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Wisconsin Agri-Business Association

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Appreciation is expressed to the Wisconsin fertilizer industry for the support provided through the Wisconsin Fertilizer Research Fund for research conducted by faculty within the University of Wisconsin System.

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2017 Wisconsin Agri-Business Association Distinguished Service Awards

Distinguished Organization Award
Ag Systems Inc.
{For Exemplary Industry Professionalism}

Education Award
Bryan Jensen, UW-Extension and IPM Program
{For Leadership & Commitment to Educational Excellence}

Outstanding Service to Industry
Sandra Smith-Loomans, Research Assistant to Rep. Lee Nerison
{F*or Dedication & Support to WABA and Its Members}*

Friend of WABA Award
Senator Howard Marklein

President's Service Award
Joey Kennicker, Greg's Feed & Seed, Inc.
{For Dedication, Service, & Leadership}

2017 – 2018
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Wisconsin Crop Production Association Scholarships

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Mike Turner Memorial Scholarship

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Jordan Schultz
Fox Valley Technical College

Wisconsin FFA Foundation

Taylor Eilers
Beth Zimmer
Collin Weltzien
Ashley Zimmerman

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ECONOMICS/MANURE AND HUMAN HEALTH

NITROGEN USE EFFICIENCY IN WISCONSIN

Matt Ruark, Abby Augarten, Eric Cooley, Kevan Klingberg, Todd Prill,
Aaron Pape, and Amber Radatz [1/]

Introduction

Calculating nitrogen use efficiency (NUE) on a field-by-field basis can be a valuable tool for assessing N management on a farm. There are four key ways to evaluate nitrogen: Partial Factor Productivity (PFP), Agronomic Efficiency (AE), Partial Nutrient Balance (PNB), and Recovery (or Uptake) Efficiency (RE). Table 1 provides calculations and interpretations.

Table 1. Definitions and calculations for four nitrogen use efficiency measurements.

Partial Factor Productivity (PFP): Is this cropping system productive in comparison to nitrogen application? $\textbf{PFP} = \frac{\text{Yield}}{\text{Amount of Nitrogen Applied}}$ Higher PFP= more efficient use of nitrogen
Agronomic Efficiency (AE): Did fertilizer improve productivity? $\textbf{AE} = \frac{\text{Yield-Yield with no applied nitrogen}}{\text{Amount of Nitrogen Applied}}$ Higher AE= more efficient use of nutrients
Partial Nutrient Balance (PNB): How much nitrogen is being taken out of the system in comparision to how much is applied? $\text{PNB} = \frac{\text{Nitrogen content of harvested portion of crop}}{\text{Amount of Nitrogen Applied}}$ <1= nutrient surplus, >1=nutrient deficiency, close to 1=minimal opportunity for losses
Recovery Efficiency (RE): How much nutrients applied did the plant take up? $\text{RE} = \frac{\text{Nitrogen updake in crop with nitrogen applied - nitrogen uptake in crop with no nitrogen applied}}{\text{Amount of Nitrogen Applied}}$ Close to 1= most efficient

However, it may also be valuable to assess the N balance of your system to see the total N that was not removed in the grain. The remaining N represents the amount that is likely to be lost to the environment, but part of which could also be stored in crop residues. Having a situation where there is relatively low efficiency and a high balance means that there is high potential for an economic benefit to changing N management practices. This can mean reduction in rate, or changing in timing, source, or placement (or a combination thereof) that would lead to more of the applied N ending up in the plant. Having an efficiency above 100% or a positive balance (i.e., removing more N than applied) can be OK in the short-term, but if continued over longer periods of time can lead to a reduction in soil organic matter. Based on results from around the

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[1/] University of Wisconsin-Madison and University of Wisconsin-Extension.

Midwest, a nice goal to shoot for would be a partial factor productivity (PFP) of 80 (lb-grain / lb-N applied) and a partial nutrient balance of 90% (i.e., 90% of the N applied removed in the grain).

Nitrogen Use Efficiency Results in Wisconsin

Data reported in Figures 1, 2, and 3 are from on-farm assessments of nitrogen use efficiency collected during the 2015 and 2016 growing season. Measurements of yield and N content of grain were collected within a sub-section of a field.

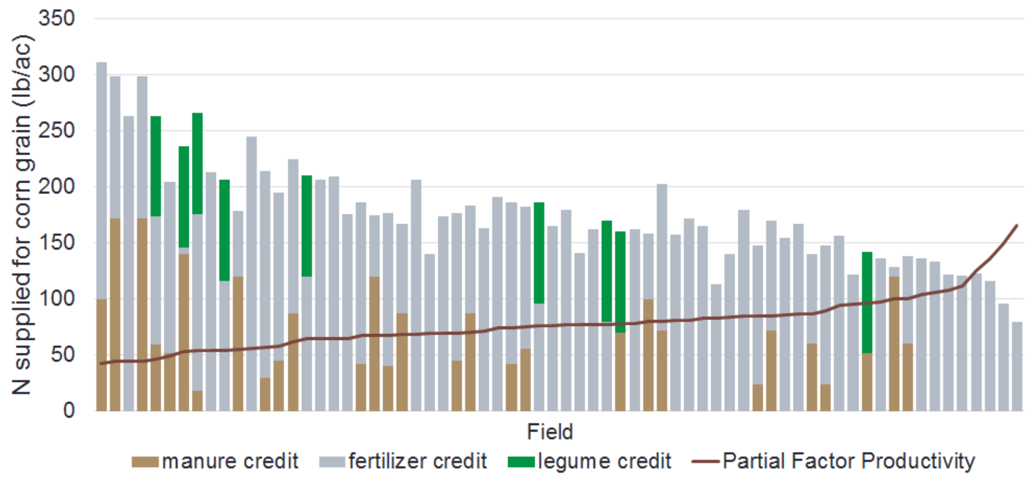

Figure 1. Total N application to corn grain (fertilizer, manure, and legume credits) and partial factor productivity (lb-grain / lb-N applied) for each field.

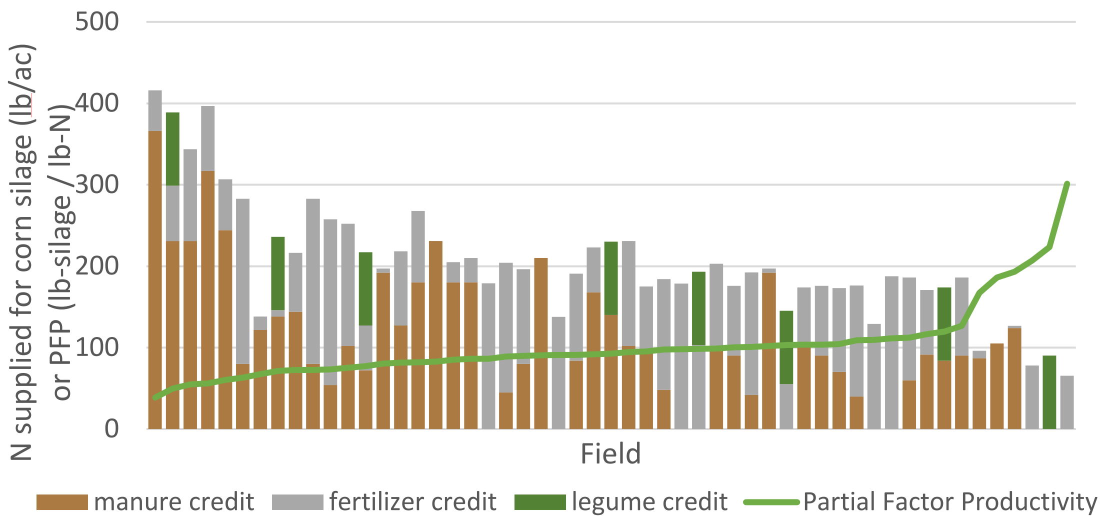

Figure 2. Total N application to corn silage (fertilizer, manure, and legume credits) and partial factor productivity (lb-silage / lb-N applied) for each field.

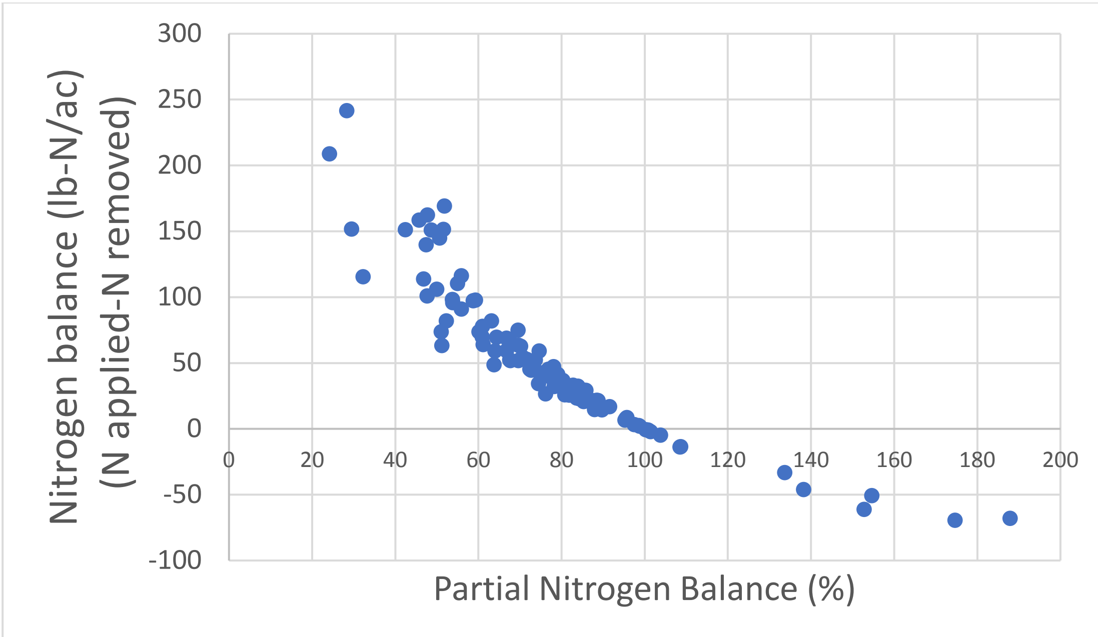

Figure 3. Relationship between partial nutrient balance (%) and actual N balance (lb-N/ac). Positive N balance indicates more N applied than removed. Partial nitrogen balance above 100% indicates more N removed than applied. Note that there can be quite a bit of variation in the N balance with the same PNB. This is driven by the yield; 60% PNB with high yields can lead to larger N balances than 60% PNB with low yields.

<u>Summary</u>

Currently we have 2 years of on-farm assessments and are currently analyzing 2017 results. This project will continue for at least 2 more years to develop regional bench-marks in Wisconsin. The data reported here can be viewed as a statewide benchmark. But, there will be some differences in region to region (and year-to-year) that will need to be accounted for to provide full value to producers and consultants.

NITROGEN FOR CORN: TIMING, RATE, SOURCE, LOSS

Peter Scharf [1/]

Nitrogen management for corn is complicated. Timing, rate, source, and placement can all have significant impacts on success.

My research findings on **N timing** have been the most surprising to me. They include:

- In the absence of excess rain, effects of N timing on corn grain yield are rare. Even quite late applications can give full yield. This probably is not true for silage corn.
- In the presence of excess rain, programs with all N applied before planting usually perform poorly. In-season N is needed to produce full yield.
- I have never seen early N stress reduce ear row number enough to worry about. In 2017, after 11 years of continuous no-till corn, the zero-N treatment was 135 bushels behind the best treatment but only 0.3 rows behind.
- Pre-plant N rarely matters. In 90 experiments comparing treatments with and without pre-plant N, there were only 2 where the treatment without preplant N lost yield. In both of these the first N was applied when the corn was thigh-high.
- Nitrous oxide emissions were cut by 60% by using all-sidedress N management.

Research findings on **N rate** have also been surprising:

- In small-plot on-farm (about 1 acre) N rate experiments, the most profitable N rate ranged from 0 to 300 (highest rate used) and was pretty evenly spread over that range.
- In field-scale research, the most profitable rate varied widely across fields, usually going all the way from 0 to 250 (highest rate used). Some fields needed much more total N than others.
- The most profitable N rate could not be predicted from yield level, soil nitrate, or soil electrical conductivity at either field scale or small-plot scale.
- Corn leaf color, measured in a variety of ways, is the only reliable way to predict the most profitable N rate that I have found. This can work for corn 1 foot tall to pre-tassel, but not earlier.

[1/] Professor of Plant Sciences, Univ. of Missouri, Columbia, MO.

In the absence of N loss, I have not found **N source** to have any effect on corn yield. However, different sources are susceptible to different types of loss, with different solutions.

- Anhydrous ammonia is the most resistant to loss in wet weather. A coated urea product, ESN, has in some cases also shown resistance to loss in wet weather. All other sources are about equal in their vulnerability to loss in wet weather.
- Urea is susceptible to loss as ammonia gas when surface-applied. When urea is surface-applied, it should be coated with a product containing NBPT unless it is to be tilled or irrigated in within 4 days. The exception is that we have not found profitable (on average) response to NBPT once corn height is 3 feet or greater.
- UAN solution is more vulnerable to tie-up on residue than other N sources, especially if broadcast. The small droplets stick to residue and the N is take up by microbes eating the residue. Injection in high-residue situations is the best practice for UAN. If injection can't be accomplished, dribbling is better than broadcast.

N loss has been a big deal across the Midwest over the past 10 years. A string of wet years has led to large losses of N through April, May, and June, leaving the corn crop N-deficient (Fig. 1). I saw terrible deficiencies in southern Wisconsin in 2008. A large influx of machines with high-clearance N application capabilities has helped farmers to replace lost N and regain yield potential. I have measured yield responses up to 80 bushels/acre to rescue N applied after the initial N applications were largely lost.

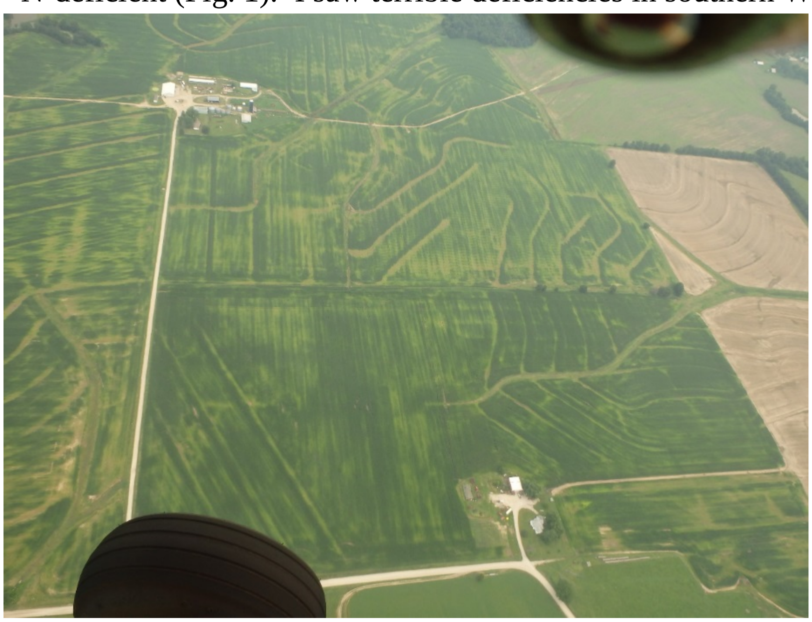

Figure 1. Aerial photo of N-deficient corn in northeastern Missouri, July 2015. I've taken or had taken thousands of pictures like this one across Missouri, Illinois, Iowa, and Indiana. Rescue N works to recover yield potential. In all of my research, the worse the N deficiency, the larger the yield response to rescue N.

ADVANCES IN NITROGEN MANAGEMENT

Peter Scharf [1/]

NVision Ag uses the color of your crop, measured from above (Fig. 1), to determine the level of N stress and how much N to apply. We supply this information in the form of a rate control file (Fig. 2). Just plug it in and drive, knowing that sound research backs the rates that you are putting out.

Fig. 1. 2017 corn field with 50 lb N/acre pre-plant.

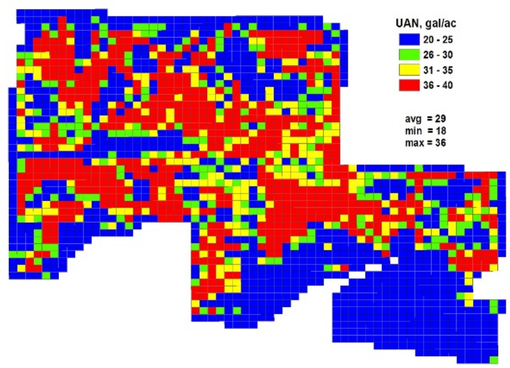

Fig. 1. Visual of UAN rate control file based on image in Figure 1. Customer set minimum rate at 20 gal/acre and maximum rate at 40 gal/acre.

This can work for you whether you are making a planned in-season N application, or have applied all your N pre-plant but are concerned whether it is still there.

In the case of potential N loss, we give you a map of estimated yield loss, along with total yield loss and dollar loss for the field, due to N deficiency. You have real numbers to decide whether it makes sense to invest in rescue N.

Every year is different. Every field is different. Some years, most of your pre-plant N is lost, along with N that was in the soil before you fertilized. Other years, the soil contributes a great deal of N and you could get by with less. Some fields do well despite excessive rain, but others suffer severe N deficiency.

Advances in nitrogen management must address this dynamic nature of nitrogen in soils. What should you do this year that you didn't do last year? Or what should you NOT do this year that you did last year?

[1/] NVision Ag.

Nearly every answer to this question is driven by how the weather is different this year than last year. Advances in nitrogen management rely on correct responses to what the weather is doing this year.

You don't know what the weather is doing until the season unfolds in front of you. If your N programs is done before you plant, the only potential adjustment is to apply more (rescue N) in years when your pre-plant was lost.

Planning an in-season N application opens doors. Adjustments both up and down in rate become possible. And easy.

Likely you will pay more for fertilizer in-season than pre-plant. And if you feel that you must have pre-plant N, this may mean an extra trip across the field. These extra expenses have to be made up by either increasing yield or cutting back on tons. Or both. In wet years, my research at the University of Missouri has often shown higher yield with less N when applied sidedress or topdress.

FLEXIBLE NITROGEN MANAGEMENT

Peter Scharf [1/]

Let's start with what happened in 2017. Lots of rain in Wisconsin April through June. Wet all along, and especially the last half of June in southern Wisconsin.

Did this cause nitrogen loss? Yes.

Was it huge? No.

Looking through August satellite images from Wisconsin, I see some fields with definite N deficiency where I would predict serious yield loss (Figure 1). But most fields looked fine or at least pretty good.

Figure 1. Planet Labs July 28 satellite image of two fields in southeastern Wisconsin. Nitrogen deficiency appears to be limiting yield in most parts of the eastern field.

Based on some phone calls that I made in June, it sounds like a fair amount of N was applied with high-clearance applicators this year. That may be part of why the corn looked pretty good even though it rained a lot. If so, that's a great example of flexible N management.

With N solution and urea, which dominate in Wisconsin, N goes down fast. There is probably not much conflict between N application and planting. But if it's the right day to plant, planting should take priority, regardless of where N application stands. Get the N applied later. Waiting to plant is far more likely to reduce profitability than waiting to fertilize. That's another great example of flexible N management.

I hear worry about early-season N stress. This is one reason why some farmers insist on finishing N application before starting to plant. I have lots of experience with later N application on N-stressed corn, and only rarely (2 of 90) has early N stress (lack of preplant N) caused a yield reduction. In those 2 cases, the first N application was when the corn was thigh-high. In many other cases when the first application

[1/] Univ. of Missouri

was made to thigh-high corn, yields were the same as or better than with preplant N in the same field. This is for corn grain. I haven't done experiments with corn silage, but what I've read suggests that early N is more important for silage.

One concern with early-season N stress is reduced row number on the corn ears. In 2017, we counted rows in plots that had not received any N over 11 years of continuous no-till corn. Yields in the zero-N plot were 135 bushels below the best treatment, but only 0.3 rows below. If that level of N stress only reduces row number by 0.3, you're not likely to see row reductions in any of your fields, even with no pre-plant N.

With increasing availability of high-clearance N applicators has come programs that emphasize split N application. The lower pre-plant N rate gives the opportunity to flex down (for example in extreme drought, I know some Missouri farmers who did this in 2012). And the machine can easily let you flex up on total N if you know that some of your preplant N was lost.

Flexibility with N means getting your priorities right and adjusting to the weather as it comes. It means being prepared with a range of options that can work. Not every field has to be managed the same way, and not every year has to be managed the same way.

AN AGRONOMIST'S VIEW OF FUTURE NITROGEN MANAGEMENT

Steve Hoffman [1/]

We currently have more tools available to help with corn nitrogen management than we have ever had. Each of these tools has the potential to help us make better decisions, but none of these tools on their own should be viewed as a complete solution.

A pre-plant or pre-sidedress nitrate soil test is an excellent way to measure the amount of nitrogen available in the soil. The problem with a nitrate soil test is that it is simply a snapshot in time of the soil nitrate level. In areas that receive excessive rainfall, we know that nitrate can be lost from the root zone through leaching or denitrification. Agronomists would love to know the current nitrate status of the soil throughout the growing season, but weather conditions do not always allow for soil sampling. I have not found it possible to sample mud. Whole field sampling of corn that is taller than 20 inches is also problematic. One approach that should be further investigated is to sample soil water at various depths for a direct in-field measurement of soil nitrate. This approach was investigated by a team at the University of Minnesota. (1)

In-season sensors that measure the greenness of crop leaves can be used to help determine the need for sidedress nitrogen. One of the problems with this technology is the need to wait for the crop canopy to become full enough so that the sensors are detecting reflection from vegetation and not from the soil surface. Greenness of the crop should also be thought of as a snapshot in time. It is not a direct measurement of soil nitrogen levels.

Some have proposed the use of plant tissue testing to determine the need for supplemental nitrogen. I believe that this could be a useful tool, but once again sampling a whole field taller than 20 inches in height is a problem. We also know that the calibration of critical tissue test nitrogen levels for different stages of growth is not currently adequate to be able to deliver a sidedress recommendation for most stages of corn development.

Several predictive models have been developed to help with nitrogen management. I am thankful to have nitrogen models available, but have come to believe that it is not realistic to expect that the current models can possibly handle all of the variables that occur across the landscape. Corn on the same soil type could have different tillage systems between farms. One farm might use cover crops while another farm does

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not. Dairy manure characteristics can vary widely from one farm to the next depending on the bedding source and design of the manure system. Does the manure system consist of a single storage pit, or are there multiple pits used for flushing barns? Does the farm have a methane digester? These are just a few of the countless variables that occur *BETWEEN* farms that make it unrealistic to expect our current models to adequately predict soil nitrogen status. A model is much more likely to be able to account for the variables found within a *SINGLE* farm if the model is custom fit to the conditions on that farm.

In my opinion, we need an adaptive nitrogen prediction model that becomes customized to the unique scenarios of an individual farm over time. We also need to be able to plug in any of the nitrogen management measurements at different growth stages of corn so that the model can be self-adjusted over time with the goal of becoming customized for the set of variables that exist on that farm. There are occasions where agronomists will want to use a soil nitrate test and other times when a different measurement tool is more practical.

Nitrogen predictive models should be “plug and play” ready so that all of the available nitrogen status tools can be used to adjust the model itself. I believe that this approach will bring us much closer to attaining precision nitrogen management.

When it comes to the multiple choices of nitrogen management tools, “all of the above” is the correct answer.

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John Brockgreitens, Dr. MinhPhuong Bui, and Dr. Abdennour Abbas
Department of Bioproducts and Biosystems Engineering, University of Minnesota, St. Paul, MN.

PERFORMANCE UPDATE ON BAYER SEED TREATMENT PORTFOLIO FROM 2017

Nick Tinsley[1]

Many soybean producers throughout the north-central United States faced challenging environmental conditions during and after planting activities in 2017. The cooler and wetter conditions experienced by many this spring increased the likelihood of experiencing a number of seedling diseases. In addition to other management practices, such diseases can be managed through the wise selection of appropriate seed treatments. A research update from 2017 related to the performance of Bayer's SeedGrowth portfolio will be shared with an emphasis on how seed treatments can reduce risk exposure and mitigate yield loss.

CURRENT STATE OF HERBICIDE RESISTANCE IN WISCONSIN

Dave Stoltenberg[1]

What is Herbicide Resistance?

Resistance is defined as the inherited ability of a plant to survive and reproduce following exposure to a herbicide dose normally lethal to the wild type (WSSA, 2017). Two important points of this definition are that the resistance trait(s) must be heritable (passed on to progeny) and that the resistance response is compared to that of herbicide-susceptible plants ("the wild type").

Herbicide Resistance is a Global Problem

Herbicide resistance is an important weed management concern worldwide (Heap, 2017). Herbicide resistance is not a new problem, but has increasingly become a concern over time. The first case of herbicide resistance was confirmed in 1955. Since that time, the global occurrence of resistance has increased to 486 unique cases (weed species by herbicide site of action) by 2017, including 253 weed species with evolved resistance to one or more herbicide sites of action. Across all 486 unique cases of resistance, weeds have evolved resistance to 23 of the known 26 herbicide sites of action. Globally, ALS (acetolactate synthase) inhibitor resistance has been confirmed in the greatest number of weed species, followed by PSII (photosystem II) inhibitors, and third, ACCase (acetyl-coenzyme A carboxylase) inhibitors.

Occurrence of Herbicide Resistance is Increasing in Wisconsin

Herbicide resistance is not a new problem in Wisconsin either (Figure 1). The first confirmed case of herbicide resistance was PSII inhibitor (atrazine) resistance in common lambsquarters in 1979. Since then, 19 unique cases of herbicide resistance have been confirmed in the state, including 13 weed species with evolved resistance to one or more herbicide sites of action. Similar to that observed globally, ALS inhibitor resistance has been confirmed in more weed species than other types of herbicide resistance in Wisconsin, totaling eight weed species, most recently giant ragweed (Marion et al., 2013, 2017), common ragweed (Butts et al., 2015), and Palmer amaranth (Drewitz et al., 2016). In comparison, resistance to PSII inhibitors has been confirmed in four species (including common lambsquarters noted above). Resistance to ACCase inhibitors has been confirmed in only two species (giant foxtail and large crabgrass).

Glyphosate resistance in Wisconsin is a relatively recent occurrence compared to instances of PSII, ALS, and ACCase inhibitor resistance noted above. Glyphosate inhibits EPSP synthase (enolpyruvyl-shikimate-phosphate synthase), a key enzyme in the synthesis of aromatic amino acids. The first confirmed case of glyphosate resistance in Wisconsin occurred in 2011 in a giant ragweed population from Rock County (Glettner and Stoltenberg 2015; Stoltenberg et al., 2012). Glyphosate resistance was subsequently confirmed in horseweed populations found in Jefferson County (Recker et al., 2013) and Columbia County (Recker et al., 2014). Following confirmation of glyphosate resistance in waterhemp populations from Eau Claire and Pierce Counties (Butts and Davis, 2015a) and Palmer amaranth from Dane County (Butts and Davis, 2015b), glyphosate resistance concerns in Wisconsin have focused mostly on these pigweed species.

[1] Professor, Dept. of Agronomy, 1575 Linden Dr., Univ. of Wisconsin-Madison, Madison, WI, 53706.

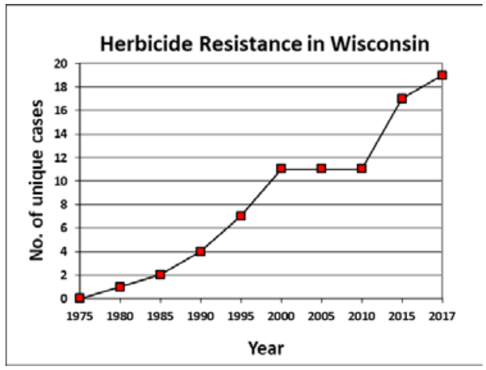

Figure 1. Herbicide resistance in Wisconsin 1975-2017. As of 2017, herbicide resistance has been confirmed in 19 unique cases (species by herbicide sites of action) including 13 weed species and a total of six herbicide sites of action.

The spread of waterhemp and Palmer amaranth has become an increasing concern in Wisconsin (Drewitz et al., 2016; Hammer et al., 2016). Both species are well-known for their competitive ability, abundant seed production, and propensity for developing herbicide resistance. Herbicide-resistant waterhemp was first confirmed in Wisconsin in 1999, when a population was found to be resistant to ALS inhibitors. More recently, glyphosate resistance was confirmed in two waterhemp populations in west-central Wisconsin (Butts and Davis, 2015a). In the short time since then, glyphosate resistance has been confirmed in waterhemp from 25 counties in Wisconsin (Figure 2). In addition to glyphosate resistance, multiple herbicide resistance (defined as resistance to more than one herbicide site of action) has been confirmed in waterhemp populations from four Wisconsin counties. In these instances, waterhemp was confirmed to be resistant to glyphosate and PPO (protoporphyrinogen oxidase) inhibitors (Figure 2).

Palmer amaranth is a relatively recent arrival to Wisconsin cropping systems, being documented for the first time in 2011 (Davis 2011). This population was found in a soybean production field in south-central Wisconsin (Rock County). The good news is that the Rock County population did not demonstrate resistance to any of several herbicide sites of action. However, a second Palmer amaranth population was identified in Dane County in 2013 (Davis and Recker, 2014) and was subsequently found to be resistant to glyphosate (Butts and Davis, 2015b). Since that time, glyphosate resistance has also been confirmed in a Palmer amaranth population from Sauk County (Figure 3).

As with waterhemp, multiple herbicide resistance has also been confirmed in Wisconsin Palmer amaranth (Figure 3). In this instance, a Palmer amaranth population found in Iowa County displayed resistance to ALS inhibitors (imazethapyr and thifensulfuron) and the HPPD (hydroxyphenyl pyruvate dioxygenase) inhibitor tembotrione (Drewitz et al. 2016). This population did not display resistance to glyphosate.

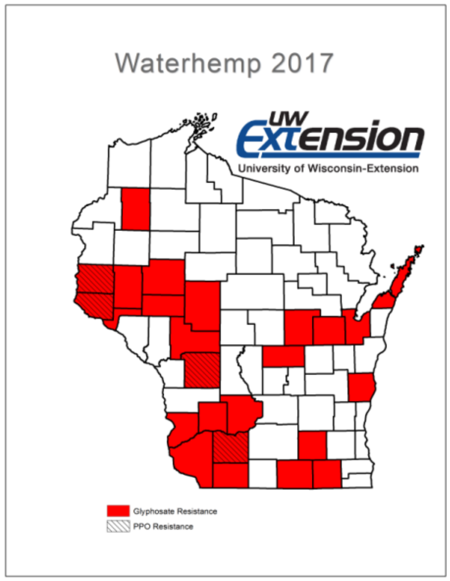

Figure 2. Confirmed herbicide resistance in waterhemp totaling 25 counties in Wisconsin as of 2017. Resistance was confirmed at UW-Madison and/or the University of Illinois Plant Clinic.

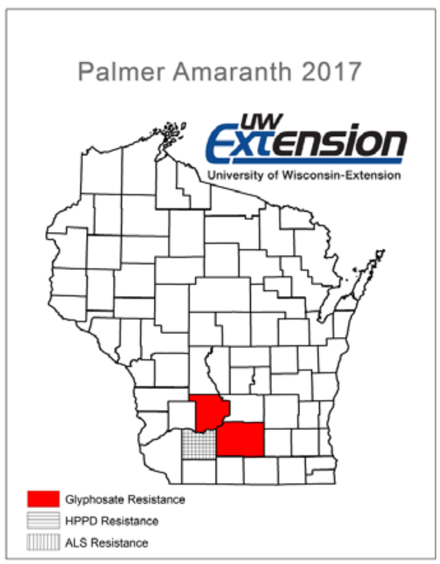

Figure 3. Confirmed herbicide resistance in Wisconsin Palmer amaranth as of 2017. Resistance was confirmed at UW-Madison and/or the University of Illinois Plant Clinic.

What Lies Ahead?

The occurrence of glyphosate resistance in waterhemp, and multiple resistance to glyphosate and PPO inhibitors, has increased rapidly in Wisconsin suggesting that waterhemp will likely increase as a management concern for many growers. Instances of multiple herbicide resistance to three, four, and five herbicide sites of action in waterhemp have been confirmed in neighboring states (Heap, 2017). Although the distribution of confirmed herbicide resistance in Palmer amaranth is currently limited to three counties in southern Wisconsin, glyphosate resistance in two populations, and multiple resistance to ALS and HPPD inhibitors in another population, also has serious management implications for Wisconsin growers. It is critical that diverse resistance management strategies be implemented to reduce the spread, persistence, and impact of these and other herbicide-resistant species (Take Action, 2017). Multiple resistance is not limited to waterhemp and Palmer amaranth. Our current research is focusing on potential multiple herbicide resistance in common ragweed and giant ragweed in Wisconsin.

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TIPS ON WATERHEMP MANAGEMENT IN SOYBEANS

Rodrigo Werle[1]

Introduction

Waterhemp has become one of the most troublesome weeds in row crop production in the Midwest. Though not as widespread like in southern neighboring states, glyphosate-resistant waterhemp populations have been confirmed in 25 Wisconsin counties; moreover resistance to ALS- and PPO-inhibiting herbicides in waterhemp have also been confirmed in the state (see Stoltenberg's paper in this proceedings for complete information). Reduced tillage, herbicide resistance, and less diversified herbicide programs and crop rotations are the main factors that have contributed to waterhemp establishment in row crop production systems (Nordby et al., 2007).

Waterhemp Biology

Understanding the key biological aspects of a weed species one is trying to manage is crucial for selection and timing of management practices. Waterhemp is a dioecious species, meaning that plants are either male or female. Cross-pollination combined with abundant pollen production by male plants and seeds by female plants greatly increase the genetic diversity of populations, making this species prone to adaptation of continuous selection pressure (e.g., use of glyphosate for weed control across growing seasons). Under ideal conditions and no competition for resources, waterhemp can produce up to a million seeds (Bradley, 2016). In 2013 and 2014, waterhemp plants were collected from commercial soybean fields in Wisconsin for estimation of seed production and retention (Schwartz et al., 2016). Waterhemp produced an average of 17,459 and 38,221 seeds per plant in 2013 and 2014, respectively. Moreover, researchers found that more than 98.5% of total waterhemp seeds produced in Wisconsin were retained to the plant at soybean maturity, indicating that seed dispersal occurs from harvest onwards. Waterhemp seeds are small and can only emerge from shallow depths. Another important aspect of waterhemp biology is seed viability in the soil seedbank. In a study conducted in Iowa, Buhler and Hartzler (2001) found 12% of the original seedbank still viable 4 years after seed burial. Waterhemp has a late and extended emergence window when compared to other troublesome weed species. In an Iowa study, waterhemp was found to emerge from May through July (Werle et al., 2014). Besides the extended emergence window, waterhemp is a C4 species with vigorous growth rate (it can

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grow up to 1 ¼ inches per day during the growing season; Bradley, 2016). All combined, these biological attributes make waterhemp an “ideal” troublesome weed for current production systems.

Waterhemp Management

For proper waterhemp management, a holistic and integrated management approach should be adopted, and the minimization of seedbank replenishment a priority. Below I discuss cultural and chemical strategies to be considered for waterhemp control in soybeans.

Tillage. Since waterhemp seeds can only emerge from shallow depths, tillage can be an effective management strategy. In a multi-state study conducted by Farmer et al. (2017), deep tillage (moldboard plow in the fall followed by spring field cultivation) was shown to reduce waterhemp density in 73% when compared to no-till. Conventional (fall chisel plow in the fall followed by field cultivation in the spring) and minimum tillage (vertical tillage in the spring) reduced waterhemp density by 11% and 6% compared to no-till, respectively. The deep tillage system had the biggest impact on waterhemp density. However, deep tillage is not a recommended practice for sites prone to soil erosion.

Row Spacing. Because of faster canopy closure, narrow-row spacing has the potential to reduce the likelihood of weed resurgence in soybeans later in the season. In a Missouri study conducted by Schultz et al. (2015), narrow row spacing (15-inch or less) was shown to have greater waterhemp suppression when compared to 30-inch row spacing. Reducing row spacing would demand a change in equipment and is not recommended for areas prone to diseases favored by fast canopy closure such as white mold.

Cover Crops. Cover crops have increased in popularity across the Midwest as a soil conservation strategy. Weed suppression has been claimed as an attribute of such cultural practice. In a Missouri study conducted by Cornelius and Bradley (2017), cereal rye cover crop provided 68% reduction in winter annual weed density and 40% reduction in waterhemp emergence. Cover crops have the potential to suppress weeds but herbicides and/or additional management practices are necessary for complete weed control. Cover crops must be properly selected, established, and terminated in order to maximize their benefits while minimizing crop yield reduction. Cover crops add a level of complexity to cropping systems and operation costs.

Herbicide Programs. According to a multi-state study conducted by Farmer et al. (2017) and a Missouri study conducted by Schultz et al. (2015), the program containing a PRE followed by POST with additional residual herbicide (practice known as “layered residuals”) provided adequate level of waterhemp control. Such strategy is recommended for weeds with extended emergence window such as waterhemp and Palmer amaranth when present at high density in the soil seedbank.

The POST application must occur when weeds are small (4-inches of less). In fields where glyphosate and PPO resistance are suspected/confirmed, the adoption of Liberty Link or RR2 Xtend technology provide farmers with the opportunity to spray an additional effective POST herbicide for waterhemp control (glufosinate or dicamba, respectively). The addition of a residual herbicide (e.g., Cinch, Dual II Magnum, Outlook, Warrant, etc.) during the POST application reduces the likelihood of additional weed emergence until canopy closure. Despite the benefits in terms of weed control, diversified herbicide programs with soil residual activity tend to cost more. For herbicide options, check the 2018 Pest Management in Wisconsin Field Crops (A3646). Always check and follow the label before purchasing and spraying a pesticide.

Integrated Weed Management. In their multi-state study evaluating tillage methods and herbicide programs, Farmer et al (2017) reported that deep tillage combined soil residual herbicides provided the highest level of control of pigweed species (waterhemp and Palmer amaranth). In a study evaluating row spacing and herbicide programs, Schultz et al. (2015) reported that narrow row spacing combined with soil residual herbicides provided the highest level of waterhemp control in Missouri. Across studies, treatments including chemical and non-chemical strategies provided better levels of waterhemp control when compared to sole strategies.

Herbicide Resistance Management. From a herbicide resistance management point of view, effective crop and herbicide rotations are key strategies for sustainable weed control. Introducing crops with different life-cycles (e.g., wheat, alfalfa) provides opportunity for direct weed suppression (i.e., established canopy reducing weed emergence and development of weeds common to soybeans). When using herbicides, mixtures of multiple effective SOA have been reported as the most effective way to prevent resistance evolution (Evans et al., 2016). Using distribution and frequency of glyphosate resistance in common waterhemp populations from more than 100 farms across Illinois, Evans et al. (2016) presented strong evidence that the likelihood and frequency of resistant individuals within a population are inversely correlated to the number of herbicide modes of action used per application per season at each farm. Roguing waterhemp escapes from a POST herbicide application and field edges is highly encouraged, particularly at the onset of infestation in a field, as a means to reduce seedbank replenishment with potential herbicide-resistant biotypes. The effective herbicide options for weed management in soybeans are limited. For sustainable weed management, holistic and integrated strategies beyond herbicides should be adopted.

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ON THE EFFECTIVENESS OF COVER CROPS FOR EROSION CONTROL*

Francisco Arriaga[1], Laura Adams[2], and Michael Bertram[3]

Introduction

The dairy industry is important to Wisconsin's economy. Corn silage is commonly used to feed dairy cows because of its dietary value. However, very little residue is left on the soil surface after corn silage harvest, increasing the risk for erosion. Manure is often applied to fields after corn silage harvest, which exacerbates the erosion problem by increasing the likelihood of phosphorus (P) losses. Practices such as no-tillage and cover crops have been shown to reduce erosion and P losses under different cropping systems (Sharpley et al., 1992; Dabney et al., 2001), but others have found conflicting results (Griffith et al., 1977; Mueller et al., 1984). Therefore, there is a need to obtain quantitative information on the impact of cover crops and no-tillage in corn silage systems. A study was conducted to determine if no-tillage and cereal rye as a cover crop can reduce erosion and P losses from corn silage production in Wisconsin.

Methods

A rainfall simulation study was conducted on a private farm at a site near Arlington, WI. The work presented here is part of a larger study that was established in 2013. Treatments consisted of two tillages, conventional (CT) and no-tillage (NT), and two cover crops, no cover crop (NCC) and cereal rye cover crop (CC). The CT management consisted of a single pass with a vertical tillage implement in the fall, and a spring soil finishing operation. Additionally, liquid dairy manure was injected into every plot after silage harvest, which created some soil disturbance. Cereal rye was seeded using a no-till drill at a 90 lb/ac rate. Rainfall simulations were performed three times to capture different time points in the cropping cycle during the 1st week of June 2016, 3rd week of October 2016, and 2nd week of April 2017. Metal frames (3-ft by 3-ft) were inserted into the ground into each plot. A tower with an oscillating nozzle at a 10-ft height was placed over each frame to generate the simulated rainfall event. Water was applied at a 3 inch/hr rate for 60 minutes. Runoff was collected into a graduated collection tank using a vacuum system. After each simulation, a composite runoff sample was collected for P analysis.

Results and Discussion

The impact of the rye cover and tillage varied for each simulation timing. For example, runoff was reduced with the NT CC management only in June, while in October there were no treatment differences (Figure 1). However, the cereal rye cover crop reduced runoff by about 50% regardless of tillage during the April rainfall simulation event. These findings highlight the importance of having soil surface coverage for reducing runoff. Sediment losses followed a similar pattern to runoff (Table 1). Also, P losses were reduced by the cereal rye cover crop but the impact varied depending on the time of the tear when the simulation was conducted. Tillage had a limited impact on reducing P losses, but this might be related to the soil disruption created by the manure injection in the no-tillage management, and the addition P with the manure to the soil.

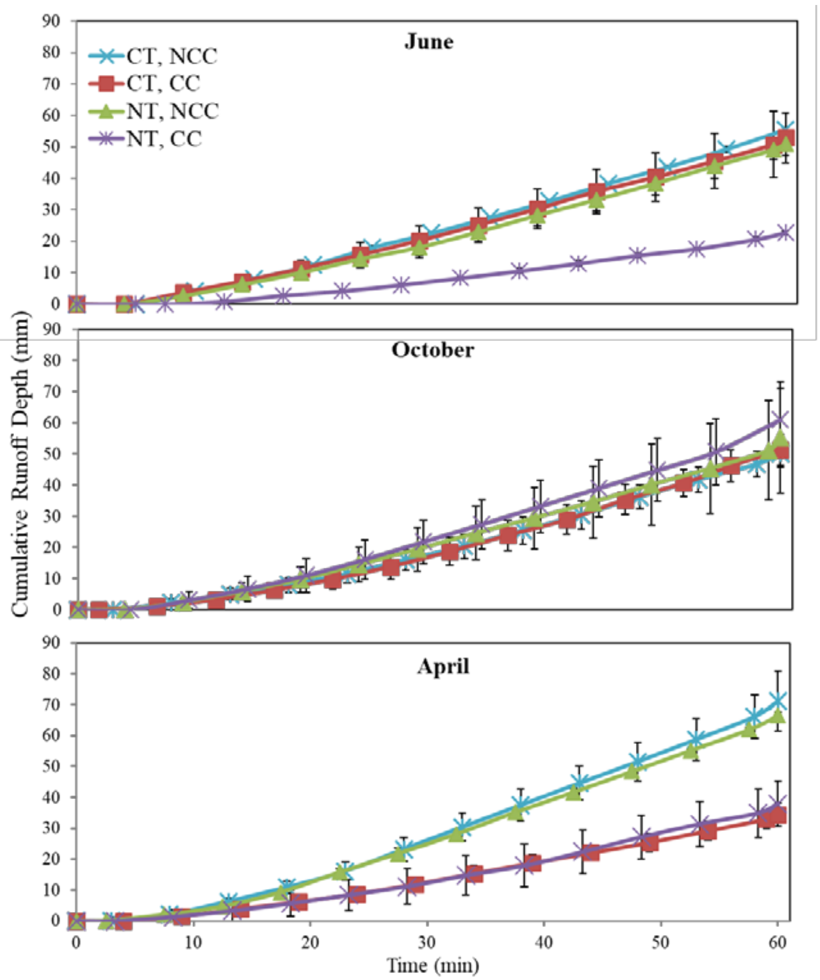

Figure 1. Cumulative runoff amounts during three different rainfall simulation timings (1st week June 2016, 3rd week October 2016, and 2nd week April 2017) for two tillage managements (CT – fall vertical tillage/spring finisher, and NT – no-tillage), and two cover crop treatments (NCC - no cover crop, and CC – cereal rye as a cover).

Table 1. Total sediment losses after three different rainfall simulation timings (1st week June 2016, 3rd week October 2016, and 2nd week April 2017) for two tillage managements (CT – fall vertical tillage/spring finisher, and NT – no-tillage), and two cover crop treatments (NCC - no cover crop, and CC – cereal rye as a cover).

Treatments		Sediment load		
Tillage	Cover crop	June	October	April
		------------ tons/ac ----------		
CT	NCC	2.1	0.8	2.3
	CC	1.3	1.3	0.6
NT	NCC	1.6	2.8	2.2
	CC	0.4	1.4	0.7

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WINTER RYE COVER CROP AND FORAGE COMPARISON FOLLOWING CORN SILAGE IN WISCONSIN

Kevin Shelley[1], Jaimie West, and Matthew Ruark[2]

Corn silage provides an economically important source of feed for dairy and beef cattle, with nearly one-million acres harvested in Wisconsin annually. Corn silage may present environmental challenges, however, as very little crop residue remains in the field and manure is often applied after harvest. This creates conditions possibly vulnerable to soil erosion and nutrient loss from runoff over the fall-to-spring fallow period.

In the U.S. Upper Midwest, fall-planted winter cereal grains can be used as a cover crop to prevent soil erosion and surface water runoff as well as immobilize soil nitrate (NO_3) susceptible to leaching. Winter cereal rye (*Secale cereale*) has been the most popular choice due to easy fall establishment, winter hardiness, rapid spring growth and relatively low seed cost. Planted in the fall as an over-wintering cover crop, the rye can be terminated early the following spring, or can be left to grow and harvested as an early season (late May), high quality forage crop, thus diversifying a farm's forage options.

Farmers, crop production professionals and conservation planners have offered observations and questions relative to using rye as a cover crop, or as a forage crop after corn silage. These include: If rye scavenges soil NO3-, does it provide a nitrogen credit to a following corn crop? And, what are the economics of using rye as a forage crop in an otherwise continuous corn silage rotation? In fall of 2011, a trial was established at the UW-Madison Arlington Agricultural Research Station (South Central Wisconsin) to gain experience with these issues, and was continued through 2016.

OBJECTIVES

- Evaluate winter rye as a cover crop following harvest of corn silage, and managed either as a spring-terminated cover crop or as an early season forage crop preceding the next corn silage crop;
- Determine differences in corn silage yield response to varying nitrogen (N) rates following fall manure application with rye as a cover crop, forage crop and no rye;

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- Measure the extent to which rye cover and forage crops affect the yield of a following corn silage crop?
- Quantify total forage production and estimate the economic impact (+/-) from including rye as cover or forage in a continuous corn silage rotation?

STUDY DESIGN AND METHODS

- Plano silt loam soil (Typic Argiudolls); very deep and well-drained
- Continuous corn silage, no-till planting
- Fall-applied liquid dairy manure at 9,700-12,000 gal/ac
    - ~64-106 lb N/ac available in the first year

RCB split plot arrangement; three replicates

Whole plot factor was fall-seeded cover crop:

- Winter rye as cover crop (90 lb/ac PLS) terminated with a standard burndown rate of glyphosate in early spring
- Winter rye as forage (90 lb/ac PLS) harvested at boot stage
- No cover crop (No CC)

Split-plot factor was N fertilization rate:

- 60, 100, 160 lb/ac of N applied at sidedress as ammonium nitrate. The 100 lb N rate approximates the UWEX recommended rate (UWEX A2809, MRTN rate) considering manure N credits.

Economic return from adding rye as a cover or forage crop is determined via partial budget analysis considering:

Net value to adding rye ($/ac) = Value of all forages produced (corn silage and rye forage) ($/ac) – Relevant costs associated with rye cover or forage ($/ac). Forage value estimated via *Milk/Ton Dry Matter (TDM) Forage*, an index of milk production potential based on energy content using forage analysis parameters crude protein, neutral detergent fiber (NDF), in vitro NDF digestibility, starch, and non-fiber carbohydrate and an estimate of dry matter intake (Shaver, et al. 2001) * Ave mailbox milk price ($/cwt). Corn silage yields at 100 lb N rate.

FIVE-YEAR TRIAL RESULTS

Corn silage yield was subjected to an ANOVA using the MIXED model procedure in SAS (9.4) and statistical significance was determined at $\alpha \leq 0.10$.

- Neither rye as cover crop or forage affected optimal N rate in any study year. There was no effect of N rate treatment in 2012, 2014, 2015 or 2016, with slight increase in yields (all cover crop treatments) at 100 pounds N per-acre in 2013, compared to the low N rate of 60 pounds N per-acre.
- Fall-seeded winter rye as a cover crop (terminated early spring) did not reduce corn silage yields compared to the no cover crop treatment, and was nearly cost-neutral over the five years.

- Rye harvested as forage decreased subsequent corn silage yield in three of the five study years. However, total forage yields, when adding rye forage, were equal to or greater than corn silage produced with no rye in each of the five study years. Reasons for corn silage yield reductions following rye forage are not determined, but could not be overcome with the higher rate of (sidedressed) N.
- Economic return favored the rye forage to corn silage treatment three of five years, with a negative return in only one year, when considering potential milk production using the Milk per Ton of Dry Matter forage quality index.
- Late-planted rye with minimal biomass accumulation resulted in good spring growth. However, planting rye 10-15 days earlier in the fall would likely produce closer to a suitable yield goal of 2 ton DM/ac.

DO BIGGER STORMS MEAN BIGGER LOSSES?

Tim Radatz[1/] and Eric Cooley [2/]

There is an ever-increasing focus on climate change and corresponding changes to rainfall patterns. It seems like more extreme rainfall events are observed every year. Wisconsin and Minnesota Discovery Farms Programs have monitored 127 site years of edge-of-field surface runoff. During these site years, 2,184 surface runoff events were measured. These runoff events and the corresponding rainfall data were analyzed to answer the following questions:

- Are a large portion of nutrient and soil losses driven by extreme rainfall events?
- Can you control the weather (or the impact of it) on your crop fields?

Most nutrient and soil losses happened in a limited number of runoff events.

The majority of the nutrient and soil losses happened in about 200 of the 2,184 runoff events. The top 10% of surface runoff events accounted for 46% of the total runoff, 59% of the total nitrogen, 65% of the total phosphorus, and 80% of the total soil lost throughout the entire dataset.

Most runoff events took place during storms of an 'expected' size, not extreme events.

All the surface runoff events were paired with rainfall data, including depth, duration, intensity, and maximum 5, 10, 30 and 60-minute intensities. Intensity data was then compared with NOAA data from each location to define rainfall return periods for each runoff event.

A rainfall return period is an estimate of the likelihood of a rainfall event to occur. In general, as the return period increases, so does the rainfall or rainfall intensity.

- A rainfall event with a 100-year return period would be expected to occur once in 100 years.
- The probability of a 100-yr rainfall event occurring in any given year is 1/100 or 1%.

Out of 2,184 total runoff events from 127 site years of data, there were 375 runoff events with a rainfall return period greater than one year. There were 11 runoff events with a rainfall return period of greater than 25 years and four with a rainfall return period estimated to be greater than 1,000 years.

Extreme rainfall events did not significantly impact edge-of-field nutrient losses. 70-75% of surface runoff, total phosphorus, and total nitrogen losses were NOT driven by extreme rainfall.

Most of the surface runoff, total phosphorus, and total nitrogen losses were from surface runoff events that had rainfall return periods of less than one year (see blue bar on Figure 1). This means these runoff events resulted from common rainfall events or snowmelt.

However, over 50% of the soil loss happened with runoff events with a rainfall return period greater than one year. Extreme rainfall events had more of an impact on soil loss.

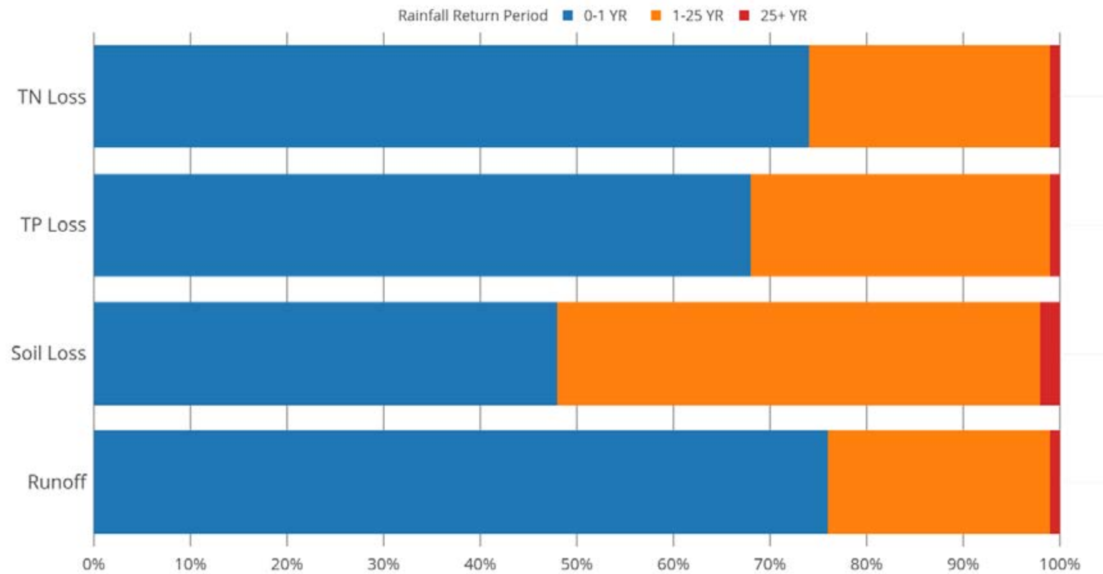

Figure 1. Percent of total runoff or soil, total phosphorus or total nitrogen loss.

Often a 25-year rainfall event is used as design criterion for conservation practices in agricultural fields. Surface runoff with a rainfall return period of greater than 25 years had very little influence (1 to 2%) on surface runoff losses in this dataset. This could be a result of effective conservation practices designed to withstand larger rainfall events or the relatively few 25-year rainfall events that have been monitored. In fact, only 11 surface runoff events had a rainfall return period greater than 25 years.

Timing of extreme rainfall matters.

An extreme rainfall event in April or May will have a different surface runoff response than an extreme rainfall event in July or August. This is largely because of a difference in crop cover for annual crops. In April and May, there is limited crop cover and soil protection. This period also tends to have wetter soils because of the lack of plant growth and transpiration. Annual crops are usually fully canopied by July and August, providing great cover and soil protection. Soils are also typically drier during this period because of the greater water use by a fully canopied crop.

Most of the extreme rainfall events in this dataset were in June, July and August (Figure 2). June is a transition month where the annual crops typically move to fully canopied fields, but July and August are periods that will provide more protection. If the timing of these extreme rainfall events were to shift to earlier in the year, the surface runoff influence would likely increase.

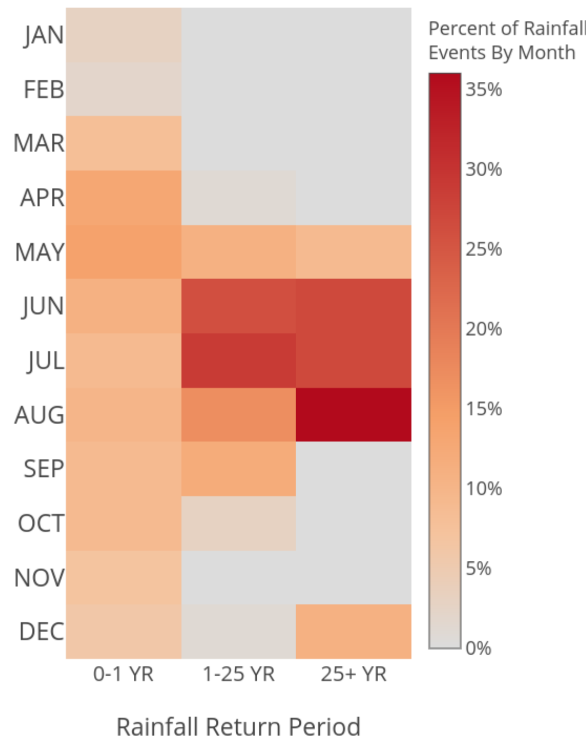

Figure 2. Percent of rainfall events by month within defined rainfall return periods.

Snowmelt is still a significant part of the water budget and decreases the influence of extreme rainfall events in Wisconsin and Minnesota.

Over half of the surface runoff measured in Minnesota and Wisconsin occurred during frozen soil and snowmelt conditions (Figure 3). This is an important period for runoff in the Upper Midwest. This period is also important for phosphorus and nitrogen movement. However, soil movement is limited during snowmelt. The amount of snowmelt runoff and nutrient losses diminishes the impact of extreme rainfall events. If runoff and nutrient loss occurring with snowmelt decreases, it would likely increase the influence of extreme rainfall events.

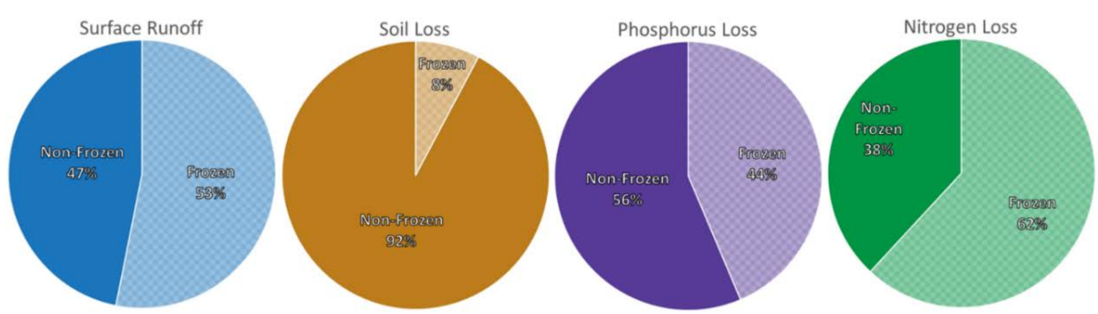

Figure 3. Percent runoff and associated soil, phosphorus and nitrogen loss during frozen and non-frozen soil conditions.

Takeaways to consider from this analysis:

- Most surface runoff losses happen in a limited number of runoff events.
- Extreme rainfall events did not significantly impact edge-of-field losses except for soil loss.
- Timing of extreme rainfall events matter. If extreme events occur earlier in the year it would likely increase their impact on surface runoff.
- Snowmelt is still a large driver and decreases the influence of extreme rainfall events in WI and MN.
- There is a need for a site-by-site assessment to explore differences by region, soil type and level of conservation practices.

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TILLAGE, MANURE, AND WINTER RUNOFF*

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Introduction

Wintertime land-applications of manure are a common practice because of the high cost of manure storage (Srinivasan et al., 2006). However, the presence of frozen soil and snow creates challenges for on-farm nutrient retention, as up to 75% of annual runoff can occur during thaws (Good et al., 2012). Therefore, we 1) tested practical management techniques that may reduce runoff on fields receiving winter applications of liquid dairy manure, and 2) used a soil physics approach to identify weather and soil properties that control infiltration, runoff, and nutrient losses during thaws.

Methods

A 2-year (2015-2017) field study was conducted at the UW Arlington Agricultural Research Station in Arlington, WI. A total of 18 plots (15-ft by 50-ft each) were established on a 6% slope in a continuous corn for silage cropping system. Management treatments included conventional fall tillage (chisel plow) versus no-tillage, and manure application timing (unmanured controls, early December, and late January applications). Treatment combinations were replicated three times. The manure application rate was 4,000 gal/acre. A flume was used to divert runoff at the bottom edge of each plot and collected using a gravity bucket system. Samples were collected after each runoff event.

Results and Discussion

Plots with no-tillage were twice as likely to produce runoff compared to plots with tillage during the frozen seasons. During the 2015-16 winter season, there was more runoff with no-tillage than fall chiseling (Figure 1). A similar pattern was observed during the 2016-17 winter season, but differences between tillage practices were lower.

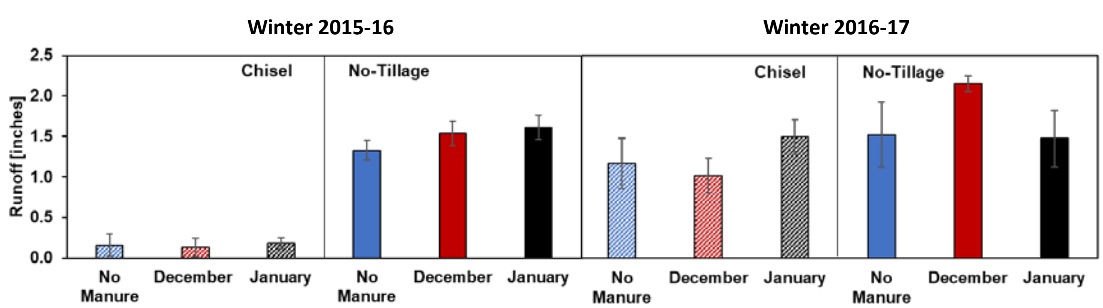

Figure 1. Total runoff amounts during the winter seasons of 2015-16 and 2016-17 for two tillage managements (fall chisel and no-tillage), and three liquid dairy manure application timings (no manure control, December, and January).

Phosphorus losses followed a similar pattern to runoff amount, where greater losses were observed with no-tillage (Figure 2). Seasonal phosphorus losses ranged from 0.0 to 0.3 lb/ac under tillage and 0.1 to 3.3 lb/ac under no-tillage. Similarly, seasonal nitrogen losses ranged 0.5 to 2.7 lb/ac under tillage and 0.7 to 25.2 lb/ac under no-tillage.

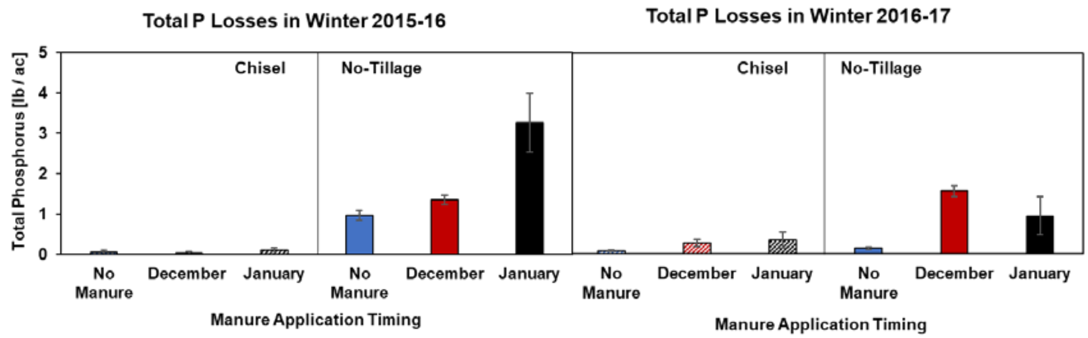

Figure 2. Total phosphorus losses during the winter seasons of 2015-16 and 2016-17 for two tillage managements (fall chisel and no-tillage), and three liquid dairy manure application timings (no manure control, December, and January).

Fall chisel tillage created depressions on the soil surface that collected meltwater, which increased the time water had to infiltrate into the soil. Manure application increased sunlight absorption, which accelerated snowmelt. This field study provides additional understanding of winter runoff processes and evaluates nutrient retention.

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RESTORING SOIL HEALTH: EFFECTIVENESS OF SHORT- AND LONG-TERM CONSERVATION PRACTICES

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Abstract

Soil health is the ability and capacity of soil to function within environments and ecosystems to promote plant and animal health, sustain biological productivity, and maintain environmental quality. Intensive agricultural land use has been widely shown to degrade soil quality and health. Functional and structural integrity of the soil can be improved or potentially return to pre-disturbance conditions with soil conservation practices. The goal of this work was to 1.) quantify the effects of land conversion from native vegetation to agricultural cultivation and 2.) measure the rate and degree of soil recovery from both short-term (less than 15 years) and long-term (greater than 15 years) soil conservation practices. Conservation measures ranged from management modifications that maintain crop productivity including practices such as conservation tillage and cover crops to removal of sensitive land from crop production through the Conservation Reserve Program (CRP). A variety of soil physical, chemical, and biological parameters were investigated including bulk density, aggregate stability, infiltration, total organic carbon, carbon dioxide flux, and microbial biomass. Results show land conversion slightly impacted (less than 20% change from pre-disturbed condition) aggregate stability, moderately impacted (20-50% change from pre-disturbed condition) bulk density, total organic carbon, and carbon dioxide flux, and severely impacted (greater than 50% change from pre-disturbed condition) infiltration and microbial biomass. Both short and long-term crop management modifications (cover crops and conservation tillage) showed minimal recovery of soil quality indicators. CRP enrollment showed some recovery of soil quality indicators in the short-term with more significant recovery over longer timescales; however, even 30 years of grassland management was not sufficient to recover all parameters to their pre-disturbed state. Our findings reinforce the importance of investing in significant long-term conservation initiatives.

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TILE DRAINAGE BENEFITS, RISKS, AND DITCH MAINTENANCE ISSUES

John Panuska [1/]

Maintaining proper root zone soil moisture conditions optimizes yields and improves field trafficability. When soil voids are free of drainable water, air flow can occur that supports important chemical and biological processes needed for plant growth. Other benefits include deeper plant rooting depth and a dry soil will warm up more quickly in the spring than a wet soil. However, tiled soils have an increased risk of manure, pesticide and pathogen losses to surface waters. Macropores (earth worm burrows and shrinkage cracks) and tile surface inlets can act as direct conduits to tiles and in turn surface waters. Replacing tile surface inlets with blind inlets can help reduce this risk. Tile typically drain into surface drainage ditches. Maintenance of tile outlet ditches is critical to the proper performance of the tile system. When maintenance should occur is dictated by site specific conditions, particularly tile and ditch grade along with what a landowner is willing to tolerate. Ditches should be inspected annually and after major storm events to identify problems before they become severe. Clearing of trees and debris will likely be required more frequently than sediment removal. There are both private ditches and ditches that are part of the public drainage system created under WI Chapter 88 of Wisconsin Statutes. This law established the county drainage districts. Maintenance of and connecting to private ditches are the responsibility of individual property owner(s), which can lead to conflicts and disagreements. The public drainage system was developed to coordinate and better address drainage ditch issues involving multiple landowners. Any connections to or maintenance of public ditches must involve the County Drainage Board. It is also important to keep in mind that drainage ditch maintenance may require permits or review by government agencies such as the Wisconsin Department of Natural Resources, Natural Resources Conservation Service, the Army Corps. of Engineers and your local County Planning and Zoning Office. Additional information on tile drainage can be found on the UWEX tile drainage web site at the following URL: *fyi.uwex.edu/drainage*/.

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NEW AND EMERGING CORN DISEASES: WHAT WE'VE LEARNED ABOUT BACTERIAL LEAF STREAK

Tamra A. Jackson-Ziems [1/]

Bacterial leaf streak (BLS), caused by *Xanthomonas vasicola* pv. *vasculorum*, was reported for the first time in the United States in Nebraska in 2016. Since then, the disease has been confirmed in 60 Nebraska counties and 8 additional states, including Colorado, Kansas, Illinois, Iowa, Minnesota, Oklahoma, South Dakota, and Texas. Previously, the pathogen had only been confirmed on corn in South Africa and on sugarcane in numerous other countries around the world. Numerous other grass and palm hosts were identified in other countries, as well, including sorghum species. Results from additional host range testing conducted in Nebraska also confirmed several additional crop, weed, and native perennial grass species as hosts. Symptoms on corn can be difficult to differentiate from other diseases, especially the gray leaf spot fungal disease. Typical symptoms of the disease on corn and other hosts are narrow interveinal streaks that can appear bright yellow when backlit. The pathogen overwinters in infested crop debris thus, disease develops in the same areas repeatedly when susceptible hybrids are grown and favorable weather conditions persist. Severity of the disease varies considerably on corn hybrids, particularly on some popcorn hybrids that can be quite susceptible. High relative humidity and leaf wetness favor disease development. Results from additional research trials will be shared, as well as more information on additional emerging diseases, such as tar spot and Diplodia leaf streak.

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INTEGRATED APPROACHES IN WHITE MOLD MANAGEMENT

Megan McCaghey[1], Jaime Willbur[1], Ashish Ranjan[2], Scott Chapman[3], Carol Groves[4], Jake Kurcezewski[5], Mehdi Kabbage[6], and Damon L. Smith[7]

Introduction

Sclerotinia sclerotiorum, the causal organism of white mold, can cause significant yield losses to growers when environmental conditions are favorable for disease. Management of white mold includes a multi-prong approach of rotation with non-susceptible hosts, chemical control, and deploying tolerant varieties. However, commercial varieties lack a high level of white mold resistance. This work provides a useful and novel breeding method for selecting lines that have physiological resistance to white mold while maintaining agronomic qualities. The germplasm identified will serve as a valuable sources of physiological resistance to white mold that can be improved through further breeding. The full assessment of lines can be found in the open access article entitled, “Development and Evaluation of Glycine max Germplasm Lines with Quantitative Resistance to *Sclerotinia sclerotiorum*” (McCaghey and Willbur et al., 2017). Subsequent crosses with promising lines analyzed in this study were performed in 2016, and new lines were identified for novel crosses that will be performed in the field and greenhouse in 2018.

As an additional approach to enhance resistance to white mold, we are using the biotechnological method of RNA-interference (RNAi). RNAi reduces the expression of proteins that are essential to pathogenic success, and it has demonstrated effectiveness against various pests including *Meloidogyne* (Huang et al., 2006), *Fusarium* (Koch et al., 2013), and *S. sclerotiorum* (Andrade et al., 2016). *S. sclerotiorum* requires the secretion of oxalic acid (OA), a key virulence factor, to avoid host recognition and facilitate infection. Virus-induced gene silencing (VIGS) using *Bean pod mottle virus* (BPMV) was used to target OA biogenesis in *S. sclerotiorum*. Results from VIGS studies indicate promise for durable resistance through the generation of transgenic RNAi soybean plants that can effectively reduce the pathogenicity of *S. sclerotiorum.*

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Enhanced resistance in soybean germplasm and RNAi transgenic plants will provide another set of tools to add to our "toolset" of using cultural practices, predictive models, and fungicide application to manage white mold.

Objectives

1. Improve white mold resistance and agronomic properties of soybean through breeding in multiple environments and through multiple generations.
2. Improve white mold resistance through RNA-interference and transgenic plants.

Materials and Methods

Soybean germplasm was developed by crossing two sources of white mold resistance, W04-1002 and AxN-1-55, with lines exhibiting resistance to *Heterodera glycines* and *Cadophora gregata* in addition to favorable agronomic traits. Following greenhouse evaluations of 1,076 inbred lines derived from these crosses, 31 lines were evaluated for resistance in field tests during the 2014 field season. Subsequently, 11 white mold resistant breeding lines were moved forward for field evaluation in 2015, and seven elite breeding lines were selected and evaluated in the 2016 field season. The seven elite germplasm lines were also re-evaluated within a greenhouse using a cut petiole technique with multiple *S. sclerotiorum* isolates to test the durability of physiological resistance of the lines in a controlled environment. Following these evaluations, crosses were conducted with the assistance of Dr. Asheesh Singh's lab at Iowa State University between 51-23 and 52-82B and SSR 51-70 and 51-23 to further improve disease resistance and yield, and seed was increased in the greenhouse. During the spring and summer of 2017, F2 plants were selected in the greenhouse at West Madison Agricultural Research Station (WMARS), at Arlington Agricultural Research Station (ARS) in a field with a prior history of soybean cyst nematode (SCN) and sudden death syndrome (SDS), and at Hancock Agricultural Research Station (HARS) in a white mold nursery.

In order to generate RNAi silencing constructs, a sequence of 366 bp, corresponding to a *S. sclerotiorum* gene essential for OA biogenesis, was inserted into a BPMV vector in an antisense orientation. BPMV constructs were introduced into soybean using particle bombardment, and viral symptoms paired with RT-PCR were used to confirm viral replication prior to rub inoculations. Leaves confirmed to possess the silencing vector were then used to rub inoculate unifoliate seedlings. At the V4 growth stage, the plants were petiole-inoculated at the third trifoliate with pipette tips containing agar plugs of *S. sclerotiorum.* Disease progress was monitored by measuring lesions with digital calipers over five days and calculating the area under the disease progress curve (AUDPC), and the experiment was repeated. To assess expression of the silenced target, 6 cm of stem tissue surrounding the petiole was collected from plants 0-5 days post inoculation (DPI) for RNA extractions and RT-qPCR. Three biological replicates will be collected from each time point and expressions levels will be compared.

Results and Discussion

This work demonstrates that genetic gain can be made for white mold resistance in soybean while maintaining agronomic qualities, protein and oil content, and resistance to other pathogens. Breeding efforts using a novel source of white mold resistance followed by greenhouse and field screening, resulted in the development of several promising soybean lines for release as cultivars or use as parents in breeding programs. These candidate lines include 91-38, 52-82B, SSR51-70, and 51-23. Line 91-38 achieved an average yield of 2,802.5 kg ha^{-1} (44.8 bu ac^{-1}), which is 360.2 kg ha^{-1} (5.8 bu ac^{-1}) higher than W04-1002, the white mold resistant parent, and a mean DSI value of 11.4 across all field years evaluated. Line 91-38, which possessed the novel resistance-associated marker region on chromosome 16, also had one of the lowest disease severity rankings in both field and greenhouse trials compared to the susceptible check, Dwight, and other commercial lines in 2016. Additionally, line 52-82B had one of the best yields, a three-year mean of 3,547.1 kg ha^{-1} (56.8 bu ac^{-1}), and a low DSI mean of 27.5. Line SSR51-70 consistently exhibited among the lowest disease scores for all years in both field (mean DSI of 10.7) and greenhouse studies. With a three-year mean yield of 2,972.5 kg ha^{-1} (47.6 bu ac^{-1}) and DSI of 26.2, line 51-23 also exhibits promising yield potential and a high level of white mold resistance. All lines yielded on average between 2,700 (43.2) and 3,600 kg ha^{-1} (57.6 bu ac^{-1}) and were consistently near or above the yearly state averages for 2014 (2,953.03 kg ha^{-1}), 2015 (3,322.15 kg ha^{-1}), and 2016 (3,691.27 kg ha^{-1}) (National Agricultural Statistics Service et al., 2014-2016). Overall, the yield performance, elevated disease resistance, and high protein and oil contents of these four lines provides strong evidence for their candidacy in future white mold resistance breeding programs. 2016 field and greenhouse results are available in Figure 1, and complete evaluations are available in McCaghey and Willbur et al. (2017). F3 seed from all six populations originating from 2016 crosses was sent to Chile for increase this winter in order to enhance the efficiency of the inbreeding and selection process. Selection will continue with increased seed in the summer of 2018. Additional lines for novel crosses continue to be identified with the objectives of improving white mold resistance and agronomic properties.

Concurrent work to enhance soybean resistance through RNAi has produced encouraging results. Plants containing BPMV vectors targeting OA biogenesis showed enhanced resistance to *S. sclerotiorum* compared to empty-vector control plants, in replicated experiments (Figure 2) and expression of the OA target sequence trends to reduction based on preliminary results. We propose that RNAi strategies targeting OA biogenesis, and perhaps other pathogenicity factors, will provide new tools for resistance to *S. sclerotiorum* in soybean. These promising results provide confidence to move forward with the generation and screening of resistant, transgenic plants targeting OA biogenesis.

Summary

In this study, we identified four germplasm lines; 91-38, 51-23, SSR51-70, and 52-82B exhibiting a high level of white mold resistance combined with desirable agronomic traits, including high protein and oil contents. We have validated a proof of concept that genetic gain for physiological white mold resistance can be achieved, independent of escape mechanisms such as flowering date or plant architecture that confer field tolerance, through selection in a controlled greenhouse environment. We were able to identify several soybean lines that have excellent potential as parents in a breeding program or as varieties themselves, as evidenced by the planned release of 91-38. In addition, crosses have been performed using lines 51-23, SSR51-70, and 52-82B to identify new germplasm lines with enhanced resistance through combining sources of resistance while maintaining yield potential. Improved germplasm and RNAi strategies will provide new tools for resistance to *S. sclerotiorum* in soybean.

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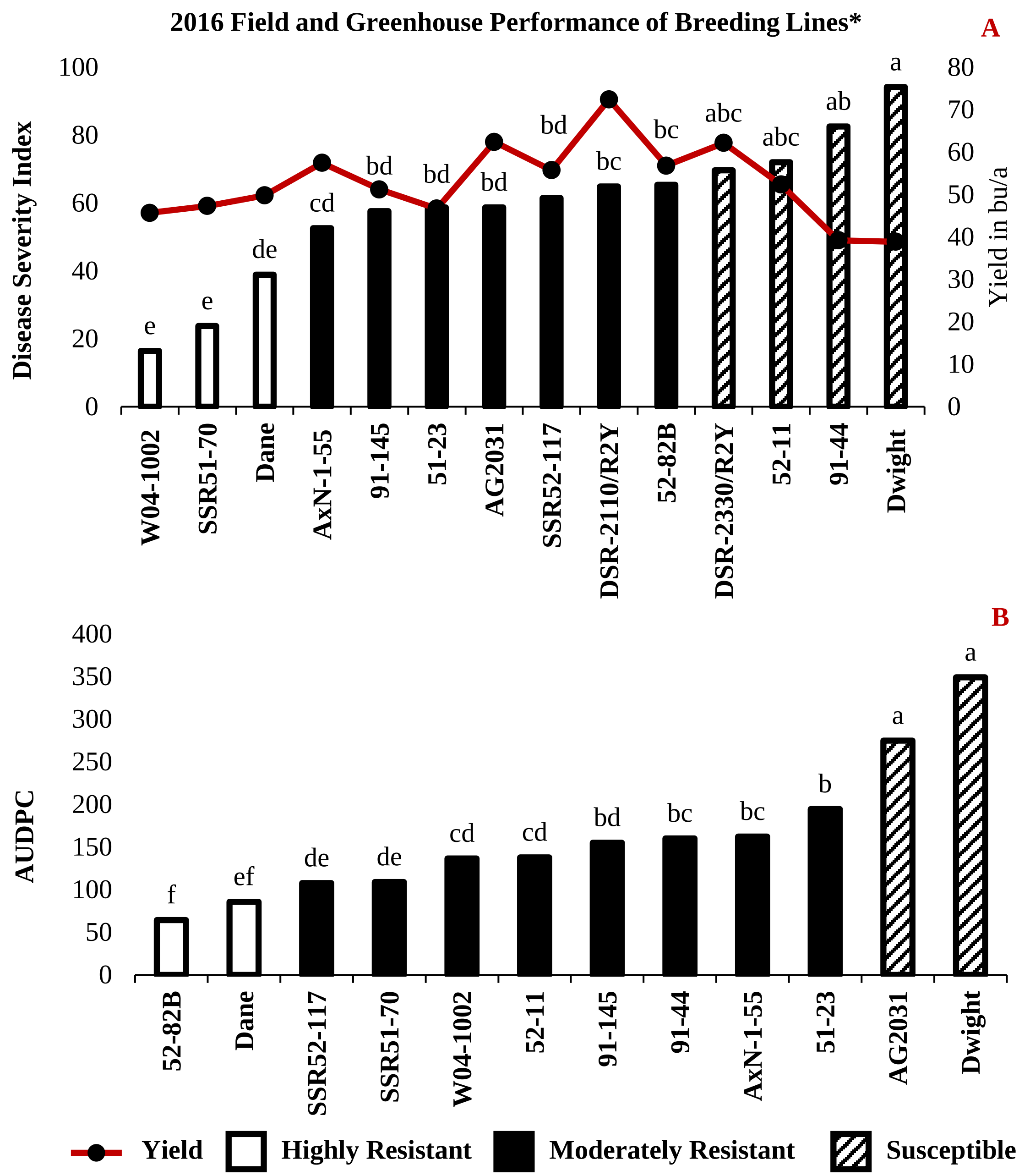

Figure 1. (A) White mold was measured using the disease severity index (DSI) which was generated by rating 30 arbitrarily selected plants in each plot and scoring plants on a 0-3 scale: 0 = no infection; 1 = infection on branches; 2 = infection on main stem with little effect on pod fill; 3 = infection on main stem resulting in death or poor pod fill. The scores of the 30 plants were totaled for each class and divided by 0.9. (B) Area under the disease progress curve (AUDPC) results from 2016 greenhouse evaluations.
*Means followed by the same letter are not significantly different based on Fisher's Least Significant Difference (LSD; α=0.05).

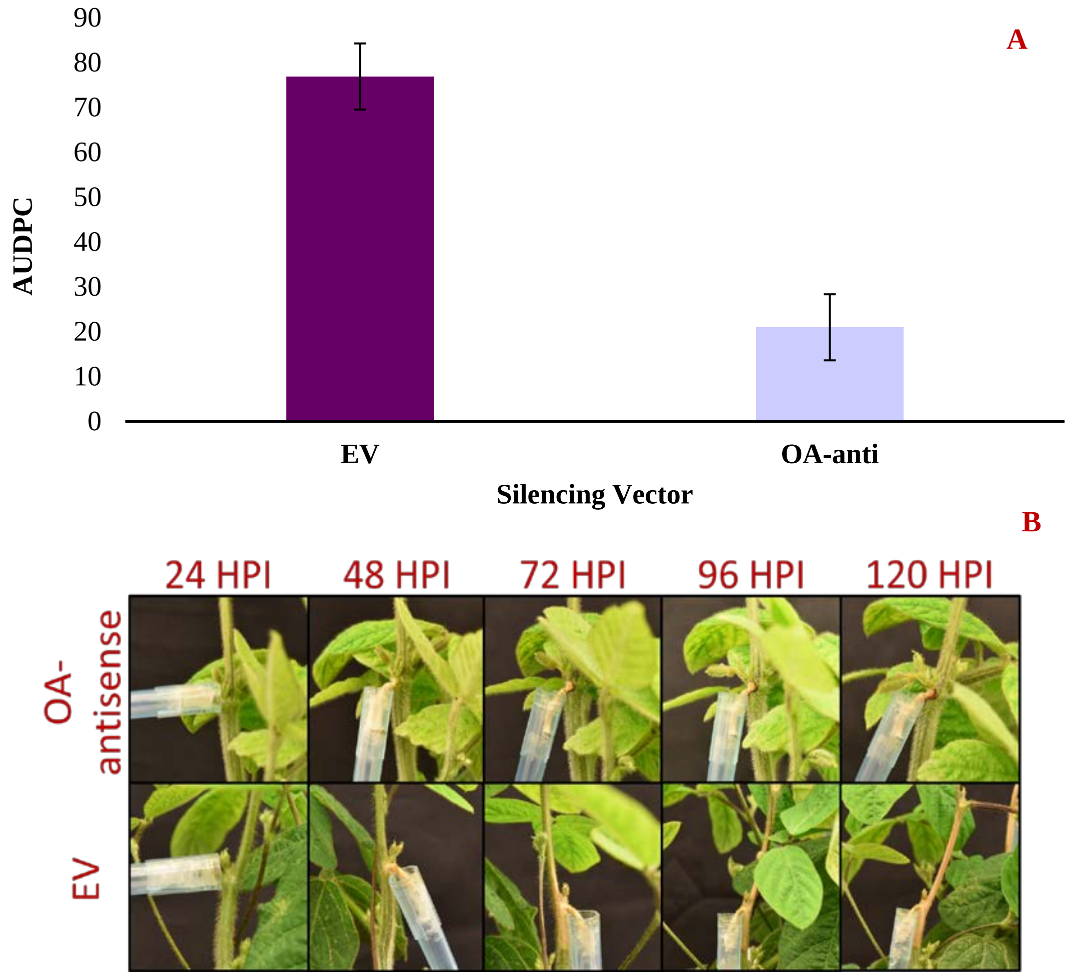

Figure 2. (A) The AUDPC was lower in soybeans transformed with the OA-antisense silencing construct compared to soybeans containing the EV (*P*=0.0035). (B) Lesions measured 24 -120 hours post inoculation (HPI) showed visual differences in the OA-antisense and EV transformed plants. Lesion development was delayed and lesions were smaller in the OA-antisense plants, whereas EV-containing plants had large, often girdling, lesions at 96 HPI.

CORN DISEASE MANAGEMENT AND FOLIAR FUNGICIDE USE: THE NEBRASKA EXPERIENCE

Tamra A. Jackson-Ziems [1/]

Foliar fungicide use in field corn has increased dramatically in some areas of the country during the past decade. The benefits of foliar fungicides for managing several fungal leaf diseases has been well-documented. Although, questions about application timing, plant health benefits, and which products to choose can make fungicide treatment decisions difficult. In this session, we will review results from foliar fungicide trials conducted on corn in Nebraska.

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MANAGING WINTER WHEAT DISEASES IN WISCONSIN

Brian Mueller[1/], Scott Chapman[2/], Shawn Conley[3/] and Damon Smith[4/]

Introduction

Since 2010 in Wisconsin, several diseases of winter wheat have become extremely impactful. The first is stripe rust, caused by the fungal plant pathogen *Puccinia striiformis* f. sp. *tritici* (*Pst*). Stripe rust has been an increasing problem in the central Great Plains and areas of the upper Midwest due to milder winters (Chen, 2005). The second disease is Fusarium head blight (FHB), which is caused by several species in the *Fusarium graminearum* species complex. The last important epidemic of FHB in Wisconsin, occurred in 2015. This epidemic caused considerable issues in the feed supply due to grain being contaminated with mycotoxins. This resulted in financial losses for farmers around the state, due to dockage at the elevator.

The occurrence of both stripe rust and FHB in winter wheat in Wisconsin results in much confusion about proper disease management. Unfortunately, management practices can differ for both diseases on winter wheat. Furthermore, changes in the epidemiology of *Pst* and the species complex of *Fusarium* have added to this confusion. In the spring of 2017, the University of Wisconsin-Madison Field Crops Pathology laboratory documented several cases where *Pst* was able to overwinter on winter wheat in Wisconsin. Prior to this finding, it was assumed that *Pst* had to be transported via spores on air currents from southern states to initiate epidemics each season. Overwintering of *Pst,* may create a challenge for Wisconsin winter wheat farmers, as this could result in earlier and more severe epidemics.

The University of Wisconsin-Madison Field Crops Pathology laboratory has also conducted surveys of winter wheat fields in Wisconsin to document the *Fusarium* species complex affecting winter wheat. We identified more than one species of *Fusarium* affecting wheat (Mueller et al., 2018). This may lead to an increase challenge in management of FHB on wheat in Wisconsin. To better understand this challenge, knowledge of the *Fusarium* population is needed. Specifically, understanding the chemotype (mycotoxin signature) of *Fusarium* isolates collected from winter wheat fields in Wisconsin will help pathologists develop better management recommendations. Species within the *F. graminearum* complex produce deoxynivalenol (DON or vomitoxin) and forms derivatives of the compound based on its acetylation cites. The fungus is profiled into chemotypes based on these derivatives; 3 acetyldeoxynivalenol (3ADON) chemotype, 15-acetyldeoxynivalenol (15ADON) chemotype, and nivalenol (NIV) chemotype. The challenges related to these pathogens and the diseases they cause has led to research to address the following objectives.

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Objectives

1. Evaluate stripe rust-resistant cultivars and fungicide timings (integrated management) in the wheat-growing region of Wisconsin for control of stripe rust.
2. Identify the primary chemotype of the *Fusarium* species complex in Wisconsin and understand the impact chemotype has on isolate aggressiveness on winter wheat.

Methods

Stripe rust integrated management study. The experimental design was a 3 x 2 x 5 factorial arranged in a randomized complete block with four replicates per treatment. Three soft red winter wheat cultivars, which consisted of susceptible cultivar 'Pro Seed 420', moderately susceptible cultivar 'Kaskaskia', and resistant cultivar 'Pro Seed 380'. Cultivars were selected based on disease assessment from Wisconsin winter wheat variety trials in 2015 (data not shown). Two fungicide products were chosen to be applied to the wheat cultivars. These included: prothioconazole (0.21 kg/L active ingredient; a.i.) + tebuconazole (0.21 kg/L a.i.) as the formulated product Prosaro 421 SC® (Bayer Crop Science Inc., Leverkusen, Germany) and Pyraclostrobin (0.25 kg/L a.i.) as the formulated product Headline SC (BASF Chemical Company, Research Triangle Park, NC). Pyraclostrobin was applied at a rate of 0.66 L/ha and prothioconazole + tebuconazole was applied at 0.48 L/ha. Five fungicide application programs were chosen. Fungicides were applied at Feekes 6, Feekes 8, and Feekes 10. To compare these single application programs to the best possible fungicide protection scenario, an additional full-season fungicide program was also implemented where fungicide was applied at Feekes 6, Feekes 8, and Feekes 10 and Feekes 10.5.1. Pyraclostrobin was used for Feekes 6-10 applications, while prothioconazole + Tebuconazole was used for Feekes 10.5.1 applications. Finally, a non-treated control was included to round out the five fungicide application programs. Feekes 6 fungicide applications were applied on April 18 in 2016 and April 24 in 2017. Feekes 8 fungicide applications were applied on May 13, 2016 and May 19, 2017. Feekes 10 applications applied on May 20, 2016 and May 25, 2017. Feekes 10.5.1 fungicide applications were made on June 1, 2016 and June 4, 2017.

Winter wheat plots were planted on September 24, 2015 for the 2016 growing season and on September 27, 2016 for the 2017 wheat crop. Plots were 6.4 m long and 2.3 m wide with 1.2-m alleys between plots in 2016. In 2017, plots were and 6.1 m long and 2.3 m wide with 1.2-m alleys between plots. In both years the seeding rate was 3.75 million seeds/ha. Urea was applied at 140 kg/ha in early spring according to local recommendations. Natural sources of pathogen inoculum were relied upon for disease. Fungicides were applied using a CO_2 pressurized backpack sprayer equipped with TTJ60-11002 Turbo TwinJet flat fan nozzles calibrated to deliver 187 l/ha at 30psi. Plots were harvested on July 19 in 2016 and August 1 in 2017.

Stripe rust was evaluated by visually estimating average disease incidence (% plants with symptoms) and average disease severity (% flag leaf covered by stripe rust symptoms) per plot with the aid of standardized area diagrams. Plots were rated for disease on Jun 6 and again on Jun 17 in 2016. Ratings for 2017 were on Jun 9 and again on Jun 21. Disease index (DX) was calculated by converting disease incidence (DI) and disease severity (DS) to proportions and then multiplying them together (DX = DI x DS; Zeng and Luo, 2006). Yield was determined by harvesting the center 1.5 m width of the entire length of each plot using an Almaco (Nevada, IA) SPC40 small-plot combine equipped with a HarvestMaster (Logan, UT) HM800 Classic Grain gauge.

***Fusarium* isolate collection and chemotype identification.** Wheat heads were collected in 12 counties throughout Wisconsin during the 2016-2017 growing seasons. Locations were chosen with an emphasis of targeting major winter wheat growing areas. Specifically, 1-2 wheat fields per county were sampled each year, arbitrarily collecting 10 FHB symptomatic heads per field while walking in a Z-pattern. In total, 10-20 heads were collected per county per year with GPS coordinates recorded at the field level.

Five kernels per head were surface sterilized in one-minute intervals with 95% ethanol, sterile distilled water, and 1% sodium hypochlorite, then rinsed in sterile distilled water and dried on filter paper. Kernels were then placed on potato dextrose agar (PDA) with ampicilin (250mg/ml), rifampicin (10mg/ml), and streptomycin (20mg/ml) in order to trigger mycelial growth. Antibiotics were incorporated into the sterilized PDA media before pouring into Petri plates. After 4-5 days of growth, one plug (5mm) per Petri plate was transferred onto smaller Petri plates containing PDA. This transfer resulted in what was considered a single-spored isolate. Once isolates grew to a diameter of approximately 50 mm, plugs were transferred into petri dishes filled with potato dextrose broth (PDB) and placed on the lab bench to grow. Mycelial mats were grown for 7-10 days at room temperature and vacuum filtrated to collect mats as material for DNA extractions. Extractions were performed using FastDNA kit (MP Biomedicals, Irvine, CA) according to the manufacturer's instructions. *Fusarium graminearum*-specific PCR multiplex primer set 3CON/3NA/3D15A/3D3A was used to confirm species and chemotype of *Fusarium* for each isolate. Amplified fragments were anticipated to be 840, 610, or 243 bp corresponding to the nivalenol (NIV), 15ADON, and 3ADON chemotypes, respectively (Starkey et al. 2007).

Greenhouse aggressiveness evaluation. From the 146 isolates positively chemotyped in 2016, isolates were grouped by county and three isolates were arbitrarily selected for each location in Wisconsin. However, 2 isolates from Monroe County were misidentified as *F. graminearum* and were removed from the study. This led to a total of 31 single-spore isolates from 11 counties used in this study.

A greenhouse experiment was conducted to test the aggressiveness of 29 *Fusarium spp.* with 15ADON chemotype and 2 *Fusarium* spp. with the 3ADON chemotype on the susceptible winter wheat cultivar 'Hopewell'. Seed was vernalized and planted (1" in depth) in Ray Leach "Cone-tainer"™ (Stuewe & Sons, Inc., Tangent, Oregon, USA). To vernalize winter wheat, seeds were surface-disinfested in 95% ethanol and 0.06 % sodium hypochlorite for one minute each. Seeds were then washed 3 times in deionized H_2O. Seeds were placed evenly on moistened filter paper in a petri plate and wrapped in parafilm. Plates were stored in refrigerator at 4 °C with no light for >6 weeks. Procedures were based on work done by Ördög and Molnár (2011) and Sasani et al. (2009).

Soil medium consisted of 10 shovelfuls of sterilized field soil to 1 bag of Pro Mix HP potting soil (ProMix Technologies LLC, Rockwall, Texas) and Nutricote Total type 100 blend slow release fertilizer (Arysta Lifescience America, Broadway, New York) containing a 13:13:13 ration of nitrogen (N), phosphorus (P), and potassium (K). A piece of paper towel was placed in the bottom of each Cone-tainer to reduce soil loss and pots were filled with 1-2 inches remaining empty at the top for watering. Plants were grown at day temperature of 22-25 °C and night temperature of 20-21 °C with a 12-hour photoperiod. Plants were irrigated daily until anthesis and fertilized weekly with Peter's (20:10:20, N:P:K) (Everris NA Inc., Dublin, Ohio) after leaf emergence.

While wheat was being grown to head emergence, single-spore *Fusarium* isolates were grown in 25ml of CMC media in a 125ml Erlenmeyer flask and placed on a shaker at room temperature for 6 days to prepare spores for inoculation. Spores were held at 4 °C until isolates were ready for inoculation. Spore concentrations were quantified with a hemacytometer and final inoculum was diluted to 1×10^5 macroconidia/ml with deionized water. Diluted inoculum was used to inoculate wheat spikes using the single-floret injection method. The central floret of a spikelet at anthesis was inoculated with 10 μl of inoculum using a pipette and denoted with non-toxic marker. Wheat heads of separate plants of the same cultivar were inoculated with 10 ul of deionized water and served as a non-treated control. Inoculated heads were covered with a plastic bag to promote infection, which was removed 3 days after inoculation. Disease measurements were taken 7, 10 and 14 days after inoculation (dai) by measuring symptomatic area on blighted spikelets using a digital caliper. Two repetitions of a single factor (isolate) experiment were conducted in a greenhouse. A randomized complete block design (RCBD) was used with four replications per isolate.

Results and Discussion

Stripe rust integrated management study. Yield and disease levels varied considerably in the 2016 and 2017 seasons. Cultivar and fungicide treatment main effects on yield and DX were significant ($P < 0.001$) (Table 1). There was no interaction of cultivar x fungicide treatment for yield ($P > 0.05$), however DX did result in a significant cultivar x fungicide treatment interaction in both 2016 and 2017 ($P<0.001$). In 2016, Pro Seed 380 and Pro Seed 420 had significantly higher yields than Kaskaskia (Table 1). However, Pro Seed 380 had significantly ($P < 0.001$) lower DX compared to Pro Seed 420 and Kaskaskia (Table 1). In 2017, Pro Seed 380 had the lowest DX and significantly higher yield than Pro Seed 420 and Kaskaskia (Table 1).

In 2016, full-season fungicide application led to significantly lower DX than the non-treated control for Kaskaskia and Pro Seed 420 (Fig. 1). There were no significant differences between treatments for Pro Seed 380. Pyraclostrobin and prothioconazole + tebuconazole applied at Feekes 8 and 10 resulted in no significant differences for DX ($P > 0.05$) when compared to the full-season fungicide application for Kaskaskia and Pro Seed 420 (Fig. 1). Feekes 6 applications of both pyraclostrobin and prothioconazole + tebuconazole resulted in no significant differences in DX compared to the non-treated control. However, Feekes 6 applications of prothioconazole + tebuconazole resulted in no difference in DX compared to full-season fungicide application on Kaskaskia.

In 2017, full season application of fungicide on Kaskaskia resulted in a 182% decrease in DX compared to the non-treated control; while DX was reduced by 184% for the same treatment compared to not treating Pro Seed 420 (Fig. 2). For Pro Seed 420, pyraclostrobin applied at Feekes 8 and 10 and prothioconazole + tebuconazole at Feekes 8 resulted in DX comparable to full-season application of fungicide. Pyraclostrobin and prothioconazole + tebuconazole applications at Feekes 6 and prothioconazole + tebuconazole at Feekes 10 differed from full-season application of fungicide, resulting in significantly lower DX than the non-treated control (Fig. 2). Applications of pyraclostrobin and prothioconazole + tebuconazole at Feekes 8 and Feekes 10 on Kaskaskia were comparable to the full-season application of fungicide. Feekes 6 application using pyraclostrobin was not different from not treating. No fungicide treatment differences were observed on the resistant cultivar Pro Seed 380 (Fig. 2).

Full season fungicide application led to the highest yields across all cultivars for the 2016 and 2017 field seasons (Fig. 3 A and B). In 2016 all other treatments were not different from the non-treated control (Fig. 3 A). However, pyraclostrobin applied at Feekes 10 and Feekes 8 resulted in comparable yields to full-season fungicide application (Fig. 3 A). In 2016, single applications of pyraclostrobin at Feekes 8 and Feekes 10 was comparable to the full-season fungicide program, which led to a 6% increase in yield.

In 2017, all fungicide treatments resulted in significantly higher yields compared to not treating, except for prothioconazole + tebuconazole applied at Feekes 8 (Fig. 3 B). Furthermore, only pyraclostrobin applied at Feekes 8 resulted in comparable yield (5896.8 kg/ha) to the full-season fungicide application. Pyraclostrobin applied at Feekes 8 produced a difference of 628.8 kg/ha when compared to not-treating which was a 11.2% yield increase (Fig. 3 B). Full-season fungicide coverage in both seasons led to a yield increase of 12-18% compared to the non-treated control (Fig. 3 A and B).

Table 1. Disease index and yield for three soft red winter wheat varieties grown in Wisconsin in 2016 and 2017.

Variety	2016		2017	
	Disease Index (DX)[y,x]	Yield (kg/ha)[x]	Disease Index (DX)[y,x]	Yield (kg/ha)[x]
Kaskaskia	0.01572 b	6598.98 b	0.03 a	5846.19 b
Pro Seed 380	0.01018 c	7022.20 a	0.01 b	6173.62 a
Pro Seed 420	0.02121 a	7044.51 a	0.03 a	5361.35 c

[y]Disease index (DX) was calculated taking proportional values of disease incidence (DI) multiplied by disease severity (DS), (DX=DI x DS).
[x]Means followed by the same letter are not significantly different based on Fisher's Least Significant Difference (LSD; α=0.05).

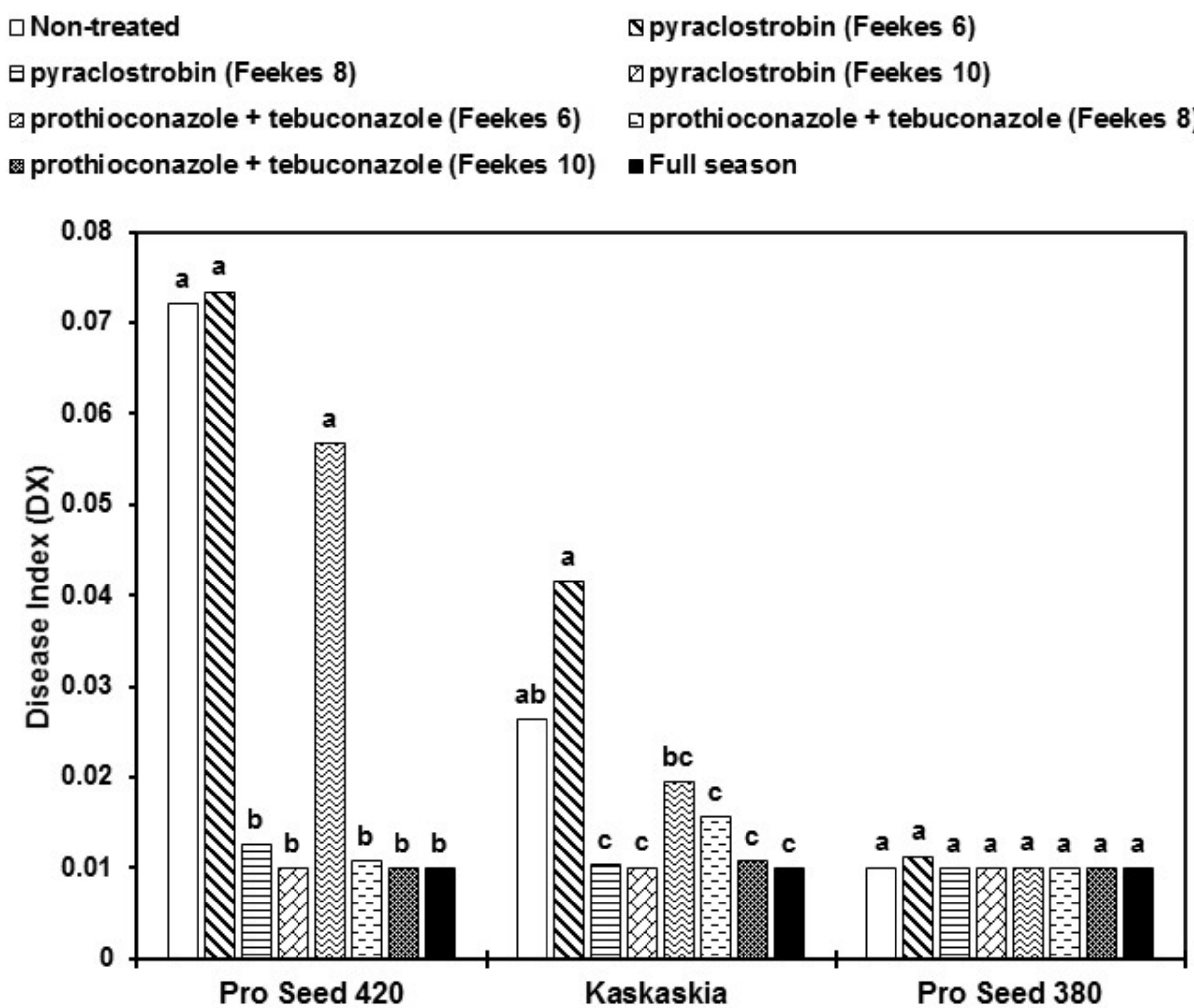

Figure 1. Mean disease index (DX) for each fungicide regime applied to three different soft red winter wheat cultivars in Arlington Wisconsin in 2016. Disease index (DX) was calculated taking proportional values of disease incidence (DI) multiplied by disease severity (DS), (DX=DI x DS).

Means followed by the same letter are not significantly different based on Fisher's Least Significant Difference (LSD; α=0.05).

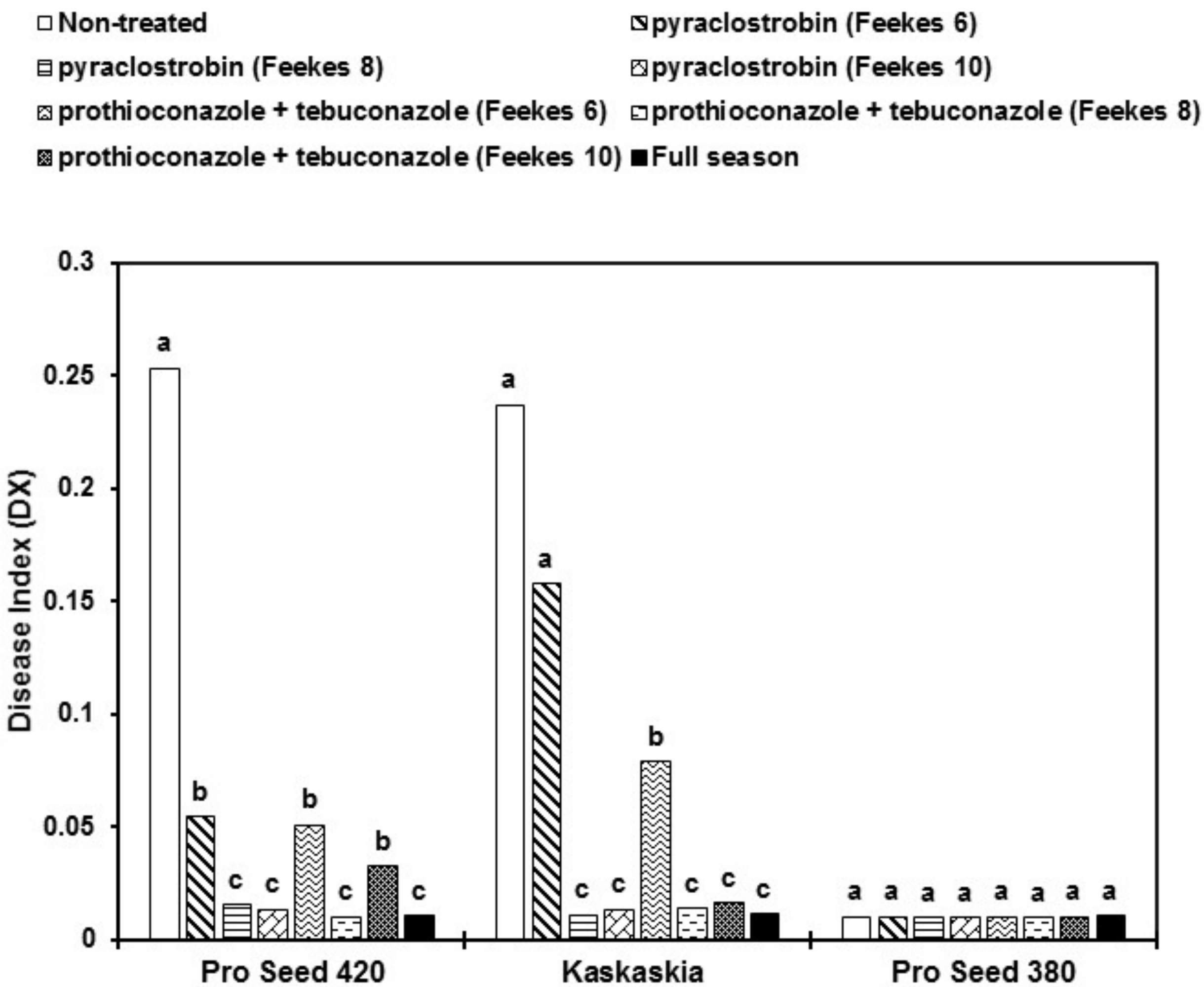

Figure 2. Mean disease index (DX) for each fungicide regime applied to three different soft red winter wheat cultivars in Arlington Wisconsin in 2017. Disease index (DX) was calculated taking proportional values of disease incidence (DI) multiplied by disease severity (DS), (DX=DI x DS). Means followed by the same letter are not significantly different based on Fisher's Least Significant Difference (LSD; α=0.05).

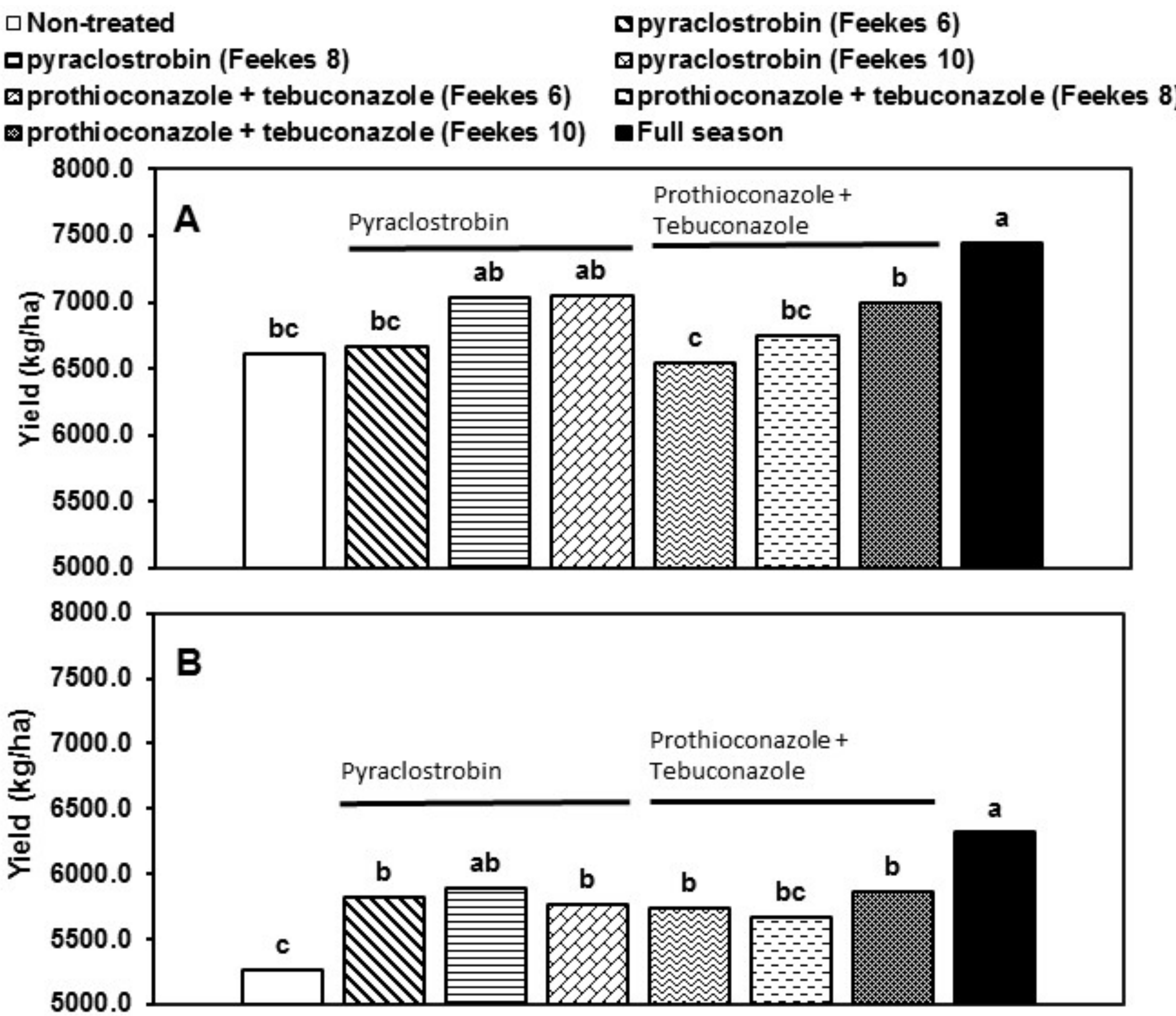

Figure 3. Yield of soft red winter wheat grown in Arlington Wisconsin and subjected to various fungicide application regimes in **A,** 2016 and **B,** 2017. Means followed by the same letter are not significantly different based on Fisher's Least Significant Difference (LSD; α=0.05).

***Fusarium* spp. identification and chemotyping.** Among 195 wheat heads collected in 2016 in Wisconsin, 145 *Fusarium* spp. were positively chemotyped as 3ADON and 15ADON. The 15ADON chemotype was predominant and amounted to 90% of the isolates, while 10% of isolates were identified as the 3ADON chemotype. In 2017, 185 samples were collected and 120 of them were positively chemotyped. Similar to 2016, 92% of the isolates were identified as the 15ADON chemotype while 8% were the 3ADON chemotype. The 3ADON chemotypes were found in six counties in 2016 and five counties in 2017. Interestingly, all 3ADON isolates belonged to counties found in the northern half of Wisconsin. Additionally, sequencing of 3ADON isolates DO12 and DO14 from the aggressiveness study identified isolates as *F. culmorum.* A total of five *F. culmorum* isolates with the 3ADON chemotype were identified in 2016. All *F. culmorum* isolates were found in a single field located in Door Co.

Greenhouse aggressiveness evaluation. The 31 isolates from 2016 tested in the greenhouse were found to have significant differences in AUDPC values ($P<0.0001$) (Fig. 4). AUDPC values ranged from 90.5 to 304.4. Isolate CO6 produced the greatest level of disease but was not significantly different from 11 other isolates. The 3ADON isolates, DO12 and DO14, were highly aggressive and were in the top 6 for AUDPC values (Fig. 4).

At the county level, there were significant differences between isolates from counties in Wisconsin (*P*<0.0001). Isolates from Door County had the highest disease level with an AUDPC value of 259.2 while isolates from Eau Claire County resulted in the lowest disease with a value of 167.8 (Fig. 5). Isolates from Door Co. resulted in disease levels that were not significantly different from isolates in 6 other counties. Isolates from Baron Co. and Walworth Co. resulted in low disease levels and were not statistically different from isolates from Eau Claire Co.

Separating counties into their eight statewide districts, isolates collected from east and south-central districts were the most aggressive with AUDPC values of 247.4 and 246.7, respectively (Fig. 6). The isolates collected from the northwest and west-central districts had the lowest disease levels. Isolates collected from the north-central, south-west and central districts resulted in disease levels that were not statistically different from those that resulted from isolates collected from east and south-central districts. Districts and counties with the most aggressive isolates fall into areas where majority of winter wheat is grown in Wisconsin.

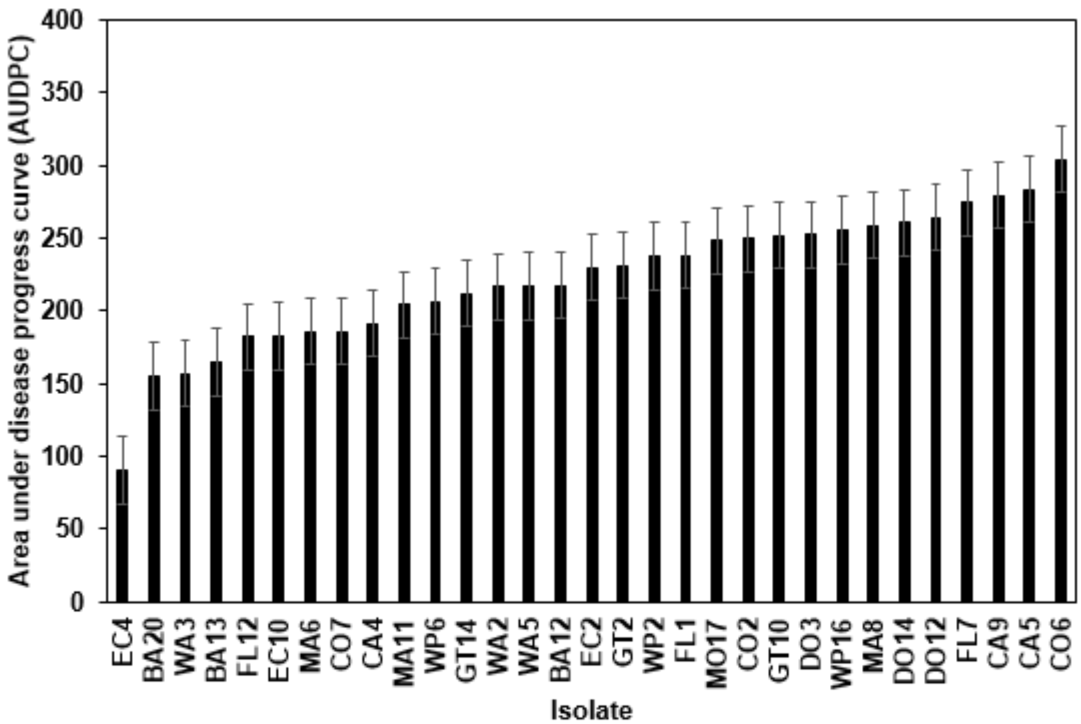

Figure 4. Area under disease progress curve (AUDPC), by isolate, for 29 *Fusarium* spp. with 15 ADON chemotype and 2 *Fusarium* spp. with the 3 ADON chemotype on the susceptible winter wheat cultivar 'Hopewell' in a greenhouse experiment.

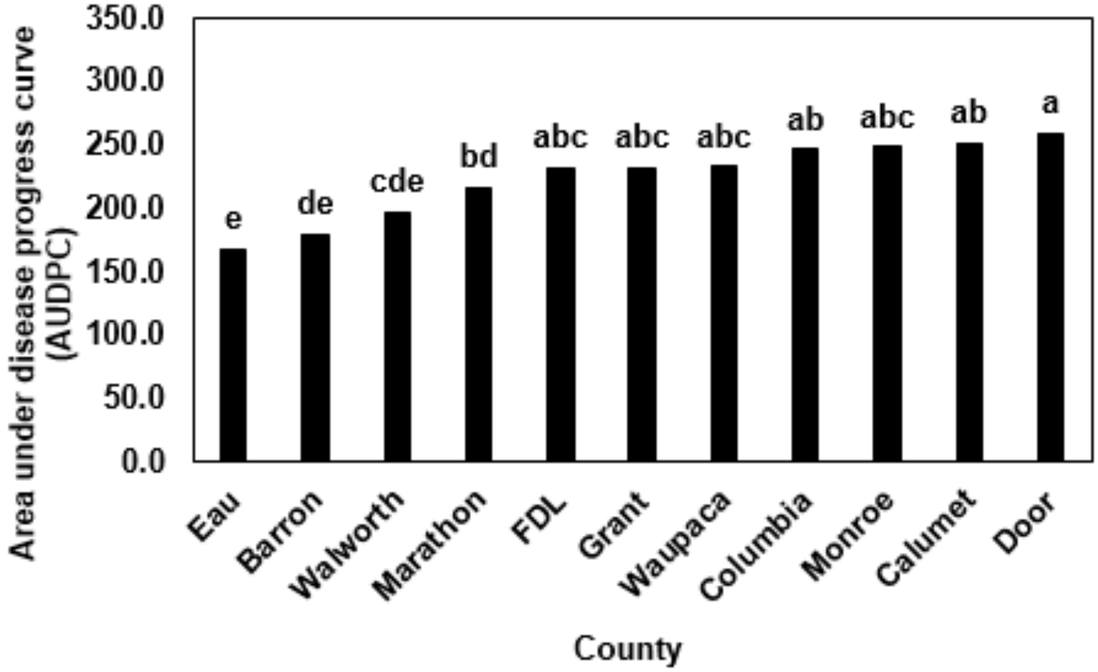

Figure 5. Area under disease progress curve (AUDPC), by county, for 29 *Fusarium* spp. with 15 ADON chemotype and 2 *Fusarium* spp. with the 3 ADON chemotype on the susceptible winter wheat cultivar 'Hopewell' in a greenhouse experiment. Bars with the same letter are not significantly different based on Fisher's Least Significant Difference (LSD; α=0.05).

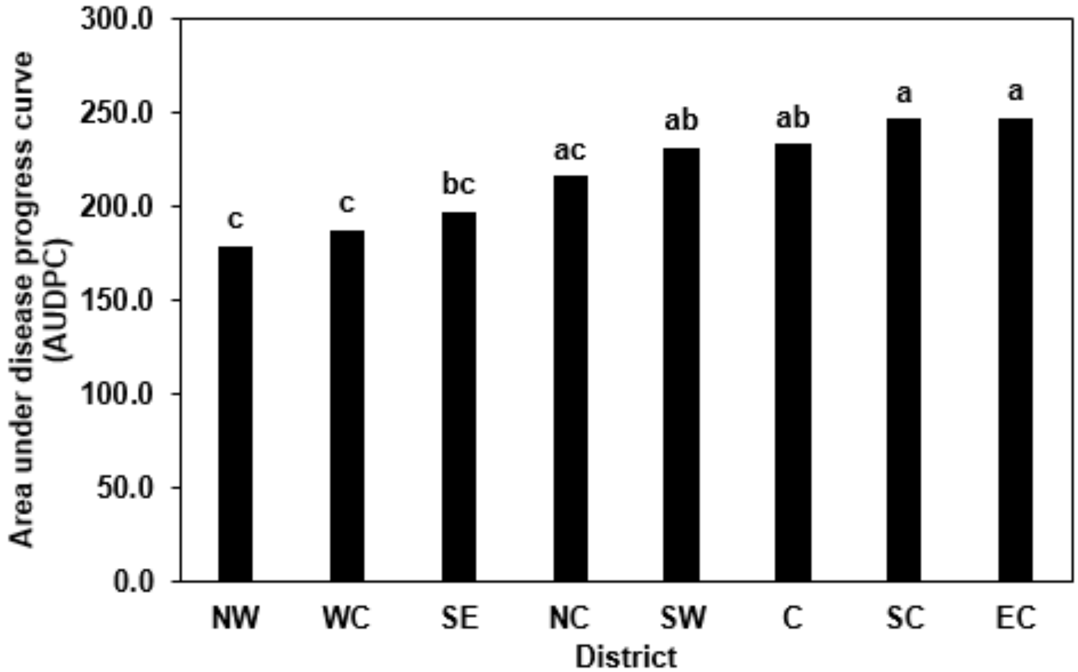

Figure 6. Area under disease progress curve (AUDPC), by district, for 29 *Fusarium* spp. with 15 ADON chemotype and 2 *Fusarium* spp. with the 3 ADON chemotype on the susceptible winter wheat cultivar 'Hopewell' in a greenhouse experiment. Bars with the same letter are not significantly different based on Fisher's Least Significant Difference (LSD; α=0.05).

<u>Summary</u>

Planting resistant cultivars and applying foliar fungicides are common management practices to control for this pathogen. In this 2-year study, two fungicides applied at three growth stages were tested on three soft red winter wheat cultivars varying in levels of resistance to stripe rust. Both fungicides (prothioconazole + tebuconazole and pyraclostrobin) applied at Feekes 8 and 10 reduced disease index (DX) and increased yield compared with the non-treated control in susceptible (Pro Seed 420) and moderately resistant cultivars (Kaskaskia). The highly resistant cultivar (Pro Seed 380), had the highest yields and fungicide treatments had no effect on disease levels. This study confirmed that cultivar resistance to stripe rust can be highly effective in managing the disease, while a properly timed fungicide application can be critical on susceptible cultivars.

This study also assessed chemotype population from 2016 and 2017 in Wisconsin. Over both growing seasons, 91% of isolates were identified as the 15ADON chemotype while 9% of isolates were positively identified as the 3ADON chemotype. Aggressiveness was quantified by area under disease progress curve (AUDPC) over 14 days post inoculation, with AUDPC values ranging from 304.35 to 90.5. The most aggressive isolates were found to be located in the highest wheat production areas in the state. 3ADON isolates were among the most aggressive. These results show the baseline frequency and distribution of 3ADON and 15ADON chemotypes observed in Wisconsin,

which should be monitored in the future. This research also demonstrates that there is a wide range in *Fusarium* population in Wisconsin. This range in population can create challenges in managing FHB, especially considering commercial cultivars only have partial resistance to FHB. **Thus, farmers should focus on choosing winter wheat cultivars that are rated with the highest resistance to stripe rust they can find. With only marginal FHB resistance, in-season fungicide management should then focus on controlling FHB.** This integrated approach can help Wisconsin farmers be profitable while efficiently managing winter wheat diseases.

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ASSESSING KERNEL PROCESSING FOR HIGH-QUALITY FEED PRODUCTION

Brian D. Luck[1]

The extent of kernel processing has an effect on animal feed quality and machine fuel usage. Current methods require laboratory equipment which results in a delay between sampling and results. An image processing algorithm to determine the size distribution of corn kernel particles was developed. The algorithm was verified through analyzing images of particles with a known diameter. Kernels processes with 1, 2, 3, and 4 mm roll gap settings were analyzed and compared with the standard sieving method. This method can accurately determine the extent of processing in the field while adjustments to the harvest can still be made.

Methods:

Typical assessment of corn kernel particle size distribution is done by either sieving a sample, utilizing the Penn State Particle Separator, or visually assessing a known volume of chopped and processed corn silage (Figure 1). These assessment methods all have problems in that they are either subjective in their assessment methods or require assessment off-site and results do not return until after harvest has been completed.

Figure 1. Typical methods of assessing corn kernel particle size in chopped and processed corn silage. From left to right: 1) Ro-Tap™ Sieving, 2) Penn State Particle Separator, 3) One liter cups.

Chopped and processed corn silage samples were collected in a production corn silage field at the University of Wisconsin-Madison Arlington Agricultural Research Station (Arlington, WI) in 2015, 2016, and 2017. A self-propelled forage harvester (SPFH) (940 Jaguar, Claas North America, Omaha, NE) equipped with Shredlage™ crop processing rolls (Scherer Design Engineering Inc., Tea, SD) was used to harvest the standing corn. The theoretical length of cut was set to 1.9 cm and the machine was equipped with an 8 row gathering head. The crop processor rolls were set at 1, 2, 3, and 4 mm roller clearances. At each roller clearance setting 15.24 m of corn was harvested and blown on the ground in separate piles. Samples, approximately 600 mL per sample, of whole plant corn silage (WPCS) were pulled from each pile at random locations. Samples were placed in plastic sealable bags (Whirl-Pak 99100125, Nasco, Ft. Atkinson, WI) and were frozen within two hours of collection to maintain sample integrity and moisture content.

These samples were assessed with image analysis as wet (fresh), dry, and post sieved. Results were compared to sieved samples that were only assessed after the sample had been dried. The image analysis software utilizes an object of known size to identify the size of each pixel in the image and then measures the Maximum Inscribed Circle Diameter of each particle within the image (Figure 2). Table 2 shows the comparison of all sample states at each roller gap settings with the sieve results for samples collected in 2016.

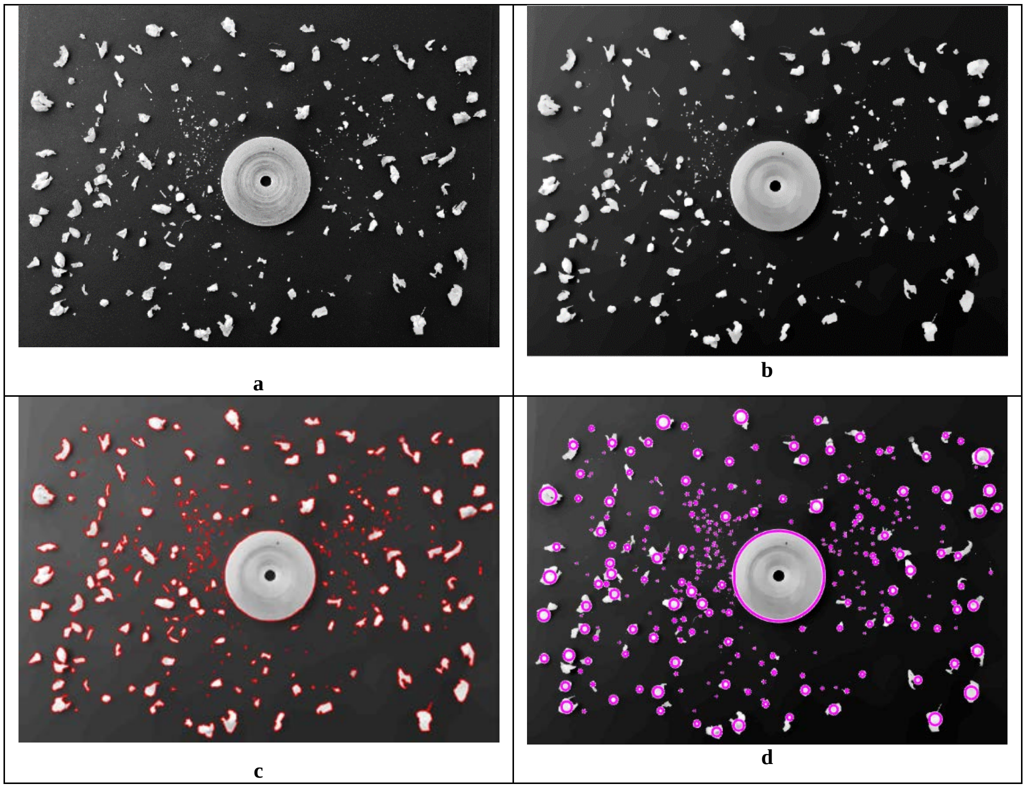

Figure 2. Example of the steps of the image processing algorithm (a) image is imported, (b) image was denoised, (c) contour of each particle was identified, (d) maximum inscribed circle of each particle was identified.

Table 1. Percent of particles smaller than 4.75 mm (Kernel Processing Score) by area (image analysis) or by mass (sieve analysis) for 2016 samples.

		Percent under 4.75 mm			
Processor Gap	Sample	Image analysis			Sieve
		wet	dry	sieved	dry
1	1	68.6	79.4	82.1	80.9
1	2	76.9	83.1	85.5	82.9
1	3	78.3	84.9	86.7	84.5
2	4	71.1	79.2	79.0	71.9
2	5	72.6	84.4	86.5	84.5
2	6	69.1	77.6	80.0	71.2
3	7	69.2	79.3	82.9	77.3
3	8	68.1	78.6	80.0	79.2
3	9	69.1	77.9	80.2	75.0
4	10	55.7	73.1	74.7	65.2
4	11	63.7	74.7	75.7	62.6
4	12	59.0	70.3	73.1	61.2

Results from this work have been translated into a smartphone application called SilageSnap (Figure 3). The application allows producers and custom harvesters to assess the particle size of the corn kernels within chopped and processed corn silage during harvest. An added step of hydrodynamic separation of the corn kernels from the plant material is required. Also, a U.S. coin will serve as the object of know size within the image and the photo must be taken on a dark background. The app is currently in the final stages of development and is slated for release in early 2018.

Figure 3. SilageSnap app for image analysis assessment of corn kernel particle size distribution in chopped and processed corn silage. From left to right: 1) Home Screen, 2) Good Results Screen, 3) Bad Results Screen.

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CAN LESS BE MORE – HOW MUCH ALFALFA SHOULD I BE SEEDING AT ESTABLISHMENT?

Kevin Jarek and Mark Renz[1]

Introduction

The alfalfa seed industry has introduced coated seeds over the last decade to improve establishment of alfalfa seedlings. These coatings can be light or heavy but are still sold in 50 pound bags. As a result, farmers are getting less **Pure Live Seed** (**PLS**) in a bag; while these coatings may enhance each individual seed's ability to establish successfully, it does reduce the total number of seeds in a bag when purchased by weight. Rhizobium bacteria, fungicide, colorant and polymers that bind the material are the most common constituents of "coated" seeds. Due to these changes, farmers have been asking UW-Extension educators ***"What seeding rate should we be using to maximize our plant establishment?"***

The most recent alfalfa seeding recommendations for the upper Midwest suggest that farmers should not be planting less than **10 pounds of pure live seed (PLS)** per acre to maximize plant establishment and overall yield. In contrast, industry recommendations often exceed those of the Midwest resulting in > 12 pounds of PLS per acre. As Wisconsin harvests approximately 1.25 million acres of alfalfa each year, the need to provide efficient and effective alfalfa seeding rate guidelines are critical.

The UW-Extension Team Forage Wisconsin Alfalfa Yield and Persistence (WAYP) project (2007-2016) has revealed that most Wisconsin farmers are planting alfalfa at rates of 15-17 pounds of seed per acre at the time of establishment regardless of the amount of coating or inert material (Wisconsin Alfalfa Yield and Persistence Program Summary Report, 2016). Seeding rates during the lifetime of the WAYP project show a range of 12 pounds per acre to 28 pounds per acre. So, with a range that wide, the question should be not how many pounds of alfalfa seed should I be planting, but, instead, ***"How many pounds of PLS alfalfa should I be seeding at establishment?"***

A typical 15 pounds/acre seeding rate would result in approximately 75 seeds/square foot. Previous work done examining alfalfa seeding rates revealed that once emergence is complete in three to four weeks, only approximately 50-70 percent of those seeds planted will have established as seedlings, leaving us with approximately 45 plants/square foot. Another 40-50 percent of those plants will no longer be present by the following spring, resulting in approximately 25 plants/square foot heading into the first full production year.

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Response

In an effort to help farmers answer the question about alfalfa seeding rate recommendations a UW-Madison/UW-Extension Badger Plot Survey was developed. Members of the UW-Extension Team Forage Agronomy Workgroup recruited farmers in their respective counties across Wisconsin to participate in a statewide effort to collect on-farm data and track alfalfa plant and stem counts over the life of a newly established stand of alfalfa from beginning to time of rotation. The effort enlisted the help of county agents tracking alfalfa fields in Calumet, Chippewa, Clark, Outagamie, Shawano, and St. Croix counties. Agents and educators were able to measure how many plants emerged and survived. Farmers were using different seeding rates with both coated and non-coated products which resulted in a diverse set of data measuring how the number of alfalfa plants and stems diminishes over time.

The experimental design that was developed asked each participating farmer to seed their alfalfa fields according to their own existing production practices. The partnering UW-Extension agent/educator was responsible for collecting a range of information from each field. In this presentation we will report on the *Seeding Rate (in PLS), Plant Stand Counts measured in the spring and fall each year, and Plant Stem Counts measured in the spring and fall each year.*

Results and Discussion

Participating farms reported alfalfa seeding rates of 12.5 pounds per acre to 22.5 pounds per acre. When converted to PLS the range was 8.8 to 17.8 pounds per acre for alfalfa fields across the state. The objective of this effort was to determine whether or not alfalfa seeding rates above the upper Midwest recommendation of 10 pounds PLS per acre result in any significant difference in plant and/or stem counts during the life of the stand.

Figure 1 illustrates the number of alfalfa plants measured per square foot in the fall of the second full production year across three different PLS seeding rates. After analysis, no significant differences (P=0.23) were noted between plant counts at the PLS seeding rates identified.

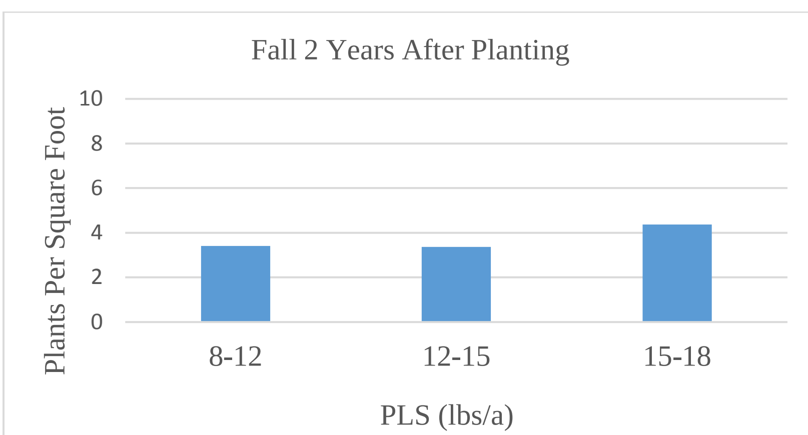

Figure 1

Stem counts are often used to determine whether or not an alfalfa field will produce an economic yield for the season. The number and size of stems often determine a field's productivity over a growing season. Figure 2 illustrates the number of alfalfa plant stems measured per square foot in the fall of the second full production year across three different PLS seeding rates. After analysis, no statistically significant differences (P=0.15) were noted between plant stem counts and the PLS seeding rates identified.

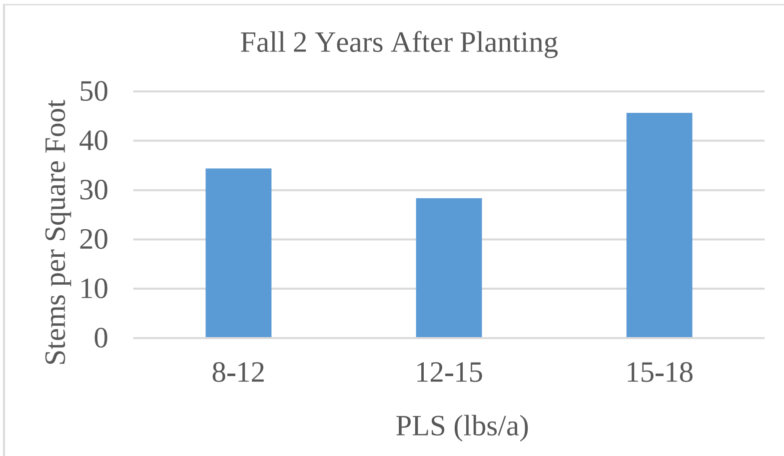

Figure 2

References

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Key Management Practices That Explain Soybean Yield Gaps Across the North Central US

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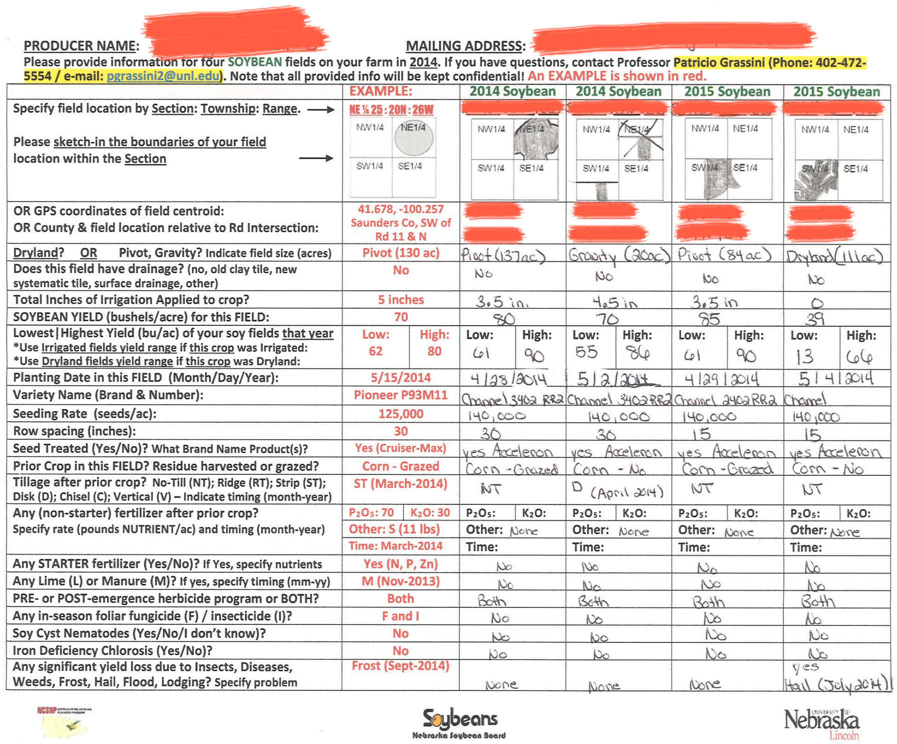
Highlights

- We developed a novel approach that combines producer survey data with a biophysical spatial framework for identifying causes of yield gaps over large agricultural areas with diversity in climate and soils.
- The approach was applied to both rainfed and irrigated soybean in the North Central US region, and it was based on producer survey data on yield and management collected from 3,568 fields over two crop seasons.
- The analysis indicated that the average regional yield potential was 71 bu ac^{-1} (rainfed) and 85 bu ac^{-1} (irrigated), with a respective yield gap of 22% and 13% of maximum yield potential.
- Planting date, tillage, and in-season foliar fungicide and/or insecticide were identified as explanatory causes for yield variation, with planting date the most consistent management factor that influenced soybean yield.

Introduction

To date identification of causes of yield gaps (difference between maximum yield potential and measured yield in producer yields) has been restricted to small geographic areas. In this study, we developed a novel approach that combines producer-reported data and a spatial framework to identify explanatory causes of yield gap over large geographic regions with diversity of climate, soils, and water regimes (rainfed and irrigated). We focused on soybean in the North-Central United States region, which accounts for approximately one third of global soybean production, as a case study to provide a proof of concept on the proposed approach. The specific objectives of

Figure 1. Example of an actual survey form from a Nebraska soybean producer that provides information for three irrigated fields and one rainfed field planted to soybean in 2014 and 2015. This survey form was used to collect information from producer fields across 10 states in the North Central US region. Note that producer name is not shown and field location was hatched in order to keep personal information confidential.



PRODUCER NAME: [redacted] MAILING ADDRESS: [redacted]
Please provide information for four SOYBEAN fields on your farm in 2014. If you have questions, contact Professor Patricio Grassini (Phone: 402-472-5554 / e-mail: pgrassini2@unl.edu). Note that all provided info will be kept confidential! An EXAMPLE is shown in red.

	EXAMPLE:	2014 Soybean	2014 Soybean	2015 Soybean	2015 Soybean
Specify field location by Section: Township: Range. →	NE ¼ 25 : 20N : 26W	[redacted]	[redacted]	[redacted]	[redacted]
Please sketch-in the boundaries of your field location within the Section →	NW1/4 NE1/4 SW1/4 SE1/4	NW1/4 NE1/4 SW1/4 SE1/4	NW1/4 NE1/4 SW1/4 SE1/4	NW1/4 NE1/4 SW1/4 SE1/4	NW1/4 NE1/4 SW1/4 SE1/4
OR GPS coordinates of field centroid: OR County & field location relative to Rd Intersection:	41.678, -100.257 Saunders Co, SW of Rd 11 & N	[redacted]	[redacted]	[redacted]	[redacted]
Dryland? OR Pivot, Gravity? Indicate field size (acres)	Pivot (130 ac)	Pivot (137ac)	Gravity (20ac)	Pivot (84ac)	Dryland (111ac)
Does this field have drainage? (no, old clay tile, new systematic tile, surface drainage, other)	No	No	No	No	No
Total Inches of Irrigation Applied to crop?	5 inches	3.5 in.	4.5 in	3.5 in	0
SOYBEAN YIELD (bushels/acre) for this FIELD:	70	80	70	85	39
Lowest|Highest Yield (bu/ac) of your soy fields that year *Use Irrigated fields yield range if this crop was Irrigated: *Use Dryland fields yield range if this crop was Dryland:	Low: 62 High: 80	Low: 61 High: 90	Low: 55 High: 86	Low: 61 High: 90	Low: 13 High: 66
Planting Date in this FIELD (Month/Day/Year):	5/15/2014	4/28/2014	5/2/2014	4/29/2014	5/4/2014
Variety Name (Brand & Number):	Pioneer P93M11	Channel 3402 RR2	Channel 3402RR2	Channel 2402RR2	Channel
Seeding Rate (seeds/ac):	125,000	140,000	140,000	140,000	140,000
Row spacing (inches):	30	30	30	15	15
Seed Treated (Yes/No)? What Brand Name Product(s)?	Yes (Cruiser-Max)	yes Acceleron	yes Acceleron	yes Acceleron	yes Acceleron
Prior Crop in this FIELD? Residue harvested or grazed?	Corn - Grazed	Corn - Grazed	Corn - No	Corn - Grazed	Corn - No
Tillage after prior crop? No-Till (NT); Ridge (RT); Strip (ST); Disk (D); Chisel (C); Vertical (V) – Indicate timing (month-year)	ST (March-2014)	NT	D (April 2014)	NT	NT
Any (non-starter) fertilizer after prior crop? Specify rate (pounds NUTRIENT/ac) and timing (month-year)	P_2O_5: 70 K_2O: 30 Other: S (11 lbs) Time: March-2014	P_2O_5: K_2O: Other: None Time:	P_2O_5: K_2O: Other: None Time:	P_2O_5: K_2O: Other: None Time:	P_2O_5: K_2O: Other: None Time:
Any STARTER fertilizer (Yes/No)? If Yes, specify nutrients	Yes (N, P, Zn)	No	No	No	No
Any Lime (L) or Manure (M)? If yes, specify timing (mm-yy)	M (Nov-2013)	No	No	No	No
PRE- or POST-emergence herbicide program or BOTH?	Both	Both	Both	Both	Both
Any in-season foliar fungicide (F) / insecticide (I)?	F and I	No	No	No	No
Soy Cyst Nematodes (Yes/No/I don't know)?	No	No	No	No	No
Iron Deficiency Chlorosis (Yes/No)?	No	No	No	No	No
Any significant yield loss due to Insects, Diseases, Weeds, Frost, Hail, Flood, Lodging? Specify problem	Frost (Sept-2014)	None	None	None	yes Hail (July 2014)

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this project were to evaluate the proposed approach for its ability to: (1) benchmark producer soybean yields in relation to yield potential of their fields, (2) identify key management practices that explain yield gaps, and (3) explain the drivers for some of the observed (M)anagement × (E)nvironment interactions.

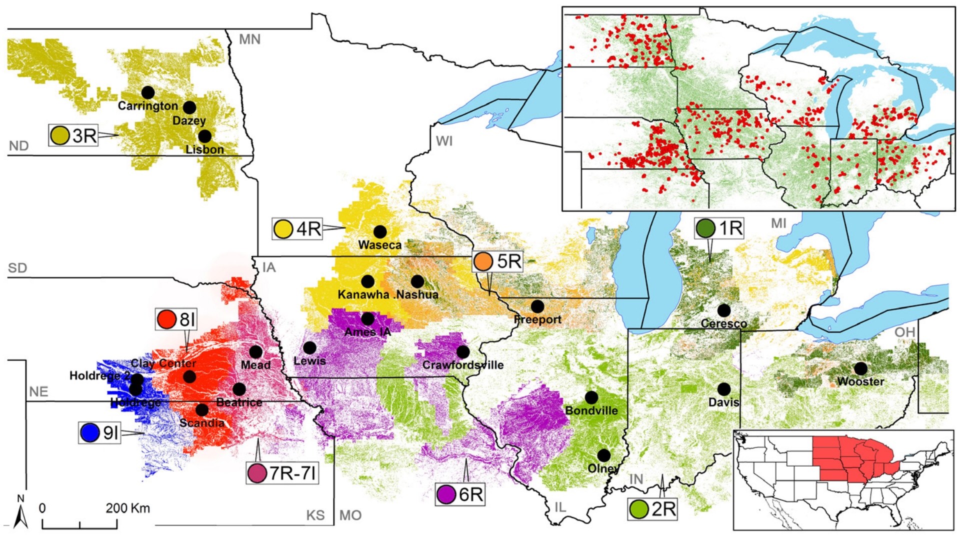
Producer data collection and quality control

Data on soybean yield and management practices were collected over two crop seasons (2014 and 2015) from fields planted to soybean in 10 states in the North Central US region: Illinois (IL), Indiana (IN), Iowa (IA), Kansas (KS), Michigan (MI), Minnesota (MN), Ohio (OH), Nebraska (NE), North Dakota (ND), and Wisconsin (WI). Soybean producers provided data via returned surveys distributed by local crop consultants, Extension educators, soybean grower boards, and Natural Resources Districts (Figure 1). Briefly, producers were asked to report the range of average field yield across the fields planted to soybean in each year and water regime and to provide data for a number of fields that portray well that yield range. Requested data also included field location, average field yield, crop management (e.g., planting date, seeding rate, row spacing, cultivar, and tillage method), applied inputs (e.g., irrigation, fertilizer, lime, manure,

Figure 2. Map of the North Central US region showing nine technology extrapolation domains (TEDs) and meteorological stations (solid circles) selected for the present study. A coding system (from TED 1 to 9) is used to identify each TED (shown with a unique color) and its associated water regime (I: irrigated, R: rainfed). There were actually 10 TED-water regimes (denominated as just TEDs for simplicity) because rainfed and irrigated fields co-existed in TED 7 (7R and 7I, respectively).

Top inset. Soybean harvested area in year 2015 (green area; USDA-NASS, 2016b) and location of the 3,216 surveyed soybean fields (red dots).

Bottom inset. Location of North Central US region — 12 states within the conterminous US.



and pesticides), and incidence of biotic and abiotic factors (e.g., insect pests, diseases, weeds, hail, waterlogging, and frost). Survey data were inputted into a digital database and screened to remove erroneous or missing data entries. We were interested in yield variation as related with management factors; hence, a few fields with extremely low yield due to incidence of unmanageable production site adversities (hail, waterlogging, wind, and frost) were excluded from the analyses. After quality control, the database contained data from a total of 3,216 fields planted to soybean in 2014 and 2015.

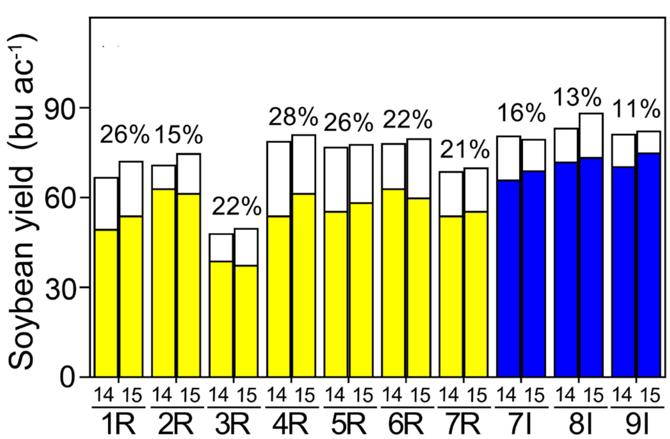
Producer data stratification based on soil-climate conditions

A major challenge with this kind of data is how to cluster producer fields in order to identify management factors that consistently lead to higher yields for a given climate-soil combination. In the present study, surveyed fields were grouped based upon their climate and soil using the spatial framework developed for the central and eastern US by the Global Yield Gap Atlas (http://www.yieldgap.org). This framework delineates regions [hereafter called technology extrapolation domains (TEDs)] based on four biophysical attributes that govern crop yield and its inter-annual variability: (1) annual total growing degree-days, which, in large part, determines the length of crop growing season, (2) aridity index, which largely defines the degree of water limitation in rainfed cropping systems, (3) annual temperature seasonality, which differentiates between temperate and tropical climates, and (4) plant-available water holding capacity in the rootable soil depth, which determines the ability of the soil to supply water to support crop growth during rain-free periods. We selected TEDs that portrayed the diversity of climate, soils, and water regimes in the North Central US region (Figure 2). Six TEDs included only rainfed soybean fields (1R, 2R, 3R, 4R, 5R, and 6R) while two TEDs included only irrigated soybean fields (8I and 9I). One TED included both irrigated and rainfed soybean fields (7I and 7R). Because the impact of management factors on yield is influenced by water supply, we separated water regimes (WR; rainfed and irrigated) within the same TED. Hence, a total of 10 TED-WR combinations were eventually used in this study, which are referred hereafter as TEDs for simplicity (total of 10 TEDs). Selected TEDs included 38% of the surveyed fields (total of 1343 fields) and accounted for 25 and 45% of US rainfed and irrigated soybean area, respectively. Each individual TED contained ≥98 (rainfed) and ≥59 (irrigated) surveyed fields, with an average of 137 fields per TED.

Yield potential, average producer yield, and yield gaps

Annual yield potential (Yp, yield potential of irrigated field) and water-limited yield potential (Yw, yield potential of rainfed fields) were estimated using measured daily weather data (including solar radiation, rainfall, and maximum and minimum air temperature) collected at 2–3 meteorological stations located within each TED, preferably in proximity to the areas with the highest density of surveyed fields. Yw and Yp were used as benchmarks for calculating yield gap for rainfed (TEDs 1R, 2R, 3R, 4R, 5R, 6R, and 7R) and for irrigated TEDs (7I, 8I, and 9I). The yield gap was calculated as the difference between Yp (or Yw) and average producer yield and expressed as percentage of Yp (irrigated) or Yw (rainfed).

Figure 3. Yield potential for rainfed (Yw) and irrigated (Yp) soybean in each of the 10 TEDs in 2014 (14) and 2015 (15). Solid and empty portions of the bars represent the average producer yield and yield gap, respectively. Values on top of the bars indicate the (2-year) average yield gap, expressed as percentage of Yw (rainfed) or Yp (irrigated).



Average Yw ranged from 48–80 bu ac^{-1}, while Yp varied from 80–91 bu ac^{-1} across TEDs (Figure 3). TED 3R exhibited the lowest Yw due to lower seasonal precipitation in relation with other TEDs. In contrast, Yp was highest in TED 8I due to non-limiting water supply and high incident solar radiation. Upscaled to the entire North Central US region, Yw and Yp averaged 71 and 85 bu ac^{-1}, respectively. Average producer yield was consistently lower than Yw (or Yp) across all TEDs ($p < 0.01$), and there was a large variation in average annual yield across TEDs, ranging from 39–73 bu ac^{-1}. Yield gap, expressed as percentage of Yp (irrigated) or Yw (rainfed), tended to be larger in rainfed (range: 15–28%) than in irrigated TEDs (range: 11–16%). At the regional level, the rainfed yield gap averaged 22% in contrast to the irrigated yield gap of 13%.

Figure 4. Producer soybean yield plotted against planting date in 10 technology extrapolation domains (TED) in the NC USA region, including rainfed (A–G) and irrigated (G–I) production areas. Solid line corresponds to the fitted boundary function using quantile regression (percentile 90th). Separate boundaries were derived for rainfed (empty symbols) and irrigated (solid symbols) soybean fields in TED7. Slope of the fitted boundary function (b) is shown, with asterisks indicating significance at $p < 0.1$*, $p < 0.05$**, and $p < 0.01$*** for the null hypothesis of $b = 0$.

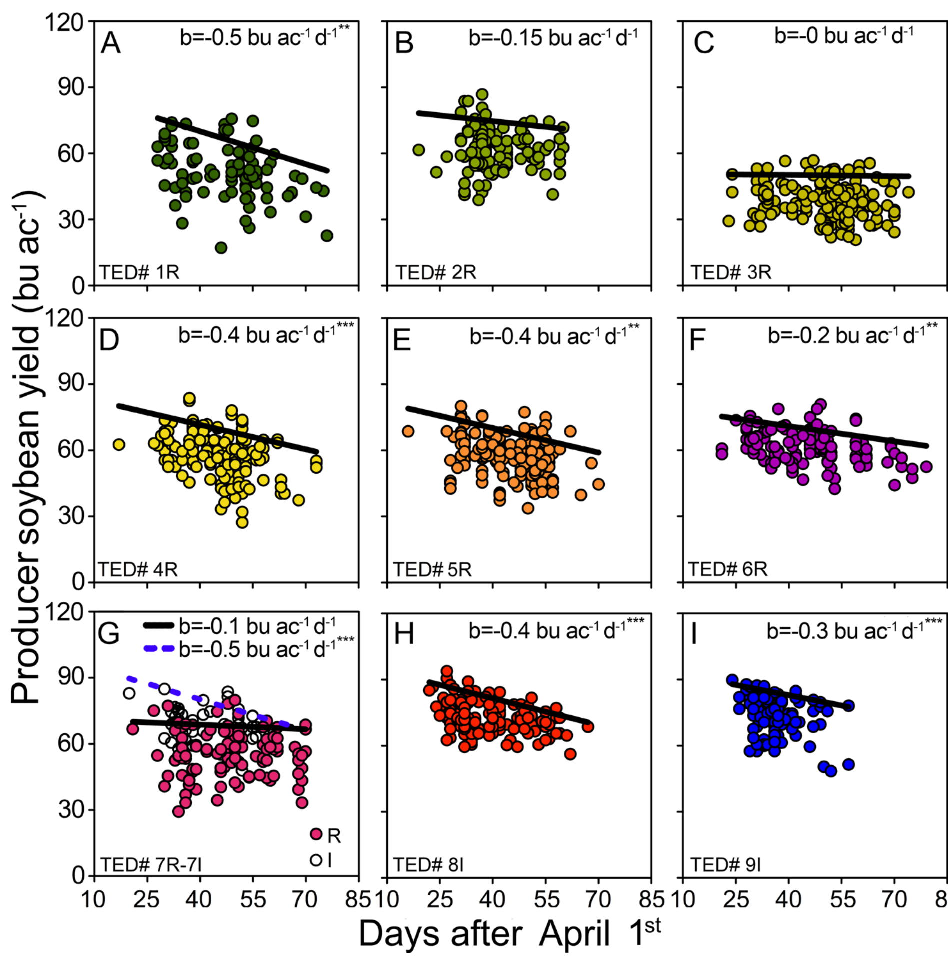
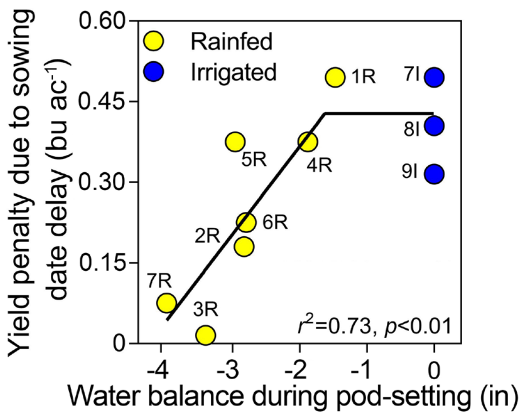


Figure 5. Soybean yield penalty due to planting date delay as a function of water balance during the pod-setting (R3–R5) phase across 10 technology extrapolation domains (TEDs) including rainfed (yellow circles) and irrigated (blue circles) production environments (averaged over 2014–2015). Water balance was estimated as the difference between rainfall and simulated non-water limiting crop evapotranspiration and set at zero for irrigated crops. Parameters of the fitted linear-plateau model (solid line) and coefficient of determination (r^2) are shown.



Management practices explaining yield gap between high- and low-yield fields

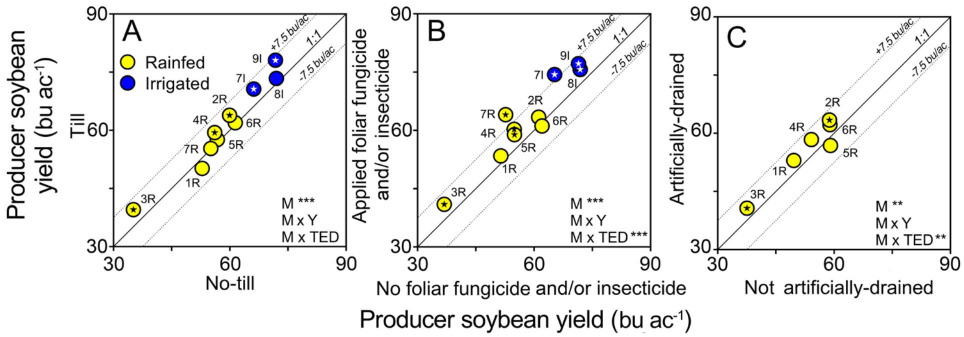
As a first approach to identify factors explaining yield gap, high-yield (HY) and low-yield (LY) field classes were identified based on their respective presence in the upper and lower terciles (top 1/3 versus bottom 1/3 of fields) of the field yield distribution within each TED. Analysis of management practices allowed identification of candidate factors explaining yield gap in each TED. Differences in planting date, tillage, in-season foliar fungicide and/or insecticide, drainage system, and soybean cultivar maturity group (MG) between high- and low-yield fields were statistically significant in half or more of the 10 TEDs ($p < 0.10$).

Planting date: The main explanatory factor

Planting date had the most consistent impact on soybean yield (Figure 4), representing 28% of the total yield gap across TEDs (range: 2–56%). HY fields were sown, on average, 7 days earlier than LY fields in both irrigated and rainfed conditions. There was a strong planting date × TED interaction on yield as indicated by the wide range in yield penalty across TEDs, ranging from 0 to -0.5 bu ac^{-1} day^{-1} (Figure 4).

Assessment of the observed TED x M interactions, in relation to weather dynamics during the growing season, revealed a relationship between yield response to planting date and the degree of water deficit during pod setting (R3–R5) phase (Figure 5). Yield penalty (or response) to planting date was negligible when water balance was <-4 inches, but increased linearly up to nearly -1.6 inches. Yield response to planting date remained relatively unchanged at water balance >-1.6 inches, ranging from 0.3–0.5 bu ac^{-1} day^{-1}. The

Figure 6. Comparison of average producer soybean yield between groups of fields with different management practices across ten technology extrapolation domains (TEDs): (A) tillage (tilled versus no-till), (B) in-season foliar fungicide and/or insecticide (treated versus untreated fields), and (C) artificial drainage (fields with and without artificial drainage system). Star inside symbols indicate statistically significant difference for a given TED (t-test; $p < 0.1$). Asterisks indicate significance of the impact on yield with respect to the specified management factor (M), and its interaction with year (M × Y) or with TED (M x TED) as evaluated using F-test at $p < 0.1$(*), $p < 0.05$(**), and $p < 0.01$(***). Data from the two crop seasons were pooled for the analysis because M × Y influence on yield was not statistically significant. TEDs 7R, 7I, 8I, and 9I are not included in (C) because of the low number of fields with artificial drainage.



role of water balance in influencing the yield response to planting date was evident for TED 7, where irrigated and rainfed crops exhibited a six-fold difference (0.5 versus 0.1 bu ac^{-1} day^{-1}, respectively) (Figure 4). In other words, these findings indicated that yield response to planting date diminished as the degree of water limitation in the pod-setting period of the production environment increases. It was notable that yield response to planting date delay exhibited much higher explanatory power with the degree of water deficit during pod setting phase ($r^2 = 0.73$, $p < 0.01$) relative to the other crop phases (early vegetative phase, late vegetative phase, and seed filling) or entire crop season ($r^2 < 0.38$, $p > 0.06$).

Tillage, fungicide and/or insecticide applications, drainage system, and soybean maturity groups

Similarly to planting date, other management practices also exhibited a significant M x TED interaction (Figure 6). For this analysis, fields were categorized as either no-till or tilled, with the latter including chisel, disk, strip-till, ridge-till, vertical, field cultivator, and moldboard plow. We did not find evidence of no-till fields outperforming yield of tilled fields in every TED; indeed, tilled fields yielded significantly more in half of the TEDs (2.3 bu ac^{-1}; $p = 0.02$) (Figure 6). However, there may still be other functional reasons for producers to adopt no-till despite the observed yield penalty. For example, no-till can help control soil erosion and reduce irrigation water requirements. Indeed we found that, on average, total irrigation was 2.5 inches less in no-till versus tilled fields ($p < 0.01$).

While there was an overall statistically positive impact of foliar fungicide and/or insecticide (4.6 bu ac^{-1}, $p < 0.01$) and artificial drainage (2.7 bu ac^{-1}; $p = 0.05$) on soybean seed yield, the magnitude of these yield differences were not consistent across TEDs and not even significant in some of them (Figure 6). For example, average yield of fields treated with foliar fungicide and/or insecticide was 11.2 bu ac^{-1} higher in relation with untreated fields in TED 7R, but this yield difference was negligible (-0.9 bu ac^{-1}) and not statistically significant in TED 6R. Likewise, artificially drained fields achieved statistically higher yields compared with fields without artificial drainage in only two of six TEDs. Although differences in variety MG between high- and low-yield fields were less than one unit, there was a consistent trend towards shorter MGs in the high-yield field tercile (top 1/3) in all TEDs, except for those located in the northern fringe of the North Central US region (3R and 4R).

Other management factors with low influence on yield gap

In contrast to the aforementioned variables, there were inconsistent (and generally small) differences between HY and LY fields in relation to row spacing, seeding rate, seed treatment, nutrient (N, P, K) fertilizer application, lime, and manure. Lack of statistically significant differences between management practices need to be interpreted with caution. For example, some practices might influence yield depending upon the level of another management practice [e.g., seed treatment in relation with planting date (Gaspar and Conley, 2015)]. Likewise, the benefit of other practices may only be realized in crop seasons with unfavorable weather, which was not the case in our study [e.g., narrow row spacing, no-till (Taylor, 1980; Wilhelm and Wortmann, 2004)]. Similarly, yield impact of some practices may be masked by other field variables not accounted here. For example, lack of yield differences between fields that received fertilizer application versus those that did not receive fertilizer might reflect producer tendency to apply fertilizer only in fields where soil nutrient status is inadequate as evaluated using soil nutrient tests. It may also reflect that many producers over-fertilized the previous corn crop expecting the subsequent soybean crop to benefit from the residual soil fertility. Finally, there are management practices that exhibited a very narrow range (e.g., MG) or inputs that are applied in amounts well above their optimums. For example, on-farm average soybean seeding rate ranged from 147,000 to 172,000 seeds ac^{-1} across TEDs. These densities are higher than the required plant density for maximum yields (100,000–145000 plants ac^{-1}) (Grassini et al., 2015); hence, our analysis will not fully capture the influence of these management factors on soybean yield.

Final consideration

Beside the identification of yield gap causes, another contribution of the present study is to provide a solid basis to assess what would be the extra crop production, at both local (TED) and regional (North Central US) levels, that would result from complete producer adoption or fine-tuning of a given management practice. For example, the potential extra production derived from earlier soybean planting can be calculated based on the (1) specific yield response to planting date in each TED, (2) the degree to which the current average planting date differs from the optimal one, and (3) soybean harvested area in each TED. For example, a 2-week shift towards early soybean planting in TED 4R, from current average planting on May 17 to a hypothetical, yet realistic, May 3 planting, would result in 5.2 bu ac^{-1} yield increase and 18.5 million bu production increase, leading to a 10% and 0.7% increase in soybean production in TED 4 and North Central US region, respectively. This example illustrates the power of this approach for impact assessment to support policy and investment prioritization and for monitoring the impact of research and Extension programs.

Conclusion

Soybean yield gap and its causes were assessed for the North Central US region using a novel approach that combines a spatial framework and producer self-reported data. The framework applied in this study explained the largest portion of the spatial variation in yield and management practices across the North Central US region. Soybean yield gap in the North Central US were relatively small, averaging 22% (rainfed) and 13% (irrigated) of the estimated yield potential. Planting date was the most consistent factor explaining yield variation within the same TED and year, with magnitude of yield response to planting delay dependent upon degree of water deficit during pod setting phase. Other practices also explained yield variation (tillage, and in-season foliar fungicide and/or insecticide, and artificial drainage), but the degree to which each of these practices influences yield depended upon TED. The combined use of producer data and a robust spatial framework that captured regional variation in weather and soils represents a cost-effective approach to identify causes of yield gap across large geographic regions, which, in turn, can help inform and strategize research and Extension programs at both local and regional levels.

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NO-TILL PLANTER SET-UP FOR HEAVY RESIDUE: AFTERMARKET CLOSING WHEEL ASSESSMENT

Brian D. Luck[1]

No-till planting into high residue environment remains a challenge for Wisconsin producers, especially when considering planting into cover crop residue. There are several aspects to planter set-up that can have an impact on seed placement and emergence. To maintain a reasonable scope for this study a set of differing closing wheels was selected for assessment.

Methods:

A John Deere 1700 Planter was utilized for this study (Figure 1). The planter was 3-point hitch mounted and was equipped with variable rate seeding technology (hydraulically operated) and down pressure was controlled by air bags on each row unit. Down pressure could not be varied between row units. Four different closing wheels were assessed:

1. Dawn Curvetine
2. Yetter Paddle
3. Martin Spike
4. Standard Rubber (control)

A pair of each closing wheel was installed on each row and rows were treated as replicates within the study. After each pass of the planter the closing wheels were randomized between rows to remove any effect that an individual row had on the performance of the closing wheel. The down pressure on each closing wheel was set in the "second notch" to maintain consistency.

Four plot locations were planted across Wisconsin. These locations were in Rock County, Dane County, Dunn County, and Marathon County. Soil types contained within these locations spanned the types of soils encountered within Wisconsin from a heavy clay to sandy loam soil. Plots consisted of several border rows (8 minimum) and 120 replicate planter passes per location. Two corn hybrids were used in this study. The southern locations received Pioneer ™ P0339AMXT and norther locations received Tracy Seeds T068-26 GTA.

Emergence was counted at each location several times. The intent was to assess emergence rate along with final emergence to assess closing wheel performance. Emergence rate was assessed based on growing degree units past planting.

Figure 1. Planter setup for closing wheel study. From left to right, standard rubber, Martin Spike, Dawn CurveTine, and Yetter Paddle. Replications were randomized by row meaning the closing wheels were removed and re-installed every planter pass. Four sites were assessed (Rock Co., Dane Co., Dunn Co. and Marathon Co.) with ~120 replications per site. Emergence rate and yield were measured.

Figure 2. Differing closing wheel results after a single planter pass. The planter used for this study was a John Deere 1700 with MaxEmerge™ row units. Trash sweeps ran ahead of the opener discs and no seed firmer devices were installed. From left to right, standard rubber (x2), Martin Spike (x2), Dawn CurveTine (x2), and Yetter Paddle (x2).

<u>Results:</u>

None of the results reported here were statistically significant! A second year of the study will be completed in 2018 to increase the statistical power of the study to hopefully achieve statistical significance. However, numerical difference among the closing wheels did exist. Figure 3 shows the emergence rates for the different closing wheels at the four different plot locations.

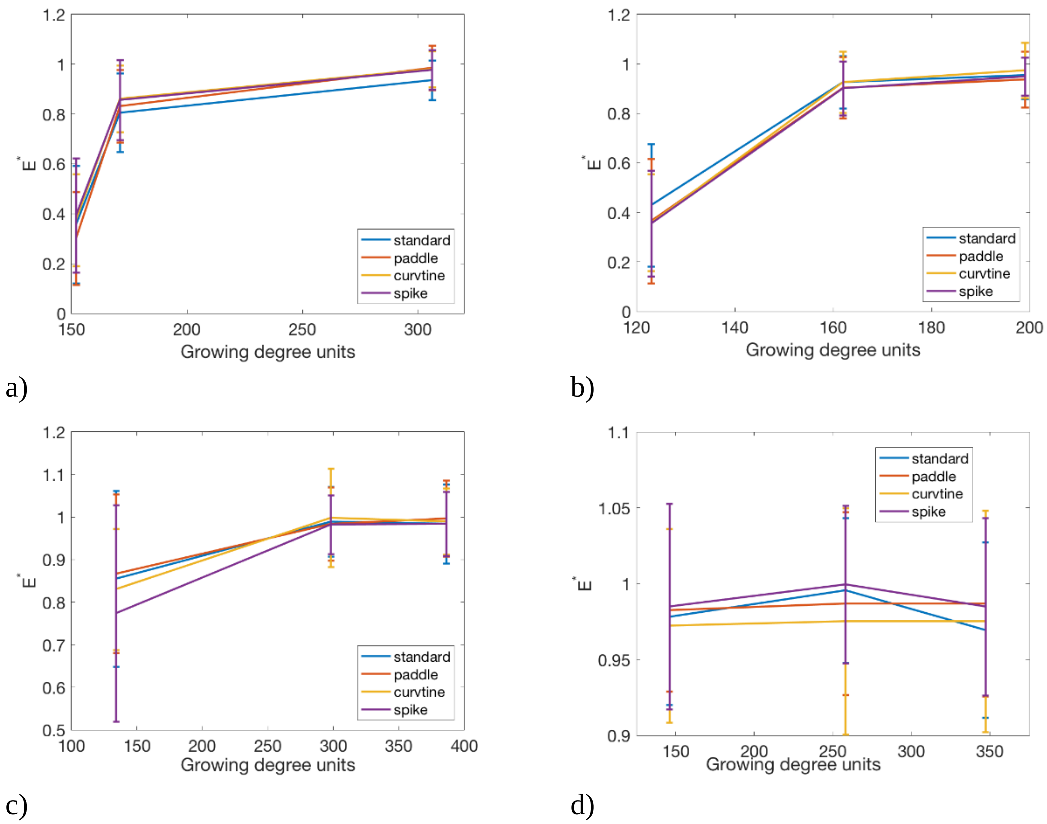

Figure 3. Emergence rate of corn at the four different plot locations: a) Rock Co., b) Dane Co., c) Marathon Co., and d) Dunn Co.

Table 1 shows numerical means of final emergence by wheel type (not statistically significant) and plot location (significant). Preliminary interpretation shows that the aftermarket closing wheels, specifically the Dawn Curvetine, yielded numerically better emergence than the rubber closing wheels in Dane Co. This is not to say that you should invest in these currently, but we are hopeful that a second year of the study will result in statistically significant differences from these treatments. Stay tuned!

Table 1. Percent emergence for all closing wheel types and locations (α = 0.10).

Wheel Type	Location	Emergence	Statistical Significance
Standard	all	96%	No
Yetter Paddle	all	98%	No
Dawn Curvtine	all	98%	No
Martin Spike	all	97%	No
all	Rock Co.	97%	Yes
all	Dane Co.	95%	Yes
all	Dunn Co	99%	Yes
all	Marathon Co.	98%	Yes

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FSMA Hazard Analysis for Feed Mills

Wayne Nighorn [1/]

The Food Safety Modernization Act is something that affects nearly all animal food production facilities. The deadline for CGMP compliance for small and large companies has come and gone.

For small facilities, September of 2018 is the compliance deadline for the preventative control and hazard analysis part of the Food Safety Modernization Act. We will be talking about how to identify hazards at your facility, along with how to use your SOP's and policies to create a prerequisite program to handle those hazards. We will also be discussing when we may have to use preventative controls and what that looks like.

[1/] Agres Consulting LLC.

DRIFT REDUCTION ADJUVANTS: UNDERSTANDING WHAT'S IN YOUR TANK

Daniel Heider[1]

In a world where we can splice genes, split atoms and transplant organs it is hard to believe that we still have not figured out a way to spray agricultural pesticides with zero spray drift. Although newer developments in application technologies have helped to contain spray drift; nearly all focus on increasing or stabilizing droplet size as their primary goal. Nozzles, pulse width modulation, boom add-ons, and even drift reduction adjuvants can all be placed in this category. As an applicator, it is critical to understand the technologies you are utilizing for proper sprayer management in drift prone conditions.

Understanding Drift

Pesticide application through spray nozzles results in droplets that as a result of surface tension are roughly spherical in shape. Droplet size is measured in microns with 1 micron = 1/1,000,000th of a meter. Small droplets, those less than 150 microns, are highly susceptible to off-site movement.

As the spray solution exits the elliptical orifice of a fan nozzle (most commonly used type today) it does so as a thin sheet of fluid moving at speeds up to 60 feet per second (49 mph). Droplets are formed at the edge of this sheet of fluid. Unless the spray particles are electro-statically charged or propelled with an air assist boom, the forces of gravity and air resistance take over quickly on the emerging droplets. Small droplets, which have less mass and greater surface area will fall much slower than larger droplets due to more friction with the surrounding air. Larger droplets which are capable of maintaining a downward velocity longer are more likely to be deposited on the intended target. How far can you "push" a droplet before gravity and air resistance completely take over? A 100-micron droplet moving at an initial velocity of 33 feet per second can only be "pushed" approximately 5 inches. A 500-micron droplet moving at the same initial velocity can be "pushed" roughly five times as far.

Managing Droplet Size

From the previous discussion it is apparent that larger spray droplets maintain velocity longer, and are less prone to drift. If that is the case, why not simply choose a nozzle which produces droplets so large that drift becomes nearly impossible? At some point a droplet becomes so large that too few are being deposited for effective pest control. In fact, pesticide performance can vary greatly due to droplet size and will require the applicator to adjust their target size droplet accordingly.

Nozzle selection is one of the most critical aspects in determining spray droplet size. Today we have many nozzle manufacturers producing quality products to meet application needs. Much verifiable data exists on nozzles and droplets produced, so that with a bit of research, the applicator can make very informed decisions on nozzle selection.

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Role of Adjuvants

Pesticide labels may dictate the addition of either activator adjuvants (those which enhance a pesticides performance) or special purpose adjuvants (which includes compatibility agents, drift control agents, etc.). Activator adjuvants like surfactants, crop oil concentrates and seed oil concentrate all function a bit differently, but also all reduce the surface tension of the spray solution. Reducing the surface tension is often referenced in helping the spray droplets to spread out over a greater surface area on the target. Reduced surface tension however also causes the sheet of water released from the nozzle to break into smaller droplets. Most nozzle testing is done with water only, so realize that your experience of droplet size produced may differ somewhat from nozzle manufacturer charts based on the composition of the spray solution.

Special purpose adjuvants include products like drift control additives. According to the Compendium of herbicide adjuvants, there are over 150 different drift control products available to choose from that fall roughly into three classes:

Thickeners – these tend to be polyacrylamide or polyvinyl polymers which thicken the spray solution and increase droplet size.

Encapsulators – these products do not affect overall droplet size, but encapsulate the pesticide into droplets to help minimize evaporation losses during product delivery.

Spray Modifiers – these products tend to be vegetable oil based and intend to reduce the amount of fine driftable droplets without increasing the size of the larger droplets.

The addition of a drift reduction adjuvant will never eliminate the potential for drift. As with all other tools in the drift reduction toolbox, these adjuvants are intended to improve your ability to reduce drift. Which product to use? Unfortunately, there is not enough time or resources to test all adjuvants in combination with all pesticides, so personal experience and testing on your rig will play an important role – remembering that no tank additive will make it completely safe to spray on that next marginal day.

WISCONSIN VEGETABLE WEED MANAGEMENT UPDATE

Jed Colquhoun, Daniel Heider, and Richard Rittmeyer[1]

Regulatory updates:
We're still waiting on some national regulatory reregistration decisions that may affect herbicides used in potato and vegetables, including diquat and linuron. Stay tuned for updates on any label changes that may result from that process. Additionally, the Wisconsin special local need labels for a few herbicides expired in 2017, including Dual Magnum on several vegetable crops and Tough on mint (as well as Stinger on strawberry and cranberry in the fruit world). In each of these cases the registrant has or is submitting a new special local needs request that will be evaluated by WI DATCP.

At a national level, much attention has been directed toward alleged cases of off-target dicamba and resulting injury to susceptible crops, including non-dicamba tolerant soybean and specialty crops. As a result, the U.S. Environmental Protection Agency has issued new rules for dicamba use in resistant crops, including classifying the dicamba products used on these crops as restricted use, requiring specific training and detailed record keeping, reducing the wind speed allowance, outlining specific tank-cleaning procedures to avoid contamination and reducing the times during the day in which applications can be made. EPA will monitor the success of these and other new requirements in the 2018 growing season.

Research updates:
From a research standpoint, the future looks bright. The 2017 growing season was very busy but productive for our program thanks to the dedicated work of Dan Heider and Rich Rittmeyer. This research pays dividends for vegetable growers and the industry by optimizing production, reducing risk and securing new economically solvent and efficient management tools. Selected highlights include:

- In potato, we're currently working four active ingredients toward registration. All four of these active ingredients pose particularly low risk of weed resistance development and are unique sites of action in potato. Three of the four are very near registration (one has now been registered for use in Canada with the US following, for one the registrant is conducting residue work to establish a potato tolerance, and one would be an expansion of a regional label to include Wisconsin). We're now refining the use patterns for these herbicides to establish the optimum timing, rates and tank-mixes for more holistic integrated management programs.

  We conduct similar research on the vegetables grown in rotation in potato. In recent years, this has included replicated field studies in horseradish, onion, celery, beans (dry, lima and snap), cabbage, carrot, pea, garden beet, sweet potato, processing and ornamental pumpkin and mint. This process typically starts with a multi-species herbicide screen, where we take a first look at many herbicide active ingredients across more than a dozen vegetable crops. Those that show promise are moved on to crop-specific replicated studies, and if there remains to be crop safety, added value for weed control and registrant interest, we then conduct refined studies to evaluate crop

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variety/type tolerance, weed control spectrum, multiple soil types and viable use patterns (timing, rate, adjuvants, tank-mixes, etc.).

- We continued work to identify potential new potato vine desiccants and alternative vine management strategies that can be integrated with herbicides. In the past year we completed a multi-year research project looking at various mechanical and physical vine management strategies with a particular focus on early fresh market potato production, where vines can be most challenging but market incentives are typically high. This work included yellow-fleshed and red-skinned varieties and investigated the influence of vine management on tuber yield and size distribution, skinning and stolon separation at harvest and after three weeks of storage. Strategies such as flail-chopping the top third of the potato plant eight days prior to diquat application adequately pre-disposed the vines to better kill with herbicides. Additionally, non-chemical strategies such as flame burning followed by flail-chopping adequately managed vines and would be applicable to organic production.
- We've spent much time in recent years investigating the effect of off-target herbicides, such as through tank contamination, on potato seed crops and commercial production in the year after exposure. This continues to be a significant issue in commercial production, where we've observed fields with emergence reduced up to 85%. This is particularly problematic when potato is grown in rotation with nearby grain crops, where many of the herbicides are long-lasting and very active at low doses. In many cases the herbicide symptoms aren't visible in the seed crop but appear in the following year, making detection a challenge. In our current work we're looking at simple, affordable ways to detect non-visual stress in winter grow outs with a hand-held NDVI sensor - in essence, creating an NDVI "signature" for herbicide-damaged seed.
- In carrot, we've conducted much research recently to find ways to manage weeds by making the crop more competitive. Strategies in development include the selection of new varieties that rapidly emerge and form a dense canopy, new seeding configurations and timing to favor the crop over weeds, and using small amounts of gibberellic acid to enhance top growth without reducing root yield. We have few herbicides in carrot and weed resistance is becoming problematic, so an approach that integrates multiple strategies will be needed.
- Our work has expanded beyond the pest management realm by grower and industry request and with creative opportunities to advance production. As such, we continue to develop and manage the Wisconsin Water Stewards program to customize and optimize farm-specific water use in the Central Sands, we're evaluating the carbon and water footprints of new vs. older potato varieties and we're working on a "big data" machine learning project that will allow growers to move precision agriculture from decision support to decision making.

Pesticide labels change often. As always, read and follow the label prior to any pesticide use.

A COMPREHENSIVE LOOK AT IRRIGATION TECHNOLOGIES FOR PROCESSING VEGETABLES

Yi Wang [1/]

Irrigation management is vital for the production of processing vegetable crops in Wisconsin. The use of water and improving the long-term sustainability of this absolutely critical resource has become a hot topic in the Wisconsin vegetable industry in recent years, because there has been increasing pressure to manage irrigation more efficiently and reduce unneeded agricultural water use.

Irrigation management includes adopting efficient irrigation systems such as sprinklers or drip irrigation, and scheduling irrigation to apply water at the right time with the right amount. Center pivot is the most common irrigation system for the Wisconsin processing vegetable growers. Based on previous studies conducted out west, dropping nozzles close to crop canopies can help increase irrigation efficiency from about 65% to above 90%. However, its application in Wisconsin is not thought to be as promising, due to the humid weather and warm groundwater temperature during the growing season. Drip irrigation has not been used for commercial processing vegetable production in Wisconsin because of its high cost and labor-intensive nature. A new technology called precision mobile drip irrigation (PMDI) combines sprinkler with drip irrigation, where drip tapes are attached to the center pivot and dragging on top of the soil surface. PMDI has the advantages of both center pivots and drip irrigation, but the lying tapes can be bitten by rodents, leading to maintenance challenges for the growers.

Common irrigation scheduling methods include hand feel, using crop evapotranspiration (ET), or using soil moisture probes. The hand feel method has been widely applied, but it requires years of experience for the growers to apply this method. Using crop ET requires data collection by weather stations. Thus if the weather stations are not installed on or near specific fields, estimating of crop ET might not be accurate, causing over- or under-irrigation. Soil moisture probes measures the indirect crop response to environmental water conditions, but they cannot indicate spatial variability within the fields. A recent irrigation scheduling technology mounts a sensor that measures canopy temperature onto the center pivot, which makes it possible to calculate in-time crop water use during growing

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season. Studies in Texas has shown that this technology can produce the same or higher crop yield compared with irrigation scheduling based on soil moisture probes. However, this new technology is cost-prohibitive and has not been routinely applied to commercial farms.

In summary, efficient irrigation management requires well-functioning irrigation systems and timely irrigation scheduling. Growers should make informed decisions based on their crop type, rotation history, soil condition, and financial budget to achieve sustainable irrigation water use.

NUTRIENT USE IN HIGH-YIELDING SNAP BEAN

Matt Ruark and Jaimie West [1/]

Introduction

Previous research (Wang et al., 2015) on snap bean response to N provided interesting results, but it is unclear if the results are applicable to all fields. This previous research was conducted in Plover, WI with high yielding DelMonte varieties. Results suggested that 100 lb-N/ac was the optimal N rate (20 lb-N/ac in starter and 80 lb-N/ac in-season) when yields are greater than 9 ton/ac. However, typical yields for snap bean are in the 4-5 ton/ac range (personal communication with processing crop agronomists), which may not require 100 lb-N/ac (current UW recommendations are 60 lb-N/ac for yields up to 6.5 ton/ac). In addition, the previous research also indicated that for non-nodulating varieties (i.e. varieties that do not allow root infection of rhizobium, and thus do not directly obtain N fixed from the atmosphere), had an N utilization efficiency of 68% when 100 lb-N/ac was applied. For nodulating varieties (in this case the high-yielding Del Monte varieties) additional analysis using ^{15}N stable isotope concentrations was necessary to determine the true removal efficiency as it is unknown how the addition of N fertilizer will inhibit the amount of N that is fixed. Preliminary analyses of these results indicate that the 100 lb-N/ac rate completely inhibits N fixation in snap beans. Now, it may seem counter-intuitive, but this is actually beneficial for water quality. It means that the applied N is replacing the N fixed by the atmosphere and is actually well-utilized in the system. If applying N fertilizer did not completely inhibit N fixation, then much of the N that was applied would not be used and thus leached to groundwater. However, 100% inhibition of N fixation occurred at the 100 lb-N/ac rate, with lower N rates inhibiting a small percentage of N fixation. Now, if more commonly used varieties require less N inputs (in the 50 to 80 lb-N/ac range) it is important to know what the true N use efficiency is as less N on lower yielding varieties may be less efficient than more N on higher yielding varieties. With all of the issues concerning nitrate concentrations in the Central Sands, we know little about the actual fate of N (or at least the utilization of applied N) in snap bean production systems.

The other big issue in snap bean production is a lack of modern measurements on removal rates of all nutrients. There are recommendations in the A2809, but it is not clear how these recommendations were developed – it's possible that they were estimated from other similar plants or from research in other states. The goal of this project is to develop N recommendations to snap beans that are variety specific and are considerate of water quality. The objectives of this study are to: (1) determine agronomically and economically optimum N rates for nodulating and non-nodulating varieties based on linear or quadratic-plateau regression and (2) determine the N

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removal and N uptake efficiencies at agronomic and economic optimum N rates to assess the potential impact on groundwater nitrate. A secondary objective is to quantify the P, K, S, Ca, Mg, B, Zn, Mn, and Cu removal rates from the production system with snap bean harvest.

Materials and Methods

The research was conducted at the Hancock Agricultural Research Station in 2016 and 2017. The experimental design was a randomized complete block, split plot study with four in-field replications. The study will also be replicated twice per growing season, comparing two different planting dates to evaluate the effect of planting date, as well as to obtain additional site years within a 2-year study. The whole plot factor will be snap bean variety, which will include publically available varieties of Huntington and Pismo (non-nodulating) and two non-nodulating varieties. The split plot factor will be N rate and include rates of 20, 50, 80, 110, 140, and 170 lb-N/ac. Since starter fertilizer is a common management practices (with a rate of 20 lb-N/ac), there was not a true zero N rate in the study.

Results

Results from 2016 show again the difference between non-nodulating (Fig. 1) and nodulating varieties (Fig. 2). Non-nodulating varieties do not fix their own nitrogen and the economic response to N is quite clear. Nodulating varieties do fix their own nitrogen, but there is still an economic incentive to apply N. Interestingly yields with 20 lb-N/ac as starter fertilizer were quite good at the Hancock Agricultural Research Station, indicating there is quite a bit of nitrogen available through mineralization of plant residues or through irrigation water.

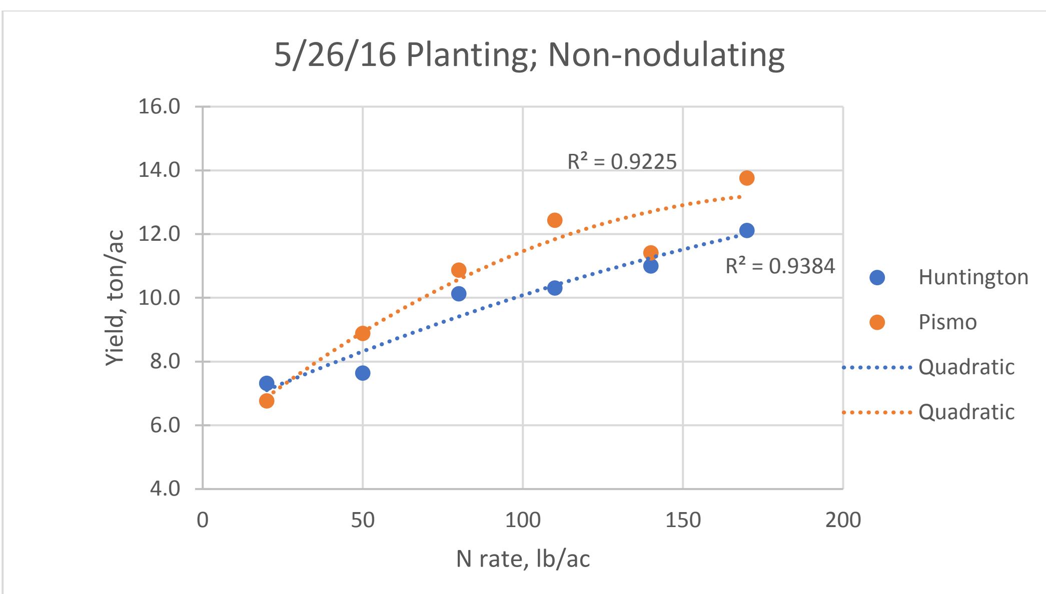

Figure 1. Snap bean yield (fresh weight) response to nitrogen fertilizer in 2016 for non-nodulating varieties.

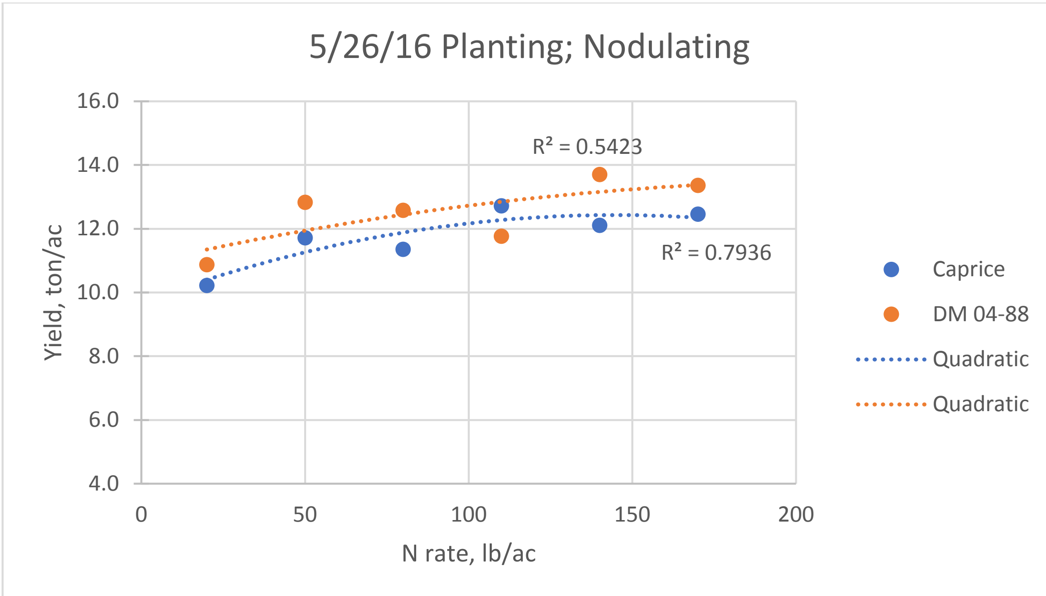

Figure 2. Snap bean yield (fresh weight) response to nitrogen fertilizer in 2016 for nodulating varieties.

Table 1. P, K, and S removal rates (lb/ac) from four varieties in 2016.

	P		K		S	
Variety	Avg.	St Dev	Avg.	St Dev	Avg.	St Dev
	---------------------------- lb/ac ----------------------------					
Non-nodulating #1	9.1	1.7	51	7.7	4.1	0.9
Non-nodulating #2	9.3	0.7	55	5.3	4.3	0.6
Nodulating #1	9.2	1.6	53	7.5	3.9	0.4
Nodulating #2	11.5	1.1	56	4.1	5.3	0.7

Removal rates for P, K, and S were similar for across all varieties, not varying by more than 2 to 5 lb/ac for any nutrient. Thus, the actual removal of nutrients is relatively low compared to other crops, but may not reflect actual nutrient need of plant. Snap bean is typically grow in rotation with potato, so soil test P and K are often high and sufficient to supply most of the nutrient demand.

Summary and Future Work

Research was completed in 2017 and yield results are currently being analyzed. These results can be used to provide variety specific or planting date specific N fertilizer recommendations if appropriate.

BIG DATA IMPLICATIONS FOR AGRICULTLURE

Terry W. Griffin[1/]

Introduction

Farm data has become a current topic in agriculture as well as other industries and is known as ‘big data’. Debate regarding the ownership of the data and who should receive value from the use of that data are hotly debated. The myths of big data in agriculture are dispelled here and insights into best management practices with respect to using data isolated to a given farm as well as within a larger community are offered.

The valuation of agricultural data has been elusive whether from a single field or data aggregated in near real time across many farms. Data from a given farm has finite value to that specific farm, but data aggregated into a community is considered to have much greater value.

Big data includes geospatial data and the associated meta-data on production, machinery, and environmental factors including seeding depth, seed placement, cultivar, machinery diagnostics, time and motion, tillage dates, planting, scouting, spraying, and input application. In addition to data on the products and how those products are applied, information on precipitation events, evapotranspiration, and heat unit accumulation supplement the data.

It is intuitive that value exists in agricultural data. Raw data in its original form often has no value, at least until it has been converted to information suitable for making decisions. The control of data is deemed valuable, however data valuation is elusive and determining that value has not been straightforward. Agricultural value is usually expressed as land values or production stemming from grain and animal products, but agriculturalists must think differently about the storage, analysis and value of this intangible resource.

Data is not like grain or other physical goods. For instance, a farmer can retain ownership of grain even when that grain is stored in an elevator comingled with other producers’ grain. Since data are electronic as opposed to physical, copies of raw data are indistinguishable from the original and may be considered identical (Griffin et al., 2016). Essentially, once a copy of the data has been made available to another party, the originator of the data has minimal control of the data such that multiple entities may have access to viable copies of the data (Ellixson and Griffin, 2016).

Furthermore, data is considered a “non-rival” good because the consumption or usage of data by one person does not alter another person’s ability to consume or use the same data. A classic example is motion pictures; multiple people can watch the same movie without loss of value to any one viewer by an additional person watching that movie. Agricultural examples of non-rival data include accessing weather reports or USDA crop production. In these examples, the value to a given farmer is not affected by another farmer acquiring the information. The same is true of data; a farmer and multiple other entities can consume the farmers’ data without reducing the value initially enjoyed by the farmer.

Data may be considered “excludable” or “non-excludable” depending upon access rights to the data. Ownership of “excludable” goods carries a right to exclude others from having access. Thus, most privately held goods typically are excludable. Using the non-rival example from above, weather data may be privately held and only available to subscribers such that the data are excludable. If the weather data were reported by a government entity such as USDA, then that data would be non-excludable. Privately held agricultural data can be excludable only while it is controlled by the party that generated it; however, once it has been shared with other parties or aggregated, that excludability is likely significantly reduced or eliminated.

Farm data may be more valuable when shared within a community. Analyzing data pooled across many farms may reveal patterns impossible to determine while examining individual farm data. The information that can be derived from community analyses frequently increases with the number of parties sharing data. This "network externality" effect means that the value of participating in a network increases with the number of participants.

Excluding others from benefiting from one's own data usually means avoiding the community and therefore forfeiting any potential benefits. The general population has at least some reluctance in sharing data regarding themselves; and farmers tend to be even more so. To explain farmers' behavior, data can be thought of as a resource. When a farmer gives up control of their intangible resource, it is common for them to believe they are also giving up their 1) competitive advantage, 2) bargaining power, or 3) control over something that may be used against their favor.

Discussion

Although farm data is not as mature as some other industries, services surrounding agricultural data are catching up quickly. Agriculturalists should think of data as an intangible good rather than physical goods such as grain, livestock, machinery, farmland or even subsurface minerals. Agricultural data are digital and non-rivalrous. Data valuation continues to be an area researched by economists.

The agricultural industry is being impacted by the advent of big data although in its infancy. Barriers are likely to continue impeding adoption of both big data and precision agriculture. An overview of big data implications that agricultural attorneys, farm management advisors, and their clientele should be cognizant of has been provided. On-going studies are underway to quantitatively address how the open market and society will value farm data.

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Soybean Response to Nitrogen Application Across the U. S.

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IN A BEAN POD:

- **Nitrogen application decisions had a small effect on soybean yield**
- **Major management decisions (e.g., irrigation, seeding rate) interact with nitrogen response**
- **Limited nitrogen responses suggest that positive economic returns from nitrogen are unlikely**

Introduction

U.S. soybean [*Glycine max* (L.) Merr.] production has increased by 60% from 1996 to 2016 due to a 30% increase in area planted to soybean, and due to better genetics and improved crop management practices. While these historic seed yield increases have been substantial, U.S. soybean producers continually search for opportunities to optimize crop management and increase soybean seed yield, including applying fertilizer N to soybean.

Soybean has a large nutrient requirement throughout the growing season, and has an especially high N requirement due to its seed protein content that averages about 40% based on seed dry weight (Bellaloui et al., 2015). Soybean N requirements peak in the R3 to R6 growth stages (Gaspar et al. 2017; Harper, 1974). The N requirement of soybean is generally fulfilled by biological nitrogen fixation (BNF) plus N uptake from soil (Salvagiotti et al., 2008). However, BNF activity can be limited by a number of environmental conditions such as low soil moisture, extremes of soil pH and temperature, and soil compaction, any of which can result in insufficient N supply to the soybean plants (Purcell and King, 1996).

Extensive research to date has documented the impacts of N fertilizer source, application rate, application method, and seasonal timing on U.S. soybean yield. Many of these studies show inconsistent response of soybean yield to N application within and across states which may have been due to differences in soybean cultivars, soil properties, climatic conditions during the growing season, topography, and crop management practices (Osborne and Riedell, 2006). Because a single study was not conducted at multiple U.S. locations for several years, we combined data from multiple soybean N fertilization studies across multiple locations and years. Thus, the objectives of this study were to examine the effects of N fertilizer in terms of N-application number (single or split applied), N-method (soil surface, soil incorporated, foliar, or a combination of these), N-timing (pre-plant, at-planting, Vn or Rn growth stages, or combination of these), and N-rate on soybean seed yield across the U.S.

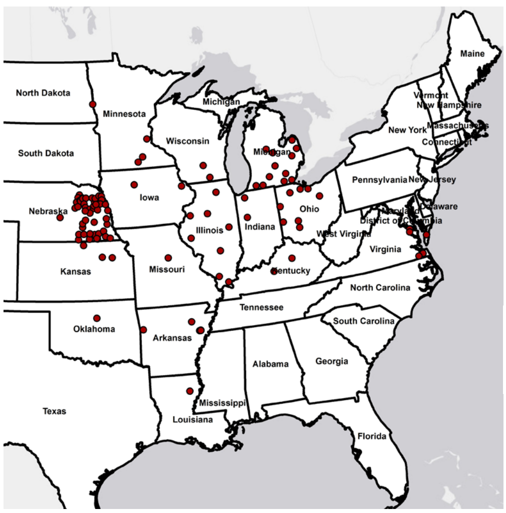


Figure 1. Locations of individual studies from which data were combined into a single database.

Materials and methods

Soybean yield data were aggregated from replicated field experiments established from 1996 to 2016, at 105 locations within 16 states across the U.S. (Fig. 1). The resultant database consisted of 5991 plot-specific yield data derived from a total of 207 environments (experiment × year). All individual trials were replicated within their respective environments.

For every experiment, the data were coded for the four N-related variables and for five major management variables (hereafter called "MM".) The N variables were:

(A) N-applications (i.e., zero N control, one, or two applications),

(B) N-method (i.e., zero N control, applied to the soil surface, soil-incorporated, foliar-applied, or a combination of these methods),

(C) N-timing [i.e., zero N control, pre-plant applied (pP), applied at planting (P), or at a vegetative stage (Vn), or at a reproductive stage (Rn), or split-applied at planting then at an Rn stage (PR), or split applied at two Rn stages (RR)], and

(D) N-rate (0-505 lb/ac).

The MM variables considered in our analysis were: irrigation (irrigated or rainfed), tillage (conventional or reduced tillage), previous crop (cereal or legume), seeding rate (range of 123,000 to 256,000 seeds/ac), and crop row width (range of 7 to 40 inches).

Among all experiments, most plots received a single N application, though ca. 13% of total plots did receive a split N application. Nitrogen application on the soil surface was the most common method, whereas foliar, soil incorporated, and other combinations were used less frequently. Similarly, a single N application during an Rn stage was the most common timing, with pre-planting (pP) and split N applications (PR, RR) used less frequently. The mean and median N rates were 67 and 40 lb/ac, respectively. These results show that across all experiments, the most common N treatment involved a single, surface-applied N application during reproductive growth.

Multilevel modeling was used to quantify N and non-N related sources of the observed soybean yield variability. To test the average effect of N-rate across all experiments, the linear and quadratic forms of N-rate were included in the model. Additionally, conditional inference regression trees methodology was used to identify the effects of MM decisions and N variable interactions on soybean yield across the examined region.

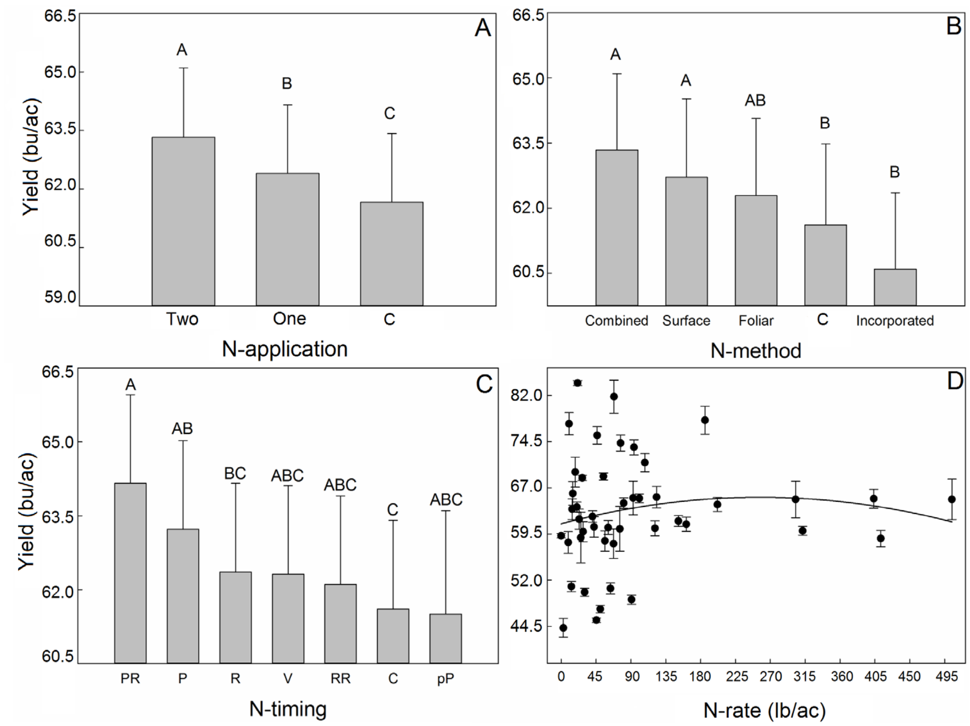
Results and discussion

Among all experiments, only a small fraction (<1%) of total variability was attributed to each N variable within experiment × year. This result shows the small N-related effect on soybean yield relative to other sources of variability (e.g., weather, soil, and MM decisions). The among-experiment average effect of N-application on soybean yield was significant (Fig. 2 A). A single N application was 0.9 bu/ac greater yielding than the control, and the split N application also resulted in 1.6 bu/ac greater seed yield than zero N plots, as did the split N application with more than one application method, which yielded 1.8 bu/ac more than non-treated plots (Fig. 2 B). Split application of N with more than one application method (e.g., surface and foliar) resulted in the greatest average soybean seed yield (63.4 bu/ac), but not significantly more compared to when N was surface- or foliar-applied (Fig. 2 B). Nevertheless, the yields attained with the combined N-methods of application were significantly greater than the yields generated from non-treated plots and soil-incorporated N, respectively.

Small differences were observed among different N application timings (Fig. 2 C). The greatest average yield was observed for PR, which was significantly greater than control and a single N application during Rn. Nevertheless, the 0.9 to 2.7 bu/ac yield differences from the other N application timings were not statistically different.

Soybean yield response to N-rate was quite variable at the lower N rates (up to ca. 1.9 bu/ac), for which there were many experimental data points (Fig. 2 D), but when coupled with the fewer data points at the higher N rates, the use of all experimental data generated a second-degree N polynomial function that was significant ($p=0.0297$), and it projected the N rate of 300 lb/ac for maximization of soybean yield. The large yield differences among individual experiments where a similar N rate was applied was attributed to in-season weather variability among the diverse growing environments (e.g., north vs. south), and to MM practice differences. These results suggest

Figure 2. Mean effect of individual N variables on soybean seed yield, when averaged over all experiments, for A) N-applications, B) N-method, C) N-timing, and D) N-rate (lb/ac). Note: C - no N control, One - single N Application, Two - split N applications, C - No N control, Combined - soil surface- and foliar-applied, Surface - soil surface-applied, Foliar - foliar-applied, Incorporated - soil incorporated, PR - split applied between planting and a reproductive (Rn) stage, P - applied at planting, R - applied at a Rn stage, V - applied at a vegetative (Vn) stage, RR - split applied between two Rn stages, pP - pre-plant applied. Vertical lines represent standard errors of the mean. Yields with the same letter were not significantly different at alpha=0.05.



that other, non-N practices might affect soybean yield alone, or in interaction with N decisions. Nevertheless, in most individual environments, the effect of a greater N-rate on soybean yield was not significant (Fig. 3). From the 207 environments included in the analysis, only 13 of the N slopes were significant ($p<0.05$) with an estimated yield increase of 0.14 to 0.5 bu/ac for every 10 lb of applied N. These environments included irrigated experiments in Arkansas and rainfed experiments in Illinois, North Dakota, and Ohio. Among these environments, yield ranged from 50.6 to 86 bu/ac. This result implies that despite the yield differences among environments, soybean response to N was minimal across the examined regions.

To identify and quantify the management variables that influenced soybean yield across all experiments, the fitted conditional inference tree included four MM variables (irrigation, seeding rate, tillage, and row width) and two N variables (N-timing and N-rate) (Fig. 4). The results of the model suggest that in irrigated experiments, a single N application during a Rn stage, or split N applications during Vn and Rn stages, or during two Rn stages resulted in 3 bu/ac greater yield than the rest of the N timings. However, in rainfed experiments, the addition of supplemental N was significant only

Figure 3. Environment-specific effect of N-rate (lb/ac) on soybean seed yield in 207 environments (experiment × year combinations). Note: Bottom and upper solid red reference lines delineate the bottom and upper specification and the middle dashed red reference line denotes the average.

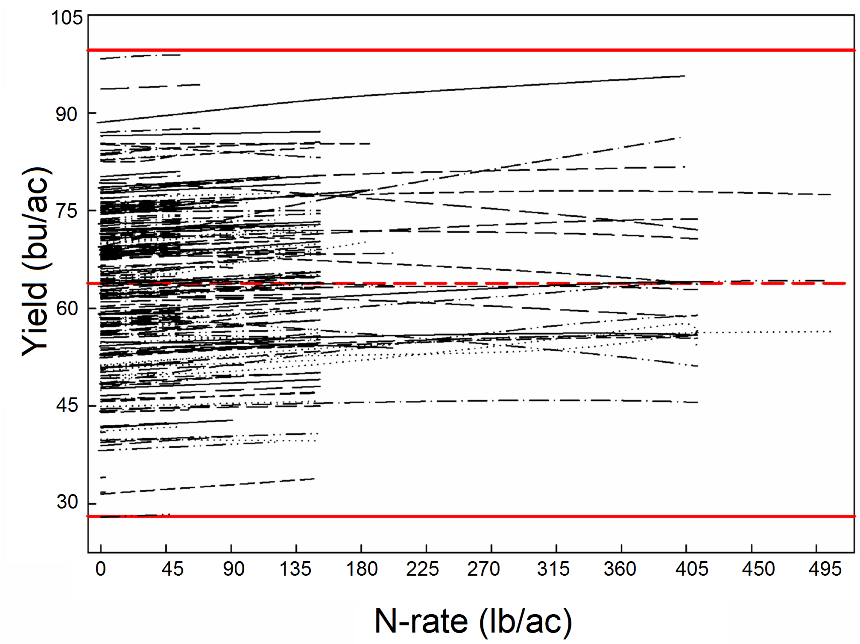
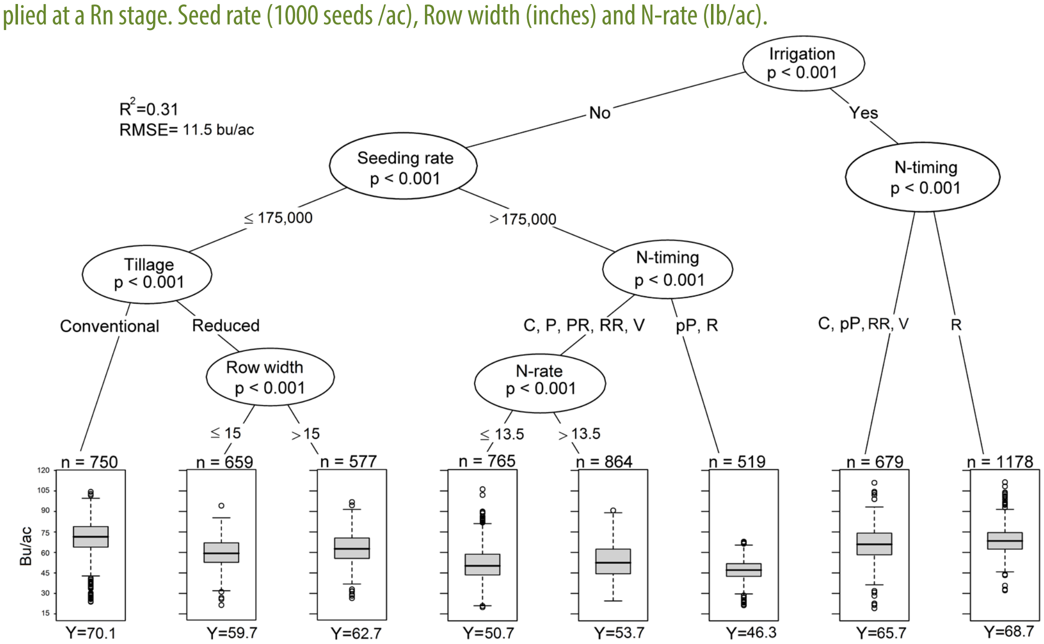


Figure 4. Conditional inference tree across the examined region. In each boxplot, the central rectangle spans the first quartile to the third yield quartile. The solid line inside the rectangle is the mean, whose numerical value is shown at the boxplot bottom (Y). The vertical lines above and below the rectangle denote the maximum and minimum, respectively. White circles represent outlier yields. Note: n=number of plots, Y=average soybean yield within a terminal node (bu/ac), C -No N applied, P - applied at planting, PR - split-applied between planting and a reproductive (Rn) stage, RR - split-applied between two Rn stages, V - applied at a vegetative (Vn) stage, pP - pre-plant applied, R - applied at a Rn stage. Seed rate (1000 seeds /ac), Row width (inches) and N-rate (lb/ac).



when seeding rates were >175,000 seeds/ac. From the total 5991 N-treated soybean yields, 36% were associated with such high seeding rates. In these experiments, N rate >13.5 lb/ac (and up to 505 lb/ac) at P, PR, RR, and V growth stages resulted in 3-6 bu/ac greater yield when compared to the other N timings and rates. These results indicate that non-N practices interact with N decisions and thereby affect soybean yield response to N application.

Conclusions

The analysis revealed that N management decisions had a measurable, but small, effect on soybean yield. Overall, the limited responses to N effects in our study, as well as the costs associated with N application, indicate that these small positive effects would be unlikely to result in positive economic returns from N fertilization decisions. The research findings we present here suggest that N management can only be optimized when considering the cropping system because non-N management practices such as irrigation and seeding rates interacted with N-timing and N-rate.

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WISCONSIN SOYBEAN MARKETING BOARD

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STINK BUGS AS AN EMERGING THREAT TO CROP PRODUCTION: OVERVIEW OF THEIR BIOLOGY, IMPACTS AND MANAGEMENT

Robert Koch [1/]

Stink bugs are emerging as a new threat to crop production in the region. An invasive species, the brown marmorated stink bug, is spreading through the region. In addition, reports from several states indicate that the abundance of native stink bugs may also be increasing. Because stink bugs have historically been infrequent pests in northern states, many growers and consultants have little experience managing these pests.

About 50 species of stink bugs occur in the north central U.S. Some of these species are beneficial and some have little or no impact on crops. However, several species (brown marmorated stink bug, one-spotted stink bug, brown stink bug, green stink bug, and red-shouldered stink bug) are of increasing concern in the region.

In general, stink bug adults have shield-shaped bodies, 5-segmented antennae and piercing sucking mouth part. Eggs are barrel-shaped and often laid under leaves. Nymphs are smaller in size and have a more rounded shape than adults. In addition, nymphs have no wings or small undeveloped wings. Identification of the species of concern will be discussed.

Most species of stink bugs undergo 1 to 2 generations per year. Among the plant-feeding species, many feed on various crop and wild plants. Most of these species overwinter as adults under leaf litter, crop debris or loose bark; but, some are household invaders.

Stink bugs penetrate plant tissues with their piercing-sucking mouthparts, inject digestive enzymes, and remove nutrients. They generally prefer to feed on reproductive tissues of plants. In soybean, stink bugs feed on pods and developing seeds. In corn, stink bugs will feed on developing ears and kernels, but can also be problematic feeding on corn seedlings. Feeding by stink bugs can cause abortion, deformation, and discoloration of seeds/kernels, which can affect yield and quality. In soybean, feeding can also cause delayed plant maturity ("stay-green syndrome"). Scouting and management recommendations for stink bugs in soybean and corn will be discussed.

[1/] Assistant Professor and Extension Entomologist, University of Minnesota.

UNDERSTANDING AND MANAGING SECONDARY BELOW GROUND

INSECT PESTS ON CORN

Bryan Jensen[1]

A secondary insect pest is an insect species that, because of a natural or man-made disturbance, has become an economic problem. The focus of this article will be on the below ground insect pests in corn. These insects, especially seedcorn maggot, wireworm and white grub, are difficult to manage because only preventive treatments are effective. An understanding of the insect biology can help target control practices when needed.

Seedcorn maggot: There are several generations of seedcorn maggots/year. The first generation peak adult flight occurs at approximately 360 degree days (Base 39 º F) and it is this generation which usually causes most of the damage to corn and soybeans planted during a "normal" Wisconsin planting season. That peak adult flight, for southern Wisconsin, occurs late April. The second generation peak (1080 DD) is not likely to occur until Late-May. Late planted field corn, sweet corn and especially soybean will likely be affected by the second generation.

The seedcorn maggot adult fly is about ½ the size of the common housefly. However, it is the maggot that causes crop damage. Seedcorn maggots are cream-colored and do not have legs. Adults are attracted to recently tilled soil as well as green/livestock manure to lay eggs. Maggots will only feed on the seed and unemerged shoots. They will not feed on emerged foliage. Cooler weather will likely increase the amount of damage because of longer exposure during the susceptible (unemerged) stage.

Seedcorn maggot injury is usually random within a field. Symptoms includes both poor emergence and holes in the cotyledon (first leaf) but rarely in the second true leaf. Once the shoot is emerged, that corn plant is unlikely to have economic yield loss. If you have poor emergence, look for the seed to determine if the problem was planter related or seedcorn maggot injury. You may, or may not, find the maggot because of either your response time or because of their short generation time. Finding maggots is sound seed is a good sign of seedcorn maggot feeding because saprophytic maggots (non-pest) will not infest sound (hard) seed. Conversely, if the corn seed is rotten and maggots are found there is a greater likelihood that something else killed the seed and the saprophytic maggots are only feeding on a rotten seed.

Wireworms: Wireworms are hard-shelled, whitish, yellow or copper colored and have three sets of jointed legs. Don't confuse wireworms with millipedes which are a non-pest. Milipedes are dark-gray and have a fringe hair-like legs the length of their body.

Like seedcorn maggots, wireworms will feed on the ungerminated seed but also within the shoot at either above or at the growing point. However, unlike seedcorn maggot, wireworm damage is usually clumped within a field. Above-ground symptoms of the shoot feeding can

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be described as either holes in the newest emerging leaves if the feeding site is above the growing point or wilted whorl leaves if the feeding site is at the growing point. These symptoms are often referred to as “wilted whorl” or “dead-heart.”

There are several species of wireworms and all have multiple year life cycle. Timely scouting will usually result in finding wireworm larvae near some of the damaged plants. However, wireworm larvae will move down within the soil profile during the late-spring and summer months.

Although there are many different species of wireworms that attack corn, their biologies are similar. Wireworms overwinter as either adults or larvae. Adults become active in the spring and females will lay egg in grassy areas including grass sod, pastures, alfalfa and grassy weed infestation in row crops. Eggs hatch in a relatively short period of time and small larvae will begin to feed on grass roots including corn. Depending on the wireworm species present, it may take up to 6 years to complete their life cycle. Damage to second and subsequent corn crops be higher than first year corn.

Symptoms of wireworm damage will usually show up during scheduled stand count or when monitoring for cutworms. Although rescue treatments are ineffective it is important to develop a field history and use a preventive control the following year if corn is to be planted.

For those fields which are rotating out of CRP or sod pasture, the use of solar bait station is advisable, however, this process is very labor intensive. Two stations are recommended per acre starting at least 3 weeks prior to planting. Dig a hole 4 inches deep and 9 inches wide and place ½ cup of a mixture of untreated corn and wheat. Back fill the hole with loose soil and cover with black then clear plastic. An average of 1 wireworm/bait station may indicate an economic population. Developing a field history is important and can help decide if a preventive treatment is needed the following year.

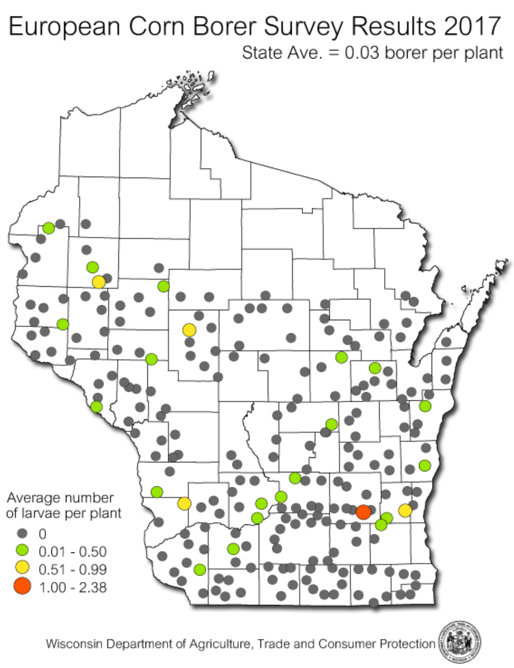
True White Grubs: True white grubs have a 3-year life cycle. Adults are active from late-April through June and will feed on several tree species including aspen, cottonwood and willow. Females usually move from these feeding sites and lay eggs in grassy areas. Eggs hatch within a few weeks. Larvae are c-shaped and cream-colored, range in size from ¼ to > 1 inch and feed for 2 years before pupating. Initially feeding occurs on small corn roots. But as larvae mature, larger roots will be consumed and grubs may burrow into corn plants below ground. Because of the root feeding, above ground symptoms may be similar to other plant stresses including nutrient deficiency, seeding diseases and perhaps herbicide injury. If larvae burrow into the below ground shoot, above ground symptoms are usually described as “dead-heart” or with advanced feeding the entire plant is wilted. These symptoms may be similar in appearance to wireworm, black cutworm, stalk bore and hop vine borer. Scouting is important to develop a field history which could indicate if a preventative treatment is needed the following year. If significant number of first year larvae are present a soil insecticide or seed treatment may be economical in next year’s corn field. Damage to soybean is uncommon as is damage to corn after soybean.

WISCONSIN INSECT SURVEY RESULTS 2017 AND OUTLOOK FOR 2018

Krista L. Hamilton[1/]

European Corn Borer

The fall European corn borer population declined to 0.03 larva per plant, tying 2012 and 2014 as the second lowest state average in the survey's 76-year history. The lowest average of 0.02 larva per plant was recorded in 2015. Minor population reductions from 2016 were found in six of the state's nine agricultural districts, while an insignificant increase was noted in the east-central area. The northeast and southeast district averages remained unchanged at 0.0 and 0.04 larva per plant, respectively. One hundred and ninety-six of the 229 (86%) fields examined showed no evidence of corn borer infestation. Results of the 2017 survey suggest that Wisconsin corn producers are maintaining a high Bt use rate which continues to provide overall effective suppression of the European corn borer.



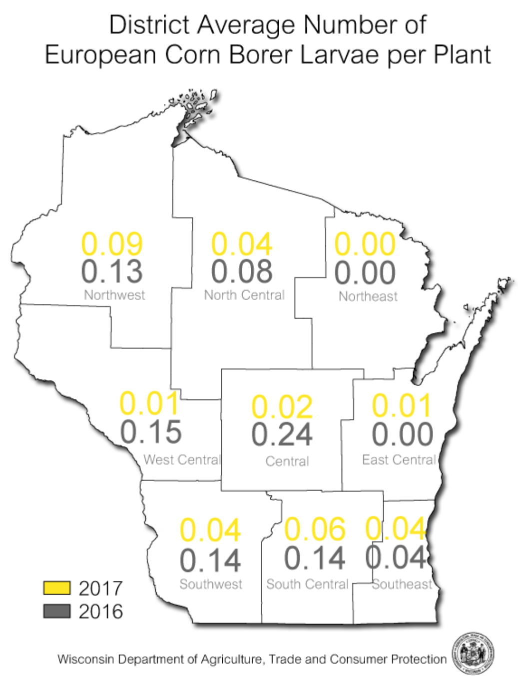


Table 1. European corn borer fall survey results 2008-2017 (Average no. borers per plant).

District	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	10-Yr
NW	0.12	0.06	0.08	0.15	0.04	0.07	0.06	0.03	0.13	0.09	0.08
NC	0.18	0.10	0.02	0.07	0.01	0.02	0.04	0.00	0.08	0.04	0.06
NE	0.12	0.12	0.19	0.13	0.05	0.02	0.01	0.04	0.00	0.00	0.07
WC	0.04	0.10	0.08	0.12	0.09	0.06	0.12	0.03	0.15	0.01	0.08
C	0.11	0.06	0.06	0.05	0.01	0.01	0.00	0.01	0.24	0.02	0.06
EC	0.20	0.09	0.01	0.03	0.01	0.01	0.01	0.04	0.00	0.01	0.04
SW	0.05	0.06	0.12	0.03	0.03	0.06	0.00	0.03	0.14	0.04	0.06
SC	0.07	0.02	0.07	0.20	0.01	0.08	0.01	0.02	0.14	0.06	0.07
SE	0.04	0.00	0.00	0.01	0.00	0.01	0.00	0.00	0.04	0.04	0.01
WI Ave.	**0.09**	**0.06**	**0.07**	**0.09**	**0.03**	**0.04**	**0.03**	**0.02**	**0.11**	**0.03**	**0.06**

[1/] Entomologist, Department of Agriculture, Trade and Consumer Protection, 1812 Park Ave., La Crosse, WI 54601.

Black Cutworm

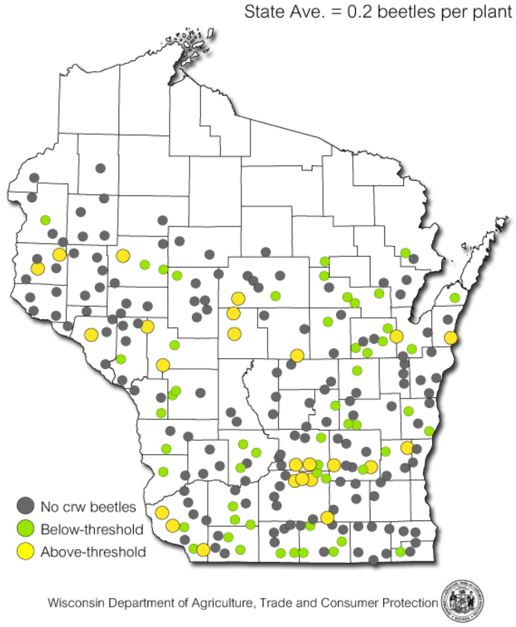
Many corn acres were under a high threat of infestation in May and June. Delayed spring tillage and planting, wet field conditions, and late weed control all favored black cutworm oviposition and larval development, while repeated heavy flights of 200-635 moths per week throughout April and May signaled an elevated risk for widespread, damaging problems. Larval feeding in emerging corn became noticeable by early June, but most injury observed in fields surveyed by DATCP was light and involved less than 1-2% of plants. Although the spring cumulative count of 3,228 moths in 45 traps was substantially larger than last year's capture of 1,835 moths in 43 traps, economic injury (>3% of plants damaged) was rare.

Corn Rootworm

Adult corn rootworm counts decreased to the lowest level since surveys for this pest began in Wisconsin in 1971. The annual survey conducted from July 28-August 16 found a state average of just 0.2 beetle per plant, less than half of last year's average of 0.5 per plant and far below the 0.75 beetle per plant economic threshold used to inform rootworm management decisions for the following season. Numbers declined across all nine crop districts as compared to 2016, with district averages ranging no higher than 0.3 per plant. Only 24 of the 229 (10%) cornfields sampled had above-threshold averages of 0.8-2.9 beetles per plant, while 54 (24%) had below-threshold averages in the range of 0.1-0.7 per plant. No corn rootworm beetles were observed in 151 (66%) of the fields.

Reasons for the historic decrease in beetle abundance are unclear but likely include a combination of factors such as heavy spring rains that led to saturated soils during larval hatch in June, the significant use of pyramided Bt-rootworm (Bt-RW) hybrids, and the practice of overlaying soil insecticides on Bt-RW hybrids during planting. The low beetle pressure documented this season may have resulted in fewer eggs being deposited into cornfield soils, and an overall lower risk of larval root damage next summer.

Corn Rootworm Beetle Survey Results 2017
State Ave. = 0.2 beetles per plant



District Average Number of
Corn Rootworm Beetles per Plant

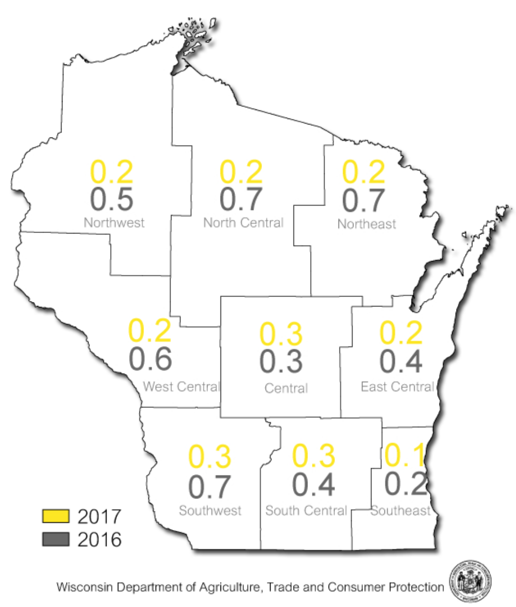
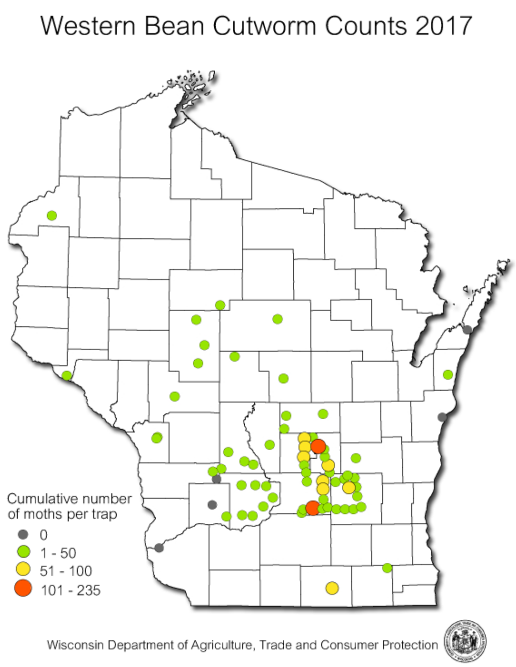


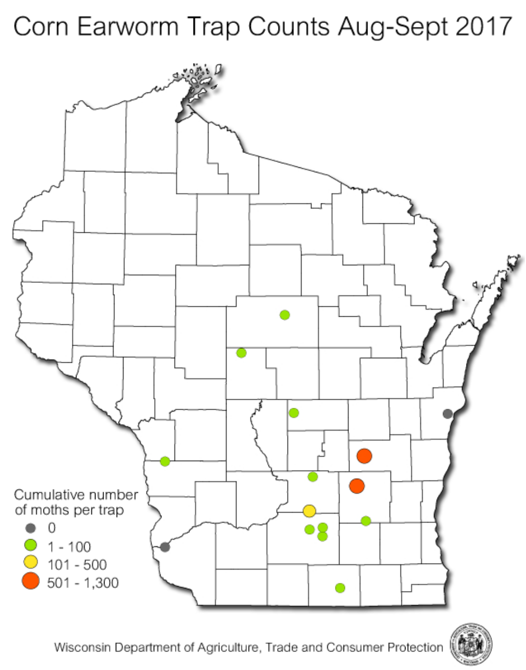
Table 2. Corn rootworm beetle survey results 2008-2017 (Average no. beetles per plant).

District	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	10-Yr
NW	0.5	0.4	0.3	0.1	0.5	0.7	0.5	0.2	0.5	0.2	0.4
NC	0.9	0.4	0.1	0.1	0.3	0.2	0.2	0.5	0.7	0.2	0.4
NE	0.6	0.6	0.1	0.3	0.6	0.2	0.1	0.2	0.7	0.2	0.4
WC	0.6	0.5	0.4	0.6	0.4	0.4	0.6	0.3	0.6	0.2	0.5
C	0.5	0.4	0.4	0.8	0.5	0.2	0.2	0.5	0.3	0.3	0.4
EC	1.0	0.6	0.3	0.5	0.4	0.3	0.3	0.8	0.4	0.2	0.5
SW	1.1	0.7	0.3	1.1	0.8	0.6	0.9	0.8	0.7	0.3	0.7
SC	1.5	1.1	0.3	1.4	0.9	0.5	0.3	0.8	0.4	0.3	0.8
SE	1.6	0.3	0.2	0.7	0.9	0.8	0.4	0.7	0.2	0.1	0.6
WI Ave.	**1.0**	**0.6**	**0.3**	**0.7**	**0.6**	**0.5**	**0.4**	**0.6**	**0.5**	**0.2**	**0.5**

Western Bean Cutworm

Moth counts increased from 2016 and larval injury to corn was slightly more common in 2017. The state trapping program captured a total of 1,856 moths in 70 traps (27 per trap average) from June 18-August 23, which was larger than last year's 1,530 moths in 75 traps (20 per trap average) and also higher than the 13-year survey average of 23 moths per trap. Larval infestations were found in approximately 10% of the 458 corn sites surveyed in August and September, compared to 9% last year.





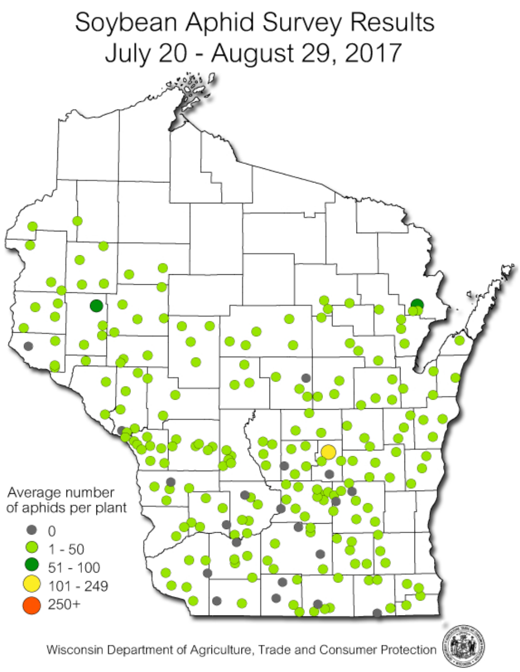
Corn Earworm

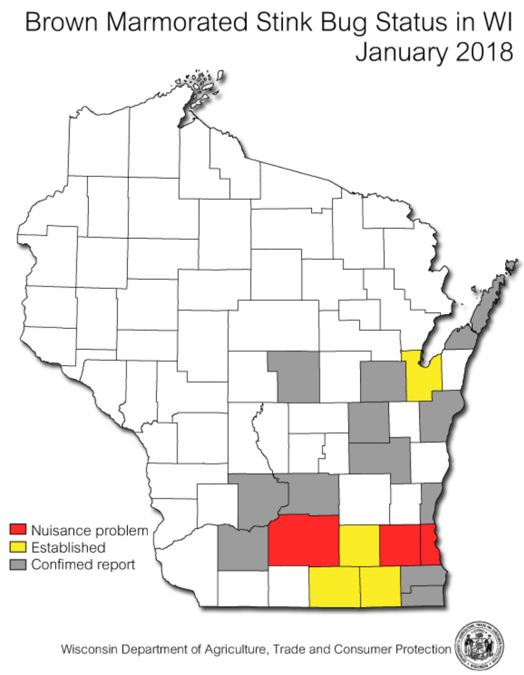
The late-season trapping survey captured a cumulative total of 2,760 moths in 15 traps. Nearly one-half of the moths (1,284) were collected at the Ripon monitoring location, most of which arrived during the last two weeks of September. Compared to 2016 when 6,402 moths were captured in 16 traps, this year's migration was much smaller, with the heaviest flights (>250 moths) limited to three sites in Columbia, Dodge and Fond du Lac counties.

Twelve other pheromone traps in Dane, Grant, Manitowoc, Marathon, Rock, Vernon, Waushara and Wood counties all captured fewer than 100 moths from August through September. Corn earworm flights ended about October 9.

Soybean Aphid

Densities were the lowest since the first detection of soybean aphid in Wisconsin 17 years ago. The annual survey found a statewide average count of six aphids per plant, a slight decline from eight aphids per plant in 2016 and the lowest on record. Two hundred and twenty-eight soybean fields in the R2-R6 growth stages were sampled from late July through August. Aphid populations were below 50 aphids per plant in 96% of the fields and only 4% had moderate averages in the range of 51-100 per plant. A single Green Lake County field had the survey's highest average of 163 aphids per plant, while no fields sampled by DATCP had an above-threshold count of 250 per plant. Results of the survey confirm that aphid densities were low in most fields this season and insecticidal control was generally unwarranted.





Brown Marmorated Stink Bug

Established populations of this invasive pest now occur in at least seven Wisconsin counties. Dane and Rock have been generally infested for 2-5 years, while Brown, Jefferson, Milwaukee, Walworth and Waukesha counties were added to the list in 2017. Citizen reports indicate the actual distribution of brown marmorated stink bug (BMSB) in the state is much wider. Specimens have been confirmed by the UW and DATCP from 19 counties since 2010, with most reports concentrated near Madison, Waukesha and Green Bay. Densities in the Madison, Milwaukee and Waukesha areas are high enough that BMSB can be considered an urban nuisance.

SOYBEAN APHID RESISTANCE TO PYRETHORID INSECTICIDES: RETHINKING HOW WE MANAGE SOYBEAN APHID

Robert Koch [1/]

Soybean aphid remains a significant pest of soybean in parts of the north central U.S. Recent development of insecticide resistance in this pest creates a new challenge for soybean production. Multiple lines of evidence, including reports of field level failures, and data from replicated efficacy trials and laboratory bioassays, that indicate that some populations of soybean aphid from Minnesota, North Dakota, South Dakota, Iowa and Manitoba have developed resistance to some pyrethroid insecticides (bifenthrin and lambda-cyhalothrin).

The development of insecticide resistance in soybean aphid is likely due to several factors. First, management of soybean aphid has relied on only a few insecticide groups (mainly pyrethroids and organophosphates) for 15+ years. Second, soybean aphid infestations in Minnesota and neighboring states have been more persistent than in other parts of the region, which has resulted in a long history of selection pressure for development of resistance. Third, certain management practices (i.e., application of insecticides below economic threshold, tank mixing insecticide with herbicide applications) have resulted in soybean aphid populations being exposed to insecticides more than necessary, which further increased selection pressure.

In response to the challenge posed by insecticide-resistant soybean aphids, I encourage growers, consultants and applicators to rethink how this pest is managed. First, treat fields only when needed. Doing so will reduce the selection pressure for further development of resistance. Fields should be scouted on a regular schedule and the economic threshold (250 aphids per plant) should be used to determine when to apply insecticides. Second, if a field needs to be treated, make sure the insecticide application is performed correctly (e.g., effective insecticide, proper nozzles, spray volume and pressure, and favorable environmental conditions). After insecticide applications, scout fields again after 3 to 5 days to ensure the product provided the level of control expected. Third, if a field needs to be retreated due to a failure, alternate to a different insecticide group for the follow-up application. For example, if a field was treated with a pyrethroid and a follow-up insecticide application is needed, then an insecticide from different insecticide group, such as an organophosphate, should be selected.

[1/] Assistant Professor and Extension Entomologist, University of Minnesota

Until aphid-resistant soybean varieties and other management tactics become more widely available, management of soybean aphid will continue to rely on scouting and threshold-based application of insecticides. There are few insecticide groups available (labeled) for management of soybean aphid. This short list of insecticide groups is under threat of getting even shorter due to development of pest resistance to insecticides and potential regulatory actions. The agricultural community must work together to preserve the effectiveness of and continued access to these products for protection of soybean and other crops from pests.

PESTICIDE LABEL - WHAT YOU AND YOUR CUSTOMER NEED TO KNOW

Glenn Nice [1/]

"The Label is the Law," a statement you probably have heard over and over again. However, this is a simple as it gets. When you purchase or use a pesticide you enter into an agreement that you will use this tool according to its label. However as custom applicators you are being contracted out to go on other people's property to use this tool. Communication between you and your customer is important, in fact it can be state law.

Having an idea from your records or from your customer of sensitive areas around the application site is important. Arial applications require at least 24-hour notice before the application. Although it is the landowner's responsibility to notify any bee keepers who have requested pre-application notification, it is your responsibility to let the customer know that you are applying a pesticide that is "Highly Toxic to Bees," and in enough time for them to do this.

The Worker Protection Standard requires that your customer notify their workers orally or by signs of fields that have been treated. They are also required to post information about the applications that occur on their farms. For a customer to do this, they will need to know that you are applying and what. At the time of application any important safety information has to be provided. An example of this might be the Restricted Entry Interval. Provide any specific safety information that might be on the label just before or just after application.

Finally, record keeping is the responsibility of the applicator. However, there is information that has to be given to the customer after application. You have 30 days after application to provide after application information. Most companies provide this in their bill of sale or invoice of service. These include: Applicator or business phone number; applicator license number; the crop; commodity or site to which the pesticide was applied; specific location of application; date; start and stop time; pesticide brand name or product name or chemical name; EPA Registration Number; amount applied; Post-application precautions (pre-harvest interval, REI, irrigation restrictions, etc.); copy of pesticide label or notice that they can get one on request.

[1/] Pesticide Applicator Training, Univ. of Wisconsin-Madison.

MANURE, TOXIC GASES, AND HUMAN HEALTH

John M. Shutske [1/]

This article is based directly on a recently published article that appeared in the Center for Disease Control's journal: Morbidity and Mortality Weekly Report (MMWR) by Shutske, et al (2017). See full reference at the end of this document.

Original adapted article title: *Notes from the Field: Death of a Farm Worker After Exposure to Manure Gas in an Open Air Environment — Wisconsin, August 2016*

On August 15, 2016, at approximately 6:30 a.m., a previously healthy male employee of a Wisconsin beef farm was found dead near the edge of an outdoor 60,400 square foot (1.4 acre) manure storage basin. The basin was approximately 15 feet (4.6 meters) deep and nearly full. The victim, aged 29 years, was discovered by another worker; the coroner was notified at 6:50 a.m., and he pronounced the victim dead at the scene. Thirteen dead cattle were discovered in an adjoining pen; three others were struggling to stand and were euthanized. The owner of the farm reported that at 3:00 a.m., the victim had used a tractor-powered agitator to agitate the manure,[2/] which a contractor was scheduled to pump and spread on cropland later that morning. The last contact from the victim was a social media post at 4:10 a.m. At the time he was discovered, he was approximately 3 feet downslope from the rear of the tractor, which was running.

Weather conditions from a nearby airport reported temperatures at 4:15 a.m., 5:15 a.m., and 6:15 a.m. of 54.5°F (12.5°C), 53.6°F (12.0°C), and 52.9°F (11.6°C), respectively, with no wind. The high temperature the previous day was 80°F (26.7°C), and reached 87°F (30.6°C) the preceding week (August 7–13), which was 10°F (5.6°C) warmer than the historical weekly average. Relative humidity measured at the nearby airport during these same time intervals ranged from 97% to 100%. The National Weather Service's Green Bay office documented a temperature inversion in the area that morning, citing warmer air temperatures 1,000–1,300 feet (300–400 meters) above ground level.

The man's death was initially attributed to methane, a physiologically inert gas produced through anaerobic decomposition of organic matter in manure and released through liquid manure. Methane deaths are usually the result of asphyxiation (1). The coroner reported foam coming from the decedent's mouth and nose, suggesting pulmonary edema; there was no indication of external trauma, and an autopsy was not conducted. A University of

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[2/] This agitator was attached to a tractor and driven by a rotating shaft exiting the rear of the tractor. The agitator extended approximately 40 feet (12 meters) outward into the liquid slurry. Agitation action includes a large, rotating propeller that stirs aggressively. The agitator also pumps and sprays the thick liquid backward or to the side to move the manure and break up crusted surfaces.

Wisconsin farm safety expert advised the coroner to test the decedent's blood for evidence of hydrogen sulfide exposure; blood thiosulfate level was 9.2 μg/mL, consistent with lethal hydrogen sulfide exposure as the cause of death (2). The cattle deaths were also assumed to have resulted from hydrogen sulfide exposure, although this was not laboratory-confirmed.

University staff members visited the farm on September 26, 2016, to ascertain potential sources of sulfur that might have caused elevated hydrogen sulfide levels in the stored manure, such as gypsum animal bedding (3). Ambient air was not tested, because no agitation was occurring at the time of the visit, and weather conditions were considerably different than they had been on the day of the event. Although no gypsum was used, the animals' diet did include distiller's syrup, a by-product of corn-based ethanol production. The sulfur concentration in a tested syrup sample (collected the day of the visit, stored in a refrigerator, and tested on January 20, 2017) was 1.53% of dry matter; 18–20 pounds of syrup were fed per day to each animal. At the recommendation of a cattle nutritionist, the farmer was providing thiamine supplementation to prevent polio-encephalomalacia, a neurologic disease of ruminants that has been associated with thiamine status and high sulfur intake (4). Previous laboratory tests of the herd's mixed feed analyzed on September 16, 2016, found a sulfur concentration of 0.44% of diet dry matter. Cattle nutrition references recommend that for feedlot cattle, the maximum tolerable limit for dietary sulfur is 0.3% of diet dry matter, with 0.15% considered sufficient (5).

Manure tested twice during the previous year had sulfur levels of 9.67 and 6.94 pounds per thousand gallons for samples tested on April 15, 2015, and November 9, 2015, respectively. No additional manure samples were taken immediately before or after the incident. The average manure sulfur level for Wisconsin beef operations is 1.6 pounds/thousand gallons (6).

Asphyxiation deaths associated with manure storage typically occur in confined spaces not intended for continuous occupancy (1). This incident was unusual because human and cattle deaths occurred in an outdoor, ambient air environment. It is possible that the temperature inversion and zero wind velocity suppressed air mixing, leading to an accumulation of lethal concentrations of hydrogen sulfide at ground level as agitation occurred.[3/] Additional research on the impact of weather and other environmental conditions on outdoor gas dispersion, as well as production practices that increase hydrogen sulfide exposure risk is needed. Monitoring for toxic gases and adequate oxygen is important even near outdoor manure storage sites. Improved understanding of factors that contribute to toxic outdoor hydrogen sulfide concentrations is needed to develop worker safety recommendations and to inform outdoor air monitoring strategies. Public health officials and forensic toxicologists

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[3/] Occupational Safety and Health Administration documents lethal concentrations to be 700–1000 ppm with "rapid unconsciousness, 'knockdown' or immediate collapse within 1 to 2 breaths, breathing stops, death within minutes." (https://www.osha.gov/SLTC/hydrogensulfide/hazards.html.) In addition, the relative gas density of hydrogen sulfide is 1.19 (https://www.cdc.gov/niosh/npg/npgd0337.html); hydrogen sulfide gas is heavier than air, so the gas being released during agitation was less likely to be dispersed and remained close to the ground surface.

who evaluate manure gas incidents should always consider tests for hydrogen sulfide exposure. Farm owners, operators, and employees, as well as professional and volunteer responders in rural areas, should receive additional manure gas education that includes information about hydrogen sulfide, other lethal gases, and the production practices and conditions that increase risk.

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RevEx Results:

Changes to Wisconsin Pesticide, Fertilizer and Feed Licensing Fee Structure

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The recently signed 2017-19 state budget contained changes to the fee structure for Wisconsin's pesticide, fertilizer and feed licensing fees and structure. These changes result from the RevEx project, DATCP's Bureau of Agrichemical Management's outreach effort to representatives from regulated agribusinesses with the goal of aligning the Bureau's revenues and expenditures to be more fair, efficient and effective. Changes include a fee holiday for the ACCP surcharge, meaning it will not be assessed in 2018for the 2018 license year (dates vary). The surcharge holiday will be extended if the ACCP Fund balance on May 1 exceeds $1.5 million. and probably for several years beyond. License years have been adjusted in a few cases as well. This is a summary of the changes. More detailed information is available online at https://datcp.wi.gov/Pages/Programs_Services/RevEx.aspx.

ACCP

- **Fee holiday**
  - *No surcharge on pesticide products or pesticide & fertilizer license fees in 2018*
  - *No surcharge for the ACCP portion of fertilizer tonnage beginning July 1, 2018*
  - In future, half fee will be charged if ACCP fund falls below $1.5 million; full fee will be charged if fund falls below $750,000, based on balance May 1 each year
- **Lifetime reimbursement** level increases to $650,000, as of costs incurred July 1, 2017
- **Facilities built after July 2013** now eligible for ACCP reimbursement

Pesticide products

- **Flat $500/product** beginning in 2018
  - Fee no longer tied to sales or product type
  - Must reconcile fees for final time for Jan. 1Oct. 1, 2016-Sept. 30, 2017

- **$250 penalty for unregistered 25(b) products** found in the marketplace; no fee to register them
- **No percent-of-sale charge** permitted on retail invoices after Oct. 1, 2017
  - Dealer will be required to refund to customers if charged

Fertilizers

- **License period** changes to October 1-September 30, with licenses issued August 15, 2017, extended to September 30, 2018
- **$30 license fee** unchanged, but $11.20 ACCP surcharge dropped for license year beginning October 1, 2018
- **Tonnage reporting year** remains July 1-June 30
- **Tonnage fee** will drop to $0.62/ton for reporting year beginning July 1, 2018
- **Product permits** will have to be added, maintained or discontinued every year when license is renewed
- **New bulk storage location surcharge** beginning in 2019.
  - No charge if the ACCP fund is over $1.5 million on May 1
  - $12.50 if ACCP fund balance is $750,000-$1.5 million on May 1
  - $25 if ACCP fund balance is less than $750,000 on May 1

Soil and Plant Additives

- **License period** is the only change,changes to October 1-September 30, with licenses issued August 15April 1, 2017, extended to September 30, 2018
- **Tonnage reporting year** remains changes from Jan. 1-Dec. 31 to July 1-June 30
- **Product permits** will have to be added, maintained or discontinued every year when license is renewed
- **All fees remain the same** as in the past
  - $25 license fee
  - $0.45/ton or $25 minimum tonnage fee

- License has never been subject to ACCP surcharge

Feed

- **$25 license fee** unchanged; has never been subject to ACCP surcharge
- **Tonnage fee structure** changed
  - **Reporting year** changes to March 1-April 30, beginning in 2019
  - 2018 reporting period will be January 1, 2018-February 28, 2019
  - $0.25/ton for production or distribution over 200 tons/year, beginning with tonnage reporting for Jan.uary 1, 2018-February 28Dec. 31, 20189
  - **New minimum $50 fee** for production or distribution less than 200 tons/year, beginning with tonnage reporting for Jan.uary 1, 2018-February 28Dec. 31, 20189
  - **Tonnage fees now required** for sales into or within Wisconsin
  - **No longer need to indicate on sales receipt or invoices** whether the tonnage fee was paid, but still must maintain records
- **Exempt buyers** and exempt buyers credit eliminated
- **Out-of-state sales credit** eliminated

Questions?

Online:
https://datcp.wi.gov/Pages/Programs_Services/RevEx.aspx or
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