaf weeds.

Group 15 herbicides were developed in the 1950’s, and remain an effective tool for preemergence (PRE) control of annual grasses and small-seeded broadleaves, such as waterhemp. Previous field research on two multiple-herbicide-resistant waterhemp populations (MCR and CHR) demonstrated poor control with S-metolachlor. Further research at the CHR site (2016–2017) revealed very few effective Group 15 herbicide options, with S-metolachlor providing 27% or less control 28 days after treatment (DAT) (Figure 13).

Figure 13. Response of the CHR population to several Group 15 herbicides at 1x rates 28 days after application.

CHR and MCR are resistant to s-triazines, HPPD-, and ALS-inhibitors. Responses of progeny generated from each population to several Group 15 herbicides were compared to two sensitive populations in greenhouse dose-response experiments. Resistance levels based on seedling survival (LD50) ranged from 4.5- to 64-fold. The similarities between the CHR and MCR populations led us to hypothesize that a physiological factor within the plant, such as metabolic inactivation, was responsible for the decreased control with S-metolachlor. Investigation of radiolabeled S-metolachlor metabolism was conducted in seedlings from the CHR and MCR populations in comparison to two sensitive waterhemp populations and corn. Qualitatively, thin layer chromatography (TLC) revealed that CHR and MCR seedlings metabolized S-metolachlor faster than either sensitive population 2-24 hours after treatment (HAT). Within the 24-hour time course, complete conversion of parent S-metolachlor to more polar metabolites was observed in CHR and MCR, and their metabolite profiles were different from either sensitive population or corn. The corroboration of field, greenhouse, and metabolism experiments indicates that the CHR and MCR populations have developed metabolic resistance to S-metolachlor (Figure 14).

Figure 14. Thin layer chromatography plate showing metabolic resistance to S-metolachlor in two waterhemp populations.

Resistance to a soil-applied herbicide can be hard to detect. Generally, resistance will first appear as a gradual decrease in residual control. Even when a PRE does not provide the expected control, this does not immediately imply resistance. The effectiveness of any soil-applied product can be greatly influenced by environmental factors (temperature, rainfall, soil-type, and even the timing of waterhemp emergence). It is important to be aware of individual field characteristics and practice regular crop scouting to control weed populations. Overall, this first instance of Group 15 resistance demonstrates the need to implement best management practices and use every available option to limit further seed contribution to the soil-seedbank. Research on herbicide resistance at the University of Illinois is ongoing to help understand troublesome weed populations and provide insight for the agricultural industry to combat pests and optimize crop yield.
Effects of foliar fungicide application on the corn silage

Phil Cardoso, Associate Professor, Animal Sciences

In 2014, the United States Department of Agriculture (USDA) reported that 89.4% of dairy operations in the United States included corn silage in the diet for lactating cows.

Our group concluded that applications of fungicide on corn may be positively affecting corn silage quality when fed to cows. Corn silage from corn that received fungicide application at V5, V5+R1, and R1 had greater lactic acid and total acid compared to control (Figure 15). Lastly, corn silage from corn that received fungicide application at V5 numerically had less ADF and NDF when compared with control (23.76 vs. 25.03% for ADF, and 38.94 vs. 41.15% for NDF, respectively). Fungicide application on corn seems to alter the fiber content within the plant material and fermentation products of corn silage.

Frequent scouting in the cornfield and awareness of changing weather conditions are crucial in helping to limit fungal development on corn. Applications of fungicide on corn can prevent fungal disease in the field, which may decrease the number of fungal pathogens ensiled in corn silage.

Preventing disease on corn early may decrease NDF and ADF content. Ideally, decreasing NDF, ADF, and lignin content of corn plants may increase NDF of corn silage when fed to dairy cows. Furthermore, ensiling corn silage with fewer fungal pathogens may increase lactic acid content of the silage. By increasing ruminal digestibility and increasing the fermentative quality of corn silage, diets may increase conversion of feed to milk, making dairy production more efficient (Figure 16).

Figure 15. Lactic acid (%) for corn silage in control (CON), one application of foliar fungicide at V5 (V5), one application of foliar fungicide at R1 (R1), or two applications of foliar fungicide at V5 and R1 (V5+R1) ensiled for either 0, 30, 90, or 150 days post-harvest.

Figure 16. BMR corn harvested at 12 and 22 inches.
Insect management: What are we learning from a challenging season?

Nick Seiter, Research Assistant Professor, Crop Sciences

2019—A challenging year for producers
Producers in 2019 have been forced to deal with substantial delays in planting due to heavy rainfall. This has altered the timing of insect population dynamics in relation to crop growth stage and, in some cases, management decisions for insects such as corn rootworm, armyworm, and bean leaf beetle (Figure 17).

Current Research
Ongoing research seeks to inform management decision-making for these and other pests in corn and soybean production systems, including those that include a rye cover crop.

We are currently evaluating Bt traits, soil insecticides, and seed treatments for control of corn rootworm. While these experiments are ongoing, preliminary data are available to demonstrate the effectiveness of controls and assess the development of resistance to these tools.

Monitoring Tools
Additionally, we are developing improved monitoring tools to assess insect abundance and damage potential in corn and soybean.

We will discuss the development of these recommendations in the context of 2019, including: 1) how the delayed start to the season has impacted pest management; 2) what late/wet springs mean for corn rootworm pressure this year and going forward; and 3) what pests might cause issues at the end of the season due to later-than-normal crop maturity.
How are insects responding to the wild weather in 2019?

Kelly Estes, State Pest Survey Coordinator, Illinois Natural History Survey

Insect surveys in 2018 revealed increased populations of several insects in Illinois corn and soybeans. Japanese beetles numbers remained high, with population averages higher in every crop reporting district when compared to the previous year. Other soybean pests such as cloverworms, loopers, bean leaf beetles, and stink bugs were also more noticeable in several areas. Western corn rootworm numbers continue to fluctuate each year, trending on the low side with highly variable numbers from field to field (Figure 18).

As is normal during the winter months, entomologists often get asked about insect survival. There was no shortage of speculation this past January as we found ourselves in a seemingly endless cold spell. Despite colder-than-average temperatures in January, with some of the coldest temperatures recorded in decades at the end of the month, winter averages were relatively close to the long-term average according to the office of the Illinois State Climatologist.

Also above the long-term average was winter precipitation. And the above-average precipitation trend during the winter months continued right through spring. In fact, May 2019 will go down in history with its record-breaking precipitation. At nearly 4 inches above the long-term average, May marked the sixth consecutive month of above-average statewide precipitation. Repeated rain events left soils more than saturated, with flooded fields and delayed planting a common scene (Figure 19).

As we head into summer, our question now becomes how will these insect populations respond? Time will tell, as will the results of the 2019 survey.

Figure 18. Soybean sweep sample from summer 2018.

Figure 19. A wet spring delayed planting statewide and prevented planting in some areas. Will it affect insect populations this summer?
Bt resistance and Illinois corn rootworm populations

Joseph Spencer, Principal Research Scientist, Illinois Natural History Survey

Northern and western corn rootworms (WCR) are historic corn pests whose biology is tied to corn. Heavy infestations are capable of 50% yield reductions. Combined costs of rootworm management tactics and rootworm-attributable yield losses likely approach $2 billion annually in the U.S. (Figure 20).

Commercialization of corn hybrids expressing Bt toxins that specifically and very effectively targeted corn rootworm larvae revolutionized the management of these devastating pests. Bt hybrids were rapidly adopted; today 90% of Illinois corn acres are planted with a Bt corn hybrid.

In spite of resistance-management efforts, broad reliance on just two rootworm Bt modes of action (MOA) for more than a decade has selected for varying levels of resistance across the Corn Belt. Because some areas of resistance are known for all Bt traits, the remaining efficacy of this first generation of Bt toxins is limited. Corn Belt resistance to the Cry3 Bt MOA is common and evidence of resistance to the other mode of action is documented from multiple locations. In East Central Illinois, bioassays of WCR field populations indicate that they remain susceptible to corn hybrids expressing the Cry34/35Ab1 MOA. However, there is field and laboratory evidence for Cry34/35Ab1 MOA resistance genes at low frequency in populations (Figure 21).

Adopting integrated approaches to rootworm management that combine rootworm monitoring, rotation of management tactics (including non-Bt hybrids), and farm-level Bt-efficacy data can provide effective root protection and minimize selection for greater Bt resistance. Yearly conditions that suppress WCR abundance should be exploited to reduce selection for Bt resistance.

Figure 20. Mature western corn rootworm (Diabrotica virgifera virgifera, WCR) larva in a damaged corn root.

Figure 21. View of bioassay damage to Cry3 Bt corn roots caused by Bt resistant WCR larvae.
Five years of cover cropping in Illinois

Gevan D. Behnke, Postdoctoral Research Associate, Crop Sciences

Nitrogen scavenging is a well-documented benefit of many cover crop species. Therefore, implementation of cover crops can utilize residual soil nitrogen, which keeps it from reaching waterways; the subsequent decaying cover crop residues can then be used by the cash crop. The goal of this study was to monitor soil-available nitrogen from six different cover crop treatments throughout the state of Illinois (Figures 22 & 23).

The experimental design was a split-block randomized complete block design with four replications within each phase of the corn-soybean rotation from six locations. Two levels of tillage were present: chisel plow and no-till. Cover crop treatments had six levels, differing based on the following cash crop. Hairy vetch [Vicia villosa Roth] and red clover [Trifolium pretense L.] occurred as treatments only in plots preceding corn [Zea mays L.], with cereal rye [Secale cereale L.] and spring oats [Avena sativa L.] growing only before soybean [Glycine max (L.) Merr.] crops. The effects of rapeseed [Brassica napus L.], daikon radish [Raphanus sativus L.], and annual ryegrass [Lolium multiflorum Lam.] were tested before both corn and soybean, along with an unseeded control plot. Results indicated that a substantial amount of soil nitrogen was present.

Overall, the cover crop species that consistently grew the best throughout the state were annual ryegrass, cereal rye, and hairy vetch, likely due to their ability to survive the harsh Illinois winter. Following 3-5 years of cover crop implementation, we saw a decrease in soil nitrate and phosphorus from species that took advantage of the entire cover crop growing period.

Figure 22. Side by side view of a cereal rye cover crop strip versus an unseeded control strip taken from an on-farm cooperator located in Greenville, IL in mid-April.

Figure 23. Field view of actively growing cover crop treatments taken Urbana, IL in mid-November.
Shorebird conservation acreage via drainage water runoff control (SCARC)

Ben Williams, Agricultural Habitat Specialist, Natural Resources and Environmental Sciences (NRES) & Illinois Natural History Survey

Illinois is an important stopover state where many shorebird, waterfowl, and waterbird species rest and refuel during their spring migration (Figure 24).

The Shorebird Conservation Acreage Via Drainage-Water Runoff Control (SCARC) program is focused on creating much-needed habitat for these northbound migrants in central Illinois. The SCARC program provides technical assistance and financial incentives to farmers who are interested in actively managing the water drainage on their fields to create temporary wet spots and surface water.

Participants in the SCARC program hold back water in their fields with water control structures from February through mid-April, which is during peak migration and typically before planting begins. Thousands of shorebirds and waterfowl use the wet areas created by the control structures during the spring as they migrate from the southern U.S. and South America up to the northern states and Canada.

Additionally, large concentrations of American Golden-Plovers utilize the temporary wet areas created by the SCARC program (Figure 25). The American Golden-Plover is a species of conservation concern in Illinois that relies on wet agricultural fields during spring migration. After migration is over, participants in the SCARC are able to drain their fields in less than a week and plant crops as usual. Consequently, the SCARC program highlights how modern agricultural practices can be used for the betterment of conservation, and is a unique demonstration of conservation and agriculture coexisting.

Figure 25. Radiotagged American Golden-Plover.
Precision cover cropping and strip-tillage for organic sweet corn production

Carolyn Lowry, Research Ecologist, Agricultural Research Services

Weed competition and soil nitrogen (N) deficiency are the primary challenges preventing the adoption of reduced-tillage organic systems. Cover crops are used to both suppress weeds and increase soil inorganic N availability, however, cover crop species vary in their capacity to perform different ecosystems services. For example, legumes provide N via biological N fixation, but are often poor at suppressing weeds. Cereal grasses produce large quantities of biomass, but can tie-up and decrease soil N. Therefore, cereal grasses and legume mixtures can balance the trade-off between soil N and weed suppression.

Precision cover cropping involves the strategic placement of cover crops within a field to enhance their provisioning of ecosystems services (Figure 26). We examined whether the technique of ‘precision cover cropping’ could enhance the ecosystem services provided by a cereal rye-hairy vetch mixture when combined with strip-tillage (Figure 27). Through precision cover cropping, planting of rye and vetch was segregated into functionally distinct high-N (vetch) and low-N (rye) zones. Hairy vetch, a legume, was sown in a strip directly in-row with future crop establishment to provide N directly to the crop. Simultaneously, cereal rye was planted between crop rows where it may be used as a mulch to suppress weeds.

Precision cover cropping increased the concentration of N-rich vetch residue and reduced the C/N ratio of both above- and belowground rye-vetch biomass within the planting zone of the subsequent crop. This resulted in greater inorganic N availability within the crop row, and greater crop competitiveness against weeds early in the season. However, we found no effect on sweet corn yield.

Figure 26 (below). Cereal rye and hairy vetch planted in a uniform mixture (left) compared to a rye-vetch mixture planted using precision cover cropping (right). In the precision cover cropping treatment, the rye and vetch are planted into functionally distinct zones: the N-rich vetch is planted in a zone in line with the future cash crop row, and the cereal rye is planted between future cash crop rows.

Figure 27 (below). Strip-tillage (ST) confines soil disturbance and incorporation of organic residues to a narrow strip directly within the crop row (right). For our study we used a two-row strip-tiller (Hiniker Model 6000, Mankato, MN) that was equipped with cutting-coulter, shank point assembly, berming discs, and rolling basket.
Using precision technology to conduct on-farm research trials for data-intensive farm management

David Bullock, Professor, Agricultural and Consumer Economics

Background
In 2015, the Illinois Nutrient Loss Reduction Strategy (INLRS) was developed to guide state efforts in improving water quality at home and downstream by reducing nitrogen and phosphorus levels in our lakes, streams, and rivers. Fertilizer management is a significant concern to researchers and farmers, but the lack of sufficient and reliable data has posed a challenge in the past. Data-Intensive Farm Management (DIFM) is a $4 million research project funded by the USDA National Institute of Food and Agriculture, tackling this issue by the use of precision technology, readily available in today’s farm equipment.

Trial implementation: What is DIFM doing different?
Historically, generating the data needed to accurately predict optimal management decisions was both labor-intensive and expensive. As a result, studies in the past were often short-term and data was limited to just a few small strip-trial plots, conducted in a similar geographic location. DIFM’s approach allows farmers to conduct their own field experiments on their farms by utilizing the precision technology readily available in their modern equipment. With DIFM’s method, all experimental protocols are programmed into the farm machinery, requiring little effort on behalf of the farmer. Through the use of DIFM software, Certified Crop Advisors (CCAs) and farmers work closely together to easily create the on-farm field trials, collect and evaluate the data, and make optimal fertilizer management decisions based on the analyzed data and field characteristics for that specific field.

Summary
DIFM’s revolutionary approach provides farmers and CCAs a hands-on decision-making tool, with the overall goal to increase farmer profits and reduce nutrient runoff through optimal management practices (Figures 28 & 29).
Looking forward at corn and soybean profitability

Gary Schnitkey, Professor, Agricultural and Consumer Economics

Two recent events have had significant impacts on the profitability of corn and soybeans. First, major problems exist with marketing soybeans to China. Trade difficulties between the U.S. and China became apparent last year, resulting in China introducing tariffs on soybeans imports from the United States. Combined with the Chinese soybean tariffs is the introduction of African Swine Fever (SF) in China, further reducing Chinese demand for soybeans. Since the introduction of Chinese soybean tariffs, average cash prices for soybeans in the U.S. have fallen from $9.84 per bushel in May 2018 to prices well under $9.00 per bushel. In May 2019, soybean prices averaged $8.02 per bushel (Figure 30).

The second factor impacting profits is the recent wet weather that delayed 2019 planting across much of the Midwest. The full acreage and yield impacts of the 2019 season are not entirely known, but corn and soybean supplies likely will be lower, leading to higher prices, particularly for corn. How much prices increase will determine how low incomes will be in 2019. At this point, it seems reasonable to expect low 2019 incomes, even given sizable Market Faciliations Program (MFP) payments.

The relative profitability of corn and soybeans likely will shift as a result of difficulties with the China market and the reduced grain supplies. Between 2013 and 2018, soybeans were more profitable than corn. Lower soybean prices relative to corn prices lead to projections of corn being more profitable than soybeans. As long as soybean prices are projected to be $9 per bushel and below, soybean profitability will suffer relative to corn profitability.

Projections are for low incomes in 2019 and 2020, resulting from lower soybean prices than in the years immediately preceding 2019. In 2018 and 2019, Market Facilitation Programs increased incomes. Whether these payments continue in 2020 is an open question (Figure 31).
Partnering crop improvement research with stakeholders using technology and digital platforms

Anthony J. Studer, Assistant Professor, Crop Sciences

Consumers are increasingly demanding sustainable food production while growers face extreme variability in weather patterns and tight markets. Technological advances are having transformative, but also sometimes disruptive, impacts on agricultural systems. In the past, growers often looked to land grant universities for third party information on the most recent discoveries. However, the rapid pace of innovation and growing industrialization has strained this traditional path for information exchange. New capabilities for “digitizing” and sharing outcomes of agricultural research, and engaging researchers in production relevant issues, offer new possibilities for communication among researchers and growers.

A team of researchers from the College of ACES, University of Illinois Extension, and the National Center for Supercomputing Applications at U of I are competing for a federal grant to enhance partnerships between researchers and growers. To do this, we propose to create the Digital Infrastructure for Research and Extension on Crops and Technology for Agriculture (DIRECT4AG) platform. This web-based platform will be designed and developed for translating information about cutting-edge production-relevant agricultural research directly to growers. Furthermore, growers will have input into the system and can provide feedback on the project. DIRECT4AG will connect a network of four University research farms that will be highly instrumented with a suite of sensors. Our network will expand outward from these hubs through a partnership with the University of Illinois variety testing program and also through grower cooperators. The data collected from these farms will be streamed through a web interface and accessible to both the researchers and growers. The initial experiments will focus on improving nitrogen-use efficiency (NUE), water-use efficiency (WUE), and targeted technology adoption that will aid in better on-farm management decisions.

Digital Infrastructure for Research and Extension on Crops and Technology for Agriculture

Come and hear about our vision for connecting growers and researchers with DIRECT4AG. We are interested in the types of data you collect on your farm, what you would like to measure but currently can’t, and about the issues facing you on your farm. Your participation can shape the outcome of the project and help us to secure funding to support this endeavor. Together we can shape the future of digital agriculture.
Does it pay to split-apply nitrogen to corn?

Emerson Nafziger, Professor Emeritus, Crop Sciences

Dividing the nitrogen fertilizer applied to corn into two or three applications has become a common practice. This is based on the idea that application made during vegetative growth enables nitrogen (N) to get into the plant quickly, and that later applications are less prone to loss of N. We tested this idea in a series of trials.

Across 27 site-years, 200 lb N applied as 1) fall-applied ammonia with N-Serve; 2) 100 lb N as fall ammonia + 50 lb N as UAN at planting + 50 lb N as UAN at V5-V6; 3) spring-applied ammonia; and 4) 50 lb N as UAN at planting + 150 lb N as UAN sidedressed at V5-V6 yielded 241, 238, 239, and 236 bushels per acre, respectively (Figure 32).

Across 18 site-years, applying 100, 150, and 200 lb N as injected UAN at planting yielded 13, 3, and 3 bushels more, respectively, than the same rates split between 50 lb at planting and the rest sidedressed (Figure 33). Finally, over 15 site-years, N rates either all at planting or with 50 lb kept back to apply at tassel showed no advantage for yield or profitability to splitting N.

That keeping some N back to apply in-season failed to increase yields consistently indicates a possible advantage to having more of the N in the soil during early growth. It’s also possible that loss of N may be less extensive than we think. At least on productive soils, costs of splitting N are likely to exceed returns.

Figure 33. All-early N compared to application of 50 lb N at planting followed by the rest as sidedressed UAN, averaged across 18 Illinois site-years, 2014-18.
Introduction to industrial hemp agronomy

Phillip Alberti, Extension Educator, Commercial Agriculture, Illinois Extension

On April 30th, the Illinois Department of Agriculture began accepting applications via their website for the cultivation and processing of industrial hemp for the 2019 growing season. Industrial hemp has the ability to be grown for grain, fiber, and cannabidiol (CBD) depending on the production system in place. Grain production is similar to small grain production, fiber to hay production, and CBD production to a vegetable or specialty crop operation. It is critical to know and understand the different types of production systems involved when growing industrial hemp. While there is interest in the future of hemp grain/fiber production at the commercial level, a majority of the grower applications will be for CBD production. Illinois does not have the infrastructure in place currently to support commercial grain/fiber operations; however, there are current plans for this to change in the coming years.

The University of Illinois is currently conducting hemp grain/fiber production experiments to determine best management practices (BMP) for this new crop. This industrial hemp pilot trial will be conducted in four locations (Northern, Central, and Southern IL) to evaluate growth and performance of six varieties believed to be suited for grain/fiber production in the region (Figure 34). Plots will be scored for key agronomic traits including: stand count, time to flowering, plant height, disease ratings, and total seed yield. Results from this pilot year would be used to expand to a more comprehensive BMP study across multiple locations in Illinois (Figure 35). If you would like more information about industrial hemp production, visit web.extension.illinois.edu/jsw/ihp.
Economically optimum plant density for machine-harvested edamame

Daljeet Dhaliwal, Graduate Research Assistant, Crop Sciences
Marty Williams, Ecologist, USDA-ARS, Crop Sciences

Background
Consumer demand for edamame, the vegetable version of soybean, has grown the last decade in North America. Domestic production of edamame is on the rise; however, research to guide fundamental crop production practices is lacking, including knowledge useful for developing appropriate recommendations for crop seeding rate. The objectives of this study were to characterize edamame growth response to plant population density, and determine economically optimum plant density (EOPD) of machine-harvested edamame.

Experimental approach
Field experiments were conducted at the University of Illinois Vegetable Crop Farm near Urbana, IL. Crop growth and yield responses to a range of plant densities (24,700 to 395,100 plants/ha) were quantified in four edamame cultivars (AGS 292, BeSweet 292, Gardensoy 42, and Midori Giant) across two years. Plots were harvested with the Oxbo BH100, a fresh market bean and pea harvester.

Crop growth and yield responses
In general as plant density increased, branching and the ratio of pod mass to vegetative mass decreased, while plant height and leaf area index increased. Recovery, the percent of marketable pods in the machine-harvested sample, varied among cultivars from 86 to 95%. Edamame cultivars showed a quadratic yield response to plant population density (Figure 36). Our results identified the EOPD for machine-harvested edamame averaged 88,000 plants/ha, resulting in an average maximum marketable pod yield of 5.2 Mt/ha.

Key takeaway
Commercial edamame cultivars should be selected in consideration to their average plant height and plant growth (determinate or indeterminate type) to optimize mechanical harvest efficiency.

Figure 36. Effect of plant density and edamame cultivars on machine-harvested pod yield.
Campus organic studies: How corn, soil health, and education interact

Carmen Ugarte, Research Specialist, Natural Resources and Environmental Sciences (NRES)
Martin Bohn, Associate Professor, Crop Sciences
Michelle Wander, Professor, Natural Resources and Environmental Sciences (NRES)

Along with the increased demand for organically produced grains, there is a growing need for seed that performs well under organic farming conditions. We are working with Midwest organic grain farmers to test the agronomic and use potentials of corn cultivars developed using different breeding styles to see how they fit within organic farming systems. We are interested in nitrogen efficiency characteristics, competitiveness with weeds, standability, and yield potential as well as nutritional value.

Controlled studies conducted on farms and in our on-campus trial let us look more closely at how organic management practices alter soil health and how this alters the roots and microbial associations of different cultivars. The field day will include multiple stops, with one showing how conventionally bred cultivars developed using University of Illinois’s elite lines compare with lines developed for the organic sector by the Mandaamin Institute in Wisconsin and other private breeders. You can also see an organic nursery that is producing hybrids, and how corn varieties and root systems grown under high- and low-fertility regimes perform in the field. We will also share results from 2018, covering crop response, soil health, and grain quality collected from our strip trials, which were conducted on 13 organic farms, and two controlled studies conducted at Goldmine Farm in Pana IL, and in Macomb IL, at Western Illinois University’s Allison Farm. Posters will share how our educational network is exploring ways business models, intellectual property, and participatory testing networks influence your access to quality seed and showcase student research to demonstrate U of I’s education in action. Come learn how corn varieties, soil quality, and education interact!

Replicated Trials:
2018 Pana (Jack Erisman) and Macomb (Joel Gruver)
2019 Pana and Urbana

Investigate how corn cultivars respond to gradients of soil fertility and weed pressure

Explore the effects of soil type and management on plant performance and soil health

- 2018 offered 15 cultivars selected from the U of I collection and 2 private breeding programs
  - Food grade quality
  - High protein (methionine)
  - N efficiency
  - Good agronomic characteristics
Grain quality: A numbers game  
Carrie Butts-Wilmsmeyer, Research Assistant Professor, Crop Sciences

Every industry, including the agriculture industry, is becoming more data-driven. Thanks to developments in robotics, engineering, chemistry, and many other areas, the ability to collect data is easier than ever before (Figure 37).

The question now is what to do with the data.

Using a combination of agronomic knowledge, statistical models, and advanced computational resources, it is now possible to mine that data and look at questions that, before, were too complex to be answered. Many of these questions revolve around grain quality and looking at how we can improve the quality of our crops without diminishing yield (Figure 38).

Research in this area includes everything from making grain crops more nutritious for humans and animals, to designing grain crops that can be converted to biofuels more efficiently, to selecting crops that can withstand pest and drought stresses with heightened resilience. This presentation provides an overview of the novel ways data can be used to direct grain quality improvement efforts.

Corn grain quality is used as a case study, with a spatial analysis of 2018 yield and economic data verifying that yield (or regional abundance) alone was not indicative of the price received for grain, and that access to regional specialized markets exerted a heavier influence. Continuing research in this area includes increasing the level of phenolic compounds in maize grain to naturally improve pest and environmental stress response while also allowing Illinois farmers to tap into niche markets.

Figure 37. Corn prices by state in 2018.

Figure 38. Corn yields per acre by county in 2018.
Improving soybean oil quality

Brian Diers, Professor, Crop Sciences

Soybean is primarily grown for the protein and oil that is processed from its seed. Soybean grown in Illinois has approximately 40% protein and 20% oil on a dry weight basis. The crop is highly valued as a protein source for animal feed because it has a good balance of amino acids. There is, however, a need to improve the quality of soybean oil because of the presence of polyunsaturated fatty acids that oxidize when heated, imparting a rancid flavor to food. This problem was previously overcome through hydrogenation of the oil. However, this results in the formation of trans fatty acids that were shown to have a negative impact on human health, resulting in a loss of market share for soybean oil.

To counter this issue, soybean that is high in the mono-unsaturated fatty acid oleic and low in the poly-unsaturated fatty acid linolenic have been developed through a number of methods. High oleic/low linolenic soybean varieties developed through genetic transformation are being sold by Corteva and Bayer and through gene editing by the Minnesota based company Calyxt. Through the support of the United Soybean Board, the University of Illinois soybean breeding program is developing high oleic/low linolenic soybean through combining four mutated genes. This has resulted in the development of experimental lines with greater than 80% oleic acid and less than 3% linolenic, which should increase the value of the oil (Figure 39).

Figure 39. A comparison of fatty acid levels of two check cultivars and two experimental lines developed by the University of Illinois that have high levels of oleic acid and low levels of linolenic acid. The oil in the experimental lines has greater than 80% oleic acid and less than 3% linoleic acid, resulting in a healthier oil that oxidizes at a lower rate than commodity soybean oil.
Improving photosynthetic efficiency in rice to increase yields and water-use efficiency

Liana Acevedo-Siaca, Ph.D. Candidate, Crop Sciences

Combating stagnating global rice yields
Rice is one of the most important cereal crops in the world, providing more than 50% of the daily caloric intake for millions globally. However, in recent years yield increases in rice have stagnated, posing a threat to our ability to feed an increasing human population in the future. Nevertheless, there’s some good news: improving photosynthesis, the process by which plants make food from the sun, is widely considered an effective strategy to increase both crop yields and water-use efficiency.

Using our genetic resources to make photosynthesis better
The International Rice Research Institute (IRRI) in the Philippines preserves over 127,000 accessions of rice in its genebank, however, scientists and farmers globally only utilize a small fraction of the genetic diversity currently available. Natural variation found in crop landraces or wild relatives is key to developing new crop varieties through conventional and transgenic plant improvement approaches. However, without a greater understanding of the diversity that currently exists, we cannot make use of it. This project aims to characterize preexisting natural genetic variation for photosynthetic traits in rice varieties to improve photosynthesis in rice in the future.

What we’ve found
This project has found an exciting amount of natural variation in rice for different traits related to photosynthesis. This variation could help us breed or engineer plants that can photosynthesize more effectively, consequently improving yields, crop water-use efficiency, and help us reduce food insecurity.

Sources
Modeling genotype-to-phenotype relationships and what it means to plant breeding

Alexander E. Lipka, Assistant Professor, Crop Sciences

Making use of the relationship between genotypes and phenotypes has great potential to enable future generations to benefit from modern agronomy. For instance, quantitative approaches that accurately model the relationship between genotype and phenotype could facilitate the dissection of genetic sources of agronomically important traits in crops. It is then possible to incorporate this relationship on a genome-wide scale to predict which seeds and clones are most likely to have optimal breeding values; such genomic selection endeavors have the possibility to significantly speed up genetic gains and advance breeding cycles at unprecedented speed (Figure 42).

One crucial aspect towards translating the potential of these quantitative approaches into tangible agronomic gains is ensuring that the most statistically rigorous yet biologically accurate genotype-to-phenotype models are being used. To this end, the Lipka Lab is developing, applying, and evaluating cutting-edge statistical genotype-to-phenotype approaches and making these approaches available in easy-to-use software. In this presentation, we highlight the most recent developments of the statistical genotype-to-phenotype approaches studied the Lipka Lab and illustrate how they can advance plant breeding efforts (Figure 43).
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