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DOES TILLAGE AFFECT THE OPTIMUM NITROGEN RATE FOR CORN?

Francisco J. Arriaga and Nicholas Bero ^{1/}

Introduction

Conservation tillage practices, such as no-till, reduce the potential for soil erosion and help improve soil quality. However, adoption of these reduced tillage practices has been slow in Wisconsin. A significant reason for the low adoption rates is that crop yields with no-tillage tends to be lower when compared to conventional tillage practices. Hindered seed germination is typically identified as the cause for lower yields with no-till due to slower soil warm-up in the spring (Nielsen, 1996; Bitzer, 1998; Carter et al., 2013; NCR344, 2013). However, other conservation tillage practices can help bridge the yield gap relative to conventional tillage. Strip-tillage might provide a compromise between the soil conservation and quality benefits of no-tillage, and the greater yield capability of conventional tillage practices. Fall strip-tillage has been shown to produce equal corn yields compared to conventional (Randall et al., 2001). In contrast, Edwards et al. (1988) reported a reduction in continuous corn yield with no-tillage and strip tillage when compared to conventional practices. However, when corn was rotated with soybean, or soybean and wheat, no-tillage and strip tillage showed to be superior than conventional tillage practices. Further, strip tillage can increase soil temperature and improve seed emergence in comparison to no-tillage (Licht and Al-Kaisi, 2005).

Another reason often cited for reduced yields with no-tillage is the greater amount of crop residue left on the soil surface, which is believed to immobilize soil N during decomposition and limit N availability to the crop (Rice and Smith, 1984; Cochran, 1991; Green and Blackmer, 1995; Recous et al., 1995). However, Andraski and Bundy (2008) in a study conducted in Wisconsin concluded that soil temperature had a larger impact on net soil N mineralization in no-tillage corn systems with high residue. Their results suggest that greater N rates, up to 30 lb/ac, might be needed in no-tillage systems to overcome the reduced soil N mineralization rate. It is important to note that the study by Andraski and Bundy (2008) did not monitor N use by the crop, and only focused on no-tillage systems (i.e., other tillage practices were not included).

Although the slower soil temperature rise in the spring and N immobilization with no-tillage have been studied individually, the interaction and impact of these two factors have not been studied jointly. Further, the influence of tillage on N use efficiency (NUE) has received little attention. For example, a report from a 3-year study in Minnesota indicated that although the apparent N recoveries with no-tillage and strip-tillage were greater than

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chiseling (75, 76, and 70%, respectively), yields with the chisel plow were 9 and 3% greater, respectively (Vetsch and Randall, 2004). Total N uptake was greater with chisel plow, which might indicate a greater contribution from the previous soybean crop.

Increasing our understanding of the interaction of the effects of soil temperature, residue, and tillage type would potentially aid in developing new recommendations for corn production under reduced tillage practices. Therefore, the overall goal of this study was to determine the impact of conservation tillage on NUE and productivity of corn in Wisconsin.

Approach

The study was established in fall 2015 at the Arlington and Lancaster Agricultural Research Stations, in south central and south west Wisconsin, respectively. Soil at Arlington was Plano silt loam with 0% slope; soil at Lancaster was a Palsgrove silt loam with a 12% slope. Treatments include four tillage practices (main plot) and five levels of N fertilization (sub-plot) for grain corn, arranged in a split plot design with three replications. Tillage treatments were: conventional (chisel/disk), no-till, and strip tillage. A fourth treatment consisted of no-tillage plots, to which corn residue was removed in the fall after grain harvest. This fourth treatment served as a control to determine the combined impact of corn residue and soil temperature on corn yield and N rate response. Chiseling operations were performed in the fall after corn harvest and a finisher in the spring for the conventional tillage treatment, while strip-tillage will be conducted in the fall. Rates of N fertilization to corn were 0, 75, 150, 225, and 300 lb N/ac broadcast at V4-V6 as urea. Each plot was 35 ft in length by eight rows wide with 30-inch spacing between rows.

Corn grain yield was measured by cutting entire plants near the ground from 5-foot row lengths from two middle rows (rows 3 and 6) in each plot. The two row lengths were bundled together and transported to the edge of the field, where the ears were separated from the plant. Ear weights were recorded in the field, and ears were placed in a forced air drier until they achieved constant weight. Dried ears were weighted, and the grain separated from the cob using an electric table-top sheller. Grain and cob weights were recorded. Grain weights are reported as 15.5% moisture. Other measurements related to soil temperature and crop emergence were taken but are not reported here. This report concentrates on yield response of N rates for the four tillage systems.

Economically optimum N rates were examined using linear-plateau, quadratic-plateau, and quadratic response models for the four tillage systems to determine best fit. Two different NUE approaches were used to evaluate the relative contribution of different N uptake and distribution processes that affect the overall efficiency of N use (Moll et al., 1982). The partial factor productivity (PFP) was determined as the grain yield divided by the N applied. A N agronomic efficiency (NAE) was calculated as,

$$NAE = \frac{yield_{x\ rate} - yield_{no\ N}}{N\ rate_{x\ rate} - N\ rate_{no\ N}}$$

where $\text{yield}_{x \text{ rate}}$ is the yield at a specific N rate (x) for the tillage of interest, $\text{yield}_{\text{no N}}$ is the grain yield from the respective tillage treatment not receiving any N fertilizer, $\text{N rate}_{x \text{ rate}}$ is the N fertilizer rate of interest, and $\text{N rate}_{\text{no N}}$ is equal to 0 (no N applied).

An economic return for the 5-year grain yield average was calculated using a partial budget approach taking into consideration the cost of urea fertilizer, custom tillage rates, and the average corn grain price in Wisconsin. The cost of urea was calculated as a 5-year average for Wisconsin from a fertilizer survey conducted every year by the Division of Extension (C. Laboski, personal communication). Custom tillage rates were obtained from surveys conducted in 2013, 2017 and 2020 by USDA-National Agricultural Statistics Service (NASS) and summarized by Wisconsin Department of Agriculture, Trade, and Consumer Protection. Corn grain price was obtained from USDA-NASS reports for Wisconsin. The 5-year average cost of urea for the study period of 2016 to 2020 was \$0.38 per pound, and corn grain was \$3.54. The average cost of chiseling was \$17.60, finisher \$14.75, and strip-tillage \$18.65. No other costs were accounted for, such as cost of seed, land rental, other fertilizer applications or weed management. However, weed management was the same for all systems as was the corn variety and seeding rate.

Data were analyzed using standard least squares (JMP Pro 15.2.1, SAS Institute Inc., Cary NC) to detect differences between treatments. Significant treatment mean differences were evaluated using Tukey HSD with a significance level of $p=0.05$.

Results and Discussion

Average corn grain yields were greatest in 2016 at both locations (Table 1). Strip tillage had the greatest yield in both sites in 2016; however, strip tillage was no different to no-tillage at Arlington. Grain yield for chisel plow was similar to no-tillage and no-tillage/no stover in Arlington, while chisel plow was similar to no-tillage/no stover in Lancaster. No-tillage had the lowest yield in Lancaster. There was no significant difference in tillage in 2017 at Arlington and Lancaster. In 2018, tillage had a significant impact on corn yield in Arlington but not in Lancaster. In this year at Arlington, chisel plow and no-tillage/no stover had the greatest yields, while strip tillage and no-tillage had the lowest but similar to each other. A similar pattern was recorded in 2019 at Arlington, when chisel plow and no-tillage/no stover had the highest grain yields, but no-tillage/no stover yield was similar to no-tillage. The yield between no-tillage and strip tillage were similar. Corn yield in 2019 Lancaster were greatest for chisel plow, no-tillage/no stover, and strip tillage. Chisel plow at the highest yield in Arlington in 2020, followed by no-tillage and strip tillage, while no-tillage/no stover had the lowest yield. However, no-tillage/no stover had the greatest grain yield in Lancaster, followed by chisel plow and strip-tillage, while no-tillage had the lowest yield. Overall, it appears chisel plow provided greatest corn grain yields in the Mollisol in Arlington, while strip tillage had highest yields over the 5 year period in Lancaster. Nevertheless, as the grain yields reported in Table 1 are averaged over all N rates, it is important to consider the N response and the cost of each tillage system.

Since the tillage response and the soil at the Arlington and Lancaster sites were different, the N response was explored for the two sites separately. The corn response to N fertilizer rates followed a quadratic pattern for all tillage systems at both locations with coefficients of determination ranging between 0.9820 and 0.9996 (Fig. 1). The 5-year average N fertilizer response for chisel plow in Arlington was higher than the other three tillage systems. At Lancaster, the response of no-tillage was lower than the other three tillage systems. The economic optimum N rate (EONR) for the 5-year average in Arlington ranged between 155 and 186 lb N/ac between the four tillage systems (Fig. 1). In Lancaster, the range of EONR was narrower and ranged between 140 and 157 lb N/ac. These EONR ranges are in agreement to current N fertilizer recommendations using the maximum return to N (MRTN) approach for Wisconsin. The MRTN recommendation for both sites are the same. With a 0.10 ratio, which was close to the calculated ratio of 0.107 using the 5-year average cost for urea (\$0.38 per lb N) and grain price (\$3.54), the recommended N rate was 165 lb N/ac with a lower and upper range of 155 and 180 lb N/ac, respectively. The range for MRTN rate is within range of the calculated EONR at both locations. This suggests that there was no need to change the N fertilization rate based on the tillage systems studied.

Nitrogen use efficiency was used to explore differences in N use between tillage systems. The partial factor productivity (PFP) was different for the two locations, with Arlington having greater PFP values than Lancaster (Fig. 2). Although PFP values between tillage systems were different at low N rates, they were similar at EONR in both locations. This is further evidence that there was no need to modify MRTN rates based on the tillage systems compared. However, the range in PFP values at EONR was much narrower in Lancaster than in Arlington, noting closer NUE between tillage systems in Lancaster. Similar to PFP, the N agronomic efficiency (NAE) varied between tillage systems in Arlington and Lancaster (Fig. 3). There were greater ranges in NAE values than PFP between tillage systems. Also, the NAE had a parabolic response for no-tillage while the response for the other tillage systems were closer to linear. Since the NAE accounts for N supply by the soil, this parabolic response indicates that at lower N rates the no-tillage system had less available N, likely from lower mineralization rates due to slightly colder soil temperatures early in the season (data not shown). However, at EONR there was little differences in NAE between tillage systems in both locations. Also, similar to PFP, NAE values were greater in Arlington than Lancaster. These differences in NUE due to tillage and between locations can be attributed to differences in N mineralization due to differences in soil temperature and soil organic matter content.

Economic return per acre using partial budget approach shows similar economic return at EONR for the different tillage systems at both locations (Fig. 4). Note that the no-tillage system should have a lower initial monetary investment as it has lower production costs, and therefore, the economic risk should also be lower.

Table 1. Corn grain yield between four tillage systems averaged over five N fertilizer rates in Arlington and Lancaster, Wis. Means followed by different letters are significantly different at $\alpha=0.05$ within a site and year. ns = not significantly different.

Year	Tillage	Grain yield, bu/ac	
		Arlington	Lancaster
2016	Chisel plow	215 b	172 b
	No-tillage	221 ab	144 c
	No-tillage/no stover	217 b	165 b
	Strip tillage	237 a	195 a
2017	Chisel plow	157 ns	138 ns
	No-tillage	149	135
	No-tillage/no stover	152	136
	Strip tillage	149	124
2018	Chisel plow	159 a	159 ns
	No-tillage	133 b	148
	No-tillage/no stover	151 a	149
	Strip tillage	130 b	156
2019	Chisel plow	176 a	120 a
	No-tillage	158 bc	97 b
	No-tillage/no stover	164 ab	124 a
	Strip tillage	148 c	123 a
2020	Chisel plow	213 a	92 b
	No-tillage	186 b	77 c
	No-tillage/no stover	178 c	109 a
	Strip tillage	190 b	96 b

Conclusions

The response to N fertilizer rates at two locations in Wisconsin were similar between different tillage systems. In general, yields were greater in Arlington than Lancaster, likely due to more productive soils in Arlington. Overall yields were higher for chisel plow in Arlington and for strip tillage at Lancaster. The EONR varied between tillage systems, but these were within the range of current recommended N fertilization rates using MRTN. Similarly, NUE varied between tillage systems, with overall greater NUE in Arlington than Lancaster. However, the range in NUE between tillage systems was narrower in Lancaster. The data presented here suggest that there is no need to adjust N application rates based on tillage system in Wisconsin. Nevertheless, it would be useful to include other soils, conditions, and locations in future comparisons. Also, the no-tillage system at the two

locations should be considered transitional during the study period and not a long-term system. It is possible that long-term (> 6 years) no-tillage will respond differently to N fertilization rates, with the most likely scenario of higher yields at lower N rates than a short-term no-tillage system.

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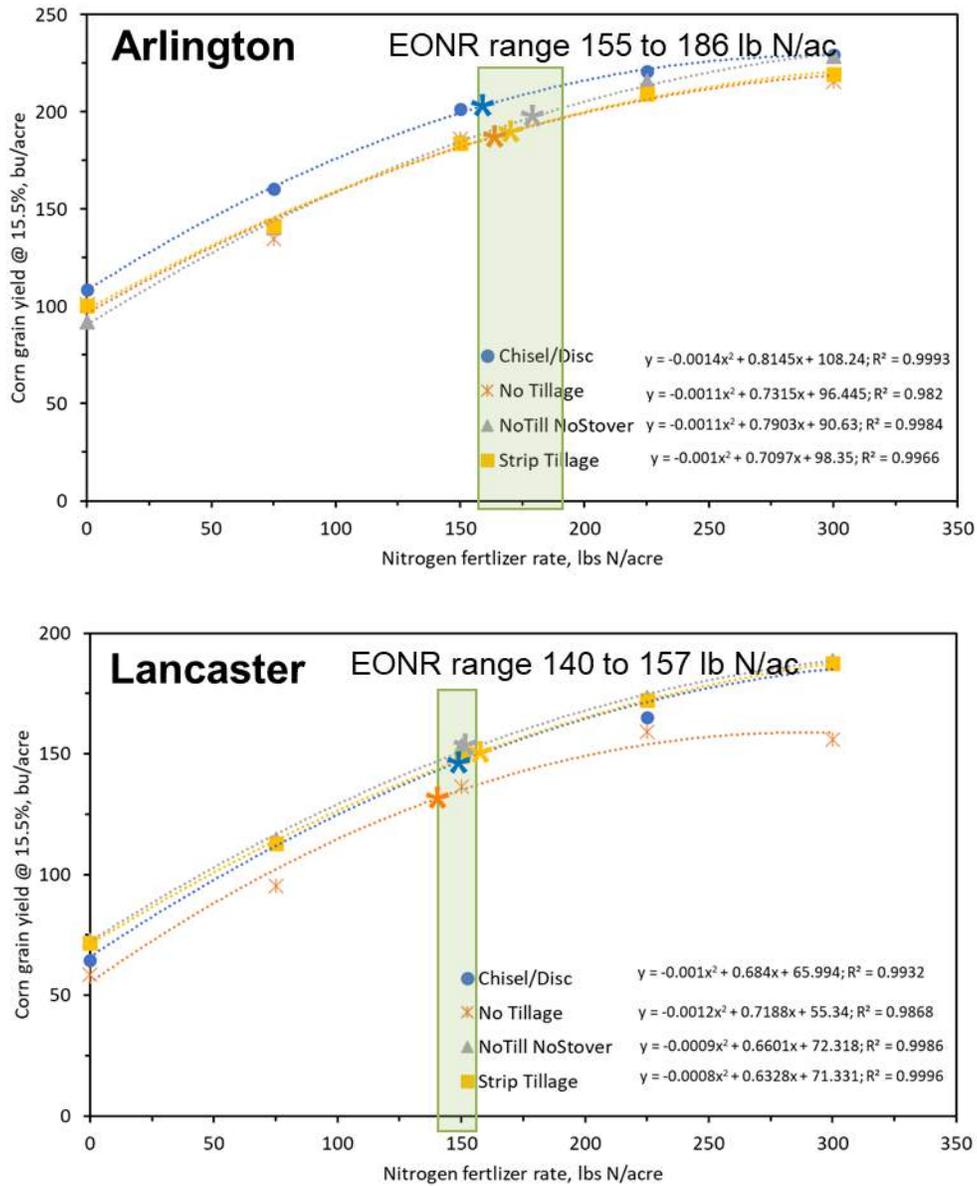


Figure 1. Five-year average N response curves for four tillage systems in Arlington and Lancaster, Wis. The green bar denotes the range of economic optimum N rate (EONR) and the asterisks (*) show the actual EONR for a specific tillage system.

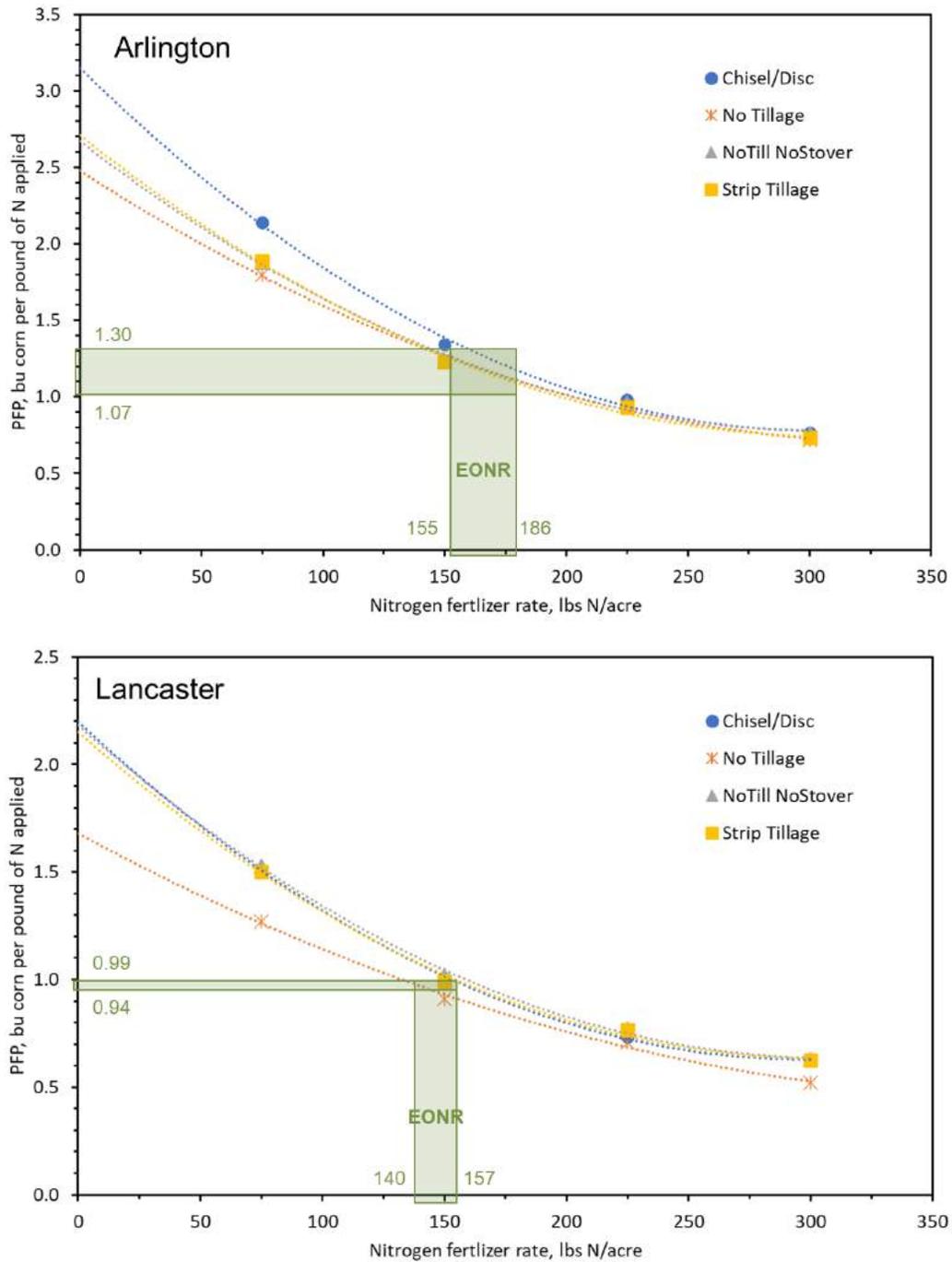


Figure 2. Partial factor productivity (PFP) N use efficiency (NUE) for four tillage systems in Arlington and Lancaster. The vertical green bar denotes the range in economic optimum N rate (EONR) and the horizontal the range in PFP values.

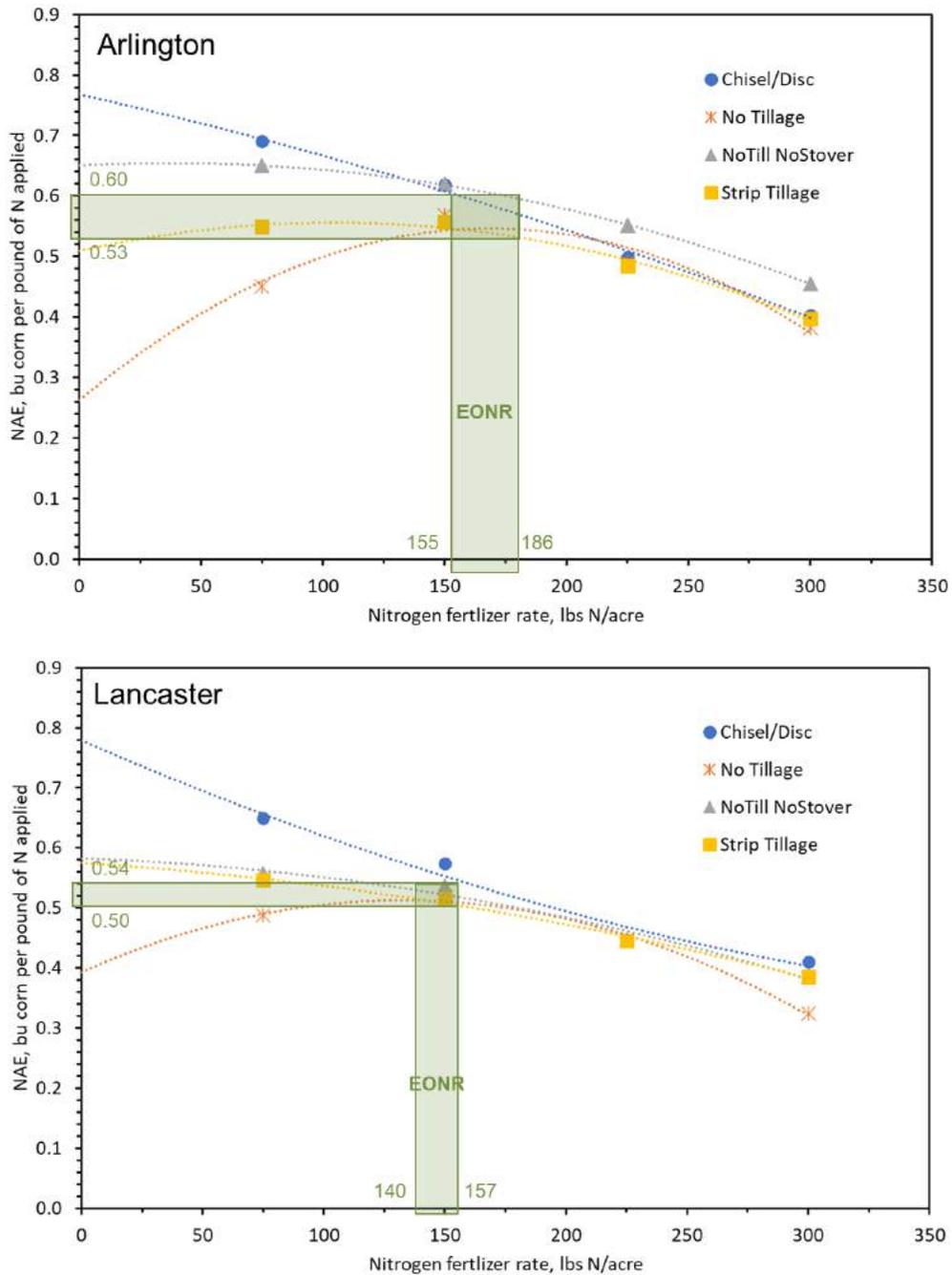


Figure 3. Nitrogen agronomic efficiency (NAE) N use efficiency (NUE) for four tillage systems in Arlington and Lancaster. The vertical green bar denotes the range in economic optimum N rate (EONR) and the horizontal the range in NAE values.

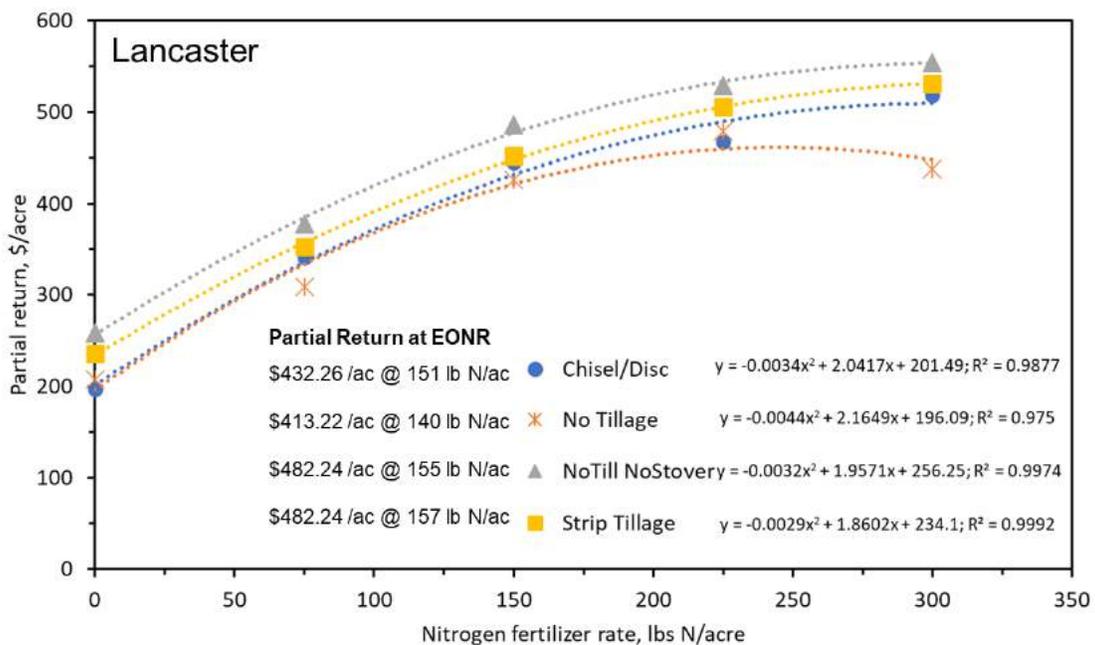
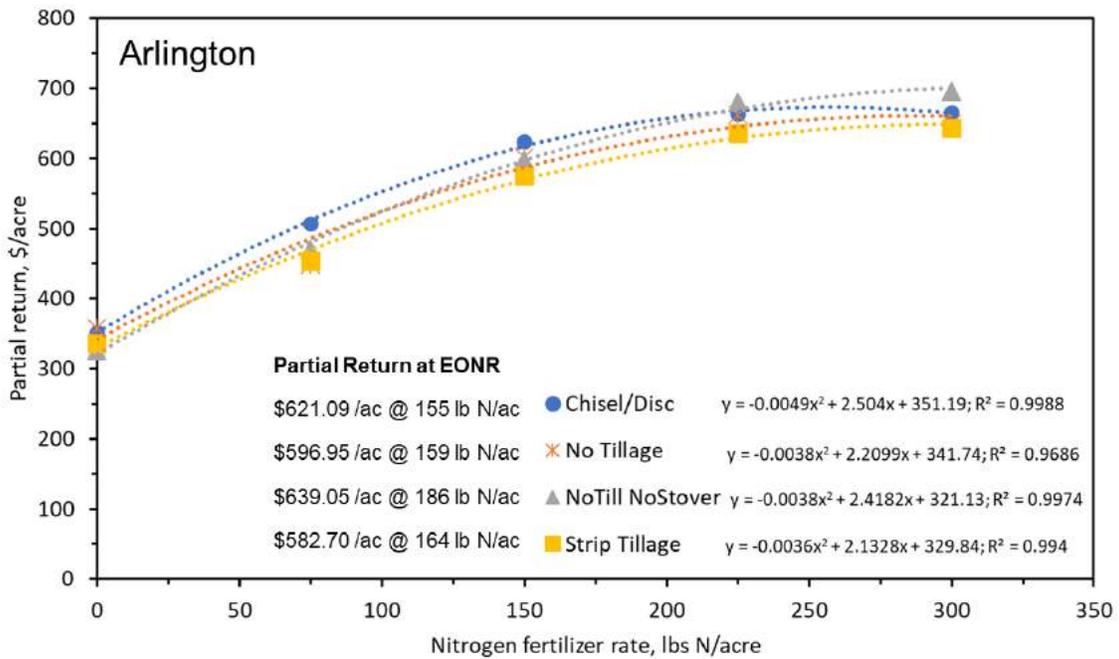


Figure 4. Economic return per acre using a partial budget approach that takes into account the cost of urea N fertilizer and custom tillage operations, and revenue from corn grain sales. Returns, costs, and corn price are based on 5-year averages for Wisconsin. Cost of weed management, planting, land, and others are not considered in this comparison as they are considered to be the same or very similar between tillage systems.

TILE DRAINAGE SELF-ASSESSMENT: WHAT CAN I EVALUATE?^{1/}

Eric Cooley^{2/}, Tim Radatz^{3/} and Aaron Wunderlin^{4/}

Background

Many farmers in the Upper Midwest use agricultural tile drainage to produce crops. Farmers in Wisconsin and Minnesota have been using agricultural tile drainage for decades. Tile drainage is used to achieve moisture conditions that improve field access, promote crop growth and yield, and decrease surface runoff. Tile drainage can also serve as a conduit for sediment and nutrient transport to surface waters and more information and education is needed to reduce this potential pathway for transport.

Most of the farmland that contains tile drainage in Wisconsin is in the Lake Michigan Basin, and in Minnesota, most is in the Mississippi River Basin. Delivery of nutrients to the Gulf of Mexico through the Mississippi River results in a hypoxic zone that affects aquatic life and the industries that depend on it. Delivery of nutrients to the Great Lakes or other freshwater sources in Wisconsin and Minnesota results in algal blooms and eutrophic conditions that are harmful to aquatic life and interfere with intended uses. Water quality impairment in both states is largely attributed to intensive agricultural land use.

Discovery Farms is an edge-of-field water quality research and outreach program focusing on farmer leadership, credible research design and implementation, and effective communication of results. The Discovery Farms programs in Wisconsin and Minnesota have been collecting edge-of-field surface runoff and tile flow data for 15 to 20 years. Many relationships between farming practices, sediment, and nutrients of surface runoff and tile flow have been quantified through the program's extensive monitoring network. However, this type of intensive edge-of-field water quality monitoring is expensive to operate and difficult to site, which limits the number of farmers able to participate.

This project significantly added to the existing tile water quality monitoring efforts and knowledge, specifically:

- Demonstrated the potential add-on or alternative to current edge-of-field NRCS practice standards making edge-of-field monitoring a more accessible diagnostic for farmers and farm advisors.
- Identified agricultural practices and field conditions where the potential for loss from tile drainage is high and assessed available practices to reduce losses.
- Provided multiple approaches to information transfer, allowing information from the project to reach many farmers and stakeholders.

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Methods

Three tiers of water quality monitoring were assessed: intensive, intermediate, and basic. Intensive tile flow and water quality data was collected from 8 locations, one in each specified county area (Fig. 1). Intensive sites utilized automated sampling equipment and a flow based sampling approach, including dataloggers, ISCO water samplers, and remote communications. Water samples from intensive sites were analyzed for suspended sediment, total Kjeldahl nitrogen, ammonium, nitrate, total phosphorus, dissolved phosphorus, chloride, total organic carbon, and dissolved organic carbon. Bi-weekly grab samples were also taken at these sites to assess the lower cost monitoring approach.

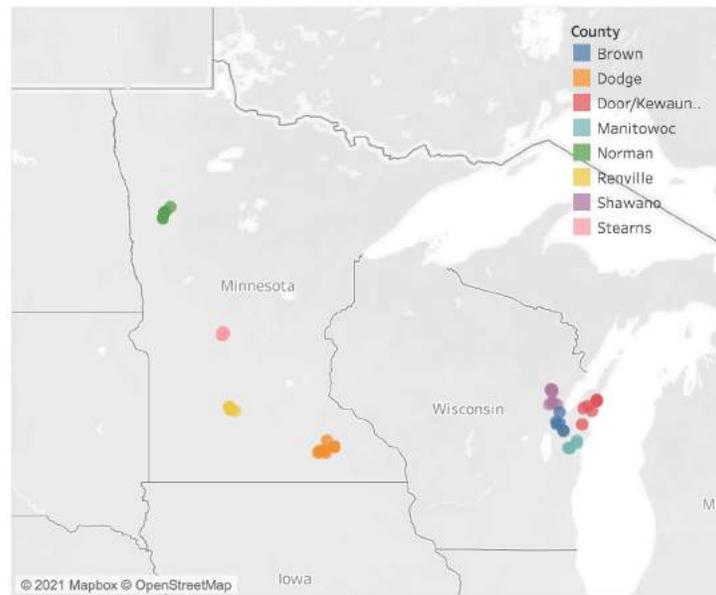


Figure 1. Tile drainage monitoring locations in Minnesota and Wisconsin.

There were 20 intermediate sites and 20 basic sites in the project. Intermediate sites included continuous flow monitoring and bi-weekly water sampling. Basic sites included bi-weekly flow monitoring and water sampling. Water samples from the intermediate and basic sites were analyzed for suspended sediment, dissolved phosphorus, total phosphorus, and nitrate. Agronomic information was collected for each location to correlate cropping and field management practices to water quality results.

Results

If measuring flow is a necessity, the intensive and intermediate approaches in this project would produce reliable results. Flow measurement of the intensive approach was reliable under all conditions. The only flow measurement limitation of the intermediate approach is during pressurized flow conditions where water levels don't necessarily correspond to flow rates. This happened at different sites throughout the project, although these pressurized flow periods had limited impact on annual runoff totals. The basic approach is insufficient for annual flow measurements as there is too much variability to only measure once every 2 weeks.

Bi-weekly samples were taken at intensive sites along with the flow based automated sampling to compare results of these two methods. Flow weighted mean concentrations (total weight lost per year divided by the total volume of tile flow) of the flow based automated sampling were compared with annual averages of the bi-weekly grab samples at all intensive sites. The bi-weekly sampling approach underestimated sediment, total phosphorus, and dissolved phosphorus concentrations (Fig. 2). This is likely because bi-weekly sampling events missed most of the high flow periods where sediment and phosphorus concentrations are typically higher. The bi-weekly sampling approach produced excellent results for nitrate concentrations, average bi-weekly concentrations were consistent with flow weighted mean concentrations. The intermediate and basic sampling approach produced reliable nitrate concentration values, but underestimated sediment and phosphorus. If reliable sediment and phosphorus concentrations are needed, an automated flow-based approach is essential.

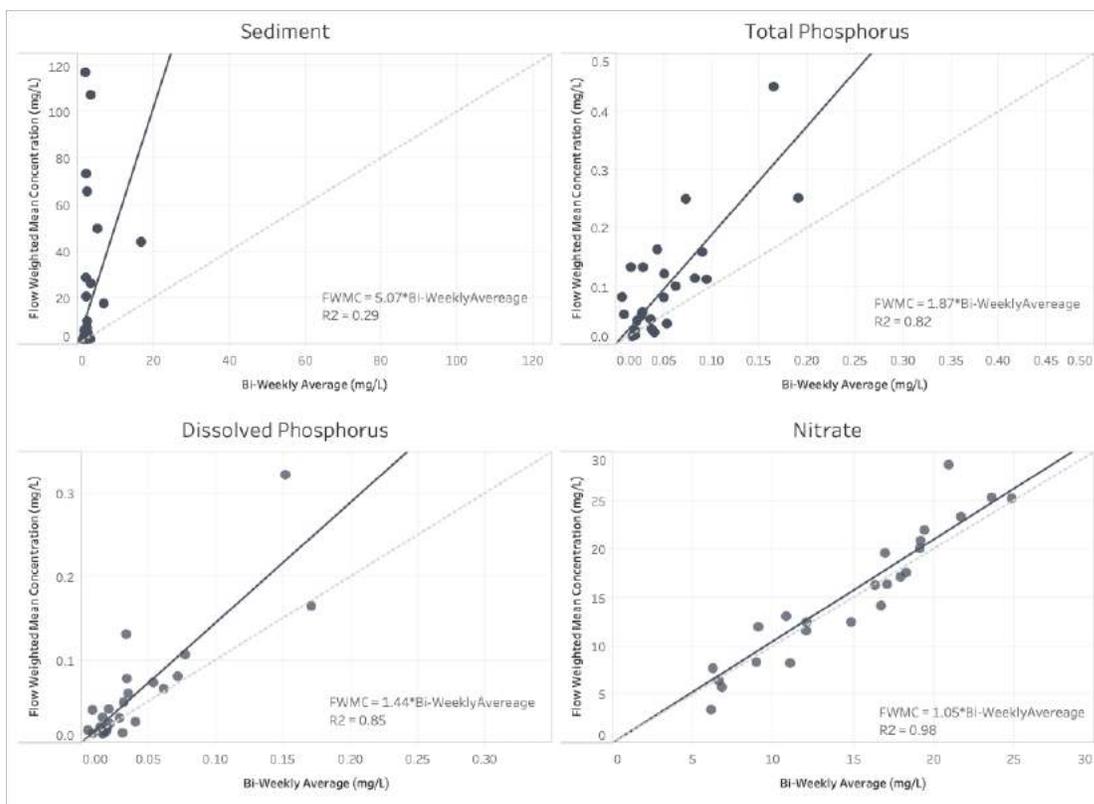


Figure 2. Comparison of continuous flow weighted mean concentration to biweekly concentration for sediment, total phosphorus, dissolved phosphorus, and nitrate in tile drainage water.

Discussion

The bi-weekly sampling approach for nitrate concentration produced results that representative for continuous flow monitoring. Therefore, grab sampling for nitrate may provide a good self-assessment tool for nitrogen management in tile drained cropland. Seasonal nitrate concentration values can aid in the assessment of nitrogen products, rates, timings, and methods of nitrogen management programs to gain knowledge of nitrogen use efficiency and decrease nitrogen losses to tile water (Table 1).

Table 1. General guidelines for interpreting NO₃-N concentrations in tile drainage water. The interpretation is derived from numerous studies conducted throughout the cornbelt and highlights land management strategies commonly found in association with a concentration measured in tile as the tile leaves the edge of the field. (Brouder et al., 2005)

NO ₃ -N concentration (ppm)	Interpretation
≤ 5	Native grassland, CRP land, alfalfa, managed pastures
5 – 10	Row crop production on a mineral soil without N fertilizer Row crop production with N applied at 45 lbs/acre below the economically optimum N rate† Row crop production with successful winter crop to “trap” N
10 - 20 Row crop	Row crop production with N applied at optimum N rate Soybeans
≥ 20	Row crop production where: <ul style="list-style-type: none"> • N applied exceeds crop need • N applied not synchronized with crop need • Environmental conditions limit crop production and N fertilizer use efficiency • Environmental conditions favor greater than normal mineralization of soil organic matter
† Economically optimum N rate is the rate that maximizes the return on investment in N fertilizer and therefore may be slightly lower than the N rate that maximizes crop yield.	

It should be noted that some monitored tile systems, specifically in Wisconsin, flowed continuously. A few of these tile systems with continuous flow produced more flow volume than total precipitation, therefore indicating interception of groundwater or perched water tables. Concentrations of all monitored analytes were comparatively low in these tile systems as compared to those that flowed less continuously. Knowing tile flow trends is important for proper assessment of nitrate concentrations in tile.

Reference

Brouder, S., B. Hofmann, E. Kladviko, R. Turco, A. Bongen, and J. Frankenberger. 2005. Interpreting nitrate concentration in tile drainage water. Agronomy Guide. Purdue Extension AY-318(W). West Lafayette, Indiana.

SOIL HEALTH IN SOYBEAN SYSTEMS: PRACTICAL MEASURES FOR ADOPTION?

Lindsay C. Malone ^{1/2/}, Matt Ruark ^{3/}, and Shawn P. Conley ^{2/}

Although there is a great deal of research on soil health, the concepts are still loosely defined, and there are not clear resources for farmers to determine their farm’s impact on soil. More research is needed to determine the most effective methods of measuring soil health, and whether those measurements relate to management decision and crop yield. This community-based project uses four soil health measures that center on both soil carbon and nitrogen stocks:

Assay	Biological Relevance
Permanganate-oxidizable carbon (POXC)	<ul style="list-style-type: none"> ● Measure of active soil carbon pool ● Organic matter stability ● Carbon-sequestration capabilities of the soil
Mineralizable carbon (Min C)	<ul style="list-style-type: none"> ● Measure of active soil carbon pool ● Short term soil organic carbon pool
Potentially mineralizable nitrogen (PMN)	<ul style="list-style-type: none"> ● Organic nitrogen that can be easily broken down ● Nitrogen likely to become available to plants in that growing season
Autoclave citrate extractable nitrogen (ACE-N)	<ul style="list-style-type: none"> ● Nitrogen present in proteins ● Related to aggregate formation

These four measures are relatively inexpensive, and can be conducted on dried, stored samples. Additionally, these measurements were chosen as estimators of soil health that are likely to relate to crop performance. A total of 385 samples were collected between 2019

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and 2021, each from a different production soybean field and sent in by farmers or CCAs. Samples came from a range of soil types across Wisconsin and surrounding states.

The two objectives of the study are to relate management and soil health indicator values, and to determine if there is a relationship between soil health indicator values and soybean yield.

We would like to thank all of the farmers, CCAs, and Extension personnel who participated in this study – without their work to collect samples and report field history, this study would not have been possible.

REAL-TIME NUTRIENT SENSING FOR PRECISION MANURE APPLICATION^{1/}

Rebecca A. Larson^{2/}, Matthew Digman^{2/}, Iris Feng^{2/}, and Joseph Sanford^{3/}

Current manure application practices require nutrient analysis procedures that can lead to significant variation in manure nutrient application. Many time manure samples are not timely, where samples are commonly obtained during application and analyzed at the laboratory using wet chemistry methods that provide results after application. This methodology only allows for updating maps and nutrient management plans to reflect the actual nutrient application rates and does not allow for adjustments during application. In addition, composite or limited samples are collected and analyzed which are used to represent the manure characteristics of an entire manure storage. These practices lead to inaccurate accounting of the manure nutrients applied to a field. This can result in yield reductions if under-applied or loss of valuable nutrients leading to negative environmental consequences if over applied. This project aims to assess the utility of a NIR nutrient prediction sensor using laboratory and fields methods to determine nutrient characteristics during application and vary the rate of manure to improve accuracy of manure nutrient applications. Data presented will show the variation in manure nutrient concentration from manure storages, variation in laboratory nutrient measurements, ability of a laboratory NIR system to measure manure nutrient concentrations, and the nutrient application rates measured in the field from a manure spreader equipped with an NIR sensor system and flow meter.

^{1/} Funded by the Wisconsin Dairy Hub.

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PHOSPHORUS DENSIFICATION AND AVAILABILITY FROM MANURE-DERIVED BIOCHAR

Joseph R. Sanford ^{1/} and Rebecca A. Larson ^{2/}

Manure nutrients are beneficial when land applied but can contribute to environmental degradation when lost as runoff, emissions, or leachate. Applying manure nutrients to better meet agronomic crop needs has potential to reduce losses but transporting manure nutrients to nutrient deficient fields is commonly cost prohibitive. Densifying manure nutrients into manure based products has the potential to reduce transport costs but current technologies, including solid liquid separation, composting, and pelleting, can remain cost prohibitive in areas of high livestock density. This project aims to assess converting manure solids to biochar and its impact on nutrient densification and availability. Data presented will show impacts on manure phosphorus and nitrogen during biochar production, and availability of phosphorous when manure-derived biochar is applied to a loam and sandy loam soil during a 182-day incubation study.

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WISCONSIN POTATO AND VEGETABLE WEED MANAGEMENT UPDATE

Jed Colquhoun, Daniel Heider, Richard Rittmeyer, and Jordan Schuler ^{1/}

Highlights of our recent potato and vegetable research include:

- In the herbicide evaluation program, we've conducted field studies on over two dozen crops in recent years. 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 aspects such as crop variety tolerance, weed control spectrum, multiple soil types and viable use patterns (timing, rate, adjuvants, tank-mixes, etc.). We continue to work across regions to custom-tailor local solutions. While new herbicide active ingredient development is rather sparse in recent years, we still have several herbicides that are registered in other crops that look promising and are in various stages of the registration process. For example, in 2021 we began to evaluate a new herbicide proposed for use in potato that in Europe has already become the most widely used product for potato weed control. We'll continue that work at multiple locations.
- We continue to work on ways to make small-seeded vegetables such as carrot, onion and cabbage more competitive with weeds in the early season and to optimize yield per unit of crop inputs, such as fertilizer and water. Our efforts recently have been focused on using natural plant growth regulators in combination with competitive varieties and seeding configurations to enhance production. We have a new graduate student starting on this project in 2022 and have established collaborations with researchers in multiple states.
- Similarly, we initiated work in 2020 to study the use of plant growth regulators to hasten uniform potato emergence and canopy development. The results of this preliminary study were interesting, suggesting that early-season potato growth can be significantly altered by low rates of plant growth regulator application. In 2021, we continued this work by looking at both seed and early foliar treatments and will follow these through harvest to determine tuber yield, size distribution and quality implications. In 2022, we'll work to refine the application rates and timing that best improve competition with weeds while also monitoring tuber size distribution and yield.

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- With rapid spread of herbicide-resistant Palmer amaranth and waterhemp in central Wisconsin in particular, we anticipate continued adoption of synthetic auxin-resistant soybean. The applied research that we've recently conducted has been used to inform regulators, growers and processors about the risks associated with potential drift, volatility or tank contamination. We'll continue to provide objective, science-based information to these important discussions such that they're grounded in reality and not just marketing. Additionally, waterhemp management in potato and rotational vegetables will be an outreach focus in 2022 based on grower and consultant input.
- In 2021, we initiated preliminary investigations of using an interseeded rye cover crop in strip plantings every 4 potato rows or between each potato row as a potential mechanism to capture leachate below the potato root zone. One of the greatest challenges in mixed species cropping is herbicide selectivity – getting acceptable weed control without killing the cover crop. In 2022, we're amending our methods to include fall-planted annual and perennial cover crops to improve that herbicide selectivity.
- We continue to lead related efforts and projects, such as serving on the DNR Groundwater Technical Advisory Committee and the Wisconsin IPM Program. We're also now investigating potential economically viable alternative crops that could further diversify Wisconsin's agricultural portfolio. In 2020, we established alternative crop studies in two central Wisconsin locations, Antigo and Arlington and continued this work through the 2021 growing season. The groundnut is of particular interest in the potato rotation and 2022 studies will focus on agronomic optimization of this crop that is a drought-tolerant, nitrogen fixing legume with high protein content.

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

2021 SWEET CORN SEEDCORN MAGGOT MANAGEMENT TRIAL
ARLINGTON, WISCONSIN, USA

Russell Groves, Bryan Jensen, Ben Bradford, Scott Chapman ^{1/}

Methods

Objective: Evaluate the efficacy of five different at-plant insecticide treatments on two different sweet corn hybrids for control of seedcorn maggot (DIPTERA: *Delia platura*).

Experimental design: This trial was conducted at the University of Wisconsin’s Arlington Agricultural Research Station, located 3 miles southeast of Arlington, WI, on a silt loam soil in 2021. Two separate plantings were established intended to evaluate efficacy against the second and third generation of the seedcorn maggot lifecycle, respectively. The second generation planting was established on May 26, 2021, at coordinates 43.316713, -89.335280, while the third generation planting was established Jun 23, 2021, at coordinates 43.317012, -89.333932. Each planting measured 120 ft. wide by 135 ft long, containing four replicates of 12 adjacent 10 ft (4 rows on 30 in. spacing) by 30 ft long plots, with 5 ft of unplanted space along rows separating replicates. Seed was planted using a 2-row planter equipped with a cone feeder. Each 30 ft. row received 45 seeds, for an approximate seed spacing of 8 in.

Treatments: Two sweet corn hybrids were used in this experiment: Syngenta GS 1453 was used for treatments 1-6, while Seminis SV1339SK was used for treatments 7-12. All seed was treated with the fungicides 42-S Thiram (5 fl oz/cwt), Apron XL (0.32 fl oz/cwt), Dividend Extreme (5 fl oz/cwt), Maxim 4FS (0.08 fl oz/cwt), and Vitavax 34 (3.6 fl oz/cwt). Insecticide treatments were as follows: treatments 1 and 7 received Poncho 600 (0.5 mg ai/seed), treatments 2 and 8 received Cruiser 5FS (0.25 mg ai/seed), treatments 3 and 9 received no insecticide, treatments 4 and 10 received Reatis (0.25 mg ai/seed), treatments 5 and 11 received Entrust (0.25 mg ai/seed), and treatments 6 and 12 received Fortenza (0.25 mg ai/seed). See **Table 1** for treatment details.

Table 1. Treatment details

Product	Unit	Syngenta GS 1453						Seminis SV1339SK					
		1	2	3	4	5	6	7	8	9	10	11	12
42-S Thiram	fl oz/cwt	5	5	5	5	5	5	5	5	5	5	5	5
Apron XI	fl oz/cwt	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32
Dividend Extreme	fl oz/cwt	5	5	5	5	5	5	5	5	5	5	5	5
Maxim 4FS	fl oz/cwt	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
Vitavax 34	fl oz/cwt	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6	3.6
Poncho 600	mg ai/unit	0.5						0.5					
Cruiser 5FS	mg ai/unit	0.25						0.25					
Reatis	mg ai/unit	0.25						0.25					
Entrust	mg ai/unit	0.25						0.25					
Fortenza	mg ai/unit	0.25						0.25					

Treatment products are shown in rows, with treatment numbers and corresponding rates are shown in columns. Hybrid variety is shown above treatment numbers.

^{1/} Department of Entomology, Univ. of Wisconsin-Madison.

Evaluation: Stand counts were performed in rows 2 and 3 in both plantings at two time points to evaluate seedling effects of either seedcorn maggot (SCM) damage or treatment-related delayed emergence. Stand counts were performed in the first planting on Jun 7 (12 days after planting, crop stage V1) and Jun 14 (19 days after planting, crop stage V2-V3). Stand counts in the second planting were performed on Jul 1 (8 days after planting, crop stage V1) and Jul 7 (14 days after planting, crop stage V2-V3). During the first stand count in both plantings, seedling damage was assessed by walking four paces into each plot and digging up five seedling in row 1 of the plot. The number of damaged plants, the number of plants with seedcorn maggot larvae present, and the total number of larvae present on the five seedlings was recorded.

Data analysis: Evaluation data was analyzed in R version 4.1.0 (R-Core Team, 2021). Stand counts are reported as percentage of total seeds planted (90 per two rows). Insect counts were $\log(x + 1)$ transformed. All response variables were analyzed using analysis of variance of a fitted linear model with the formula $response = hybrid * insecticide + rep$. This formula incorporates the hybrid corn variety, the insecticide, and the replicate as main effects, and the hybrid:insecticide interaction term.

Results – First Planting

Stand counts: There was slightly higher emergence rate in the Seminis hybrid at the first stand count, particularly evident in the Entrust and Reatis treatments ($F=4.938$, $P=.033$). In addition, there was a significant difference in emergence between insecticide treatments across both hybrids in both the first stand count ($F=5.800$, $P=.0006$) and the second stand count ($F=5.972$, $P=.0005$). Entrust and Reatis improved stand count the most, with an estimated 12.8% and 11.1% increase versus control in the second stand count. Fortenza improved stand by 9.4%, while Cruiser and Poncho improved stand by 8.9% over control.

Insect damage: There was no significant difference between hybrids or insecticide treatments in the number of healthy plants per plot or in the number of SCM larvae found per 5 plants.

Results – Second Planting

Stand counts: There was a greater difference in stand counts between hybrids in the second planting compared to the first planting, though similarly the Seminis hybrid had higher emergence. At the first count, the Syngenta plots has about 8.3% lower emergence versus the Seminis plots ($F=34.715$, $P<.0001$). There was also a significant difference in emergence between insecticides, with Reatis (+5.3% vs UTC) and Poncho (+1.7%) outperforming the other treatments ($F=2.723$, $P=.036$). At the second stand count, the difference between hybrids was more modest, with an average of 3.1% higher emergence in the Seminis plots ($F=11.330$, $P=.002$). Emergence differences among insecticide treatments were also apparent, with Reatis (+8.9% vs UTC) and Cruiser (+3.3%) outperforming the other treatments ($F=2.224$, $P=0.075$).

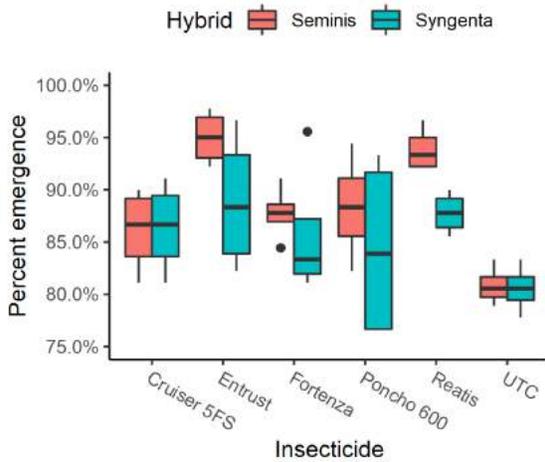
Insect damage: Unlike the first planting, there were significant differences in the number of damaged plants ($F=2.888$, $P=0.029$) and the number of larvae per 5 plants ($F=5.635$, $P=0.003$) between insecticide treatments. Cruiser and Poncho treatments had the lowest number of damaged plants, though results were mixed overall.

This research was funded in part by the Midwest Food Processors Association. (MWFPA)

First planting (May 26, colonized by second gen SCM)

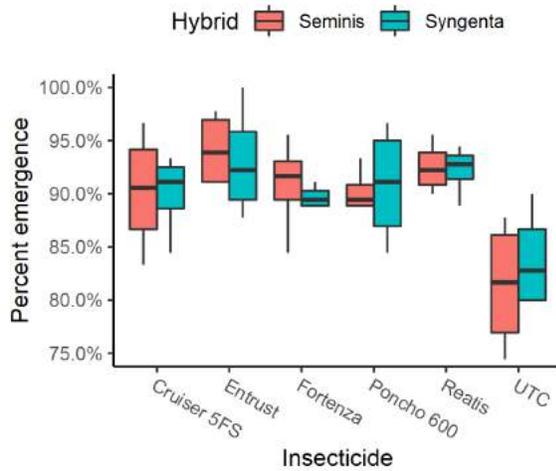
First planting

Stand count 1 (12 DAP, crop stage V1)



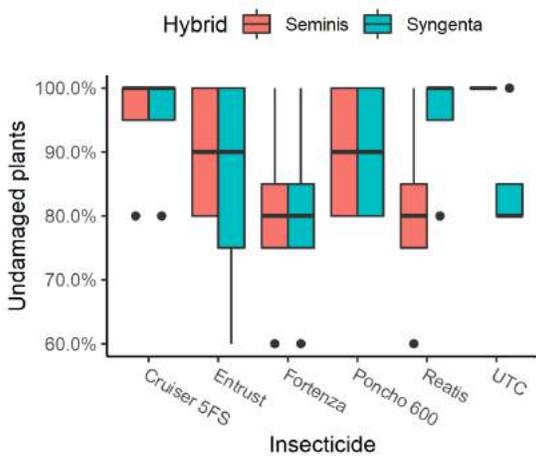
First planting

Stand count 2 (19 DAP, crop stage V2-V3)



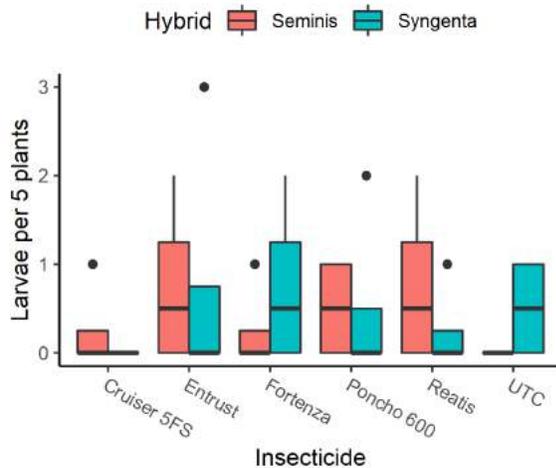
First planting

Percent undamaged plants



First planting

Larvae per 5 plants



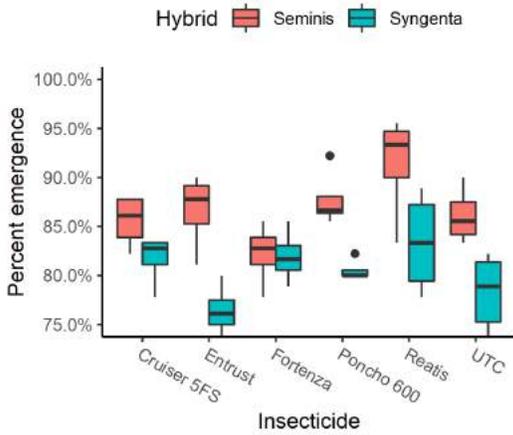
Statistical tests, first planting

Factor	df	Stand Ct 1			Stand Ct 2			Healthy plants			Larvae per 5 plants		
		F	P-value	Sig.	F	P-value	Sig.	F	P-value	Sig.	F	P-value	Sig.
Hybrid	1, 33	4.938	0.033	*	0.011	0.971	ns	0.051	0.823	ns	0.000	1.000	ns
Insecticide	5, 33	5.800	0.0006	***	5.972	0.0005	** *	1.312	0.283	ns	0.505	0.770	ns
Rep	3, 33	1.104	0.361	ns	0.582	0.631	ns	1.000	0.405	ns	0.595	0.623	ns
Hybrid*Insec.	5, 33	0.717	0.616	ns	0.187	0.965	ns	1.149	0.355	ns	0.625	0.682	ns

Second planting (Jun 23, colonized by third gen SCM)

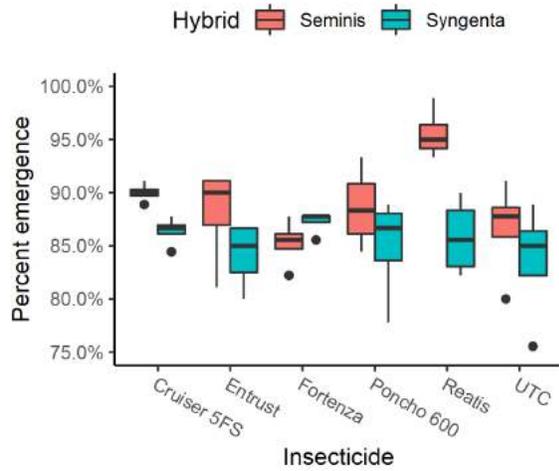
Second planting

Stand count 1 (8 DAP, crop stage V1)



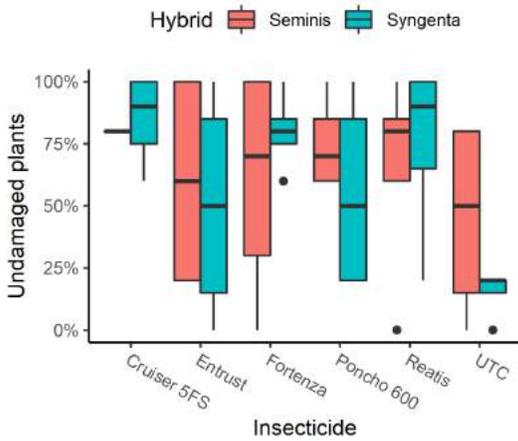
Second planting

Stand count 2 (14 DAP, crop stage V2-V3)



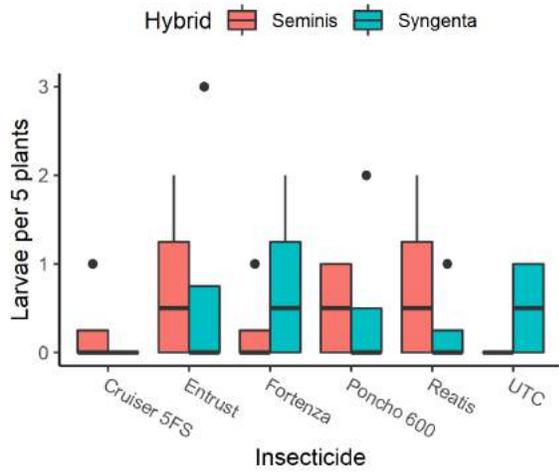
Second planting

Percent undamaged plants



Second planting

Larvae per 5 plants



Statistical tests, second planting

Factor	df	Stand Ct 1			Stand Ct 2			Healthy plants			Larvae per 5 plants		
		F	P-value	Sig.	F	P-value	Sig.	F	P-value	Sig.	F	P-value	Sig.
Hybrid	1, 33	34.717	<.0001	***	11.330	0.002	**	0.231	0.634	ns	0.002	0.965	ns
Insecticide	5, 33	2.723	0.036	*	2.224	0.075	.	2.888	0.029	*	5.740	0.001	**
Rep	3, 33	0.461	0.712	ns	0.016	0.997	ns	5.274	0.004	**	5.635	0.003	**
Hybrid*Insect.	5, 33	1.897	0.121	ns	1.936	0.115	ns	0.806	0.554	ns	0.532	0.750	

USING PRECISION AGRICULTURE PRACTICES IN PRODUCING VEGETABLE CROPS IN WISCONSIN

Yi Wang and Alfadhil Alkhaled^{1/}

Remote sensing is an innovative, timely, non-destructive and spatially comprehensive approach to improve existing in-season crop production management practices. Remote sensing typically provides several narrow spectral bands (~ 3 to 10 nm), which can capture fine absorption features of crop nutrients (e.g., leaf chlorophyll, water and nitrogen). So far many studies have indicated that remote sensing can be effectively applied to predicting crop parameters/variables, such as leaf area index, biomass, foliar N concentration, and leaf chlorophyll content.

The methods used to predict/model crop biophysical (e.g., LAI, biomass, yield) or biochemical (e.g., leaf nitrogen, leaf water, chlorophyll) variables mainly focus on building predicting algorithms between spectral signals and field measurements. A typical model predictor is vegetation indices (VI), which are mathematical combinations of reflectance at two or more spectral bands. VIs allow for reliable spatial and temporal inter-comparisons of terrestrial photosynthetic activity, quantify vegetation biomass, investigate canopy structural variations, and evaluate plant vigor for each pixel in a remote sensing image. Overall, VIs can measure the state of the plants' health based on how the plant reflects light at certain spectral bands. In addition, VIs contribute to maximizing sensitivity to the vegetation characteristics while minimizing confounding factors such as atmospheric effects, directional or soil background reflectance. For example, normalized difference vegetation index (NDVI) has been widely used in previous studies due to its simple application to monitoring vegetation dynamic at regional and global scales.

There has been ample evidence showing that foliar N in a wide variety of crops can be mapped from remote sensing imagery, but most studies are based on commodity crops. Our proposed project will take advantage of different vegetation indices using machine learning methods on multiple vegetable crops over three growing seasons. The result will be an app that generates immediate ("low-latency") maps of crop foliar nitrogen concentration indicating the instant crop N status at different growth stages across the field, as well as in-season predicted maps of final yield over the entire field. This app will offer a tremendous opportunity for highly efficient near real-time vegetable crop nutrient management by vegetable farmers.

We have used three machine learning models {decision tree (DT), support vector machine (SVM), and random forest (RF)} that used normalized difference vegetation index (NDVI) to predict the N status and final yield of four potato cultivars (two russets

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including Silverton and Lakeview Russet, two chippers including Snowden and Hodag) grown at the Univ. of Wisconsin Hancock Agriculture Research Station (HARS) in 2018 and 2019. Our preliminary results demonstrate that NDVI has great potential of predicting the potato N status indicated by petiole NO₃-N, whole leaf total N, or whole vine total N as well as end-of-season total yield (Table 1). We used R² that ranges from 0 to 1 to measure goodness-of-fit for the models. The higher the R², the better the prediction. It is considered to be very good prediction if R² is higher than 0.75.

For nitrogen status, using NDVI to predict petiole nitrate-N generated the best R² results for both potato types, compared to whole leaf total N and whole vine total N. For total yield prediction, DT and RF were better than SVM, and the results for 2019 was better than 2018 (Table 1).

Table 1. The petiole, whole leaf, whole vine, and total yield coefficient of determination R² results for the two potato types in the 2018 and 2019 seasons. DT = decision tree; SVM = support vector machine; RF = random forest.

	Chipping potato			Russet potato	
Regression models	2018	2019		2018	2019
	Petiole Nitrate-N				
DT	0.813	0.916		0.769	0.958
SVM	0.809	0.913		0.664	0.932
RF	0.814	0.931		0.773	0.957
	Whole Leaf Total N				
DF	0.755	0.872		0.797	0.914
SVM	0.184	0.162		0.144	0.133
RF	0.813	0.856		0.809	0.935
	Whole Vine Total N				
DF	0.800	0.216		0.722	0.650
SVM	0.145	0.132		0.089	0.019
RF	0.819	0.315		0.728	0.676
	End-of-season Total Yield				
DF	0.332	0.627		0.361	0.742
SVM	0.126	0.426		0.005	0.461
RF	0.444	0.738		0.418	0.794

So far, we have found that: (1) decision tree and random forest are better than support vector machine for predicting both in-season N status and end-of-season yield for potatoes; (2) petiole nitrate-N can be better predicted using NDVI and machine learning models compared to the other potato traits. We need to validate the models and expand this work using more years of data collection on more vegetable crops.

AGRONOMIC STABILITY AND RESILIENCY OF THE CORN-SOYBEAN ROTATION IN THE U.S. CORN BELT

Joseph G. Lauer ^{1/}

The corn-soybean rotation of the U.S. Corn Belt is the dominant cropping system. It is a relatively young cropping system that is currently challenged by many abiotic and biotic factors. A question often asked, “Is it sustainable?” Resilient, stable, and productive cropping systems are needed to endure increasingly frequent climatic extremes. Our objectives were 1) To identify superior corn-soybean cropping sequences for stability and resilience across environments, and 2) To explore the relationship between productivity, stability, and resilience of corn-soybean rotations. **Productivity** is the average yield across normal years. **Stability** is the minimal variability of yields across normal years. **Resilience** is the ability of a system to withstand a climatic crisis with high yields and not deviate during the crisis with the ability to recover from a crisis and the speed of this recovery. An experiment initiated in 1983 involving tillage and corn-soybean rotations was used to evaluate stability and resiliency. Crop rotations included continuous corn, continuous soybean, corn-soybean rotation, and 5-yrs corn followed by 5-yrs soybean. In every year all phases of the crop sequences was established. The rotation effect lasted two years for corn and slightly longer for soybean. Greatest yields were measured during first- and second-year corn and soybeans. The pattern for corn yield response to rotation phase is different than the pattern for soybean. First year soybean following 5-yrs of corn yields more than rotated soybean. In corn, stability was not affected by rotation phase. In soybean, stability decreases as rotation phase increases. The standard deviation range between rotation phases is ± 15 to 17 bu/A for corn and ± 5.1 to 5.6 bu/A for soybean. The resiliency of the corn-soybean yield response pattern is similar across rotation phase. Seasonal growing degree day accumulation does not affect grain yield as much as precipitation. Warm/dry stress years affect grain yield more than cool/wet years. For soybean, the year following a warm/dry stress year was better yielding than an average year. Management decisions involving cropping sequence should be based upon productivity rather than stability or resiliency.

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Evaluating the potential of an algorithm-based (A.I.) decision-making tool to increase farmers' profitability in Wisconsin

Spyros Mourtzinis, John Gaska, and Shawn P. Conley



IN A BEAN POD:

- ▶ Soybean A.I.-based cropping systems were, in general, successful in increasing yield and profit compared to typical systems
- ▶ Across all locations, following soybean A.I. recommended systems would have increased mean yield by ~7 bu/ac and mean profit by ~\$40/ac compared to typically used cropping systems
- ▶ The potential of corn A.I.-based cropping systems to increase yield and profit was not clear
- ▶ The corn A.I. tool recommended systems resulted in either increased or similar profit with typical systems by applying 19-223% lower nitrogen fertilizer rate

INTRODUCTION

Substantial crop yield variability arises from the wide range of optimal to sub-optimal management observed in farmers' soybean and corn fields. Replicated field experiments have been used to identify best management practices for several decades. Most commonly, the effectiveness of up to three management factors and their interactions are evaluated in a single location due to practical constraints (e.g., cost, logistics). It is assumed that background management practices are optimal or at least relevant to what most farmers use in the region, which in fact may not be realistic for many farmers.

Given all the well-known deficiencies of current agricultural research methods, an AI-tool, which leverages the power of artificial intelligence algorithms, claims that it has the potential to identify, among thousands of possible cropping systems a farmer can choose from in a single field, optimum cropping system for greatest yield and for greatest profitability. The AI-tool, using a combination of methods, estimates yield and projected profit by accounting for field location, soil type, weather conditions and several management practices and associated costs. Eventually, the cropping systems with highest probability of success are recommended to the farmer. The spatial coverage of the AI-tool is extensive and coincide with the region where most of corn and soybean are grown across the US (Figure 1).

The objective of the presented work is to compare yield and profitability of UW-recommended soybean and corn cropping systems with AI-recommended systems in WI in three growing seasons (2021, 2022 and 2023). Here we present results of the first year.

RESULTS

Soybean

Five experiments in five locations across WI were conducted to evaluate the effectiveness of algorithm-recommended (A.I.) cropping systems to increase yield and profit

Figure 1. Crop hectareage across the US.
Adapted from Mourtzinis and Conley, 2017.

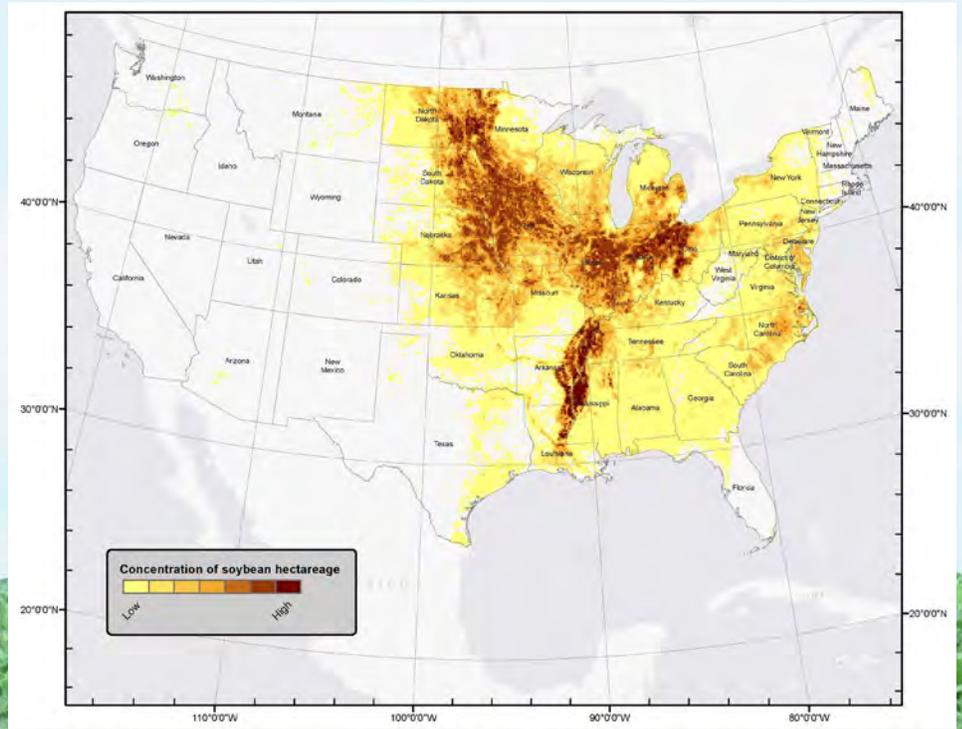


Table 1. A.I. recommended and typical cropping systems used in each location.

Location	Name	Planting date (2021)	Seeding rate (seeds/ac)	Variety	RM	Fungicide	Pre-plant nitrogen (N)
ARL	Typical	11-May	140,000	S23-G5X(T)	2.3	0	0
ARL	A.I. Yield	29-Apr	160,000	AG26X0(T)	2.6	MiravisNeoR3	0
ARL	A.I. Profit	29-Apr	160,000	AG26X0(T)	2.6	0	0
PLT	Typical	27-Apr	140,000	S23-G5X(T)	2.3	0	0
PLT	A.I. Yield	27-Apr	240,000	AG26X0(T)	2.6	MiravisNeoR3	50 lbs N/a
PLT	A.I. Profit	27-Apr	160,000	AG26X0(T)	2.6	0	0
HAN	Typical	30-Apr	140,000	AG20X9(T)	2	0	0
HAN	A.I. Yield	30-Apr	240,000	S23-G5X(T)	2.3	MiravisNeoR3	50 lbs N/a
HAN	A.I. Profit	30-Apr	165,000	S23-G5X(T)	2.3	0	0
MAR	Typical	7-May	140,000	AG14X8(T)	1.4	0	0
MAR	A.I. Yield	7-May	240,000	AG14X8(T)	1.4	MiravisNeoR3	50 lbs N/a
MAR	A.I. Profit	7-May	160,000	AG14X8(T)	1.4	MiravisNeoR3	0
SPO	Typical	15-May	140,000	AG10X9(UT)	1	0	0
SPO	A.I. Yield	20-Apr	200,000	AG10X9(UT)	1	MiravisNeoR3	50 lbs N/a
SPO	A.I. Profit	20-Apr	160,000	AG10X9(UT)	1	0	0

compared to UW-recommended systems (typical). The A.I. approach provided maximum yield (“A.I. yield”) or maximum profit (“A.I. profit”) cropping systems depending on the objective (Table 1).

Among the five locations, A.I. increased yield (Fig. 2) and profit (Fig. 3) in two locations whereas no differences were observed in the rest three locations. Across all locations, A.I. significantly increased both, yield and profit compared to typical. In cases where a farmer has multiple fields (five in our exercise), following A.I. recommended systems would have increased mean yield by ~7 bu/ac and mean profit by ~\$40/ac compared to typically used cropping systems.

Figure 2. Soybean yield comparison among algorithm-recommended (A.I.) cropping systems for maximum profit (A.I. profit), for maximum yield (A.I. yield) and UW-recommended systems (typical). In bars with the same letter yield was not significantly different at alpha=0.05. Errors represent standard error of the mean.

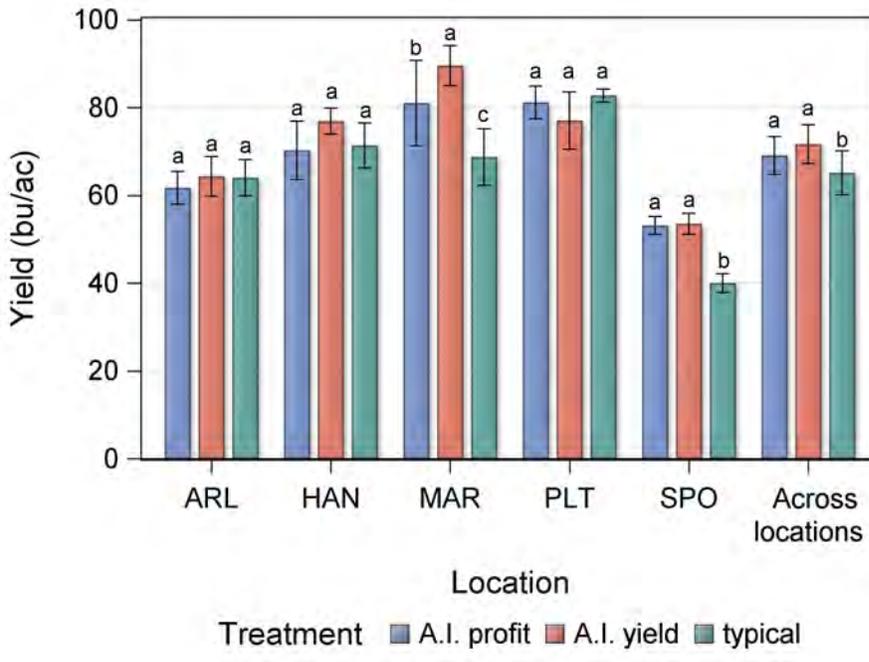
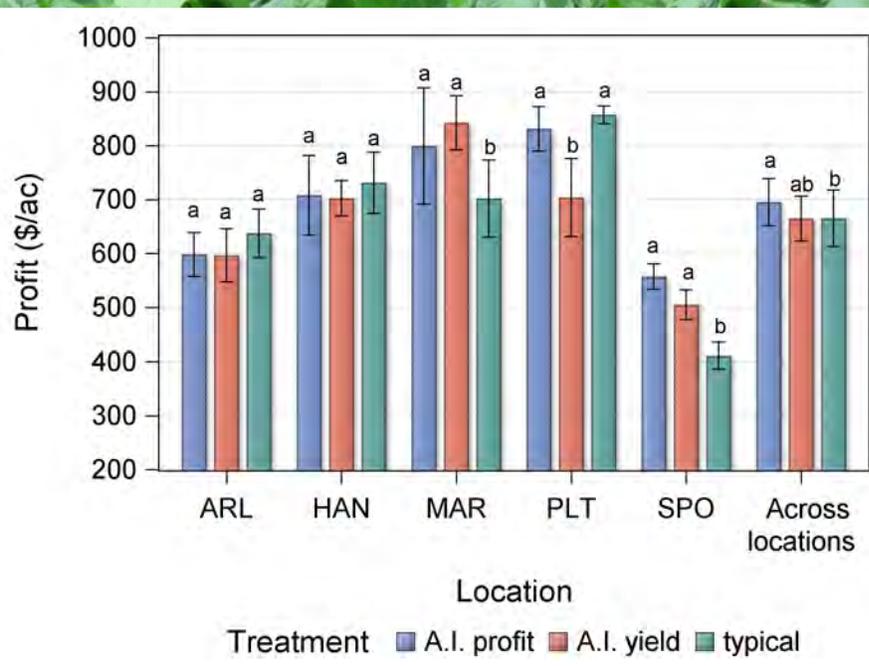


Figure 3. Soybean profit comparison among algorithm-recommended (A.I.) cropping systems for maximum profit (A.I. profit), for maximum yield (A.I. yield) and UW-recommended systems (typical). In bars with the same letter yield was not significantly different at alpha=0.05. Errors represent standard error of the mean.



Corn

Three experiments in three locations in WI were conducted to evaluate the effectiveness of algorithm-recommended (A.I.) corn cropping systems to increase yield and profit compared to UW-recommended systems (typical). Similarly to soybean, the A.I. approach provided maximum yield (“A.I. yield”) or maximum profit (“A.I. profit”) cropping systems depending on the objective (Table 2).

Among the three locations, “A.I. yield” systems resulted in lower yield in the ARL location by ~15 bu/ac and across locations by 10 bu/ac compared to typical. No significant differences were observed in the rest two locations (Fig. 4). The “A.I. profit” systems resulted in increased profit in the DAL location by \$76/ac and no other differences were observed in the rest two locations (Fig. 5). Across the three locations, the difference between “A.I. profit” and typical was not significantly different.

It is interesting to observe the profit comparison between corn A.I. profit and typical systems in every location. When compared to typical cropping systems, the A.I. tool recommended systems that either increased (in DAL) or resulted in similar profit with

Table 2. A.I. recommended and typical corn cropping systems used in each location. Note: GM= Genetically modified, RW=rootworm, F=fungicide, I=insecticide.

Location	Name	Planting date (2021)	Seeding rate (seeds/ac)	Hybrid	RM	Seed Traits	Starter Fert (N-P-K lbs/a)	Pre N lbs/a	Post N lbs N/a
ARL	Typical	29-Apr	36,000	P0720Q	107	GM+RW+F+I	30-76-60	0	207
ARL	A.I. Yield	29-Apr	38,000	W4196RIB	105	GM+F+I	30-76-60	37	55
ARL	A.I. Profit	29-Apr	34,000	199-11VT2PRIB	99	GM+F+I	30-76-60	64	0
LAN	Typical	26-Apr	35,000	W4246RIB	105	GM+F+I	14-35-45	120	0
LAN	A.I. Yield	26-Apr	40,000	W4246RIB	105	GM+F+I	14-35-45	101	0
LAN	A.I. Profit	26-Apr	30,000	W4246RIB	105	GM+F+I	14-35-45	101	0
DAL	Typical	15-May	32,500	DKC50-64RIB	100	GM+RW+F+I	39-80-60	0	141
DAL	A.I. Yield	8-May	39,000	P0339Q	104	GM+RW+F+I	39-80-60	0	176
DAL	A.I. Profit	8-May	39,000	P0339Q	104	GM+RW+F+I	39-80-60	0	71

Figure 4. Corn yield comparison among algorithm-recommended (A.I.) cropping systems for maximum profit (A.I. profit), for maximum yield (A.I. yield) and UW-recommended systems (typical). In bars with the same letter yield was not significantly different at alpha=0.05. Errors represent standard error of the mean.

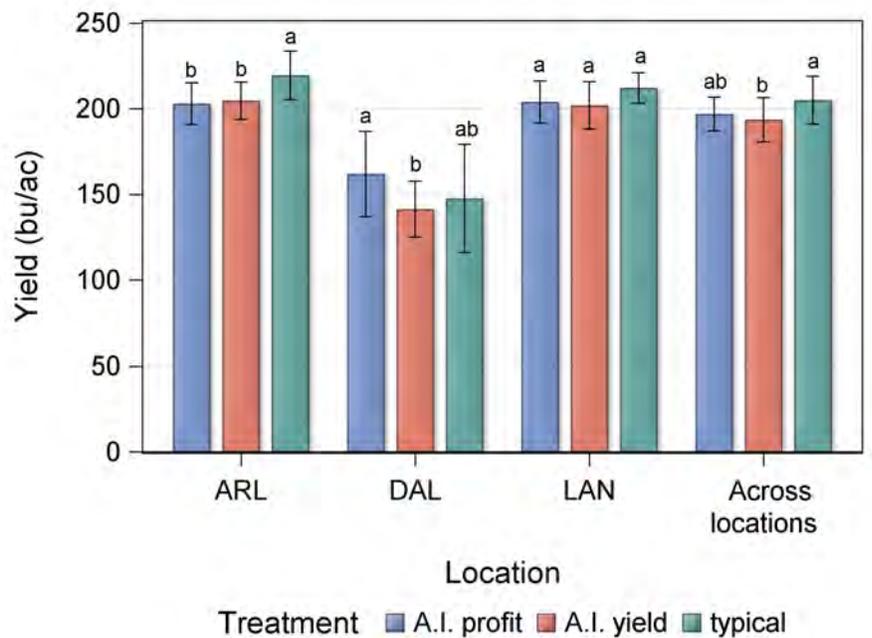
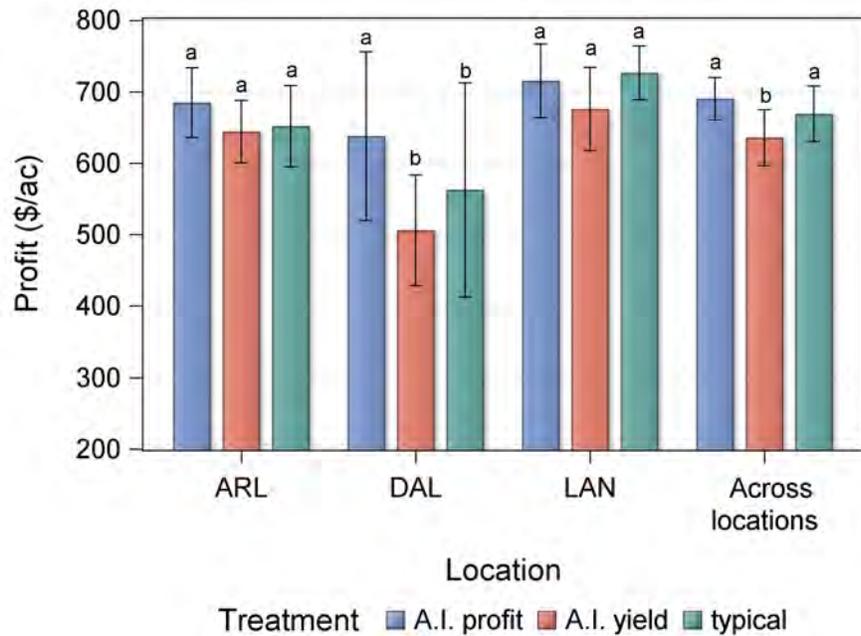


Figure 5. Corn profit comparison among algorithm-recommended (A.I.) cropping systems for maximum profit (A.I. profit), for maximum yield (A.I. yield) and UW-recommended systems (typical). In bars with the same letter yield was not significantly different at alpha=0.05. Errors represent standard error of the mean.



typical systems by applying substantially lower Nitrogen fertilizer rate (N reduction by 323% in ARL, 16% in LAN and 50% in DAL). These results suggest the potential of these algorithms to identify and recommend more environmentally friendly cropping systems without compromising farm profitability.

DISCUSSION

Algorithm-based decision making will likely play an important role in the coming years. Algorithms can capture and quantify complex relationships that can result in more informative decisions with greater probability of success (effectively increase profit) compared to current approaches. Evaluation of such tools in field conditions which involve unexpected and unmanageable yield adversities is important. In this work, soybean A.I.-based cropping systems were in general successful to increase yield and profit compared to typical systems. The potential of corn A.I.-based cropping systems to increase yield and profit though was not clear (Table 3). Additionally, Tar Spot was found and not treated at all three locations. This may have impacted the overall results of the experiment and suggest that the A.I. tool alone cannot account for in-season IPM decisions and should be paired with scouting or other management tools such as TarSpotter.

Table 3. Frequency of success/failure of soybean and corn A.I. recommended cropping systems compared to typical among individual locations.

Crop	Comparison	A.I. success	A.I. failure	Draw	Total
Soybean	A.I. yield vs. typical	2	0	3	5
	A.I. profit vs. typical	2	0	3	5
Corn	A.I. yield vs. typical	0	1	2	3
	A.I. profit vs. typical	1	0	2	3

It should be noted that the typical cropping systems have been developed by UW researchers after years of research in the specific locations and are already optimized. Therefore, identification of even more improved cropping systems is very challenging. We argue that in suboptimal cropping systems, that frequently exist in farmer's fields (Edreira et al., 2017; Mourtzinis et al., 2018), the A.I. approach has potential to increase yield and more importantly profit. The A.I. tool will be further improved and evaluated in more locations in subsequent years.

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HOW AG INDUSTRY IS USING NEW TECHNOLOGIES TO ADDRESS SUSTAINABILITY: PROGRESS AND OPPORTUNITIES

Paul Carter ^{1/} and Jeff Schussler ^{2/}

Abstract

Both abundant crop productivity and attention to stewardship of natural resources are foundations of solid agronomy and are aligned with objectives expressed as “sustainability.” These dual objectives for crop and soil management are challenging, but essential.

Commercial agricultural industry has enabled progress in sustainability, but there are major challenges and deficiencies that persist which must be addressed.

This presentation will review examples of both historical progress and how new technologies being developed in both large and small companies can be opportunities to address critical gaps which need attention for potential future sustainability improvements in these areas:

- Sustainable intensification
 - Crop productivity: Genetics x Environment x Management
- Radiation use efficiency
- Water use efficiency
- Nutrient use efficiency
- Soil health

Important areas where even more engagement from agricultural industry for sustainability progress is needed will be highlighted including

- More viable crop species diversity
- Better incentives to reduce nitrous oxide emissions
- Less tillage, more no-till
- Expanded crop roots emphasis
- More independent validation of “sustainability” products
- Engage trusted agronomy advisors
- More public-private collaboration

^{1/} Independent Agronomist, Des Moines, Iowa.

^{2/} Schussler Ag Research Solutions, Marion, Iowa.

MAIZE BREEDING 101: NEW TOOLS AND TECHNIQUES

José Ignacio Varela and Natalia de León ^{1/}

Maize (*Zea mays L.*) yields have risen continuously since the adoption of hybrid maize in the US in the 1930s. About 50 to 60% of this increase has been attributed to genetic improvement with the remainder being credited to advances in crop protection, fertilization and other cultural practices.

Modern maize breeding programs are designed based on advances in genetics, biometry and experimental design and they usually demand large amounts of genomic and phenotypic data to pursue these goals. With the rapid decrease in sequencing technologies costs, there has been a recent “bottlenecking” in the acquisition and analysis of phenotypic data in the breeder’s pipeline. This situation has brought this new science of “phenomics” to the forefront of plant breeding.

The first part of this talk will provide a broad overview of the progress of maize yield in the last 100 years focusing on plant traits that have changed significantly as a response to selection affecting directly or indirectly grain yield (as yield components). The second part will emphasize how critical it is to obtain high throughput measurements of phenotypes to achieve genetic gain in modern breeding. Four examples of recent technologies delivered by academic research laboratories will be addressed: (1) A method for computing maize ear, cob and kernel attributes automatically from images (2) A system for automated image-based phenotyping of maize tassels, (3) High throughput non-destructive prediction of maize kernel composition and morphology measurements using an NIR flatbed scanner and (4) The use unmanned aerial systems to predict plant height and its relationship with yield.

^{1/} Research Assistant and Professor, Dept. of Agronomy, Univ. of Wisconsin-Madison.

SMARTSTAX PRO TECHNOLOGY: THE FIRST COMMERCIAL USE OF RNAI TECHNOLOGY FOR MANAGING CORN ROOTWORM

Safeer Hassan ^{1/}

In 2022, Bayer Crop Science is planning a limited commercial launch of SmartStax PRO with RNAi Technology. SmartStax® PRO will be the first product with three modes of action for corn rootworm control, two from *B.t.* proteins (Cry3Bb1 and Cry34Ab1/ Cry35Ab1) and one from a unique RNAi mode of action (DvSnf7 dsRNA). Large scale field studies implemented in 2021 assessed SmartStax® PRO Technology and other leading corn rootworm products, including SmartStax® Technology, Optimum® AcreMax® XTreme Technology, Qrome® Technology, and Agrisure Duracade® Technology across a range of corn rootworm pressure. SmartStax® PRO Technology consistently had lower node injury scores compared to the other corn rootworm technologies.

^{1/} Corn Systems Manager, Bayer Crop Science, based in St. Louis, Missouri

AFRICAN SWINE FEVER VIRUS

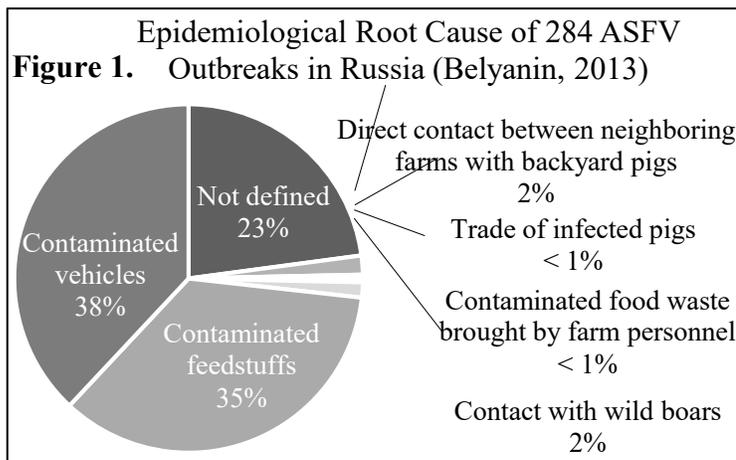
Cassandra Jones ^{1/}

As African swine fever virus (ASFV) continues to spread across Southeast Asia, classical swine fever virus (CSFV) reports occur in Japan, and foot and mouth disease virus (FMDV) spread continues with new strains emerging in China, there is increased concern that foreign animal disease (FAD) may enter naïve countries (Bachanek-Bankowska, 2018). Entry of FADs would be devastating to the livestock industry, but also to those that produce feed and ingredients. The ASFV incursion into China in 2018 illustrates this case. The disease quickly spread throughout the country, directly causing extremely high levels of swine morbidity and mortality, but also indirect repercussions throughout the entire agricultural industry. In May 2019, pig feed production was only 2/3 of the previous year's production in the Shandong Province (FAO, 2019).

Examples of FAD Entry into Previously Negative Countries via the Feed Supply Chain.

Several examples of introduction of FADs via the feed supply chain exist. Introduction of FMDV into Japan and South Korea have both been linked to feedstuffs (Sugiura et al., 2001; Park et al., 2014). The feeding of silage that was harvested from areas with wild boars infected with CSFV has led to illness in naïve pigs (Ribbens et al., 2004). Just 5 years ago, porcine epidemic diarrhea virus (PEDV) was rapidly spreading throughout the U.S. swine industry for the first time, causing high mortality in young piglets in 27 states. The root cause investigation for PEDV entry in the USA concluded the most likely cause was 1-ton polyethylene tote bags containing feed or ingredients from China (USDA 2015). Feeding contaminated feed has been categorized as a risk factor for ASFV transmission (EFSA, 2014; Belyanin, 2013; Fig. 1). This report documented feed being associated with 35% of 284 reported outbreaks in Russia.

Contaminated feed has been reported that 35% of the 284 ASFV outbreaks in Russia were linked to contaminated commercial feed. More recently, reports indicate that 1 to 2% of tested ingredients from modern Chinese feed mills were ASFV-positive, including corn, soybean meal, rice, wheat, and corn dried distillers grains with solubles (Dee and Niederwerder, 2019). Senecavirus A (SVA), a swine pathogen that causes similar clinical signs as FMDV, is endemic in swine production systems in the U.S. and was recently found to be spread via SVA-contaminated ingredients and feed in Brazil



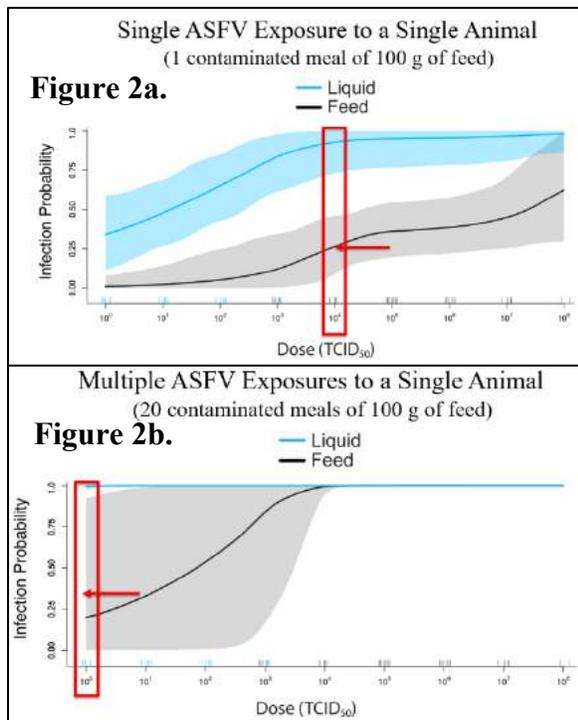
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(Leme et al., 2019). The source of virus entry into the feedstuff is oftentimes FAD-containing feces, which may be introduced into the ingredient through cross-contamination during grain drying or ingredient transportation. These examples clearly demonstrate FAD contamination risk in non-animal origin feed and ingredients; however, the respective virus must survive transport from abroad to the U.S. or within the U.S. at sufficient levels to cause animal infection to be of substantial risk.

Virus Survival during Transport at Concentrations Capable of Causing Infection

As our team recently described in Niederwerder et al. (2019), the ASFV infection risk with contaminated feed is relatively low for a single exposure (10^4 TCID₅₀/g for one meal of 100 g of



feed; Fig. 2a). However, the risk of ASF transmission through feed in an industry setting is substantially higher (see Fig. 2b) because it is unlikely that exposure to the ASF agent would be a single exposure event. Feed industry equipment and production processes are designed to efficiently mix low inclusion products uniformly throughout a batch of feed, and then deliver feed in a way that provides multiple meals with the same consistency to all pigs housed in the same location. This means that instead of a single exposure to an FAD agent, it is likely that a contaminated ingredient would be mixed into larger volumes of feed, which would initially dilute the contaminant, but also substantially increase the number of exposures to an individual animal. A single batch of feed is typically delivered to a barn of 1,200 pigs, where it takes 1.5 days for it to be consumed in a series of 20 meals per pig. Instead of a single pig being exposed to a high level of pathogen one

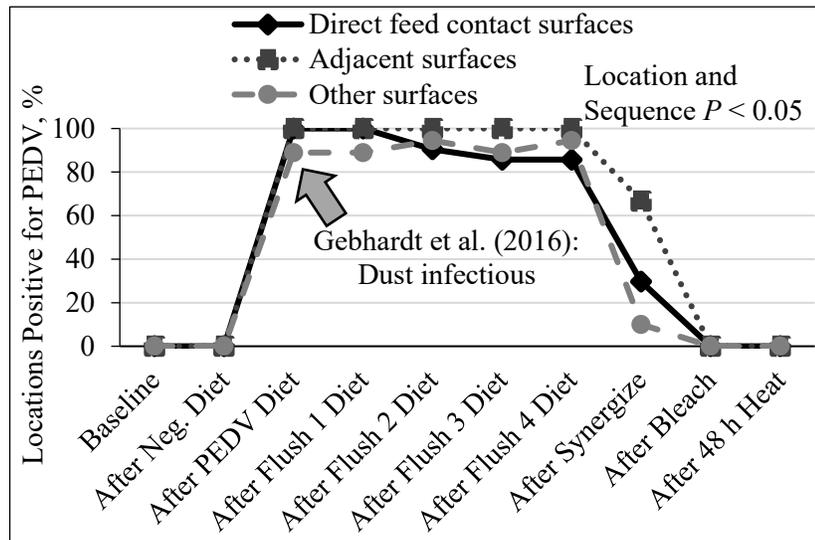
time, the exposure concentration is diluted, but the number of exposures increased to 20 meals or exposures per pig (or 24,000 exposures for 1,200 pigs) in 36 hours. This exponentially increases the probability of infection and changes the dose likely to cause infection to be 10^0 TCID₅₀/g for twenty 100-gram meals of feed (Figure 2b). The risk is expanded even further when one considers the potential role a contaminated feed mill may have on subsequent batches of feed. From this data, we can conclude that if ASFV enters the feed supply chain, ASFV infections of pigs are nearly inevitable, regardless of the ASFV concentration in the feed.

The same catastrophic impact of pathogen transmission through feed has been described with other viruses. Our team reported in Schumacher et al. (2016) that if 1 gram of feces from an acutely PEDV-infected pig entered a receiving pit, it could potentially contaminate 500 metric tons of feed, with each gram of feed having a dose capable of causing a pig infection. That is the equivalent of twenty 24-ton feed trucks being contaminated by 1 gram of PEDV feces, all of them carrying infectious material to different swine operations, leading to simultaneous infection of multiple herds. This is what was thought to occur in the 2013-2014 incursion of PEDV, when incidence of disease dramatically spiked in a manner that had never been previously observed.

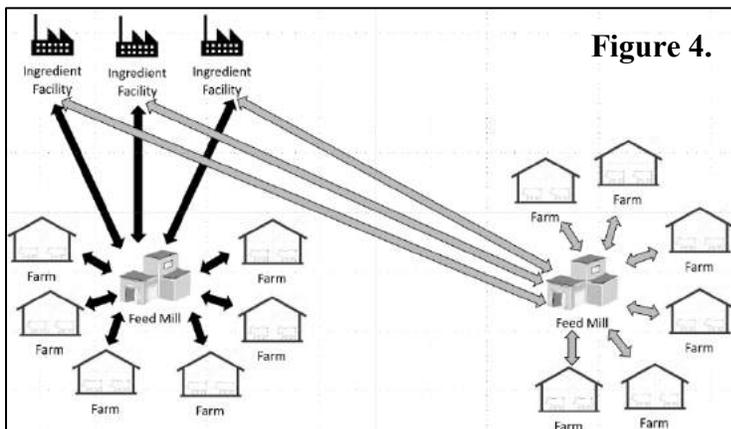
While FAD-contaminated feed is being delivered to farms, pathogens can also cause contamination of the feed manufacturing equipment. In 2017, we reported in Schumacher et al. that entry of PEDV into a feed mill leads to nearly 100% of surfaces being contaminated, including non-contact surfaces such as

walls and floors, and that manufactured additional batches of virus-free feed does not flush contaminated material out of the conveying system (Fig. 3). Subsequently, Gebhardt et al. (2018) reported that material collected from these non-contact surfaces is capable of causing PEDV infection of animals. Finally, Huss et al. (2017) reported that the cleaning and disinfection necessary to sanitize a virus-

Figure 3. PEDV contamination of feed mills



contaminated feed mill includes complete organic material removal, followed by wet-cleaning with multiple sanitizers. The U.S. feed industry is not designed for these types of cleaning and disinfection processes, so the primary focus must be on keeping pathogenic viruses out of feed mills, particularly because feed mills are a central point of cross-traffic among multiple farms or sites. Figure 4 demonstrates just a snapshot of the normal traffic flow of feed mills. Depending on mill size, it can receive dozens of ingredient delivery vehicles daily. The mill mixes ingredients together and distributes them to dozens of farms. The swine and poultry industries have developed highly effective biosecurity procedures that prevent people or transport vehicles from serving as fomites for viral transfer (Kim et al,



Kim et al, 2017; Allerson et al., 2013; Valincourt, 2015). These include protocols for changing shoes, clothing, and/or showering and dynamic biosecurity pyramids for transport vehicles. Many modern swine production systems implement biocontainment practices similar to BSL2 or 3 laboratories but on a much larger scale. However, these same procedures have not been

implemented at feed mills and with personnel or feed trucks. Therefore, feed mills have the potential to become the primary route for pathogen distribution onto farms, and a high risk for introduction of FAD agents into the U.S. livestock and poultry industries.

SIDEDRESSING CORN WITH LIQUID MANURE ^{1/}

Melissa L. Wilson ^{2/} and Chris Pfarr ^{3/}

With spring and fall seasons becoming increasingly wet and unpredictable when it comes to the weather, farmers and commercial manure applicators are looking for alternative periods of time to apply livestock manure. Applying manure to corn (*Zea mays* L.) during the growing season, referred to as sidedressing, could provide farmers with a window of opportunity while maximizing nutrient uptake efficiency. The practice needs to be fine-tuned, however, to increase adoption by farmers in the region. Four studies have been conducted to evaluate different aspects of sidedressing manure, two involving the use of a drag hose system and two involving tanker application.

- An on-farm study in central Minnesota found that when applied correctly, side-dressed liquid swine manure produced yields comparable to sidedressed anhydrous ammonia and liquid urea-ammonium nitrate (Pfarr et al., 2020).
- At two research stations, corn was dragged at different growth stages with a filled, six-inch manure hose. We found that corn can be dragged at the first, second, and third leaf collar growth stages (V1, V2, and V3 stages) without any yield loss. One corn variety (Pioneer hybrid P0339R) also was able to be dragged at the fourth leaf collar stage (V4) more reliably than a second corn variety (Pioneer hybrid P0306AM). Regardless of variety, dragging corn at fifth and sixth leaf collar stages (V5 and V6) significantly reduced yield by approximately 45 and 69%, respectively (Wilson et al., 2021).
- An on-farm study in central Minnesota used a 4,200-gallon tanker to sidedress liquid swine manure at different corn growth stages (V4 and V7) and compared it to sidedressed anhydrous ammonia at the V4/V5 corn growth stage. Tanker application of manure reduced yield by 7% when applied at V7 and by 15% when applied at V4 compared to anhydrous ammonia sidedressed around V4/V5. It is thought that compaction from the tanker may have caused the yield reduction due to root restriction or because the compaction did not allow manure to infiltrate the soil as well which resulted in volatilization losses. Adjustments with the application equipment may be able to overcome some of these limitations.
- Small-plot studies were used to evaluate 1,500-gallon tanker application at different corn growth stages (emergence, or VE, and V6) as well as different application techniques (sweep injection, disk injection, and surface broadcast). These were compared with a sidedressed commercial fertilizer (urea with a urease inhibitor) at the same growth stages and a no-nitrogen control. Liquid dairy manure was used at one research station while

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liquid swine manure was used at a second research station. This study is on-going but after the first year we found no difference in sidedress timing or application method with swine manure, though all manured and commercially fertilized plots yielded better than the no-nitrogen control. We saw similar results with dairy manure, though no treatments were different than the no-N control, not even commercially fertilized plots. Drought conditions in this past year limited yield, however, especially at the site where dairy manure was applied. A second year of this experiment will be conducted in 2022.

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INJECTING MANURE INTO A GROWING COVER CROP ^{1/}

Melissa L. Wilson ^{2/}, Manuel Sabbagh ^{3/}, and Paulo Pagliari ^{4/}

There is growing interest in using cover crops to improve soil health and protect water quality. In cool, northern climates, however, the short growing season makes it more difficult to get cover crops established in the fall, especially on farms that also fall-apply livestock manure. Traditionally, manure is applied after the cash crop is harvested followed by cover crop seeding. This leaves little time - and growing degrees - for the cover crops to successfully establish. Interseeding cover crops into a cash crop allows more time for growth and is becoming popular. But how can manure be applied into a living cover crop without damaging it? Newer injection technologies allow liquid manure application beneath a living cover crop with minimal disturbance, but many questions about the practice remain. Our primary goals for this project were to develop and demonstrate best management practices for the integration of cover crops and manure injection. Secondarily, we evaluated whether the combination of practices has added beneficial effects when compared to each practice alone.

Field trials were initiated in fall 2019 and again in the fall of 2020 in separate fields at the University of Minnesota West Central Research and Outreach Center (WCROC) near Morris, MN and the Southern Research and Outreach Center (SROC) near Waseca, MN. Each study was laid out in a randomized complete block design with split plots. Phosphorus and potassium fertilizers were applied if needed (according to soil test results) to plots prior to planting and 40 pounds of nitrogen (N) fertilizer as urea were applied at pre-plant across the entire field. All remaining fertilizer and manure application rates were adjusted to account for the pre-plant fertilizer N. In the spring for each study, the cover crops were chemically terminated (if necessary) and tilled into the soil prior to planting, usually 1 to 2 weeks ahead of time. Corn was planted and managed according to typical practices for the region. Remaining details for each study are as follows:

- A soybean (*Glycine max* Merr.) – corn (*Zea mays*) rotation using fall-applied liquid swine manure or spring applied fertilizer prior to corn was completed at both research locations at two different sites at the SROC and one site at the WCROC for a total of three site-years. Subplots included a cover crop mixture of annual ryegrass (*Lolium multiflorum*) and winter cereal rye (*Secale cereale*) overseeded into soybean near leaf drop or drilled after harvest. A no-cover crop control was included. Main plots included swine manure sweep injected after soybean harvest or spring applied nitrogen (N) fertilizer. Cover crop growth by the spring was low in both years, though higher for the overseeded cover crop (97 to 256 pounds/acre) compared to the drilled cover crop (17 pounds/acre in 2020 to 71 pounds/acre in 2021). We did not find an effect of nutrient source or cover crop on yield when averaged over both years. This indicates that over the short-term, cover crops did not reduce yield and that manure and fertilizer resulted in comparable corn yield.

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- At the WCROC, a continuous corn system was evaluated using fall-applied liquid dairy manure or spring applied fertilizer over two site-years. Subplots included a cover crop mixture of annual ryegrass (*Lolium multiflorum*) and winter cereal rye (*Secale cereale*) interseeded around the V4 (4th leaf collar) corn growth stage, the R6 (black-layer) corn reproductive stage, or drilled after harvest. A no-cover-crop control was also included. Main plots included dairy manure sweep injected in the fall when soil temperatures were above 50°F (usually late September to early October) or after soil temperatures had fallen below this level (usually late October to early November). These were compared to spring-applied N fertilizer. Above-ground cover crop biomass in the spring tended to be negatively affected by fall manure application, though differences from the spring fertilizer plots that had not been disturbed were not significant. Biomass was low in 2020 (ranging from 31 to 73 pounds/acre) compared with 2021 (ranging from 50 to 125 pounds/acre). Cover crop application timing influenced silage yield. Covers interseeded at V4 resulted in significantly higher yield than when interseeded at R6 or drilled after harvest, though none of the treatments were significantly different than where no covers were seeded. This was likely due to the higher ratio of winter rye that established at the later seeding dates that survived into the spring. Dairy manure, regardless of when it was applied in the fall, increased yield by approximately 2 tons/acre over the spring-applied fertilizer.
- At the SROC, a sweet corn-corn rotation was evaluated using fall-applied liquid swine manure or spring applied fertilizer over two site-years. Subplots included a winter rye cover crop, a forage oat (*Avena sativa*) cover crop, or a winter rye-oat-radish (*Raphanus sativus*) mix that was drilled after harvest of the sweet corn in early to mid-August. There was also a no-cover-crop control. Main plots included swine manure from a finishing barn that was sweep injected in the fall when soil temperatures were above 50°F (usually mid- to late-September) or after soil temperatures had fallen below this level (usually late October to early November). These were compared to spring-applied N fertilizer. Above-ground cover crop biomass in the spring of 2020 was higher where manure had been applied in the rye plots compared to the spring fertilized plots, though biomass was similar across nutrient sources in the cover crop mix (oat had winter killed and had no spring biomass). The early, fall-applied manure in 2021 also resulted in higher cover crop biomass in the rye and mixed cover crop plots than the spring fertilized plots, though the late, fall-applied manure had significantly lower biomass produced. The late manure application and corresponding disturbance of the cover crop did not allow enough time for the cover crop to recover in that year. Corn grain yield was affected by nutrient sources and cover crops. In both 2020 and 2021, the early-applied manure resulted in a 15 bushel/acre yield penalty compared with the spring fertilized treatment (the standard practice in the region). The late-applied manure resulted in a significant yield increase (by 33 bushel/acre) in 2020 to a slight yield decrease (by 8 bushel/acre) though the difference was not significant compared to the spring fertilized plots in 2021. There was no interaction with cover crops, suggesting that the cover crops did not limit nutrient losses enough to improve yield when manure was applied too early. Regardless of nutrient source, cover crops that included winter cereal rye tended to cause a 20 bu/acre yield reduction compared to the no-cover-crop control plots. This is likely because rye had vigorous growth in the spring (ranging from 312 to 1,634 pounds/acre of above-ground biomass) and despite being terminated and plowed under 1 to 2 weeks prior to planting, may have tied up nitrogen in the soil due to its high carbon to nitrogen ratio or caused problems with the planting bed, limiting seed to soil contact.

Overall, we found that planting cover crops as early as possible in the fall (or even the late summer) consistently resulted in more cover crop biomass than waiting to plant after harvest. Once cover crops are established, low disturbance manure injection is key to minimize damage to the cover crops. We observed that the same equipment had more or less disturbance depending on soil moisture conditions. Making adjustments to equipment (i.e., depth of injection, changing the angle of the coulter if possible, etc.) depending on soil conditions will likely be important moving forward. And finally, these results suggest that cover crops used in a field for the first time may not reduce the risk of nutrient losses from manure applied too early in the fall. Research in Iowa suggests that consistent use of cover crops may change this trend, but more long-term research is needed.

CREATING OPPORTUNITIES FOR IN-SEASON MANURE APPLICATIONS USING COVER CROPS AND ALTERNATIVE FORAGES: STORIES FROM NORTHERN WISCONSIN

Jamie Patton^{1/}

Dairy manure is a valuable nutrient source for row crop production but requires judicious management to reduce potential application risks to ground and surface water quality. The first-year nutrient “book values” of liquid dairy manure (< 4% dry matter, < 1 hour to incorporated or injected) is estimated at 7 pounds of nitrogen (N), 3 pounds of P₂O₅, and 11 pounds K₂O per 1,000 gallons (Laboski and Peters, 2012). Therefore, manure applications followed by potential nutrient runoff and/or leaching events can pose water quality risks. According to the Wisconsin Water Quality Report to Congress (WDNR, 2020), 13% of Wisconsin’s evaluated surface water bodies are classified as impaired, with phosphorus as the most frequently cited pollutant. In terms of groundwater, nitrate is the state’s most widespread contaminant, with approximately 10% of private drinking water wells exceeding the safe drinking water standard (WDNR, 2021). It is estimated 90% of Wisconsin’s groundwater nitrate enrichment results from agricultural input use, including manure and fertilizer applications (WDNR, 2021).

Manure applications to actively growing crops can potentially reduce offsite movement of applied nutrients, while increasing nutrient use efficiencies. However, the traditional corn silage-alfalfa rotation provides limited in-season manure application windows. Analyzing 2010 NASS data, Mitchell et al. (2021) determined approximately 63% of Wisconsin corn acres received liquid dairy manure, with most of the manure applied in the fall (55.6% of applications) versus spring (43.9% of applications). On many dairy farms, manure applications to alfalfa occur after first and third crop harvest. Manure is applied at low rates, ideally within a few days after alfalfa harvest, to minimize crop damage and maintain stand quality. With limited in-season application windows and fixed on-farm manure storage capacity, manure applications may occur when soil conditions are suboptimal and/or in the fall when crops are not actively growing, thereby potentially resulting in soil compaction and/or increased risk for off-site movement of sediment and nutrients.

Diversifying crop rotations has the potential to increase manure management and application options, while also providing high quality feed to meet the nutritional needs of various dairy animal groups. To reduce the volume of manure being applied in the fall, some northeast Wisconsin dairy farms are altering cropping systems, replacing and/or enhancing the traditional corn silage-alfalfa rotation with winter cereal forages, warm season grass forages and forage mixes, and perennial grasses. Such alternations in the crop rotation increase the number of manure application opportunities during the growing season, reducing manure

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storage pressures and application timing risks, while improving nutrient use, labor, and equipment efficiencies. These rotational changes also result in the production of quality forages suitable for lactating cow and heifer rations, while spreading agronomic and financial risks across diverse cropping systems.

During this session we will discuss how and why some northeast Wisconsin dairy farms are altering their crop rotations to increase the potential for in-season manure applications and the impact these changes have on on-farm manure and forage management.

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COVER CROP LESSONS FROM THE FIELD

Daniel H. Smith ^{1/}

The 2020-2021 cropping season provided some unique opportunities and challenges for cover crop incorporation into Wisconsin cropping systems. 2020 fall field conditions led to early crop harvest and cover crop establishment. This provided an opportunity for good fall growth and spring biomass production. A tremendous amount of biomass was observed from winter rye in late spring 2021. Spring crop planting conditions were challenging; dry soils, lack of rainfall, late spring frost, and on cover crop acres, tremendous biomass, created a perfect storm for challenging corn and soybean establishment. Fields were planted and, in some cases, re-planted in challenging conditions. Many issues observed in the field can be attributed to changes in anticipated conditions, but many could have been resolved with more planning. Cover crop termination plans/goals, planter set-up, down-pressure, closing wheels, and maintenance all contributed to field success and failures when planting into the greater than normal cover crop biomass accumulations. Throughout summer, cover crop biomass provided excellent weed control and help preserve moisture. With many areas of Wisconsin receiving less than normal precipitation, moisture management was going to be a key to retaining average crop yields. The lack of timely rains challenged cover crop interseeding and summer weed management program relying on residual chemistry. Late summer brought many late emerging weeds, especially waterhemp and fields with cover crop biomass helped hold off the germinating weeds. Fall conditions were ok for cover crop establishment although soil conditions remained dry in early fall. Early-November provided an excellent window for cover crop establishment. Moving into spring of 2022 keep an eye on snow cover, precipitation levels, and have a plan to terminate cover crops when appropriate. Take time to review planter maintenance, set-up and new techniques and technologies for implementing diverse crop rotations.

Further Information:

Cover Crops in Wisconsin

<http://fyi.uwex.edu/covercrop/>

Nutrient and Pest Management Program Cover Crop Resources

<https://ipcm.wisc.edu/covercrops/>

Cover Crops 101: A4176 University of Wisconsin Publication

<https://learningstore.extension.wisc.edu/collections/farming/products/cover-crops-101>

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THE RISE OF FALL ARMYWORM

Chris DiFonzo ^{1/}

Fall armyworm (FAW), *Spodoptera frugiperda*, is an uncommon pest in the Midwest. You may have heard of FAW in the past as the insect to evolve resistance in the field to Bt corn (Cry1F). That was in the mid-2000s in Puerto Rico. It has also been in the news in the last few years as an invasive pest, spreading from the Americas into tropical areas of Africa and Asia. FAW is a tropical insect. In the Americas, its native range is in South and Central America, Mexico, the Caribbean. Larvae don't diapause, and thus they can't survive freezing temperatures. In the US, moths spend the winter in southern Texas and south Florida, and occasionally into areas along the gulf coast. FAW moves north as temperatures warm. Unlike other moths such as black cutworm or true armyworm, it rarely gets to our region. If FAW does make it the Great Lakes region, it is typically in low numbers as too late in the year to be of concern. Over my career in Michigan, I have only seen it a handful of times, as a few larvae in corn ears. FAW will feed on many hosts, but prefers grasses. There are two strains, recognized genetically and also by differences in host range. The corn strain prefers corn, sorghum and broadleaf crops like cotton. The rice strain prefers rice, turf, pasture grasses and forage crops.

In late summer 2021, headlines read “Worst armyworm outbreak in 30 years” and FAW population “wreaking havoc in Wisconsin crops”. FAW infested and defoliated turf, small grains, alfalfa, clover, mixed hay, and various cover crops. This was clearly the rice strain of FAW.

Why did this happen?

- Favorable conditions (cool temps and rain) for population increase in mid-summer in the southern states; big populations appeared early
- Unusual wind patterns in late July and early August carried moths north into our region
- There were higher than average temperatures in August and well into fall, favorable for a tropical species. Several generations appear to have been completed.
- It was easy to miss feeding by small larvae, and larvae often feed at night.
- Once discovered, management was a challenge. Entomologists did not have a lot of experience with this insect. I personally kept hoping the weather would turn cold! And should sprays be done late in the season?
- Some insecticide applications ‘failed’, likely because larvae were much too large when sprays were made, thus difficult to kill. Also, insects could have been resistant to pyrethroids, since they are exposed to insecticide applications in southern crops.

What about the future? We can make a prediction that as the climate changes, FAW will become more of a problem in our region. Consider trapping for FAW so we know if/when it arrives. Lures and bucket traps are commercially available. The online Great Lakes & Maritimes Pest Monitoring Network is a place to see and contribute trap catches in the region.

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SOYBEAN DEFOLIATION RATINGS MADE EASIER

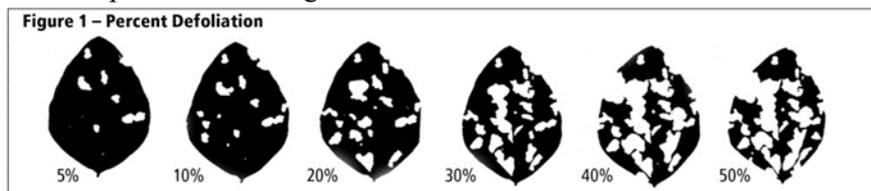
Chris DiFonzo ^{1/}

There are many defoliators in Midwestern soybean. Their feeding gets lumped together when estimating injury to determine the need to treat. Action thresholds in the region are similar among states: 30-40% in the vegetative stage, 15% at bloom, and then 20-30% up to R6 when spraying is not needed. These thresholds are good, developed in field trials in across many states, using both natural and artificial defoliation. The thresholds seem high, but remember the measurement is not of damage to pods or beans, but simply to leaf tissue which has some ability to replace itself. Also, spend some time under a typical soybean canopy - Its shady under there. While the top leaves capture full sunlight, the lower leaves aren't working at full speed. They are extra capacity which can make up for defoliation at the top of the plant where insects like Japanese beetle, bean leaf beetle, and grasshoppers tend to feed.

Significant defoliation of soybean is fairly rare in the Midwest, compared to the southern states where insect pressure is much higher and goes for longer in the season. In fact, for three years the NCSRP, North Central Soybean Promotion Committee, funded a study to measure defoliation levels in typical fields across the Midwest. Dozens of fields were sampled in seven states. This involved walking a grid pattern, stopping at points to sample for insects and estimate % defoliation by eye, then reassessing % defoliation using image software (see below). Only one field was above threshold over the entire study. Most fields were below 5% defoliation. In Michigan, most were below 1%. Lets just say it was a very boring to spend a couple hours grid sampling an entire big field, to find virtually no defoliation. And yet it was important in order to show that this is what is fairly typical beyond the field edge!

Despite this, there is still a trend to add an insecticide in the tank when going across a field with an herbicide or fungicide. But unnecessary sprays kill beneficials insects and flare hard-to-kill secondary pests like spider mite. Insurance sprays also create resistant populations - this has already happened with soybean aphid in some part of the Midwest. And why spend to spray for no good reason? Money is money, and should be in your pocket, not unneeded residue on soybean leaves.

So, entomologist say over and over 'use thresholds to make a spray decision'! Then we give you a set of dramatic pictures of damaged leaflets...

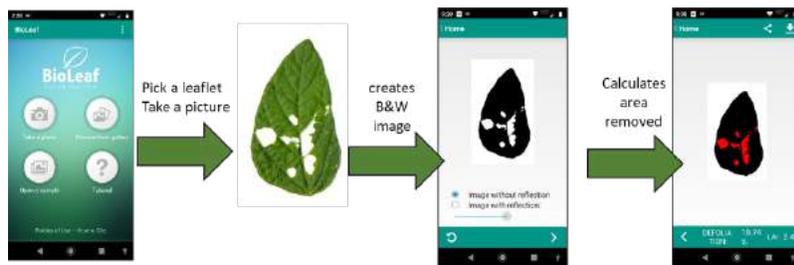


and lure you into thinking that our thresholds are based simply on finding individual leaflets with that level of injury, rather than an estimate of injury for WHOLE-PLANTS across the field. Instead, think

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about exploding a whole-plant out into its components, like the example plant below. This plant was taken from a field edge and has feeding from bean leaf beetles, Japanese beetle and grasshoppers. Defoliation was estimated in several ways:

- (1) The leaflets on the top three leaves were visually rated by volunteer who worked in soybean, and the rating were averaged (simulates using worst-case leaflets to make a decision).
- (2) The same volunteer visually rated all leaflets on the whole plant, and the ratings averaged.
- (3) Same as #2, but the Bioleaf phone app, which uses image software, was used to estimate defoliation of each leaflet:



Let's face it - no one has time for whole plant samples! Whole plant defoliation can be approximated as long as you take a good subsample of leaflets from the plant.

4) A quick subsample method: A top, mid, and bottom leaf were picked from the plant (circled on the example plant). For each leaf, the least- and most-defoliated leaflets (by eye) were thrown out. The remaining three leaflets were rated and averaged.

RESULTS

Average defoliation estimate:

Top leaflets, visual: 34%

Whole plant, visual: 12%

Whole plant, phone app: 7%

Subsample, top, mid, bottom = 10%

The quick subsample method gave a similar estimate as labor-intensive whole plant methods. Its good enough, and can be done fairly rapidly while moving across a field.

When sampling, avoid edge and walk a transect into the field. Sampling 40 plants (top-mid-bottom leaflet) is usually enough to tell the tale. In fact, if you are seeing virtually no defoliation, you can probably stop at fewer plants, as long as you've spaced samples out. At the same time you can check for other insect related things like soybean aphid infestation, spider mite stippling, stink bugs and their egg masses, and natural enemy populations.

In summary: Soybean has a lot of capacity to tolerate defoliation; 99.9% of Midwest soybean fields are below threshold for defoliation; don't estimate defoliation using tops of plant or field edges; use a top-mid-bottom leaflet sample; and improve your ratings by using a phone app.



THE POTENTIAL OF GRASSES – IN WISCONSIN DAIRY FORAGE SYSTEMS

Jason Cavadini ^{1/}

Alfalfa has been a foundational forage crop on Wisconsin dairy farms for decades, and for good reason. It has a reputation for its high quality forage and usefulness in a crop rotation. However, alfalfa has a tough time persisting in the poorly drained soils that characterize some of the state's most dairy-dominant regions, leading to more tillage, expense and frustration for farmers already on tight profit margins. While alfalfa continues to be a great crop for many parts of the state, there are more appropriate options for areas with challenging soil conditions. Before alfalfa became popular, cool season grasses were the foundational forage crop. They are well-suited for Wisconsin, and while grasses are often perceived as being inferior to alfalfa in respect to forage quality due to higher fiber and lower crude protein, that is not necessarily always true. When managed appropriately, grasses have shown the potential to produce high quality forage, but this is not widely known across the industry as many nutritional standards and guidelines have been developed around alfalfa. Furthermore, the economic and environmental tradeoffs of managing grasses for high quality forage versus alfalfa are not well understood. Trials were conducted in 2020 and 2021 at the Marshfield Agricultural Research Station to explore the potential of various perennial and annual cool season grasses when managed for forage quality goals. Several species and varieties of perennial grasses were managed under an intense cutting (5x) schedule to evaluate yield and quality through the season. Italian ryegrass was managed under a similar cutting schedule and 7 different fertilization regimes (sources, rates, application methods) to evaluate yield and quality through the season. Perennial grasses seemed to show greater yield and quality potential than Italian ryegrass with less inputs of fertilizer-nitrogen (N) than Italian ryegrass required. Italian ryegrass yield and crude protein significantly increased as fertilizer-N was increased, but high rates of fertilizer exceed University recommendations, add significant cost of production, and leave a high amount of residual N in the soil as opposed to moderate fertilizer rates and other sources of fertilizer such as manure.

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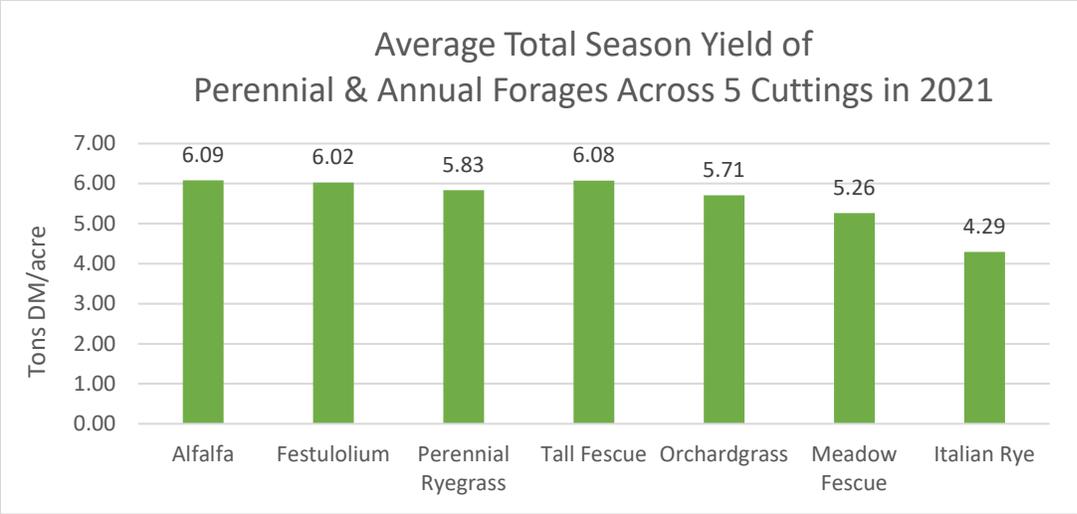


Figure 1. Average total season yield across five cuttings in 2021. Alfalfa and perennial grasses received 40 lbs/acre of nitrogen between each cutting. Italian rye received a spectrum of rates ranging from zero to excessively high, and the average yield from all rates is reported.

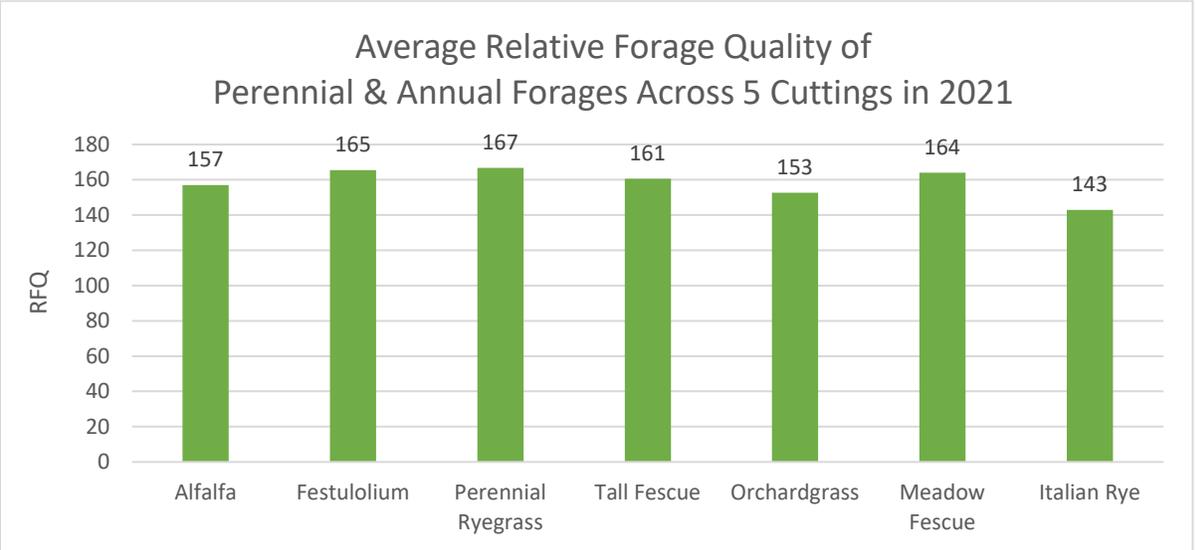
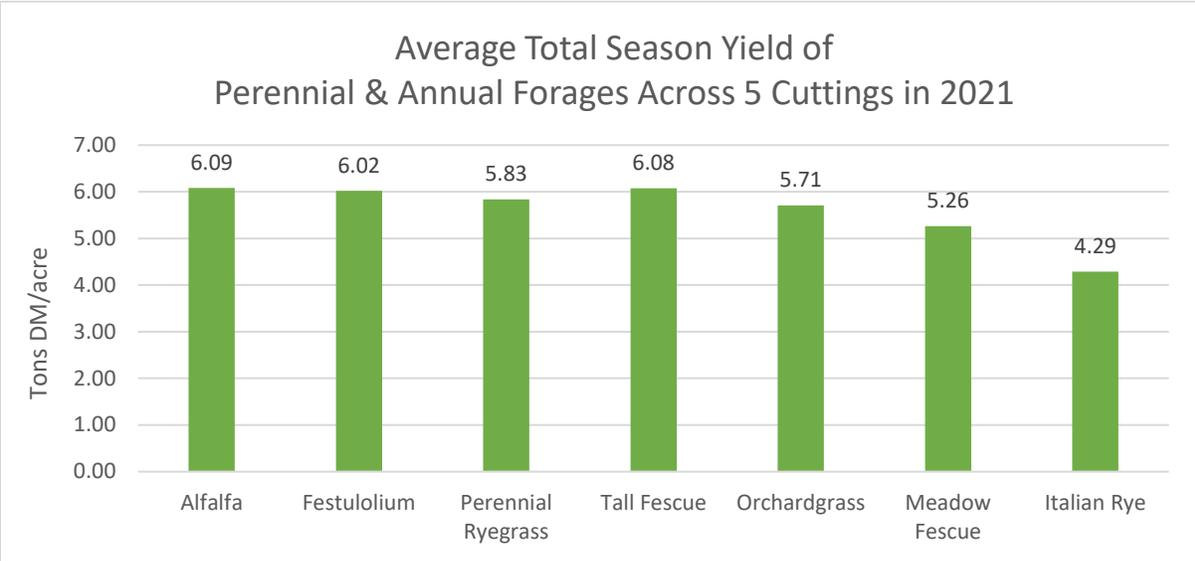


Figure 2. Average relative forage quality across five cuttings in 2021. Alfalfa and perennial grasses received 40 lbs/acre of nitrogen between each cutting. Italian rye received a spectrum of rates ranging from zero to excessively high, and the average relative forage quality from all rates is reported.

PLANTING GREEN FOR WEED CONTROL: DOES IT WORK?

Rodrigo Werle ^{1/}, Jose Junior Nunes, Kolby Grint, Nick Arneson,
Dan Smith, and Ryan DeWerff ^{2/}

Cereal rye (*Secale cereale* L.) has become a popular cover crop (CC) in corn (*Zea mays* L.) and soybean [*Glycine max* (L.) Merr.] production fields across Wisconsin and beyond. With the rise of herbicide-resistant weeds across Wisconsin, there is increased interest in adoption of cereal rye as a cover crop as part of an integrated weed management strategy. Previous research has shown that a cereal rye cover crop can be effective at suppressing small-seeded weeds such as waterhemp [*Amaranthus tuberculatus* (Moq.) Sauer]. The effectiveness of cereal rye in suppressing waterhemp is related to the amount of above-ground biomass produced which competes for resources (e.g., light, water, nutrients) while also providing a physical barrier. Achieving high cereal rye biomass can be challenging in corn-soybean rotations in the upper Midwest given the short window for cover crop growth. Research conducted in 2021 near Brooklyn, Wisconsin estimates that it takes ~7,000 lb of dry cereal rye biomass per acre to suppress waterhemp emergence by 50% however ~800 lb of dry cereal rye biomass per acre was enough to suppress waterhemp growth in 50%. Given the already narrow window which Wisconsin producers face for harvesting crops and planting cover crops, it can be difficult to obtain this level of cereal rye biomass. One strategy to help growers achieve more cereal rye biomass is targeting an earlier planting date of the cereal rye, which is not always an easy task with Wisconsin's usually wet falls. Historically, the recommendation for terminating a cereal rye cover crop is 10 to 14 days before crop planting; however, some producers have started 'planting green' into a living cover crop to maximize its biomass in the spring and weed suppression potential. Over the last three years, the University of Wisconsin-Madison Cropping Systems Weed Science Program has conducted research on the value of fall-seeded cereal rye for weed suppression in corn and soybeans. Recommendations include fall-seeding cereal rye after corn preceding soybeans, pairing the cover crop with PRE-emergence herbicides containing multiple effective sites of action, and delaying termination of the cereal rye until the time of planting or 10 to 14 days after to maximize cereal rye biomass. Results will be summarized in this presentation to provide best management practices when considering adopting cereal rye as an additional tool as part of an integrated weed management strategy.

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HERBICIDE RESISTANCE – WHAT IS GOING ON AROUND WISCONSIN?

Nick Arneson^{1/}, Felipe Faleco, Jose Junior Nunes, David Stoltenberg,
Mark Renz, and Rodrigo Werle^{2/}

Herbicide-resistant weeds have become commonplace across the Wisconsin row-crop landscape in recent years. Waterhemp [*Amaranthus tuberculatus* (Moq.) Sauer] has become one of the primary troublesome weeds for corn (*Zea mays* L.) and soybean [*Glycine max* (L.) Merr.] producers due to its aggressive growth, extended emergence window, and rapid development of herbicide resistance. At current, waterhemp accessions have been determined resistant to ALS- (Group 2; imazethapyr), EPSPS- (Group 9; glyphosate), and PPO- (Group 14; fomesafen & lactofen) inhibitors in Wisconsin. The first comprehensive Wisconsin state-wide assessment of waterhemp response to a diverse group of herbicide site of action (SOA) was conducted by the UW-Madison Cropping Systems Weed Science Program in 2019 & 2020. Results suggest that imazethapyr and glyphosate POST are ineffective for waterhemp control and that atrazine PRE is ineffective for waterhemp control on silty clay loam soils in Wisconsin. Giant ragweed (*Ambrosia trifida* L.) is another troublesome weed for Wisconsin row-crop producers due to its aggressive growth and extended emergence window. Resistance to ALS- and EPSPS-inhibitor herbicides has been previously confirmed in Wisconsin. In 2020, a putative fomesafen-resistant (PPO-inhibitor) giant ragweed accession was detected in in food-grade, non-GMO soybeans in Rock County, Wisconsin and a greenhouse experiment was conducted to confirm resistance. Results indicate that this giant ragweed accession is highly resistant to fomesafen. To our knowledge, this is the first confirmed case globally of PPO-inhibitor resistance in giant ragweed. Fall panicum (*Panicum dichotomiflorum* Michx) is a reemerging troublesome weed in corn production and in 2020, a putative ALS-inhibitor (nicosulfuron) resistant fall panicum accession was detected in a sweet corn field in Dodge County, Wisconsin and greenhouse and molecular experiments were conducted to confirm resistance. This is particularly important as nicosulfuron is commonly used for POST grass control in sweet corn production. Results indicate that this fall panicum accession is highly resistant to nicosulfuron. This is the first confirmed case of ALS-inhibitor resistance in fall panicum in the USA. During this presentation, results will be shared to generate awareness on the current status of herbicide-resistant weeds in the state of Wisconsin and to promote best management practices for managing herbicide-resistance in producers' fields.

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USING ON-FARM TRIALS TO EVALUATE WISCONSIN'S CORN NITROGEN RATE SELECTION TOOLS ^{1/}

Carrie A.M. Laboski ^{2/}, Jerry Clark ^{3/}, Carl Duley ^{3/}, Bill Halfman ^{4/}, Phil Holman ^{5/},
Dan Marzu ^{6/}, Steve Okonek ^{7/}, Jamie Patton ^{4/}, Scott Reuss ^{3/}, Kevin Schoessow ^{3/},
Ken Schroeder ^{4/}, and Dan Smith ^{4/}

Corn growers continually face many production challenges including low grain prices, high input prices and regulatory pressure to minimize nutrient losses to the environment. Nitrogen management figures prominently into these challenges with questions surrounding selection of N fertilizer rate. The objective of this study was to evaluate the profitability and efficiency of N rate selection tools currently used in Wisconsin.

From 2018 through 2021, 52 corn yield response to sidedress N fertilization trials were conducted on private farms and university research stations (37 and 15 locations, respectively). Plots were established within 3 days of planting and soil samples (0 to 6, 0 to 12, 12 to 24, and 24 to 36 inches) collected from the no N treatment. Routine analysis (P, K, pH, and organic matter) was completed on the 0- to 6-inch samples; all other samples were analyzed for nitrate. At approximately the V6 growth stage, samples were collected in the no N treatment plots to a 12-inch depth and analyzed for nitrate (presidedress nitrate test). Sidedress N fertilizer (urea with a urease inhibitor) was broadcast at rates of 0 to 200 or 240 lb N/acre in 40 lb N/acre increments. Each treatment was replicated four times. Grain yield was measured.

At each site, a model was fit to the grain yield response to N fertilization data. Using the model, the economic optimum N rate (EONR, 0.10 N:corn price ratio) for each site was calculated along with the range of N rates that produced profitability within \$1.00 per acre. The profitable range of N rates for each site was compared to maximum return to N (MRTN) recommended range of profitable N rates that would be applicable for each site (Fig. 1). The MRTN rate was adjusted for forage legume, manure, or PSNT credits if applicable to the site using guidance in UWEX publication A2809 *Nutrient application guidelines for field, vegetable, and fruit crops in Wisconsin*.

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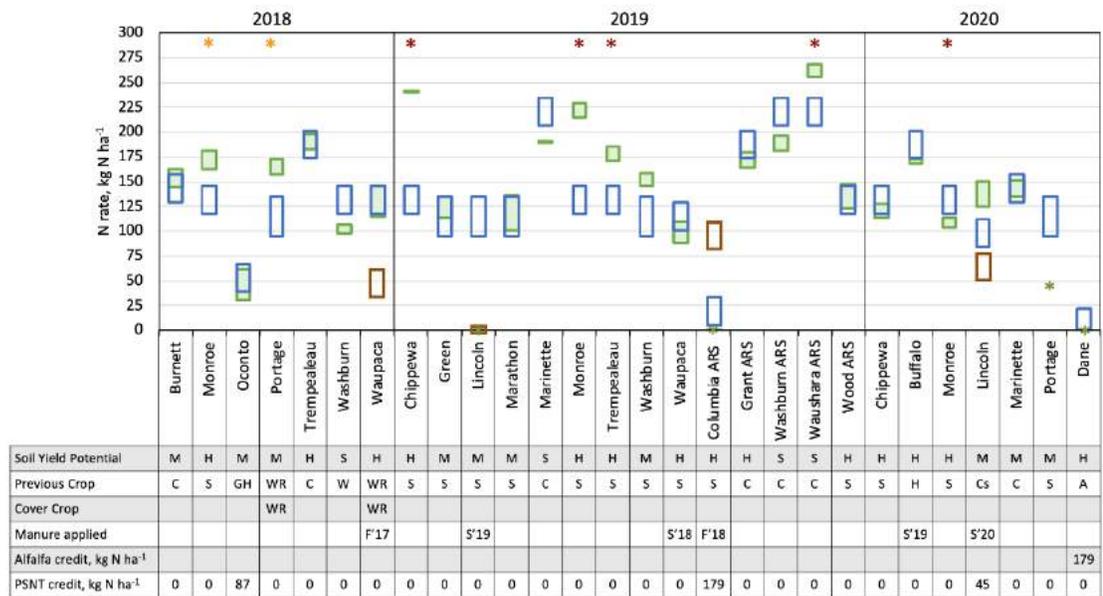
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Preliminary analysis of the data at 28 sites demonstrates that the N recommendation tool predicted the EONR at 50% of the sites. At eight sites, the MRTN underpredicted N need. High rainfall events at six of these sites likely resulted in nitrate leaching. At six other sites, MRTN overpredicted N need. There were two sites that had no first-year manure applied but had second and/or third year manure N credits. At these sites, book value estimates of second and/or third year manure N credits adjusted the MRTN recommended rate well (Waupaca 2019 and Buffalo 2020). At four sites where manure was applied for the current crop year, manure credits were more accurate than the PSNT in adjusting MRTN in Lincoln Co. in 2019 but was less accurate at three sites, under recommending N in Waupaca Co. in 2019 and Lincoln Co. in 2020 and over recommending N in Columbia Co. (ARS).

Additional data analysis will be completed and presented.



- Range of N rates that produce profitability within \$2.47 ha⁻¹ of site EONR using \$0.88 kg⁻² N and \$157 Mg⁻² grain calculated from model fit of yield response to N.
- ▭ Recommendation using MRTN profitable range minus PSNT N credits. PSNT credit is not used for prior crop of soybean. If manure was applied within 8 months of planting, then PSNT credit was used regardless of previous crop. If manure was applied > 8 months of planting, then 2nd & 3rd year manure N availability credits were used.
- ▭ MRTN range minus manure credits
- * EONR, with profitability range of 0 kg N ha⁻¹
- * High rainfall following sidedress N application, leaching likely
- * High early season rainfall

Soil yield potential:
 H = high; not limited by soil properties
 M = medium; limited by 1) excessive/somewhat excessive/poor/very poor drainage, 2) <15 cm available water in upper 150 cm of soil, and/or 3) <76 cm to bedrock
 S = sand; sand or loamy sand texture

Crop:
 A = Alfalfa; C = Corn; Cs = Corn silage; GH = Grass hay; H = Hemp; WR = winter rye

Figure 1. Comparison of the range of N rates which produced profitability within \$1.00/acre (\$2.47/ha) of the site EONR with the recommended MRTN and/or N credit adjusted MRTN rate.

PHOSPHORUS SOIL TESTS FOR NUTRIENT RECOMMENDATIONS: COMPARISONS OF ROUTINE AND SOIL HEALTH TESTING METHODS

John D. Jones ^{1/}

Soil phosphorus (P) tests used for crop nutrient recommendations should be correlated to crop yield response and calibrated to identify interpretation classes of responsiveness. Common soil P tests recommended for the U.S. north-central region have been correlated to crop yield response, and include the Bray-1, Mehlich-3, and Olsen tests. Which test is used more predominately in a state is a function of the recommendation systems in place, chemical reactions between soil constituents and the extracting solutions, and its overall intended use. Also important is the ability to use a test to extract and measure additional elements, which is the case for the Mehlich-3 test in Iowa or Bray-1 test in Wisconsin.

Interest in soil analyses that inform on the soil health status of agricultural soils has led to adoptions of soil P tests other than the routine Bray-1, Mehlich-3, and Olsen in the north-central region – most that are components of larger suites of assessment tools. A widely used suite, the Haney Soil Health Assessment, is used by farmers and agronomists to inform management decisions, and offered by private and public soil testing laboratories. While widely in use, the extracting solution used in the assessment, H3A, has not been correlated to crop yield response to P fertilization to determine how extracted-P evaluates bioavailable P. The general consensus within the scientific soil testing community is that correlations between amounts of nutrient extracted can result in inappropriate interpretations for a new soil P test, and that correlations with crop yield response to P fertilization are essential.

A field correlation study composed of single- or multi-year trials at 19 locations in Iowa investigated how the H3A test compares to routinely used Bray-1, Mehlich-3, and Olsen tests amount of P extracted and relationship with crop yield. The trials encompassed ten soil series with loam to silty clay loam texture, soil pH (0- to 6-inch depth) ranging from acidic to slightly calcareous (pH 7.3 or lower), that were managed with no-till or chisel-plow/ disk tillage. Several P fertilizer rates (0 to 112 lb P₂O₅/acre) replicated three to four times. Soil samples were taken each year from 0- to 6-inch depth before planting the crops and applying the P fertilizer. Relative grain yield response was calculated for each site-year by expressing the mean yield (across replication) without P fertilization as the percentage of the mean yield of P treatments that produced by the statistically maximum yield (the mean of all treatments, including the control, was used as maximum yield when there was no yield response).

The soil P concentration measured by the Bray-1 and Mehlich-3 tests were approximately similar and the correlation between them was the highest observed, which was expected because no highly calcareous soils were included in the study. The Olsen P

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concentrations were approximately one-half the concentrations measured by the Bray-1 and Mehlich-3 tests, and the correlations with these two tests also were high and only slightly lower, which also was expected since no highly calcareous soils were included in the relationships. The correlations involving the H3A test were the highest with the Olsen test, and were only slightly lower with the Bray-1 and Mehlich-3 tests. Critical STP concentration for each STP method ranges were defined by fitting LP and QP models (join point) and EXP models (95 and 99% sufficiency levels) between STP values and relative yield for each crop, and across crops. Relationships between the H3A test and crop relative yield indicated a slightly poorer capacity to predict yield response to STP level when compared to established routine tests, but the CC range identified can be used to provide interpretations pertaining to P sufficiency for corn and soybean in areas with similar soils. To be useful for management decisions, a soil test should then identify the degree of P deficiency or sufficiency, and direct the necessary added P to optimize crop yield. Recently adopted soil health tests that will be used to measure P need further investigation if they are to be used to make fertilizer rate decisions.

NITROGEN USE EFFICIENCY TRENDS IN WISCONSIN

Matt Ruark ^{1/}

Nitrogen use efficiency assessment in Wisconsin is an ongoing project. Please check out the following Discovery Farms publications:

Nitrogen Use Efficiency: Statewide NUE benchmarking for corn grain and silage
<https://uwdiscoveryfarms.org/wp-content/uploads/sites/1255/2020/08/DiscoveryFarms-NUE-ForOnline.pdf>

Nitrogen Use Efficiency: A guide to conducting your own assessment
<https://uwdiscoveryfarms.org/wp-content/uploads/sites/1255/2020/07/NUE-A-guide-to-conducting-your-own-assessment.pdf>

Project results will be continually updated on the Discovery Farms website (uwdiscoveryfarms.org).

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TAR SPOT OF CORN: BIOLOGY AND DISTRIBUTION

Darcy Telenko ^{1/}

Tar spot of corn, caused by *Phyllachora maydis*, is a newly established and emerging disease in the United States. Since 2018, it has had significant yield impacts on corn production in northern Indiana and regions around Lake Michigan, causing an estimated 20 to 60 bu/acre yield loss. Tar spot has also continued to spread as it has now been confirmed in 14 states and Canada. The tar spot fungus can overwinter in the upper Midwest resulting in high inoculum levels that are able to cause disease in future seasons when favorable environmental conditions occur. In 2021, significant losses expanded beyond northern Indiana to pockets in the southern part of the state. A summary of our experiences in Indiana on the distribution and spread of tar spot will be presented, as we continue to improve our understanding of this disease.

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MANAGING WHITE MOLD WITH A STRATEGIC PLAN

R.W. Webster¹, B. Mueller², D.S. Mueller³, M.I. Chilvers⁴, S. Conley⁵, and D.L. Smith⁶

Introduction

Sclerotinia stem rot (a.k.a. white mold) is a disease of soybean (*Glycine max*) caused by the fungal pathogen, *Sclerotinia sclerotiorum* (Roth et al., 2020). In highly conducive years, white mold can cause soybean yield losses of up to 61 million bushels in a single season (Bradley et al., 2021). *Sclerotinia sclerotiorum* most successfully initiates infections in soybean during flowering periods by releasing puffs of ascospores into the canopy of the crop. These ascospores then germinate and grow on senescing plant tissues such as flowers, leading to infection and colonization of soybean vascular parts. Upon full constriction of the soybean stem by *S. sclerotiorum*, the infected soybean plants begin to prematurely wilt and die, resulting in reduced seed fill and subsequent yield losses. While yield losses due to white mold can be substantial, a disease severity index (DIX) rating of 40% is needed for significant losses, with severe losses only being found at a DIX of 68% (Willbur et al., 2019). In order to prevent the development of white mold and the resulting yield losses, management practices for controlling this disease have been the focus of many independent research efforts.

Many tools for controlling white mold have been found to be highly effective at reducing disease levels and yield losses, such as the use of certain cultural practices (row spacing and seeding rates), fungicides, risk prediction tools, and genetic resistance. The use of a wider row spacing (30 inches) has been shown to reduce white mold levels compared to more narrow row spacing (15 inches; Grau and Radke, 1984). Seeding rates were also shown to impact white mold development with high seeding rates resulting in higher white mold levels compared to lower seeding rates (Lee et al., 2005, Carpenter et al., 2020). Fungicide use is also an effective method for controlling white mold development, with applications between the R1 and R3 growth stages (when flowers are present) being the most efficacious (Willbur et al., 2019). Additionally, risk prediction models have been developed to determine the risk level of ascospore presence in the soybean canopy (Willbur et al., 2018a, 2018b). These models were incorporated into a smartphone tool, Sporecaster©, which is available on both Apple and Android smartphones. This tool allows producers to better predict when the soybean crop will be at greatest risk of disease development and allow for a more informed decision on timing of fungicide applications. Lastly, genetic resistance is an effective tool for reducing the development of white mold without the need for additional inputs. While no complete resistance is present in any cultivars, there are many known cultivars with moderate to high levels of partial resistance to white mold (McCaghey et al., 2017, Webster et al., 2021).

Despite a multitude of previous work being done on each of these control practices independently, the integration of these methods has been understudied. First a study was performed examining the integration of multiple cultural practices and fungicide use. This study was performed over multiple site-years across the Upper Midwest to examine the effect of this integration on white mold DIX, yield, and partial profits. A second study was also performed examining the integration of soybean genetic resistance and risk prediction models for recommending fungicide application timing. This study examined the interaction effects on white mold DIX, yield, the accuracy of the risk prediction models for predicting the development of white mold. Through both of these studies, the relationship of these multiple management practices and their effects on white mold in soybean can be better understood.

Materials and Methods

From 2017-2019, 18 independent field trials were performed across the Upper Midwest which together were collectively called the integrated management study (Webster et al., 2022). This study examined the combination of row spacing (15 or 30 inches), seeding rates (110,000, 140,000, 170,000, or 200,000 seeds/ac), and fungicide programs (a growth stage dependent application program, a risk prediction model-based application program, or a non-treated control). The growth stage dependent fungicide program was applied at both the R1 and R3 growth stages. The model-based program was applied following the recommendations by the Sporecaster tool based on the specific location. If an application was made, that same location was reassessed 14 days later to determine if a second application was recommended. All applications were made with picoxystrobin (Approach®; Corteva Agriscience) at a rate of 9 fl oz/acre. Across all 18 site-years in this study, the effects of the combination of management practices were determined for both DIX and yield. Further, the predicted development of sclerotia, the inoculum source, was determined as every 10% of white mold disease incidence results in the production of 0.9 lbs of sclerotia (Lehner et al., 2017). A partial economic analysis was also performed to determine the most economically profitable management practices from these trials. For this analysis, three distinct grain sale prices were used (\$9, \$12, \$15 per bushel) to calculate partial profits. Locations were sub-grouped depending on the development of white mold in each respective site-year.

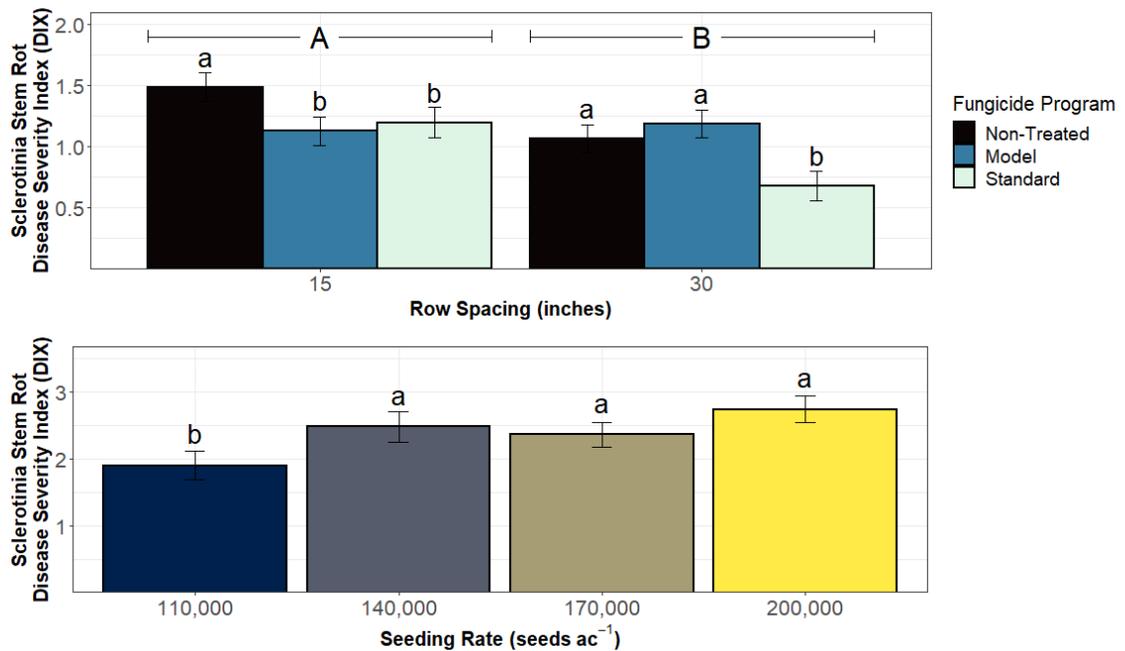
A separate set of trials had been performed during 2020 and 2021 examining the integration of soybean resistance levels into the Sporecaster tool. By incorporating these resistance levels into the already developed Sporecaster risk prediction model, error associated with difference between genetic resistance levels could be more accurately accounted for. Therefore, it was hypothesized that adjusting the action threshold (spray threshold) in Sporecaster dependent on soybean resistance level may improve accuracy of the spray prediction. For example, if a producer had planted a susceptible variety, then the threshold would need to be lowered relative to the standard action threshold, and if a highly resistant variety were planted then the action threshold could be set at a higher level relative to standard.

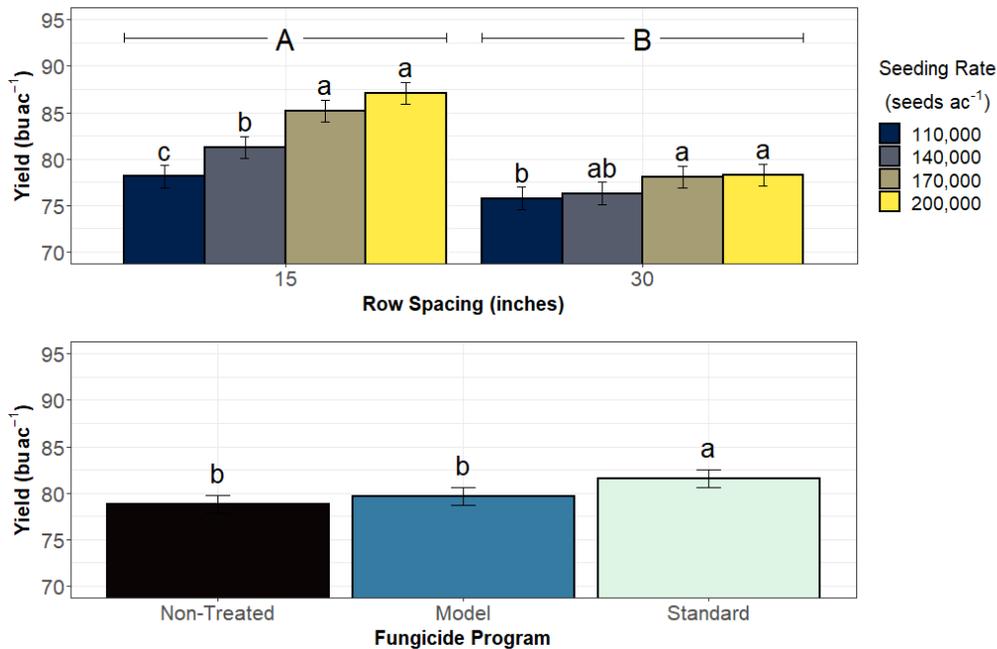
Four soybean genotypes with varying levels of resistance had previously been identified that displayed a consistent response to *S. sclerotiorum* infections (Webster et al., 2021). The lines included a public cultivar, Dwight (susceptible; MG 2.9), and three genotypes from previous breeding efforts, 51-23 (moderately resistant; MG 2.3), SSR51-70 (moderately resistant; MG 2.0), and 52-82B (resistant; MG 2.8). These four lines were grown in combination with four fungicide programs or a non-treated control. These fungicide programs included a standard phenology-based application between the R2-R3 growth stages, and three distinct application programs based on Sporecaster risk action threshold levels. These threshold programs included a low action threshold (5% for irrigated conditions and 10% for non-irrigated conditions), medium action threshold (10% for irrigated and 40% for non-irrigated), or a high action threshold (20% for irrigated and 75% for non-irrigated). All fungicide applications were made with boscalid (Endura®; BASF) at 8 oz/a. Across all five site-years in these experiments, both DIX and yield were recorded. Additionally, the accuracy of the Sporecaster models were assessed for each combination of the soybean genotype and threshold level.

Results

In the integrated management study, it was found that wide row spacings (30 inches) decreased white mold DIX ($P < 0.01$) compared to a narrow row spacing (15 inches; Fig. 1A). DIX was reduced

even further in the wide row spacing when coupled with the standard fungicide application (Fig. 1A). Additionally, seeding rates were also found to impact white mold DIX ($P = 0.002$) with a seeding rate of 110,000 seeds/ac resulting in the lowest DIX, and the three higher seeding rates all resulting in higher DIX levels (Fig. 1B). Row spacing was shown to have a significant effect on yield with the narrow row spacing resulting in higher yields overall ($P < 0.001$; Fig. 2A). Further, a significant interaction was observed between row spacing and seeding rate ($P < 0.001$). In the narrow row spacing, yields were greatest at or above 170,000 seeds/ac, and in the wide row spacing, yields were similar across all seeding rates, with the exception of the 110,000 seeds/ac resulting in the lowest yield (Fig. 2A). Yield was also affected by fungicide use ($P < 0.001$) where the standard application program yielded the highest, but the model program and the non-treated control yielded less (Fig. 2B).





Additionally, the return of inoculum (sclerotia) was predicted for both seeding rate and fungicide programs. When examining seeding rates, the three highest seeding rates examined all were predicted to yield similar levels of returned sclerotia with 200,000 seeds/ac resulting in the highest quantity of 0.33 lbs/ac (Table 1). The lowest seeding rate resulted in the lowest levels of returned sclerotia at about 0.07 lbs/ac (Table 1). Fungicides also had an effect on the levels of returned sclerotia in which the standard application program resulted in the lowest quantity of sclerotia and the non-treated resulted in the highest quantity of sclerotia (Table 2).

A partial economic analysis was also performed for both seeding rate and fungicide programs. In site-years where white mold was absent, a seeding rate of 110,000 seeds/ac resulted in the lowest economic return and a seeding rate of 200,000 seeds/ac had the highest economic returns across all three grain sale prices (Table 1). Yet, when white mold was present, a rate of 200,000 seeds/ac had the lowest economic returns, and a seeding rate of 170,000 seeds/ac had the highest economic return (Table 1). The use of fungicides resulted in similar partial profits for all treatments at the highest grain sale price regardless of the presence or absence of white mold (Table 2). However, in the site-years where white mold did not develop, fungicide applications reduced the partial profits for both grain sale prices of \$9/bu and \$12/bu (Table 2). When white mold did develop, partial profits at \$9/bu were reduced due to fungicide use, but at \$12/bu, partial profits for all treatments were similar (Table 2).

Table 1. Effect of soybean seeding rates on partial profits and estimated *Sclerotinia sclerotiorum* inoculum returned to soil when *Sclerotinia* stem rot (white mold) was either absent or present.

Disease Presence	Seeding rate (seeds ac ⁻¹)	Partial Profit (\$ ac ⁻¹)			Sclerotia Produced (lb ac ⁻¹)
		\$9 bu ⁻¹	\$12 bu ⁻¹	\$15 bu ⁻¹	
No	110,000	509.1 b	702.8 c	896.5 c	-
	140,000	524.9 a	728.3 b	931.8 b	-
	170,000	528.7 a	738.0 ab	947.2 ab	-
	200,000	538.2 a	755.1 a	972.0 a	-
Yes	110,000	492.4 bc	680.4 b	868.5 c	0.07 b
	140,000	503.3 ab	699.4 a	895.5 ab	0.18 ab
	170,000	507.9 a	710.0 a	912.1 a	0.26 a
	200,000	482.9 c	681.1 b	879.4 bc	0.33 a

Table 2. Effects of fungicide programs on partial profits and estimated *Sclerotinia sclerotiorum* inoculum returned to soil when *Sclerotinia* stem rot (white mold) was either absent or present.

Disease Presence	Fungicide Program	Partial Profit (\$ ac ⁻¹)			Sclerotia Produced (lb ac ⁻¹)
		\$9 bu ⁻¹	\$12 bu ⁻¹	\$15 bu ⁻¹	
No	Standard	508.5 c	716.1 b	923.8 a	-
	Model	526.6 b	732.5 ab	938.5 a	-
	Non-Treated	540.9 a	743.9 a	946.9 a	-
Yes	Standard	492.2 b	694.5 a	896.9 a	0.10 b
	Model	491.6 b	686.1 a	880.5 a	0.23 ab
	Non-Treated	506.0 a	697.5 a	889.1 a	0.30 a

In the second study, four soybean genotypes with a range of resistance levels to white mold were tested in combination with fungicide programs following different action thresholds from the Sporecaster tool. Across five site-years, DIX was influenced by both soybean genotype ($P < 0.001$) and fungicide program ($P = 0.01$). Confirming the results from Webster et al. (2021), the public cultivar (Dwight) was the most susceptible while the other three soybean breeding lines (51-23, SSR51-70, and 52-82B) all had higher levels of resistance (Fig. 3). No significant interaction between soybean genotype and fungicide program for DIX was observed ($P = 0.38$). However, when Dwight

was coupled with the low and medium threshold treatments, DIX was reduced to levels similar to the standard treatment, and the high threshold had drastically higher levels of DIX similar to the non-treated control. All fungicide treatments resulted in similar DIX levels as their respective non-treated controls in the other three soybean lines. Soybean genotype also influenced yield ($P < 0.001$) with both Dwight and 52-82B yielding the highest and 51-23 and SSR51-70 yielding less (Fig. 4).

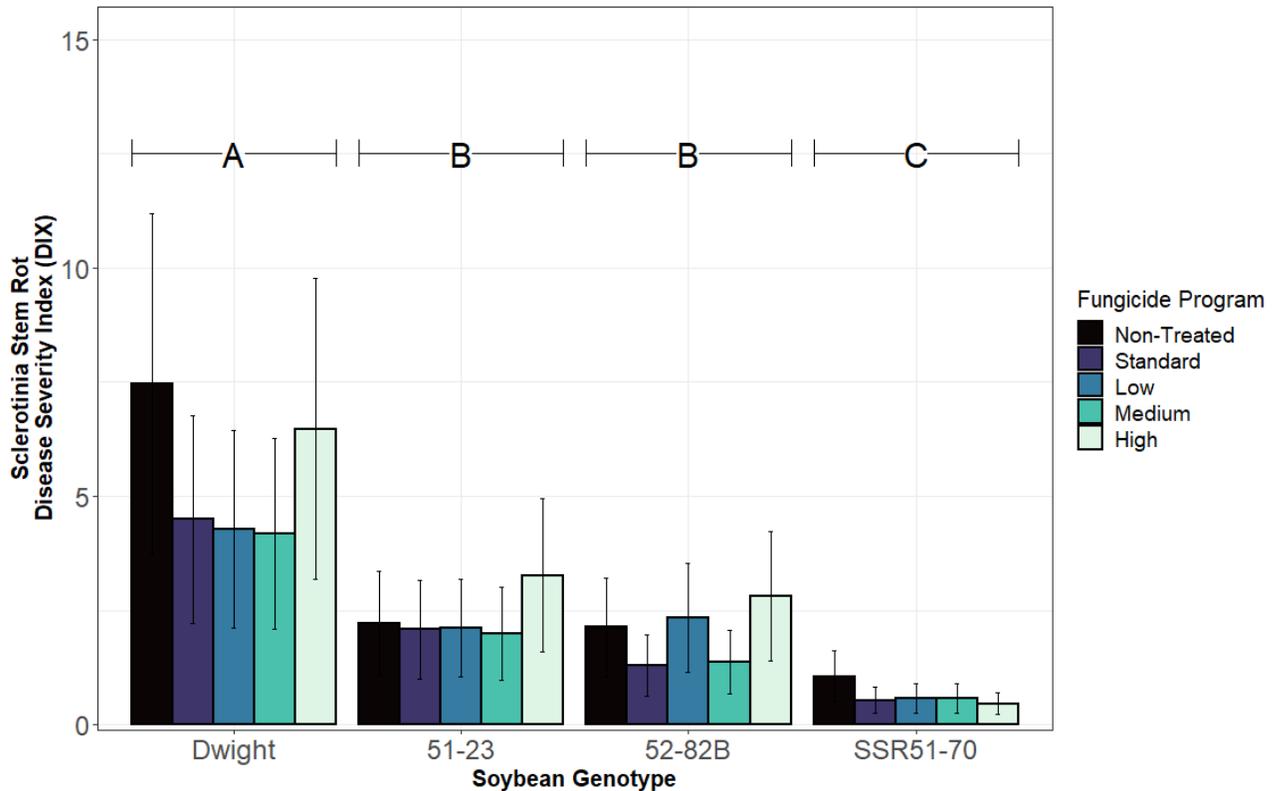


Figure 3. Effects of fungicide treatments on white mold disease severity index (DIX) when tested on four soybean genotypes across Wisconsin between 2020 and 2021 (N=5). Trials examined the use of three action thresholds (low, medium, and high) for applications of fungicide treatments based on apothecial risk prediction models, in addition to a standard application of fungicide at the R2 growth stage and a non-treated control. The low action threshold was set at a risk level of 20% in non-irrigated conditions or 5% in irrigated conditions. The medium action threshold was set at a risk level of 40% in non-irrigated conditions or 10% in irrigated conditions. The high action threshold was set at a risk level of 75% in non-irrigated conditions or 20% in irrigated conditions. All fungicide applications were made with boscalid at 8 oz/acre. Soybean genotypes sharing similar letters do not statistically differ as determined by Fisher’s least significant difference ($\alpha = 0.05$).

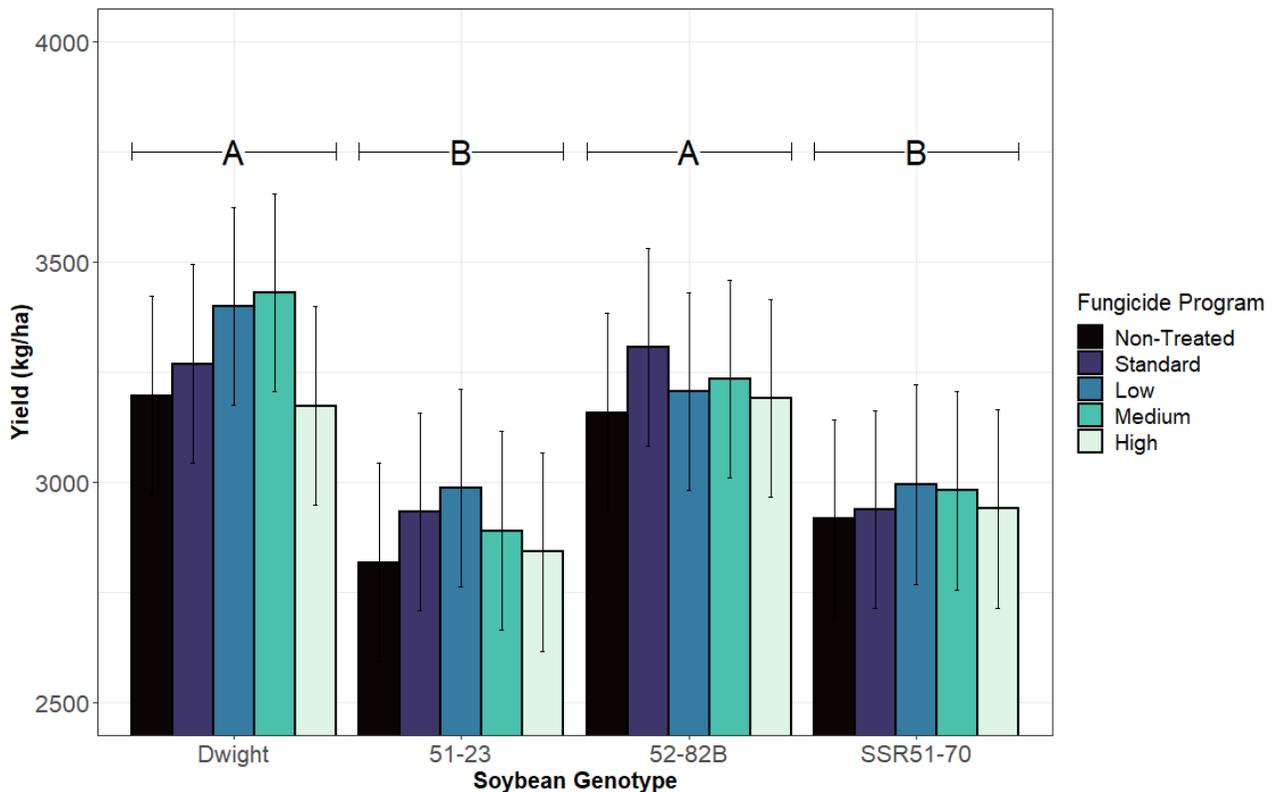


Figure 4. Effects of fungicide treatments on yield when tested on four soybean genotypes across Wisconsin between 2020 and 2021 (N=5). Trials examined the use of three action thresholds (low, medium, and high) for applications of fungicide treatments based on apothecial risk prediction models, in addition to a standard application of fungicide at the R2 growth stage and a non-treated control. The low action threshold was set at a risk level of 20% in non-irrigated conditions or 5% in irrigated conditions. The medium action threshold was set at a risk level of 40% in non-irrigated conditions or 10% in irrigated conditions. The high action threshold was set at a risk level of 75% in non-irrigated conditions or 20% in irrigated conditions. All fungicide applications were made with boscalid at 8 oz/acre. Soybean genotypes sharing similar letters do not statistically differ as determined by Fisher’s least significant difference ($\alpha = 0.05$).

The Sporecaster models were assessed for accuracy in predicting white mold for each genotype at all three of the action thresholds examined in this study. This work showed the development of white mold in Dwight was most accurate when using the low or medium thresholds in both the irrigated and non-irrigated models (Table 3). Conversely, the other three soybean genotypes all showed the highest success at the high thresholds in the non-irrigated models (Table 3). In the irrigated models, the success across these three genotypes was not as consistent.

Table 3. Accuracy (%) of apothecial risk model action thresholds predicting disease incidence of 10% for Sclerotinia stem rot from non-treated plots for four soybean genotype across environments in 2016, 2020, and 2021 (N=6).

Genotype	Model ^a	Low Threshold ^b	Medium Threshold ^c	High Threshold ^d
Dwight	Non-Irrigated Model	67	67	33
	Irrigated Model	67	67	0
51-23	Non-Irrigated Model	33	33	67
	Irrigated Model	33	33	33
52-82B	Non-Irrigated Model	33	33	67
	Irrigated Model	33	33	33
SSR51-70	Non-Irrigated Model	0	0	100
	Irrigated Model	0	0	67

^a Apothecial risk prediction models developed by Willbur et al. (2018a, 2018b). Distinct models were developed for either non-irrigated or irrigated conditions.

^b Low action threshold was set at a risk level of 20% in non-irrigated conditions or 5% in irrigated conditions.

^c Medium action threshold was set at a risk level of 40% in non-irrigated conditions or 10% in irrigated conditions.

^d High action threshold was set at a risk level of 75% in non-irrigated conditions or 20% in irrigated conditions.

Recommendations

1. If planting 15-inch rows into fields with a history of white mold, drop seeding rate to 110,000 seeds/ac.
2. If planting into fields with a history of severe white mold, widen rows to 30 inches and drop seeding rate to 110,000 seeds/ac
3. Fungicide applications are an effective tool for reducing white mold levels if applied between the R1 and R3 growth stages
4. If planting a susceptible cultivar, reduce the Sporecaster action threshold to between 20 and 30%
5. If planting a resistant cultivar, increase the Sporecaster action threshold to above 40%

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TAR SPOT OF CORN: MANAGEMENT OPTIONS ONCE DETECTED ON YOUR FARM

Darcy Telenko ^{1/}

Tar spot of corn, caused by *Phyllachora maydis*, has become a major disease issue in corn production in northern Indiana. The annual impact of this emerging disease will be a function of the weather, hybrid and when the disease epidemic initiates, earlier vs. later in the season. Our research has found that some hybrids are more resistant than others, but strong hybrid resistance can be overcome by a favorable disease environment. Fungicide application can reduce tar spot severity, but product and timing are important. Fungicide application needs to occur close to the onset of the epidemic and the number of applications and optimal timing are going to vary year by year. In 2019 and 2020 in uniform fungicide trials, fungicides significantly reduced tar spot and protected yield by 1.5 to 7.9% over the non-treated controls. Products that had two or three modes of action (MOAs) decreased tar spot severity over not treating and products with one MOA. Three MOAs significantly increased yield over not treating with a fungicide or using a single MOA group. A summary of our research in Indiana will be presented as we continue to improve our understanding of tar spot disease management options to mitigate yield loss.

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WHERE'S DON? WHAT WE KNOW ABOUT DEOXYNIVALENOL ACCUMULATION IN CORN

Damon Smith^{1/} and Maxwell Chibuogwu^{2/}

Corn for silage is an important component of a dairy cow's diet. This staple can be responsible for more than 50% of the total dry-matter intake for the cow, especially in the winter. To produce high-quality silage the use of brown mid-rib hybrids (BMR) has become common. These hybrids have lower indigestible lignin and can produce a higher-quality feed than their counterparts. However, with low lignin comes the tradeoff in low disease resistance. *Gibberella* ear rot and stalk rot have become diseases of concern in silage corn production in the northern corn production belt of the United States. *Gibberella* diseases not only damage the plant and can reduce yield and quality but can also lead to the accumulation of the mycotoxin deoxynivalenol (DON). To manage these diseases and reduce DON on susceptible corn hybrids, farmers are becoming increasingly reliant on foliar fungicide applications. Research has indicated that foliar fungicide applications can lead to mixed success in managing *Gibberella* ear rot and stalk rot. Research has also demonstrated that DON can accumulate in the stalk and ear portions of the plant independently. Weather from one year to the next may play a role in the type of disease (ear rot or stalk rot) and where DON accumulates. The location of infection by the *Gibberella* fungus and accumulation of DON likely influences the success in using fungicide to reduce DON levels in finished feed. This presentation will discuss what we know about DON accumulation in corn plant parts. We will also discuss current knowledge on managing DON accumulation using fungicide. Other aspects of *Gibberella* infection and effects on silage feed will also be discussed.

Reference

Webster, R.W., Chibuogwu, M.O., Reed, H., Mueller, B., Groves, C.L., Tenuta, A.U., Chilvers, M.I., Wise, K.A., and Smith, D.L. 2021. Disease development and deoxynivalenol accumulation in silage corn. Crop Protection Network. CPN 5008. <https://doi.org/10.31274/CPN-20211130-000>.

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IS HYBRID RYE A VIABLE CROP FOR WISCONSIN FARMERS?

Haleigh Ortmeier-Clarke ^{1/}

Cropping system diversity is an important aspect of agricultural sustainability. This is especially true in Wisconsin dairy systems where farmers seek forage and grain options that can potentially minimize nutrient loss and erosion over winter months and provide land for summer manure applications. Hybrid rye is a relatively new alternative crop option; however, we lack basic agronomic recommendations for our farmers. Two studies were conducted in Wisconsin to evaluate the nitrogen needs of hybrid rye. Studies were a split-plot design with four replications. Two varieties (KWS Propower and KWS Serafino) were fertilized at four fall (0, 17, 34, 50 kg N ha⁻¹) and six spring (0, 34, 67, 101, 135, 168kg N ha⁻¹) nitrogen rates. Trials were established in September 2020. One study evaluated nitrogen needs for forage production and the other for grain production. The forage trial was harvested at Feekes 10.1 in May 2021 and the grain trial at Feekes 11.4 in July 2021. The ‘lmer’ package in R was used for linear regression. Both fall and spring nitrogen had a significant impact on forage yield, with yields increasing as nitrogen rates increase. Results of grain yields were similar, although there was a stronger yield response to spring nitrogen application in treatments receiving no fall nitrogen. When compared to other forage and grain crops in Wisconsin, hybrid rye yields were comparable or better. Data on forage and grain yield and quality will be presented. These trials will be repeated at two locations in 2022 and data will be used to create preliminary nitrogen management guidelines for hybrid rye.

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SO YOUR SYSTEM HAS BEEN BREACHED – NOW WHAT DO WE DO?

Jen Pino-Gallagher and Emily Selck ^{1/}

Ransomware attacks continue to affect the food and agribusiness sector, with many instances hitting very close to home here in Wisconsin. It's imperative that agribusinesses understand the implications of lax cybersecurity, how to protect your operations from a breach, and, finally, what to do if your systems are attacked by cybercriminals.

The first goal of every organization when it comes to cybersecurity is to harden their defenses and make it as difficult as possible for hackers to breach the system.

Some of the key steps to shoring up your company's cyber defenses include:

Develop a robust training program.

Employees are often the weakest link in any cybersecurity program, and email is one of the most vulnerable access points for an organization. To minimize the risk to your operation, help employees spot malicious emails by creating a robust training program for every single employee who uses email.

Some basic advice from the FBI that can be reinforced through an employee training program include:

- Carefully examine the email address, URL, and spelling used in any correspondence. Scammers use slight differences to trick your eye and gain your trust.
- Be careful what you download. Never open an email attachment from someone you don't know and be wary of email attachments forwarded to you.

Your training program should also include tips on developing strong passwords that are complex and not duplicates of passwords used elsewhere.

Install Multifactor Authentication

According to a Microsoft study, installing multifactor authentication can block over 99.9 percent of account compromise attacks.

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Multifactor Authentication (MFA) is a means of providing access with two pieces of evidence to confirm your identity. This can come in a few different forms – something you know, something you have, or something you are. Presenting a debit card and PIN at the ATM is one example. This security measure goes beyond strong passwords and affords those who are logging in additional protection of their data or financial assets.

Create an Incident Response Plan

Creating an incident response plan is another critical piece of this puzzle. Many companies are familiar with the process of a plan for disaster recovery. Be it a flood, windstorm, or active shooter, companies want to be sure they are prepared for everything. When it comes to incident response (IR) planning for cyber threats, companies may be less sure. Critical components of an incident response plan include:

- Identify who needs to know if there is a suspected incident
- Have multiple forms of communication available to your teams
- Be prepared with an internal communication plan
- Identify the different protocols for ransomware, business email compromise, and social engineering
- Understand how to report a claim to your insurance

In addition to creating an incident response plan with your insurance advisor, there are basic immediate steps that a food and agribusiness organization should take to manage a cybersecurity incident:

- Do not restore data until images can be collected by the digital forensics team
- Do a global password reset
- Disconnect from back-ups
- Disconnect from the internet
- Check to see if there are any malicious inbox rules
- Obtain the ransom demand to share with the legal and forensics vendors
- Call your insurance broker to report the incident to the insurance carrier

HOW TO BENEFIT FROM AGRICULTURAL CARBON MARKETS?

Alejandro Plastina, Chad Hart, and Ann Johanns ^{1/}

A **carbon credit** is a tradable asset (similar to a certificate or permit) that represents the right to release or emit carbon into the atmosphere. Typically, each credit represents one metric ton (2,204 pounds) of carbon dioxide or an equivalent amount of another greenhouse gas. **Carbon credits** are created when entities (compared to a set baseline) reduce their carbon emissions or sequester carbon.

A growing number of private initiatives are offering farmers compensation for the generation of agriculture carbon credits as well as other ecosystem services, such as improvements in water quality. Agricultural producers can create carbon credits in a variety of ways: moving from conventional tillage to reduced or no tillage, reducing stocking rates on pastures, planting cover crops or trees, reducing fertilizer rates, or converting marginal cropland to grassland. The result of this is an emerging agriculture carbon credits market that is a mixture of coexisting programs, each with different rules, incentives, and players.

The recently released, Ag Decision Maker File A1-76, [How to Grow and Sell Carbon in US Agriculture](https://go.iastate.edu/VPHJ0J), <https://go.iastate.edu/VPHJ0J>, begins to navigate this market by comparing 11 voluntary carbon programs across two-dozen characteristics, providing valuable details to help farmers distinguish between the programs and find where they could benefit. While all programs require **additionality** to generate a credit, or for something “additional” to be occurring, not all programs require that farmers change their production practices. **Additionality** means that farmers must do something **different** to reduce carbon and increase ecosystem services. However, programs use a wide array of benchmarks to determine what is **different**. Some programs require a change of practices with respect to past practices on the same field, while some others require that practices in the field be different from common practices in the area (even if the same practices have been implemented for many years in the field under consideration).

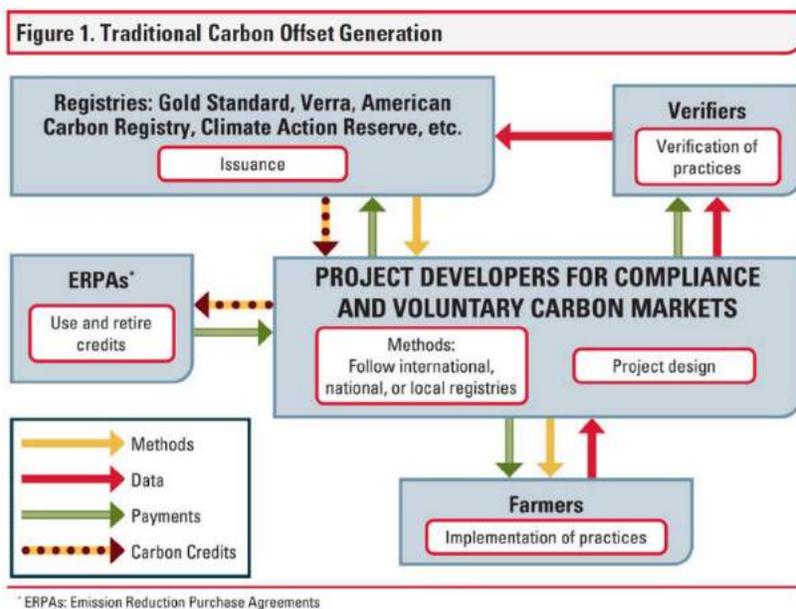
A **carbon offset** is considered a top-quality token for one metric ton of carbon dioxide-equivalent greenhouse gases (CO₂e) sequestered through practices that adhere to trusted protocols ensuring additionality and permanence, which are verified by an independent third party, certified, and registered with a unique serial number into a secure ledger called the “registry”. The registry is typically linked to a network of registries that serve as a clearinghouse of information on carbon credits (issued, unsold, sold, and retired) to avoid duplications and enhance transparency. When an owner of a carbon offset uses it to

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compensate for emissions of CO₂e somewhere else, the serial number is retired from the registry (and the transaction is transparent to the clearinghouse).

A major difference between the traditional carbon offsets and the carbon credits generated in the newer, voluntary carbon programs resides in the potential gap in their perceived qualities. A carbon credit may or may not be perceived as being of comparable quality to a carbon offset. If carbon credits are perceived as being of lower quality than carbon offsets, then they would tend to attract lower market prices than offsets do. The perceived quality of carbon credits is expected to be higher when verification and issuance are external to the carbon project, and lower when those critical processes are internal to the carbon project.

For a visual guide on these programs, the newly released publication, [How do Data and Payments Flow through Ag Carbon Programs?](https://go.iastate.edu/QGA627), <https://go.iastate.edu/QGA627>, illustrates with flowcharts, a traditional carbon offset generation (Figure 1) as well as nine voluntary carbon programs currently operating in the United States. The various actors under each program are shown with arrows pointing in the direction that data, payments, methods, and carbon credits move within each carbon program. By illustrating whether verification and issuance are external or internal processes to the carbon program, the analysis provides some basis to anticipate differences in the perceived qualities and resulting prices for agriculture carbon credits issued by different programs.



Contract Specifics

Before considering a carbon contract, a few initial questions to ask may include: What practice changes does the contract cover? How is the carbon measured? How are the payments and the costs shared? Can your practice changes be used in this carbon opportunity and other government programs? What is the contract length, terms, and exit clauses? What management data and verification are you required to provide? Are you gaining anything by being in on the “ground floor”? Consult your own trusted, legal counsel to review. You don’t want any surprises.

Additional Resources

Find publications, webinars, and further information on carbon markets on the Ag Decision Maker website, <https://go.iastate.edu/9HIN8G>.