**Vegetable Field Day 2017**
- Directly following Agronomy Day on Thursday, August 17th from 1:30 to 3:00 p.m.
- Vegetable Crops Research Farm at 2921 South 1st Street in Champaign, IL.
- Walk through research plots and hear from U of I Crop Sciences faculty sharing information about pumpkins, cucumber, tomato, squash, basil, peppers, and a new method of mushroom production! Registration is not required.

**International Agronomy Day 2017**
- Monday, August 28th from 8 a.m. to 1 p.m.
- Crop Sciences Research and Education Center South First Street Facility at 4202 South 1st Street in Savoy, IL.
- Nationally renowned faculty share the latest research in agronomy, weed science, crop production, soybean breeding, water quality and more. Registration cost: $30.
AGRONOMY DAY TOURS

TOUR A
1. Managing Nitrogen for Corn – Emerson Nafziger
2. Nitrogen on Soybean – Have We Made Progress Yet? – Joshua Vonk
3. Illinois Broomcorn: Breeding Nature’s Swiffer – Jessica Bubert
5. How to Turn a Cone Penetrometer into a Soil Eavesdropper – Tony Grift

TOUR B
2. Patterns of Bt Resistance in Illinois Western Corn Rootworm Populations – Joe Spencer
3. Pre-emergence Herbicides in a POST Resistance World – Dean Riechers

TOUR C
1. Are There Any Nematodes Besides SCN? – Nate Schreuder
2. Waste Not, Want Not: Strategies for Producing a Water-use Efficient Line of Corn – Tony Studer
3. Woodchip Bioreactors – Chippin’ Away at Nitrate Loss – Laura Christianson
4. Drones: Improving your Perspective – Dennis Bowman and Russ Higgins

TOUR D
1. The Seven Wonders of Corn Yield – Revisited – Fred Below
2. How Critical are Soil Phosphorus Test Values – Tryston Beyrer
3. Knocking Out the Continuous Corn Yield Penalty – Alison Vogel
4. Can Narrow Row Spacings be Used to Manage More Corn Plants? – Brad Bernhard

TOUR E* Transported off site for a one-hour tour of the Energy Farm at 8 a.m., 9 a.m., and 10 a.m. with limited availability. Please sign-up in advance at the registration table.
1. Technologies to Feed and Fuel the Future – Don Ort
2. Agroforestry for Food – Sarah Taylor Lovell
3. Enhanced Weathering at the Energy Farm – Ilsa Kantola
4. Field to Flame: Biomass Heating at the University of Illinois – Tim Mies
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Rate
While it’s easy to get caught up in trying to “fine-tune” N management, deciding how much N to use is the first consideration. The N rate calculator at [cnrc.agron.iastate.edu](http://cnrc.agron.iastate.edu) tells us that at current corn and N prices, the best rate for corn following soybean in central Illinois is 172 lb N per acre, and for corn following corn is 200 lb N per acre for corn following corn. The calculator uses actual N response data from hundreds of trials to create guideline rates, but it can’t predict what kind of year the crop will have, so is seldom “exact.” But it’s the best guess we have, and using higher rates to be “safe” carries economic and environmental costs we can’t afford.

Timing and Form
Over ten site-years, it took 18 more lb of N (169 versus 151) to produce one less bushel of yield (219 versus 220) using fall-applied N compared to spring-applied N. Spring-applied N netted $11 per acre more than fall-applied N. We often see more N loss through drainage tile with fall application. Compared to applying all of the N at planting, 50 lb of N at planting and the rest as side-dressed UAN required 9 lb more N and yielded 1.6 bushels more, which netted about $2.50 per acre more (Figure 1).

Among 15 treatments over ten site-years, only 10 bushels per acre separate the highest from the lowest yields (Figure 2). Dry urea with Agrotain® (urease inhibitor) or as SuperU® (with both urease and nitrification inhibitors) produced the highest yields, and the lowest-yielding treatments included UAN applied to the soil surface at different times and anhydrous ammonia injected before or at planting.

### Table

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Rank (1-15)</th>
<th>avg 10 sites (bu/acre)</th>
</tr>
</thead>
<tbody>
<tr>
<td>All N applied at planting:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>UAN injected mid-row</td>
<td>4</td>
<td>220 abc</td>
</tr>
<tr>
<td>UAN dribbled mid-row</td>
<td>13</td>
<td>215 def</td>
</tr>
<tr>
<td>Urea/Agrotain broadcast</td>
<td>1</td>
<td>223 a</td>
</tr>
<tr>
<td>SuperU broadcast</td>
<td>2</td>
<td>223 ab</td>
</tr>
<tr>
<td>ESN broadcast</td>
<td>8</td>
<td>219 abd</td>
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<tr>
<td>UAN/Agrotain broadcast</td>
<td>15</td>
<td>213 c</td>
</tr>
<tr>
<td>NH3 injected mid-row</td>
<td>12</td>
<td>216 cde</td>
</tr>
<tr>
<td>NH3/N-Serve injected mid-row</td>
<td>11</td>
<td>216 cdef</td>
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<tr>
<td>Split N application (1st at planting):</td>
<td></td>
<td></td>
</tr>
<tr>
<td>UAN 50 broadcast+UAN 100 injected V5</td>
<td>9</td>
<td>218 bcde</td>
</tr>
<tr>
<td>UAN 100 injected+UAN 30 injected V5</td>
<td>5</td>
<td>220 abc</td>
</tr>
<tr>
<td>UAN 100 inj+Urea/AT 50 broadcast V5</td>
<td>7</td>
<td>219 abcd</td>
</tr>
<tr>
<td>UAN 100 inj+UAN 50 dribbled in-row V9</td>
<td>3</td>
<td>221 abc</td>
</tr>
<tr>
<td>UAN 100 inj+Urea/AT 50 broadcast V9</td>
<td>10</td>
<td>218 cde</td>
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<tr>
<td>All N sidedressed:</td>
<td></td>
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</tr>
<tr>
<td>UAN injected mid-row at V5</td>
<td>6</td>
<td>220 abc</td>
</tr>
<tr>
<td>UAN dribbled mid-row at V9</td>
<td>14</td>
<td>214 ef</td>
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Late-split N into Tall Corn?
Applying some of the N late during vegetative growth to maintain the N supply for crop uptake after pollination has gained recent attention. Over seven trials including both corn following corn and corn following soybean in 2016, we found that N response curves were identical whether we applied all of the N at planting or kept 50 lb back to dribble into the row at tasseling. Applying the last 50 lb of N into tall corn did not cover any of the cost for such an application. Late applications to help replace N lost under wet (June) conditions might make sense, but productive soils can hold all of the N the crop needs. Planned “spoon-feeding” of N for corn involving significant costs and risk, e.g., wet weather that prevents application, is unlikely to generate positive returns.
There has been a lot of discussion about nitrogen (N) fertilizer to help supply higher N requirements for high-yield soybean. This stems from the theory that soybean can’t afford the energy to fix the N they need (3.5 to 4.0 lb. per bushel) while producing high yields. Many “contest winners” use N fertilizer, but few can show that adding N boosts yields. From 2014-2016, we studied N fertilizer outcomes over differing environments and soil types. Trial sites throughout Illinois included Chillicothe on loam soil with less than 2% organic matter (OM), Brownstown on silt loam soil with less than 2% OM, and Urbana and Monmouth on silt loam soils with more than 3.5% OM. Application timing ranged from planting to seed formation (R5), including some multiple applications. Rates ranged from 46 lb. N (100 lb. urea) to 100 lb. N per acre per time of application.

At Monmouth, Urbana, and Brownstown, we saw positive responses from repeated applications (Figure 3). A Urbana and Monmouth in which yield was increased between 3.5 and 6.5 bushels from repeated applications (192 to 400 lb. N per acre), but even these responses were not always favorable. The only significant increase from a single N application was at Brownstown in 2015 when N was applied at R3 (6 bushels per acre). Using more N with repeated applications was more likely to respond, but with little response and higher N rates, the economics of doing this would be marginal at best.

Figure 3. Soybean yields following applications of N. Yields followed by the same letter within each site year were not statistically different at p=.1 and NS denoted no significant differences. Each application in 2014 and 2016 was at 46 lb. N per acre, and in 2015 was at 100 lb. N per acre.

Chillicothe produced the most surprising results. In 2015 and 2016, applying N at planting increased yields by 22.4 (35.1%) and 19.7 (38.5%) bushels per acre. Applying N at R1, R3, or R5 produced modest yield increases, which were significant (compared to the untreated check) only in 2016. Repeated applications did not significantly improve yield compared to an application at planting. In 2016 we included several other planting-time N rates. We saw a response curve similar to corn (Figure 4). Using the soybean price of $10 per bushel and a cost of $.50 per lb. of N, the optimum N rate was 88 lb. N per acre. For 2017, we extended the rate up to 138 lb. N to further test the upper limits of soybean N response and consistency. Remember, responses to N across studies are likely to be small or none than to be large enough to pay for the N application. The response to N applied at planting is also unexpected, given that planting-time N is considered to inhibit the formation and activity of N-fixing nodules and in instances reduce yield.

Figure 4. Soybean response to nitrogen rates applied in the form of urea at planting on loam soil with less than 2% organic matter in 2016.
Broomcorn in Illinois
In an age of plastic brooms and even automated vacuums like the Roomba, interest remains high in biodegradable fibers for all-natural broom construction. Broomcorn (Sorghum vulgare var. technicum) is a type of sorghum specifically chosen for its utility in the broom-making industry. Originally introduced to the U.S. by Benjamin Franklin, by the 1860s Central Illinois was the leading broomcorn producing area. However, acreage moved to Mexico in the mid 20th century because of the possibility for year-round production and traditional broomcorn varieties were not well suited for mechanical harvesting. The Nolan Broomcorn Trust continues to support a broomcorn breeding program at Illinois, which aims to develop new varieties for local production.

Traditional Breeding
Broomcorn improvement at the University of Illinois over the past forty years has relied heavily on field breeding for desired harvest and broom quality traits. Ideal broomcorn lines (Figure 5) have an extended panicle with the seed set congregated at the very end of the panicle. The branches of begin at the top node of the stem with minimal fusing of the central branches. After harvesting the seed is removed and the panicle straw woven into brooms. The microhairs on the end of the straw act to capture dust particles while the thicker portion of the panicle provides support for the broom. Broomcorn breeding by trait selection has resulted in varieties with these traits for quality broom construction, but also for decorative purposes and biomass production (Figure 6).

Molecular Breeding
The origins and genetic relatedness among available broomcorn varieties are poorly understood. Recent advancements in low cost genotyping technologies have enabled gene discovery and molecular breeding in broomcorn. Analysis of molecular markers assessed the genetic differentiation of the broomcorn sorghum types compared to traditional sweet and grain sorghum lines. Additionally, a genome-wide survey was used to identify molecular markers and associated genes that contribute to the variation observed in the broom quality and agronomic traits. This new information is being used to accelerate broomcorn improvement.

Figure 5. The broomcorn collection includes single gene mutations that result in multi-purpose varieties, including this high biomass dwarf mutant.

Figure 6. Broomcorn lines developed at the University of Illinois for mechanical harvesting and quality broom construction.
Operator and Management Returns
Per acre operator and land return is the measure of return used in this study. Operator and land return equals gross revenue minus non-land costs and is the return before paying for farmland. Figure 7 shows operator and land average returns for the McLean County grain farms. The average operator and land return from 1995 to 2003 was $160 per acre. From 2004 to 2006, operator and land return increased and averaged $208 per acre. Then, higher returns occurred in most years from 2007 to 2013. From 2007 to 2013, operator and land return averaged $395 per acre. Since 2012, operator and land returns have trended downward, with the 2015 operator and land return averaging $184 per acre. All farms, no matter their relative profitability face the return variability depicted in Figure 7.

Differences in Returns Over Time
To illustrate profitability differences, farms were placed in three profitability groups based on operator and land return for the three-year period from 2009 to 2011. The three groups represent farms with the highest one-third of returns, the mid one-third had middle one-third returns, and the low one-third had the lowest third of returns.

Returns were tracked for these three profitability groups from 2012 to 2015 (Figure 8). Note, average returns for the three groups continued to differ after the averaging period. In 2015, the high group based on the 2009-11 ranking had an average return of $224 per acre, the mid group had $207 per acre, and the low group had $164 per acre. In 2015, operator and land return differed by $17 per acre for the high group and the mid group. The difference was $60 per acre between the high and the low group.

Factors Causing Differences in Returns
Farms in the high group differed from farms in the mid group in three ways. First, farms with higher profitability had lower machinery depreciation and interest costs. Second, farms in the high group had slightly higher soybean yields than farms in the low group. Third, farms in the high group got slightly higher soybean yields than the remainder to the farms. Costs control while obtaining excellent yields is key to profitability in grain farming.

The Illinois Soybean Association funded this research and the analysis was conducted using Illinois Farm Business Farm Management (FBFM).
Soil Texture Analysis
Soil texture is an important soil property, contributing to many aspects of soil performance, ranging from productivity to ease of tillage. Currently, a textural analysis is either estimated in the field with limited accuracy or analyzed in a laboratory setting through a time consuming and labor intensive process.

New Soil Texture Analysis Methods
This study outlines the development of a new system for in-situ soil textural analysis using an automated cone penetrometer outfitted with a microphone, where the resulting sound produced from the cone-soil interface is used to determine soil texture (Figure 9). The system was tested in a laboratory setting using soil samples with well-defined textural compositions.

Results
Correlations between the textural breakdown of the samples and the power for certain frequency ranges were made. The prediction model for clay had an adjusted $R^2$ of 0.950, while the models for silt and sand had lower adjusted $R^2$ values.

Future Research
Future research should look into the effects of soil moisture content, bulk density, and organic matter content of the acoustic signal (Figure 10).

Figure 9. Here an overview is shown of the Acoustic Cone Penetrometer (ACPT). The machine records insertion force (from a load cell), insertion torque (from the pressure/flow into the hydraulic motor) as well as acoustic data from an embedded microphone.

Figure 10. Locations in the soil textural triangle where the acoustic cone penetrometer was tested. The plan is to scout various locations in Illinois in an attempt to cover most of the triangle.
Insect populations vary year to year, but a mild winter had many people wondering if there would be more insects to contend with in 2017.

**Pest Trends in Early 2017**

Impressive black cutworm and true armyworm moth flights kept our monitoring network cooperators busy this spring (Figure 11). Large trap catches and repeated significant flights translated into increasing reports of black cutworm feeding as well as true armyworm reports in wheat. Summer pheromone trapping targets corn earworm, European corn borer, fall armyworm and western bean cutworm. These ear-feeders of corn always come up in conversation during the fall when ear injury is reported, but unfortunately, the culprit is long gone. Monitoring and scouting in-season helps identify the target(s). A mild winter will also favor Japanese beetles

![Figure 11. Black cutworm flights were once again large in 2017 with many locations seeing repeated significant flights. Using degree-days in conjunction with trapping, potential cutting dates can be calculated to let producers known when scouting should occur.](image)

**Survey Results**

Based on degree-day accumulations, corn rootworm hatch is underway. Populations have been low the past couple of years. That, coupled with a wet spring, could continue to keep those populations at low levels. Statewide summer surveys in corn and soybeans will not only indicate rootworm population levels, but also Japanese beetles, stink bugs, and other soybean pests (Figure 12).

![Figure 12. Soybean sweep samples give us an indications of different pest populations around the state.](image)
Rootworms and Resistance
The western corn rootworm (WCR) (Figure 13) is the most significant pest of U.S. corn production. The 2003 commercialization of the first Bt corn hybrids for corn rootworm revolutionized rootworm management. In Illinois and neighboring states, it provided a solution to crop rotation-resistant WCR that devastated corn fields beginning in 1995.

Figure 13. Female western corn rootworm beetle.

The first evidence of WCR resistance to Bt corn was found in Iowa in 2009 and reported in 2011. Reports of confirmed WCR resistance in continuous corn from western, northern and central Illinois followed in 2011 and 2012. In 2013 and 2014, University of Illinois (U of I) scientists documented Bt resistance to multiple Bt traits in rotated Bt corn in east-central Illinois and reduced susceptibility to Bt at multiple locations on U of I farmland. The current Illinois Bt resistance situation mirrors that in neighboring states where reports of reduced efficacy of Bt traits expressed in single-trait Bt hybrids are well documented and likely commonplace.

Are Low Population Trends Continuing?
Efforts to study resistance through on-farm research were hindered by low WCR populations due to wet soil conditions in 2015. Though WCR larval pressure was practically nonexistent in growers’ fields in 2015 and 2016, bioassays on populations that were concentrated by late-planting indicate that resistance is present where low-density populations of WCR beetles could be found. While the presence of WCR resistance to a particular Bt trait(s) in the local WCR population is an important consideration when developing a rootworm management strategy that may use a Bt hybrid, if that population’s abundance is far below any economic threshold, there is no economic justification to treat it.

Urbana, IL data on adult WCR abundance in rotated soybeans from 1998-2016 document rising and falling WCR threats to rotated corn (Figure 14) and remind us how much has changed since commercialized Bt corn. WCR populations began declining steadily in the years after rootworm Bt corn hybrids were first available. In recent years, we saw populations that are a fraction of those a decade ago. Beyond the immediate economic costs of management, the cost of resistance in the future is also not negligible.

Management Tactics
Deploying Bt corn hybrids against low WCR populations that may be in the process of developing resistance will unnecessarily expose those populations to additional selection for resistance. Years when low rootworm pressure is predicted present ideal opportunities to plant a non-Bt hybrid (perhaps with a soil insecticide) and relax the selection for Bt resistance. Adoption of an IPM-based approach to corn rootworm management that includes the use of scouting, thresholds, and rotation of tactics/modes of action is the best management practice if we wish to preserve the future utility of rootworm management technology.

1998-2016 Western corn rootworm (WCR) abundance in rotated soybean fields in Urbana, IL.

Figure 14. Mean WCR beetles/sweep in Urbana, IL soybean fields (+SE) from 1998-2016. Peak monthly mean collection rate is shown in red.
Start Early
Waterhemp is one of the most problematic weeds in Illinois agricultural production. With its extended emergence pattern and ability to produce thousands of seeds per plant, waterhemp infestations can occur quickly if proper control measures are not taken. In corn production, early season competition has the largest effect on yield, with the potential for up to 50% yield losses. Utilizing preemergence (PRE) herbicides, such as the acetamides, dinitroanilines, PSII inhibitors, PPO inhibitors, and HPPD inhibitors to provide residual weed control during early crop establishment is advantageous in limiting crop-weed competition and reducing the overall number of plants needed to be controlled by postemergence (POST) programs in corn, sorghum, and soybean.

‘Old’ Chemistries Today
Current research is being conducted by our group with a multiple herbicide-resistant waterhemp population from Champaign County (called CHR) that exhibits resistance to HPPD inhibitors, atrazine, and synthetic auxin herbicides such as 2,4-D. The CHR population, along with another multiple-resistant waterhemp population from McLean County (MCR), demonstrated variable levels of control with different acetamide herbicides PRE (Figure 15). Recent greenhouse and field experiments have explored this finding in more detail to determine whether or not the observed differential responses could be replicated. Resistance to PRE acetamide herbicides is extremely rare considering they have been widely used since the 1950s. To date only five grass species are confirmed resistant, allowing acetamide herbicides to remain effective in today’s predominantly POST world.

Understanding Resistance Mechanisms
Resistance to herbicides from six sites of action (SoA) has been documented in Illinois waterhemp. Populations on most farms are resistant to at least one SoA. We identified a portion of a glutathione S-transferase (GST) gene of which elevated expression correlates with metabolic atrazine resistance. This GST gene can be used as a molecular marker to screen resistant waterhemp populations. As technology in industry advances, knocking out this GST gene could potentially reverse atrazine resistance and make plants susceptible to the herbicide once again.

Summary
The lower frequency of populations resistant to PRE residual herbicides, paired with the ability of these herbicides to reduce weed populations, make PRE programs an effective component of an integrated weed management system. The goal is to ensure the success of POST applications and preserve yield. Research conducted at the University of Illinois is important in understanding when and how resistance occurs in an effort to provide insight for the agricultural industry as a whole to combat pests and optimize crop yield.
White mold, also called Sclerotinia stem rot, can produce significant yield losses in soybean during years when weather conditions are cool and humid during flowering. In epidemic years, yield losses from white mold can approach 50%. The disease is caused by the fungus Sclerotinia sclerotiorum, which can survive in the soil for up to 10 years as sclerotia until environmental conditions are favorable.

Management Options
Agronomic practices that produce open canopies reduce risks for white mold, but also reduce yields. Some fungicides are labeled for white mold control but add to production costs. The use of white-mold resistant soybean varieties is the most economical control method. However, only partial resistance to Sclerotinia stem rot was identified in soybean.

Soybean’s Wild Relatives
Soybean has 26 species of wild perennial relatives that are native to Australia. All are viny plants and produce small black seed (Figure 16).

In contrast to soybean, they show much wider ranges of responses to infection by S. sclerotiorum. While most perennial accessions, like most soybean varieties, are severely affected by white mold, a small number of accessions show high levels of resistance even after multiple inoculations with the fungus (Figure 17). Wild perennial relatives of soybean also have genes for enhanced yields and resistance to brown spot, soybean cyst nematode, and soybean rust. Because of the difficulty of producing fertile hybrid plants between soybean and its perennial relatives, those useful genes have been virtually untapped. The objective of this study is to map and characterize genes for resistance to white mold in the wild perennial species Glycinia latifolia so that they can be moved into cultivated soybean.

Figure 16. Perennial relative of soybean Glycinia latifolia. (B) Soybean seed. (C) Glycinia latifolia seed.

Figure 17. Lesion lengths on stems of resistant (PI 559298) and susceptible (PI 559300) Glycinia latifolia accessions.
Soybean Cyst Nematode Gets All the Headlines

The soybean cyst nematode (SCN) is considered the most important pest of soybeans in the U.S. However, SCN does not infect grasses including corn and wheat. In fact, rotation out of soybeans is essential for preventing an explosion of SCN. Since SCN does not infect grasses, does that mean that we don’t have to worry about nematodes on corn? No! There are thousands of nematode species, many of which are parasitic on corn.

“Corn Nematodes” Don’t Just Eat Corn

Occasionally, news articles and advertisements will talk about “corn nematodes.” This term provides a useful distinction from SCN, which never feeds on corn. However, many nematodes that feed on corn are also capable of feeding on and causing damage to soybeans (Figure 18). For example, lesion nematodes can reduce yields of soybeans by over 40%. In Brazil, lesion nematodes are considered more damaging to soybeans than SCN.

“Corn Nematodes” are Small and Difficult to Identify

Many growers have learned how to spot the small SCN cysts hanging onto infected soybean roots. However, the “corn nematodes” are smaller than SCN and only visible with a microscope. Therefore, field-based diagnosis of “corn nematodes” is impossible. The only way to diagnose a problem with these nematodes is through soil sampling followed by microscope identification. Unfortunately, the process for extracting “corn nematodes” does not use the same methods as used for SCN. Sampling for SCN will not tell you about the “corn nematode” population. Also, “corn nematodes” comprise a large and diverse group of different nematode species. Identification of “corn nematodes” requires extensive training. Few labs are equipped to handle this assay.

OK, Corn Nematodes are Important, What Do I Do?

Unfortunately, research on this large group of nematodes has lagged behind SCN. If you think you have an issue with “corn nematodes” you have a few options. The first step is to determine which species are the most problematic. For some species, crop rotation is a viable alternative to reduce nematode populations. There are several commercially available seed coats for corn with activity against nematodes. Finally, the use of cover crops and green manures are being investigated as a possible control strategy for these nematodes.

Figure 18. The lesion nematode, Pratylenchus penetrans, is a common parasitic nematode of both corn and soybeans in Illinois.
Water is essential for plant growth and is thus closely connected to yield performance. Fresh water is a limited natural resource, and the vast majority of corn acreage planted in the United States is rainfed. Increasing transpiration efficiency (i.e. reducing the amount of water lost through the leaves) would not only allow crops to grow in drier regions, but would also enable plants to better survive short periods of drought by making better use of the water available in the soil. This strategy is effective regardless of the timing of the drought. In the Midwest, water stress is often limited to short dry periods between rain showers. However, if these dry periods, or a drought, occur during one of the several critical points in development, there can be serious yield consequences. The Studer Lab investigates plant traits that have the potential to impact water-use efficiency in corn. Projects in the lab study the relationship between transpiration efficiency and plant architecture, leaf area, leaf number, stomatal response, and biochemical aspects of photosynthesis.

**Water-use Efficiency Under Well-watered Conditions**

Currently, water limitations exist for agricultural crops, and will become a greater issue over the next several decades due to global climate change. Therefore, crops need to be developed that yield the same (or even more) when challenged with unpredictable periods of drought. While many strategies focus on breeding drought tolerant lines of corn by selecting for performance under drought conditions, an alternative strategy is to improve water use under well-watered conditions. The Studer lab has generated data that shows corn plants grown under well-watered conditions (100% field capacity) produce the same biomass as plants grown in drier soil (80% field capacity), but the well-watered plants transpire ~10% more water (Figure 19).

This data suggests that corn is not optimized for transpiration efficiency under well-watered conditions. Our future research will use precise systems for monitoring daily transpiration from diverse corn lines to determine genetic variation in transpiration efficiency under different soil water conditions. The goal of this project is to identify lines that have superior transpiration efficiency even under well-watered conditions. Furthermore, we are also interested in understanding the genes underlying this trait, which will provide insight into the mechanisms that modulate transpiration efficiency. A 10% reduction in transpirational water loss under well-watered conditions would generate significant water savings, and conserve soil moisture that could be used during periods of drought.
Tile drainage networks significantly underpin agriculture across the US Midwest with Illinois alone possessing more than 9.7 million tilled acres. There is, however, concern about pollutants moving through these systems. One specific water quality concern is nitrate, a form of nitrogen that moves readily through the soil and is often present in clear drainage waters. While in-field practices such as 4Rs nitrogen management and cover crops will be vital to meeting Illinois Nutrient Loss Reduction Strategy water quality goals, as substantial investments in drainage systems continue to be made, edge-of-field practices like woodchip bioreactors will also be a necessary part of the solution.

A denitrifying woodchip bioreactor is made by routing drainage water through a buried trench filled with woodchips (Figure 20). A bioreactor works by taking advantage of the natural process of denitrification, the conversion of nitrate in the soil or drainage water to benign nitrogen gas. This process is carried out by bacteria living in soils all over the world and also inside bioreactors. These good bacteria, called denitrifiers, use the carbon in the woodchips as their food and use the nitrate in the drainage water as part of their respiration process. Providing these denitrifiers an ample supply of carbon to eat and giving them anaerobic conditions in the bioreactor offers them a perfect environment to remove nitrate from drainage. The fact that bioreactors work due to this biological process is why they’re called “bio-reactors.”

Two control structures are important parts of the bioreactor design, and each structure plays a different role. The inflow control structure is responsible for routing water into the bioreactor and for allowing excessive water to by-pass the bioreactor during high flow events. The outflow control structure helps to retain water in the bioreactor, so the water remains in the bioreactor long enough for the bacteria to have time to remove nitrate from the water before it leaves. Woodchip bioreactors are designed to treat drainage water from approximately 30-80 acres, last approximately 7-15 years, and generally, cost around $10,000 to construct. Bioreactors reduce the amount of nitrate leaving a field by 25-45%.
Most questions in the initial stage of agricultural drone usage revolved around the legal and hardware issues. We now have the official word from the FAA on commercial drone use. Over 30,000 drone pilots are now registered under the FAA Part 107 regulations. Additionally, the exemption and waiver system is operational.

Reliability, ease of flight, battery life and operational distance questions are well understood and documented for the major systems targeted for agricultural use. Drones are becoming “small sky tractors,” power supplying tools that pull an implement into the sky to do work.

The focus now shifts toward the automation software, the sensors collecting the data and the software analyzing the data. The integration of these three segments is the key to successful integration of drones into agricultural decision making.

Sensors

Many of the first drones used GoPro cameras. These were great for light-weight, wide field of view and high resolution. But they were also bad for lens distortion issues. Many drones still use visible light (RGB) cameras. They are relatively cheap with high resolution to cost ratio. Also, lenses have been improved to remove distortion.

Aerial imagery with RGB cameras allows farmers and agronomists to get the “birds-eye” view of the field. Often identifying patterns not apparent from the ground. However, after canopy closure corn and soybean fields often show only varying shades of green in RGB imagery.

NASA pioneered the use of NIR (near-infrared) sensors using wavelengths just beyond the visible spectrum. Healthy plants reflect most NIR light while absorbing most red light. Stressed plants will reflect less NIR and absorb less red light. Creating an image based upon the ratio of NIR to red light is the basis for NDVI (Normalized Differential Vegetative Index) images that allow us to visualize something not visible to the human eye (Figure 21).

Figure 21: Three images of a cover crop and herbicide residue interaction study. Different cover crops species planted in vertical strips. Several different herbicides were applied in horizontal strips to the previous soybean crop.
The Seven Wonders of the Corn Yield World was developed ten years ago as a tool to teach farmers and agricultural professionals the value of their individual crop management decisions. It ranks the top seven factors that can positively impact corn yields and assigns a bushel per acre value to each wonder (Figure 22). I revisit it here talking about what we learned using this concept.

**Defining a Wonder**
Some practices are important, but are not considered as yield wonders because they are either one-time improvements (tile drainage), they protect rather than increase yield (weed and pest control), or they involve decisions that don’t need to be made every year (soil pH and nutrient levels). One nuance of the seven wonders is that they interact with each other to either magnify or lessen a wonder’s impact on yield. Understanding a wonder’s ranking, and its interaction with other wonders gives farmers an opportunity to increase yields through better crop management.

**The Seven Wonders of Corn Yield**
Weather and nitrogen (N) availability are the two factors that normally have the greatest impact on corn yields. Hybrid selection is probably the most important decision farmers make each year, and most don’t realize the large difference in yield potential among elite commercial hybrids. Hybrids respond differently to growing conditions and crop management, with some tolerating low N conditions, cultivation under continuous corn, or higher planting densities better than others. Continuous corn has a yield penalty due to residue accumulation while increasing plant population (plants per unit area) is one of the management factors that has changed the most in the last 55 years (Figure 23). Plant populations will continue to increase to grow high corn yields, and narrow rows are one way to manage a higher population of plants. The last two wonders, tillage and plant growth regulators, markedly interact with all the factors mentioned above in affecting yield, either positively or negatively. The latter is a catchall group, including compounds that stimulate plant growth, such as foliar fungicides and in-furrow mixes, which can be combined to power greater yields.

**Next Up**
Recently, we’ve taken a closer look at the management factors under our control. The next stops on the tour will give you the latest updates on what happens to corn yield with changes in soil fertility, crop rotation, and plant population.
Soil Test P and Yields

The current Illinois critical level for soil P is 20-25 ppm depending on the region, indicating that any soil test levels greater than these should not produce a response from added P fertilizer. Across the 40 corn and soybean environments (74% of all environments) that were above the Illinois current P critical level, banded MicroEssentials SZ increased yield at these sites by an average of 5.5% for corn, and 5.2% in soybean (Figure 24). Regardless of the soil test level, banded P applications increased corn yield by 11.4 bushels per acre (6.1%) and 3.6 bushels (5.4%) for soybean. Neither corn nor soybean yield responses from spring banded MicroEssentials could be adequately predicted with the current P soil test recommendations. (Figure 25).

Summary

Soil testing is a valuable tool for phosphorus management. Increasing environmental concerns dictate alternative technologies of applying fertilizers to decrease nutrient loss and promote fertilizer efficiency. Soils testing below critical P levels should be corrected; however, greater yields can be obtained on soils testing above the critical levels using fertilizer in conjunction with best management practices.

Field Set-Up

Twenty-two corn and 32 soybean evaluations were conducted across Illinois to determine the response from a premium P-based fertilizer, MicroEssentials SZ (12-40-0-10S-1Zn). Soil samples were taken at a depth of 0-6 inches before planting for each evaluation and analyzed using the Mehlich III extraction method. Using 4R nutrient stewardship (right source, rate, time and place), fertilizer applications were estimated based on nutritional needs of high yields of both crops. MicroEssentials SZ was banded 6 inches directly under the crop row in the spring before planting using RTK tractor guidance at rates of 100 and 75 lbs P2O5 per acre for corn and soybean, respectively and compared to unfertilized control plots. Corn was grown in 30-inch rows and soybean was grown, and data averaged across 30 and 20-inch rows, using multiple elite commercial varieties of both crops in each environment.

Figure 24 Yield changes due to banded P fertilizer compared to unfertilized plots arranged by response magnitude over 22 evaluations for corn, and 32 for soybean.

Figure 25. Magnitude of corn and soybean yield response from banded P fertilizer compared to unfertilized plots as affected by soil test P level.
Accelerated residue degradation and nutrient cycling is necessary to maximize yield potential in corn grown continuously, in addition to other high volume residue situations such as increased planting densities, crops that annually produce greater than average yields, and reduced or no tillage. Grain yields of continuously grown corn are generally less than when corn is rotated with soybean, denoted as the continuous corn yield penalty (CCYP). The objective of this study was to test if residue management and agronomic inputs could reduce the CCYP.

Field Arena Layout
At Urbana, IL in 2015-2017, 15th-year continuous corn was compared to a long-term corn - soybean rotation (Figure 26). The previous year’s corn crop was harvested with either a combine head equipped with Calmer’s BT Chopper stalk rollers or with standard knife rollers, and both mechanical residue treatments were managed chemically with Extract Powered by Accomplish (Extract PBA), or with ammonium sulfate (AMS), and compared to an untreated control (Figure 27). In combination with rotation and residue, a standard management system was seeded to achieve a final stand of 32,000 plants/acre and received a base rate of nitrogen fertilizer only, while an intensive management system was seeded at 45,000 plants/acre and included additional sidedressed nitrogen fertilizer, broadcast and banded fertility, and a foliar fungicide application.

Management vs. Yield
From fall harvest to spring planting, residue was reduced by 52% when chopped vs. only 45% from standard knife rollers. In addition to chopping, Extract PBA boosted residue decay by 9% while AMS by 12% over the standard stalk rollers with no chemical control.

The continuous corn rotation led to less seedling emergence during the first five days compared to the corn-soybean rotation. The intensive management system led to 2.4 times the biomass accumulation at the V6 growth stage over the standard system, leading to a CCYP reduction of 69%. There was a 20% greater yield response to intensive inputs in continuous corn vs. the corn-soybean rotation (increases of 43 vs. 36 bu/acre, respectively). Regardless of input level, continuous corn grown after standard mechanical residue management tended to increase yield after fall chemical applications of AMS (3 bu/acre) or Extract (7 bu/acre) compared to the untreated chemical control.

1, 2, 3 Punch!
With an additional 7-12% of the residue degraded from the mechanical chopping and chemical applications, more nutrients could be released and readily accessible to the current crop to synchronize with crop needs. Add on sensible population, fertility, and fungicide decisions – and the CCYP was knocked down by 69% in this study, leading to greater yields in continuous corn.
Corn yields have increased significantly since the 1930s largely due to genetic improvement and better crop management. Grain yield is the product of the number of plants per acre, kernels per plant, and weight per kernel. The average U.S. corn planting density has increased 400 plants per acre per year since the 1960s. As this trend continues, narrow row spacings can be used to increase the distance between plants within a row and provide greater plant spacing across a given area. Better plant spacing provides the opportunity to capture more sunlight and increase photosynthetic potential.

**Plant Density Changes**

In 2016, eight commercial DeKalb hybrids were planted at 32,000, 38,000, and 44,000 plants per acre in a 30” row spacing and at 38,000, 44,000, and 50,000 plants per acre in a 20” row spacing. Canopy coverage was 7% greater in the narrower row spacing compared to the wider row spacing at the V8 growth stage (Figure 28). Tillering is an indication of the environment and the space around a corn plant. Better growing conditions and greater plant spacing results in tillering. The percent of plants with tillers ranged from 2% at 44,000 plants per acre in a 30” row spacing to 39% at 38,000 plants per acre in a 20” row spacing. At the R2 growth stage, leaf area per plant significantly decreased as planting density increased for both row spacings. However, when expressed on a land area basis, leaf area index was greater at the higher planting densities but unrelated to row spacing. In contrast, when averaged across hybrids, root weight per plant decreased as planting density increased but tended to be greater in the narrower row spacing. Plants with smaller root systems could devote more energy to yield, but need to be better managed, especially with fertility (Figure 29). Corn grain yield, when averaged across all hybrids, significantly increased as planting density increased at a given row spacing. The narrower row spacing yielded 6 bu per acre greater at a given planting density compared to the wider row spacing. Planting 50,000 plants per acre in a 20” row spacing achieved the greatest yield of 289 bu per acre. When comparing a standard management practice (32,000 plants per acre in a 30” row spacing) to a progressive management practice (50,000 plants per acre in a 20” row spacing), the latter gave a 44 bu per acre boost with DKC64-87, and 19 bu per acre with DKC62-08.

**Summary**

Selecting a hybrid with greater yields at the higher densities and narrower rows is critical to earning a positive return given the additional seed costs.
By 2050 the population is likely to exceed 9 billion people—who will require over 70% more food than we are able to produce today, according to the Food and Agriculture Organization. Farmers will also be tasked with growing bioenergy feedstock to sustainably offset our national fossil fuel consumption. Today we are engineering solutions to meet the agricultural demands of the future.

**Meet your Robotic Crop Scout**

You don’t have to trek through your fields in the heat of summer any longer thanks to TERRA-MEPP, a robotic crop scout developed by Girish Chowdhary and Chinmay Soman. Each iteration is brought to life by a 3D printer to facilitate rapid testing and optimization. The autonomous robot is currently geared towards crop breeders; it identifies the top producing plants in the field, pinpointing the genes for desirable traits. TERRA-MEPP measures plant height, stem width, leaf area and other critical features of thousands of plants with a suite of high-tech sensors and custom-developed algorithms. Use this low-cost, autonomous robot to keep tabs on your fields' germination, stand counts, and development throughout the growing season (Figure 30).

**Bypassing Photosynthetic Inefficiency**

Production is on track to fall short of our predicted 2050 needs—yields are increasing by just one to two percent each year. To increase yield, Don Ort’s research group is engineering plant interstates that bypass a problematic plant process. Photorespiration produces a plant-toxic compound that must be recycled, costing the plant energy and yield. Plants with a “photorespiratory bypass” yield as much as 20% more (Figure 31).

This work is funded by Realizing Increased Photosynthetic Efficiency (RIPE, an international research project funded by the Bill & Melinda Gates Foundation to sustainably increase food production, particularly for smallholder farmers in Sub-Saharan Africa and Southeast Asia).
What is Agroforestry?
The USDA defines agroforestry as “The intentional integration of trees and shrubs into crop and animal farming systems to create environmental, economic, and social benefits.” Studies show that agroforestry can benefit the landowner, by diversifying income sources and providing recreational opportunities. The implications for environmental health may be even greater, as agroforestry can build soil structure, improve water quality, provide wildlife habitat, and sequester carbon. Agroforestry can be integrated into farms through the following practices:
- Alley cropping – trees planted in rows with crops in the alleyways between
- Riparian buffers – trees and shrubs planted along the border of a waterway
- Windbreaks – vegetative barriers to protect livestock, crops, or homesteads from the wind
- Silvopasture – trees planted in a grazing pasture to provide shelter and food for livestock
- Forest Farming – production of shade-tolerant crops (e.g., mushrooms, herbs) in a forest

Agroforestry can Contribute to Food Security
While agroforestry exists in combination with crops, the systems are rarely designed so that the trees themselves provide harvestable products. This is a missed opportunity! Many trees and shrubs that grow well in the Midwest can provide an added benefit of fruit or nut products. In fact, these species can be planted together in a single row for improved productivity and environmental benefits (Figure 32). Faster-growing understory crops such as berries, hay, and vegetables can provide income while slower growing overstory trees mature to produce fruits and nuts. Together, the mixed system reduces space while diversifying a farmer’s products.

Multifunctional Woody Polyculture (MWP) Trial
The MWP is a 30-acre research site consisting of over 12,000 woody plants, established in 2015. The experiment includes four replications of seven treatments, ranging from simple monocultures to diverse species mixes. We are comparing a variety of systems that yield multiple food and fuel products including fruits and nuts. Woody species included in the trial are Chinese chestnut, black currant, hazelnut, apple, Juneberry, aronia, elderberry, pecan, persimmon, and plum (Figure 33). In the coming years, we will study the performance of these different treatments based on yields, profitability, and a wide range of environmental benefits.
Enhanced Weathering
In enhanced weathering the natural capture of CO₂ during rock weathering is accelerated by applying ground silicate rocks (basalt) to agricultural soils. Temperature, moisture, microbial activity, and plant root exudates combine to decompose the parent rock material and result in the formation of calcium and magnesium bicarbonates, which raise soil pH and shift atmospheric carbon to the hydrosphere, where it can be transported downstream and ultimately sequestered as carbonates in the sea floor (Figure 34).

Combating Atmospheric CO₂ from Ground Level
We are investigating enhanced weathering in agricultural soils as a method to combat rising atmospheric carbon while benefiting agricultural production. Terrestrial ecosystems play an important role in regulating the exchange of greenhouse gases between the land surface and the atmosphere. Intensive agriculture contributes ~14% of annual global greenhouse gas emissions, and management practices have enormous potential to alter this exchange.

At the Energy Farm we are testing the scope and feasibility of enhanced weathering in both conventional and cellulosic bioenergy crops. We have applied 5 T/ha of finely ground basalt to research plots across the Energy Farm, tilled into corn/soy fields and surface-applied to miscanthus plots. Conventional bioenergy crops (corn and soybeans) raised for food and fuel represent the dominant ecosystem of the Midwestern United States, with over 90M acres of land devoted to their production. Cellulosic bioenergy crops including perennial miscanthus are a growing percentage of US land area, and have been identified as important agents of soil carbon conservation.

Applying the Science
Finely ground basalt is applied using fertilizer or limestone spreading equipment and incorporated into conventional bioenergy crop plots during normal tillage operations (Figure 35). Basalt in cellulosic bioenergy plots is surface-applied. Basalt supplies silica, calcium, and magnesium, and has the potential to raise soil pH, a benefit to soils where nitrogen fertilizers are regularly applied. We monitor soil biogeochemistry, soil water chemistry, soil respiration, eddy covariance, and plant tissue chemistry and biomass measurements to monitor weathering rates and effects on soil and crops. This research project is part of the Leverhulme Centre for Climate Change Mitigation (lc3m.org) at the University of Sheffield, Sheffield, UK.

Figure 34. A simplified weathering cycle for soil-applied basalt.

Figure 35. Basalt application with a conventional lime spreader in late 2016.
Started in March 2017, homegrown perennial grasses replaced propane as the primary heat source for the Illinois Energy Farm’s main research greenhouse. A state-of-the-art Heizomat biomass boiler (675,000 BTU/hour rated) produced in Germany is turning biomass into hot water distributed across the research complex as the primary energy source for heating (Figure 36).

**Reduced Greenhouse Gas Emissions**

On average, the main greenhouse at the Energy Farm consumes 8,000 gallons of propane per heating season. Switching to biomass heating enables the Energy Farm to reduce its annual carbon release by ~60 tons just from replacing propane. In addition, the biomass grown in the summer sequesters carbon below ground. Plans for life cycle analysis (LCA) research projects will allow for a detailed carbon budget of the farm to fuel model (Figure 37).

**Learning Experiences for All**

The Energy Farm Biomass Boiler Research and Education Facility will:

- Demonstrate the feasibility of using non-densified energy grasses as a source for renewable energy generation on campus.
- Engage and familiarize campus utilities personnel with the design, installation, and operation of such systems with a view to accelerate the adoption of renewable energy production on campus.
- Provide a research tool that can leverage future technology to further build upon the low-carbon heating system. The boiler room is designed with a spare “bay” for future expansion.
- Support the education and training of students, power plant operator, and the community on renewable feedstock energy production.

This project was made possible by the generous financial support of the Illinois Clean Energy Community Foundation and the University of Illinois Student Sustainability Committee. Additional funding was provided by the University of Illinois Dudley Smith Initiative, the sale of campus carbon credits, and the Facilities & Services Revolving Loan Fund.
# UNDER THE BIG TENT

## TENT DISPLAYS

<table>
<thead>
<tr>
<th>ACES Office of Research</th>
<th>PubsPlus</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACES News &amp; Public Affairs</td>
<td>RIPE Project</td>
</tr>
<tr>
<td>AgriAbility Unlimited</td>
<td>Soil &amp; Water Conservation Society</td>
</tr>
<tr>
<td>Department of Crop Sciences</td>
<td>SoyFACE</td>
</tr>
<tr>
<td>Department of NRES</td>
<td>Sustainable Student Farm</td>
</tr>
<tr>
<td>farmdoc &amp; FAST Tools</td>
<td>TERRA-MEPP</td>
</tr>
<tr>
<td>Field and Furrow Club</td>
<td>USDA/ARS</td>
</tr>
<tr>
<td>Illinois FBFM Association</td>
<td>WEST Project</td>
</tr>
<tr>
<td>Illinois NREC</td>
<td></td>
</tr>
<tr>
<td>PETROSS</td>
<td></td>
</tr>
</tbody>
</table>

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