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CONSIDER SOIL DRAINAGE CLASS WHEN MAKING NITROGEN APPLICATION TIMING DECISIONS FOR CORN[1]

Carrie A.M. Laboski and Todd W. Andraski[2]

Introduction

In-season application on N on sandy soils has been well established as a best management practice to reduce N leaching and increase profitability. Over the past few years, interest in in-season or split N applications has risen because of a desire to increase N use efficiency and profitability of corn production.

A N rate and timing study was conducted from 2014 to 2016 at two locations, one well drained and the other somewhat poorly drained. Treatments included 0 to 200 lb N/a applied at preplant, sidedress (V6), split (40 lb N/a at preplant + sideress), preplant + late (various preplant rates + 40 lb N/a at V13-16), and triple split (40 lb N/a preplant + various sidedress rates + 40 lb N/a late). On the well-drained soil, N application timing did not affect yield at N applications near or greater than the economic optimum N rate (Figure 1) and split applications resulted in lower return on investment (ROI) because of the added cost associated with multiple applications (Figure 2). In two of three years on the somewhat poorly drained soil, sidedress N application resulted in the greatest yield (Figure 3), ROI (Figure 4), and fertilizer N recovery efficiency because of early season N losses associated with preplant application. These sites demonstrate that late application of 40 lb N/a can be an effective rescue treatment, through sidedressing in these situations had the greatest ROI.

Soil drainage class should be considered when making N application decisions. On sand, loamy sand, and sandy loam soils, a majority of the N should be applied in-season to prevent loss. Multiple split applications may be considered on excessively and somewhat excessively drained soils that have the greatest leaching potential. On somewhat poorly, poorly, and very poorly drained soils, a majority of the N should be applied in-season to reduce the potential for denitrification and leaching losses. On moderately well and well drained soils, N application timing less important in most years.

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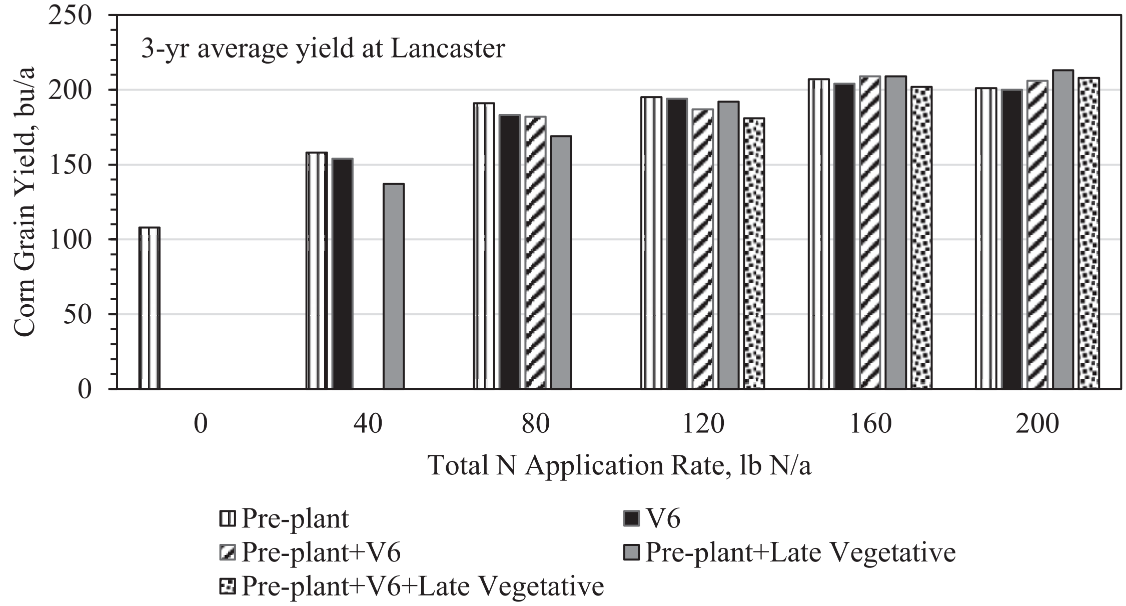

Figure 1. Effect of N application rate and timing on three-year average corn grain yield on a well-drained soil at Lancaster, WI, 2014-2016. When spit applications occurred, 40 lb N/a was applied at pre-plant and/or at late vegetative growth stage. Previous crop was corn.

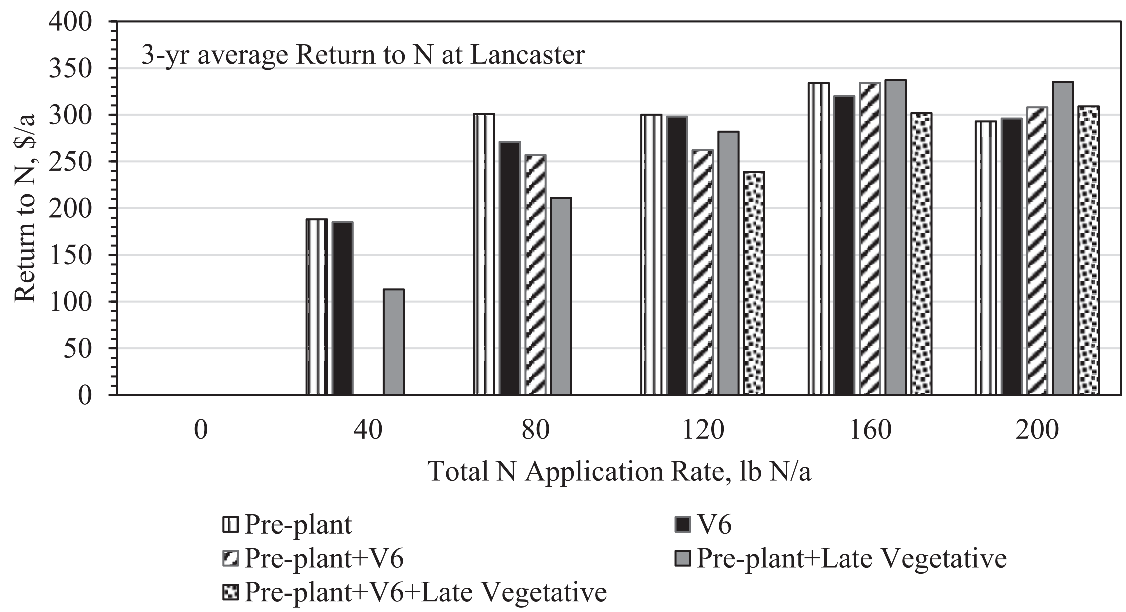

Figure 2. Effect of N application rate and timing on three-year average return to N on a well-drained soil at Lancaster, WI, 2014-2016. When spit applications occurred, 40 lb N/a was applied at pre-plant and/or at late vegetative growth stage. Return to N calculated as $0.44/lb N, $4.00/bu grain, $6/a for each N application additional N application. Previous crop was corn.

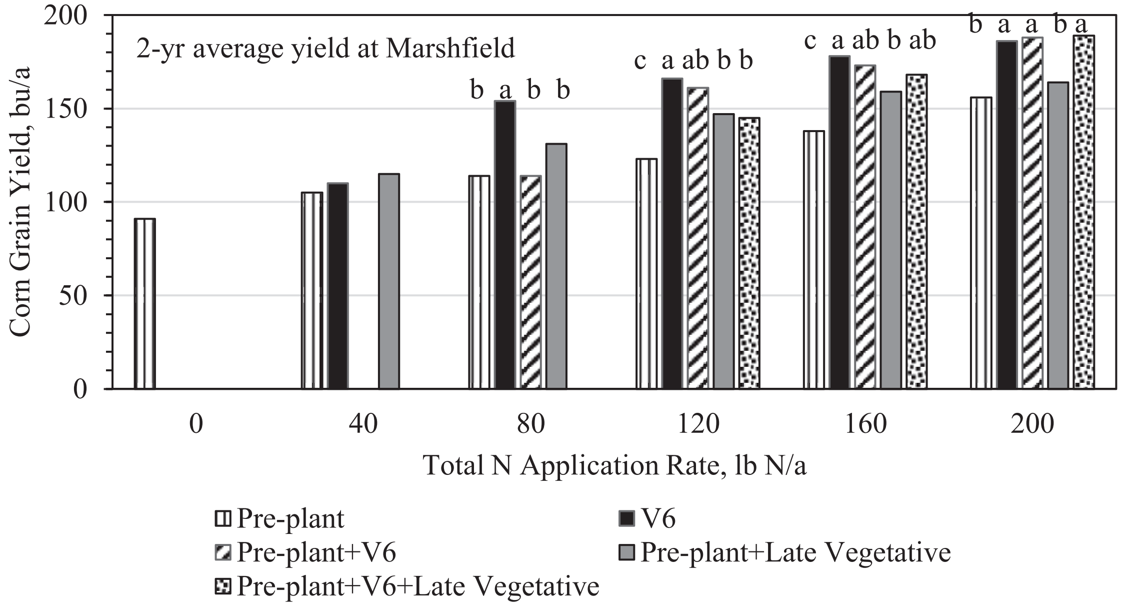

Figure 3. Effect of N application rate and timing on three-year average corn grain yield on a somewhat poorly-drained soil at Marshfield, WI, 2014-2016. When spit applications occurred, 40 lb N/a was applied at pre-plant and/or at late vegetative growth stage. Previous crop was corn. For a given N rate, N application timings with different letters are significantly different ($p<0.10$).

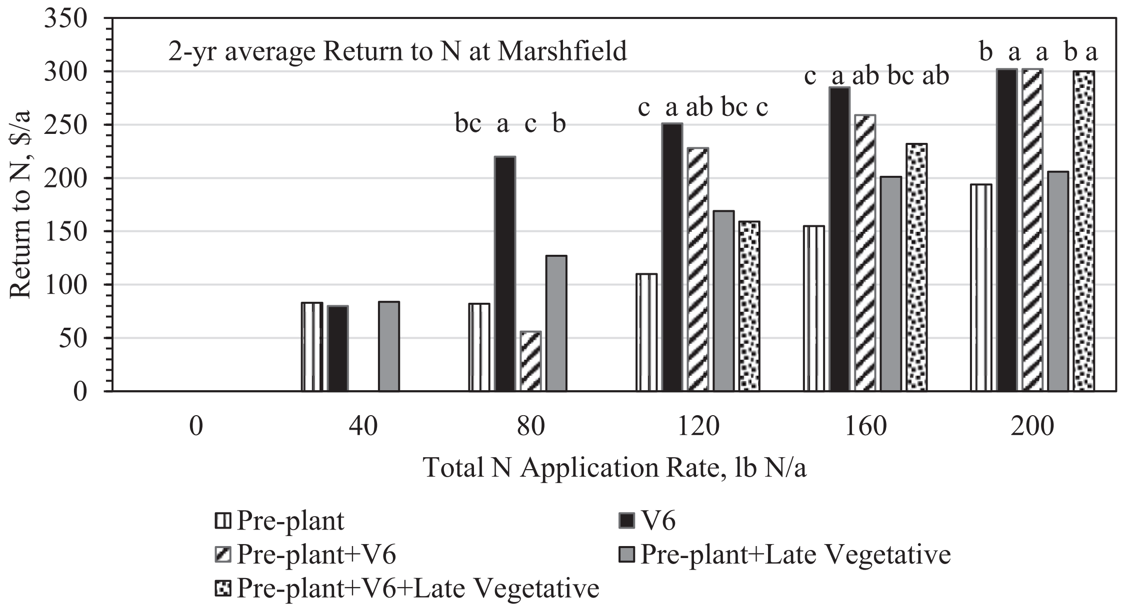

Figure 4. Effect of N application rate and timing on three-year average return to N on a somewhat poorly-drained soil at Marshfield, WI, 2014-2016. When spit applications occurred, 40 lb N/a was applied at pre-plant and/or at late vegetative growth stage. Return to N calculated as \$0.44/lb N, \$4.00/bu grain, \$6/a for each N application additional N application. Previous crop was corn. For a given N rate, N application timings with different letters are significantly different ($p<0.10$).

QUANTIFYING THE BENEFITS OF LEGUME COVER CROPS

Matt Ruark, Dan Smith, Jim Stute, Hannah Francis, and Chelsea Zegler [1/]

Introduction

Red clover, when interseeded (or frost-seeded) with winter wheat offers potential for economic return in the form of N credits, rotational yield bump and the potential for harvest as forage, all without idling cropland for the sake of cover cropping (Gaudin et al., 2014; Stute and Posner, 1995). Current UW-Extension N credits for red clover are based on the height of above ground growth: 50 to 80 lb-N ac^{-1} if greater than 6 inches tall and 40 lb-N ac^{-1} if less than 6 inches tall (Laboski and Peters, 2012). But, it is not clear what data this N credit is based on; there is no published data from Wisconsin studies that have calculated an N credit from red clover. Previous work in the early to mid-1990s (e.g., Stute and Posner, 1995) only evaluate the feasibility of frost-seeding legumes and potential yield benefit, but were not designed to determine an N credit. Other Midwestern states and corresponding land grant institutions do not provide a red clover specific credit, but rather provide a generic annual legume credit, which ranges from 30 to 80 lb-N ac^{-1} (Ohio and Michigan, respectively). In contrast, recently published studies have reported red clover N credits that are lower than those recommended by these states for unharvested red clover. In Michigan, Gentry et al. (2013) found reportable credits of 27 and 43 lb-N ac^{-1} in 2006 and 2007 and in Ohio, Henry et al. (2010) found no credit in 3 of 4 site-years, although they did find that corn yields increased 14.5% when following red clover. Vyn et al. (2000) also found a significant yield increase in corn following red clover compared to no cover in two tillage systems in 3 of 4 site years, but only when no additional fertilizer was added; yield differences were negated by the addition of 130 lb-N ac^{-1}.

Red clover can also be established in a standing corn crop. Previous research on interseeding red clover into corn in Wisconsin has shown that it is a viable system. Trials at the Arlington Agricultural Research Station in 2014 and 2015, conducted by Dan Smith with the University of Wisconsin Nutrient and Pest Management Program, have shown that red clover grows well when interseeded into corn at the V4-V5 growth stage. These trials also determined that interseeding clover did not reduce corn grain yields in the same year. However, similar research by Grabber et al. 2014, determined greater corn yields when red clover was interseeded compared to a no cover control. What remains to be studied is the effect of interseeding red clover on subsequent years corn yields and response to N. The potential N credit has not been determined. Another aspect to this research is that there is a clear yield drag when corn is grown in continuous rotation without tillage. If red clover provides a yield increase, interseeding red clover into continuous corn could serve to eliminate this yield drag. The other issue not yet addressed by current research is if the N credit from red clover in this system comes from fixed-N or from fertilizer N.

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The goals of previous research have been to quantify the N benefit (to corn) of legume cover crops either frost-seeded into winter wheat, planted after winter wheat, or interseeded into corn. Preliminary results here demonstrate the potential benefit of red clover.

Frost-Seeding Study

Experimental Design

This study was conducted during the 2017-2018 and the 2018-2019 growing seasons, with red clover being frost-seeded into winter wheat the first year and corn yields being evaluated in the second year. The study was conducted at the Arlington Agricultural Research Station. The study design was a randomized, complete block split-split plot design with four replications. The whole plot treatments were no cover crop, red clover cover crop terminated in the fall, and red clover cover crop harvested in the fall. The split plot treatments were tillage and no tillage and the split-split plot treatments were six rates of N fertilizer (0, 50, 100, 150, 200, 250 lb-N ac^{-1}). The split-split plot size will be 15 × 40 ft (144 plots). The red clover cover crop was frost seeded into winter wheat in March. Wheat grain and straw yield were measured in August by hand from a 2 × 2 m area, then mechanically harvested from the entire plot area. In November of each year, the red clover was killed chemically or harvested as a silage crop at bud stage. Both red clover as cover and for forage was be sampled prior to termination or harvest and analyzed for dry matter (DM) content and C and N concentration. The red clover for silage will also be analyzed for forage quality [hay/haylage analysis, University of Wisconsin Soil and Plant Analysis Laboratory (UW-SPAL)], which includes DM, crude protein (CP), acid detergent fiber (ADF), ADF-CP, neutral detergent fiber (NDF), NDF-CP, ash, fat, NDF digestibility (NDFD), and relative forage quality (RFQ). Soil samples (0-1 and 1-2 ft) will be taken at the time of red clover harvest and analyzed for nitrate-N. The tillage treatment (chisel plow) will be conducted after soil sampling (this treatment may require a soil finisher in the spring as well).

Preliminary Results

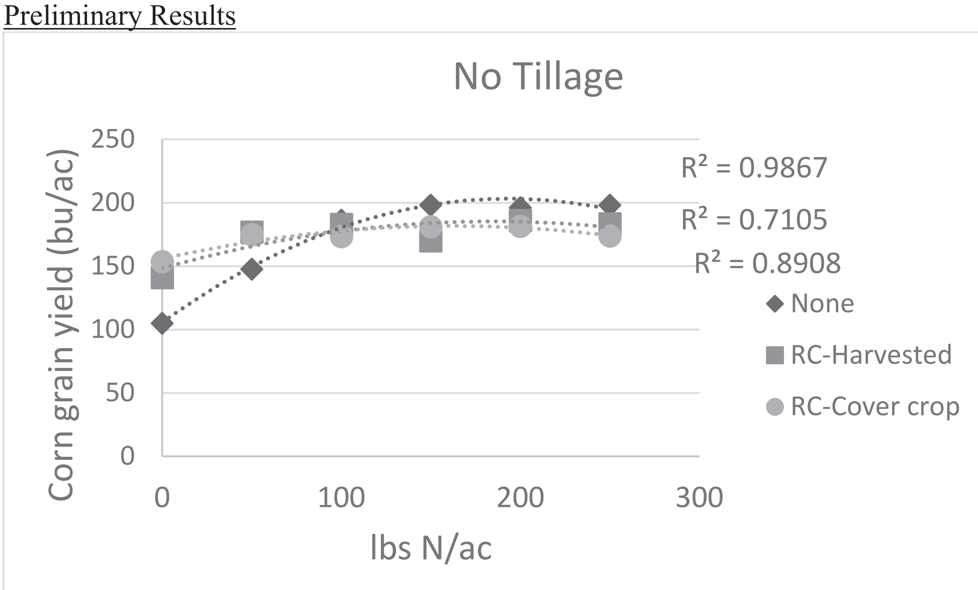

Figure 1. Corn yield following no cover crop, red clover as a cover crop, or red clover harvested as a silage crop in 2018 at the Arlington research station. Clear yield benefit from red clover at lower N rates, but greater yields were achieved without a cover crop at higher N rates.

Interseeding Study

Experimental design

Research was conducted at the Arlington Agricultural Research Station in 2017 and 2018, and will be continued in 2019. Continuous corn was grown in a no-till system. The experimental design was a randomized, complete block-split plot design, with four replications. The whole plot treatments were with or without interseeding of red clover and the split plot treatments will be eight rates of N fertilizer (0 to 280 lb-N/ac in 40 lb-N/ac increments). Based on the experimental design proposed, we evaluate dthe effect of corn yield on the interseeding year in 2017 and 2018, the effect on the subsequent corn years in 2018 and 2019. The effect of interseeding red clover on subsequent corn yields was evaluated when red clover is continually interseeded or not-interseeded to evaluate if the continual presence of red clover has an effect on the N credit. Red clover was drill seeded at the V4-V5 growth stage at a rate of 12 lb/ac with a modified grain drill operated by Dan Smith (UW-Nutrient and Pest Management Program). The drill can interseed three rows at a time, so each plot was six rows wide, with each plot being slightly offset. Nitrogen fertilizer was surface applied at sidedress near the time of red clover seeding, applied as urea coated with Agrotain®. Red clover was terminated chemically in the spring with 1 pint of dicamba and 32 oz of glyphosate. For post planting weed control, we applied 32 oz of glyphosate at V5 right before interseeding of red clover.

Preliminary Results

Table 1. Preplant sampling for nitrate and ammonium (ppm) in May 2018 (reflecting effect of 2017 treatments). No significant differences among treatments.

Preplant sampling (ppm) May 2018					
Cover crop treatment	2017 N rate	0-1 ft		1-2 ft	
		NO_3	NH_4	NO_3	NH_4
No RC	160	5.6	6.6	7.8	4.5
No RC	0	4.0	4.4	4.2	4.0
Always RC	160	4.8	5.1	6.3	4.1
Always RC	0	3.6	4.7	3.5	4.0

Table 2. Presidedress sampling for nitrate and ammonium (ppm) in 2018 reflecting the effect of the 2017 treatment. No significant difference among treatments. These results would indicate that the red clover did not increase the amount of plant available N in the soil.

Presidedress sampling (ppm) 6/28/18			
Cover crop treatments	N rate	0-1 ft	
		NO_3	NH_4
No RC	Bulk	5.5	6.0
No RC	0	4.7	6.1
Always RC	Bulk	5.9	5.4
Always RC	0	5.5	5.4

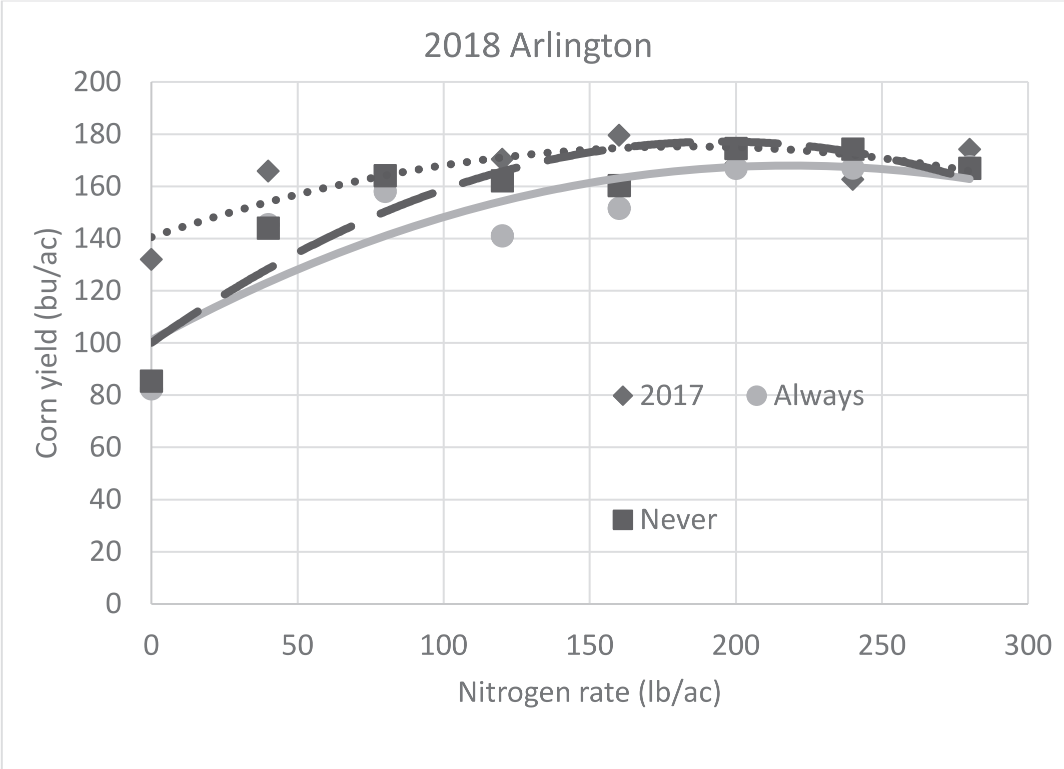

Figure 2. 2018 corn yields vs. N rates following a 2017 interseeded cover crop (2017) (dotted line), a cover crop in both 2017 and 2018 (always) (solid line), or no cover crop (Never) (long-dashed line). Results indicate yield benefit if red clover was interseeded the year prior, but not if interseeded every year.

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DO MY CROPPING PRACTICES IMPACT SOIL MICROBIOLOGY?

Lindsay A. Chamberlain and Shawn P. Conley [1/]

There is a considerable amount of excitement surrounding the idea of "soil biology" and its role in agriculture today. Maintaining healthy soil is important, and certainly involves paying attention to the living organisms in the soil. However, studying soil microbiology is complex, there are limitations to the current methods of research, and there is a lot of information and claims out there that can be hard to sift through. This session will cover how a microbiome study is typically conducted, outline some limitations of this type of study, and present results regarding crop rotation and soil bacterial communities.

A few terms to know:

- **Microbiome**: *the microorganisms in a particular environment, like the gut, or soil.*
- **Next generation sequencing**: *newer DNA sequencing technology that allows a lot of DNA sequences to be read simultaneously.*
- **16S rRNA Gene**: *a barcode-like gene that all bacteria have, that can be used to identify them. "ITS" is a similar gene in fungi.*
- **Alpha diversity**: *the total number of different types of species, also called richness.*
- **Beta diversity**: *variation in the types of species present in two different environments.*
- **Functional redundancy**: *when multiple organisms in the soil are able to carry out the same functions.*

---- Abstract for the research project ----

Crop rotation, but not cover crops, influenced soil bacterial community composition in a corn-soybean system in southern Wisconsin.

Crop rotation, the successive cultivation of different crops on the same field, has been practiced for centuries, and it is often associated with increased crop yields. Cover cropping is a less ubiquitous farming practice that also increases plant biodiversity over time. Cover crops are a soil conservation tool; they are grown between harvest and planting of the main crop to protect and enrich the soil. Increasing crop diversity with crop rotation and cover cropping may contribute to shifts in soil bacterial communities. Our first objective was to investigate the soil bacterial communities associated with growing corn (*Zea mays* L.) or soybean (*Glycine max* L.) continuously versus annually rotating these crops. Our second objective was to determine if the first season of cover cropping had an impact on soil bacteria in a corn-soybean system. Soil was collected from a long-term crop rotational study with continuous corn, continuous soybean, and annually rotated corn-soybean treatments. These rotation treatments had various cover crops established within each plot, which were sampled individually. Bacterial populations were estimated in each sample by extracting DNA and sequencing the V3-V4 region of the 16S rRNA gene. We found that soil pH, organic matter, and certain macronutrients were essential drivers in

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determining the composition of bulk soil bacterial communities. Continuously cropped corn and soybean had distinct bacterial communities, while annually rotated communities were similar in both crop phases. The incorporation of cover crops into the rotation system did not result in significant changes to the bulk soil bacterial community. This result was probably due to limited cover crop growth in the first year of establishment, and a limited amount of time for soil communities to respond to this change.

MANAGEMENT STRATEIES FOR EARLY- AND LATE-PLANTED SOYBEANS

Emma Matcham and Shawn Conley [1/]

In Wisconsin, soybean yield potential is decreased by 0.4 to 0.5 bushels per acre for every day planting is delayed after April 20. But, planting date is limited by weather and equipment availability. This research focused on in-season management decisions that can help maximize yield within early- or late-planting scenarios.

Producer data on seed yield and management decisions were collected during 2014-2016. After classifying fields by growing environment and planting date, conditional inference trees were used to identify management decisions that were associated with an increase in yield. Management decisions considered in this analysis included drainage, seed treatments, starter fertilizer, manure, foliar pesticides, herbicides, seeding rate, row width tillage, and previous crop.

Decisions associated with increased yield were different for each growing environment and between early- and late-planted fields. Across 3 of 10 growing environments each, artificial drainage, insecticide seed treatment, and lower seeding rates were associated with higher yields on late-planted fields. For late-planted fields, herbicide application timing (3 of 10 environments) and tillage intensity (2 of 10 environments) were related to higher yields. There was no individual management decision that consistently increased seed yield across all environments. This presentation will highlight management decisions to consider based on your growing environment, emphasizing management decisions that may differ in impact for early- and late-planted fields.

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HOW TO MAXIMIZE THE BENEFITS OF NITROGEN FIXATION IN SOYBEANS: CURRENT UNDERSTANDING AND PROSPECTS

Sanhita Chakraborty and Jean-Michel Ane [1/]

Soybean is the most widely cultivated crop legume in the world and was introduced into the United States in the mid-eighteenth century. Most legumes develop a symbiotic association with soil bacteria collectively called rhizobia, which leads to the development of root nodules that host nitrogen-fixing rhizobia. Soybean, in particular, associates with certain species of *Bradyrhizobium* and *Sinorhizobium*. These rhizobia are not native to the United States, so inoculation of soybeans was initially essential to establish the use of soybeans into our cropping systems. However, more than a hundred years later, the necessity to inoculate soybeans needs to be reevaluated.

We will present our results on the effect of rhizobial inoculation on soybean yield and grain quality. Rhizobia produce signals called lipo-chitooligosaccharides (LCOs) to associate with legumes, and LCO-based products, sometimes mixed with rhizobia, are commercialized. We will present our results on the impact of LCOs on soybean yield and disease resistance. Environmental conditions can also affect the survival of rhizobia in the soil. We will present the results on the impact of drought or flooding on rhizobia.

Several research groups aim at improving the benefits of rhizobia-soybean associations. These improvements can be made in either soybeans or rhizobia. On the plant side, enhanced transport of fixed nitrogen from the source to the sink tissues and delayed nodule senescence are approaches that could be used to improve nitrogen fixation and assimilation in soybean. On the bacterial side, efforts are in progress to generate desiccation-tolerant inoculants that have an improved ability to survive when applied on seeds. Current technical advances allow improving the rhizobial genome without introducing any foreign genetic component. Altogether, these ongoing approaches could help enhance the benefits of nitrogen fixation for soybean production sustainably.

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EVALUATING THE EFFECTS OF FUNGICIDE ON SILAGE CORN QUALITY AND HYGIENE

Hannah Reed[1], John Goeser, Ph.D.[2], and Damon L. Smith, Ph.D.[3]

Introduction

In Wisconsin, dairy cows eat on average 100 pounds of feed a day, about half of which typically is corn silage. Corn silage is an extremely important part of a dairy cow's diet and provides much of the needed calorie and nutrition input. When making corn silage, the whole plant, including the stalk and ear is chopped and put into bunkers. In these large, cement bunkers the chopped corn is packed down tightly and covered in order to begin fermentation as quickly as possible. Ensiling through fermentation is the best way to preserve the quality and nutrition of feed and prevent degradation. Plant diseases that originate in the field, such as stalk rots and foliar blights, can reduce overall yield and result in non-optimal moisture content of silage corn. This can influence proper bunker packing and ensiling resulting in low quality feeds and secondary problems.

Gibberella ear rot and stalk rot are caused by *Fusarium graminearum* (White, 2016). Beyond reducing the quality of silage, *F. graminearum* produces the mycotoxin deoxynivalenol, also known as DON or vomitoxin. Mycotoxins are toxic metabolites produced by some fungal pathogens during their secondary metabolisms that negatively impact the consumer. DON consumption is associated with low weights, feed refusal, and vomiting in livestock. There are estimated ranges of allowable levels of DON contamination within livestock feed, and milk production in dairy cows has been shown to be negatively impacted with as little as 1 ppm of DON (Goeser, 2015). Currently, DON levels are typically associated with ear rots in grain corn, but there is no understanding of the extent of DON accumulation throughout the rest of the corn plant (White, 2016). Because corn silage uses the entire plant, it is important to understand the impact of fungicide treatments on *F. graminearum* and DON accumulation throughout the entire corn plant. Thus, the objectives of our study were as follows:

1. Understand the impact of fungicide treatments on deoxynivalenol production by *Fusarium graminearum* in silage corn.
2. Understand the location of deoxynivalenol accumulation within the ear and stalk portions of the corn plant.

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Materials and Methods

Fungicide Trial

The fungicide trial occurred in 2018 and 2019 at the Arlington Agricultural Research Station (AARS) in Arlington, Wisconsin. Two brown midrib (BMR) silage corn hybrid varieties, P0956AMX and F2F627 were planted at a rate of 35,000 seeds per acre in 15' x 20' six-row plots. Fungicide treatments were applied between V6 and R2 growth stages stages (Table 1). Foliar disease and ear rot ratings were taken throughout the growing season for multiple diseases including Gibberella ear rot, gray leaf spot, northern corn leaf blight, tar spot, and southern rust. Lodging scores and a push test were also completed.

A small-plot silage chopper harvested the center two rows of each plot and dry-matter yield was determined. Samples were taken for forage quality and DON analyses at Rock River Laboratory, Inc. in Watertown, WI. Factors such as Dry Matter yield, moisture content, crude protein %, aNDF%, starch %, ash %, TTNDFD %, and more were measured for each silage sample. TTNDFD % is a quantitative predictor of fiber digestion (Combs, 2015).

Table 1. Fungicide treatments, timings, and application rates for 2018 and 2019 silage corn fungicide trials in Arlington, WI.

Application Time	Treatment	Year	
		2018	2019
	Non-Treated Check	x	x
V6	Miravis Neo 13.7 FL OZ/A;NIS 0.25%	x	x
V6 R1	Miravis Neo 13.7 FL OZ/A V6;NIS 0.25 % V/V V6 Miravis Neo 13.7 FL OZ/A R1		x
V14	Miravis Neo 13.7 FL OZ/A V12-V14	x	x
R1	Proline 5.7 FL OZ/A	x	x
	Headline AMP 14.4 FL OZ/A	x	x
	Delaro 8 FL OZ/A	x	x
	Miravis Neo 13.7 FL OZ/A	x	x
	Miravis Ace 13.7 FL OZ/A	x	x
	Topguard 10 FL OZ/A	x	x
	Lucento 5 FL OZ/A	x	x
R2	Miravis Neo 13.7 FL OZ/A	x	x
	Proline 5.7 FL OZ/A	x	
	Headline AMP 14.4 FL OZ/A	x	
	Delaro 8 FL OZ/A	x	

Partitioned Sample Experiment

Samples were hand harvested from rows 2 and 5 of select treatments of the silage fungicide trial at AARS. The selected treatments included the non-treated check, Headline AMP applied at 14.4 FL OZ/A at R1 (silking), and Proline at 5.7 FL OZ/A at R1. Five plants were randomly selected from each plot and stalk and ear (including husk and cobb) portions were separated, chopped, and then dried down. Deoxynivalenol concentrations in parts per million (ppm) were determined using the RIDASCREEN® DON R5906 kit from R-Biopharm, Inc. Absolute RT-PCR was used to determine the quantity of *Fusarium graminearum* DNA (pg/ng) within the sample of plant material.

Results and Discussion

In the whole plot silage samples, we found no significant differences in yield or digestibility (TTNDFD) for any fungicide treatment for either hybrid in either year. These results along with disease severity scores and DON contamination can be found in Tables 2-5 for each hybrid in both years. Due to environmental conditions, there was much higher disease pressure in 2018 than 2019. In 2018, ear rot severity was very high and DON concentrations reached up to 30 ppm (Table 3), which is 30 times the recommended amount for dairy feed. In 2019, the maximum DON concentration was 2.2 ppm (Table 4) and averaged below 1 ppm for both hybrids. For F2F627 in 2018, 4 treatments were found to significantly decrease DON contamination and 1 separate treatment was found to significantly decrease ear rot severity levels. No significant decreases of DON or ear rot severity were observed in P0956AMX in 2018. In 2019, 3 different treatments significantly decreased DON concentrations in P0956AMX, while there were no significant reductions in ear rot severity in either hybrid or DON in F2F627. The ear rot severity scores and DON concentrations were not correlated for either hybrid in each year of the trial. This lack of correlation suggests another source of DON contamination, in addition to the ear rot phase, is responsible for the DON levels observed in finished feed.

In the partitioned samples, both DON and *F. graminearum* DNA was detected in all ear and stalk samples. This shows the ability for DON to accumulate throughout the plant. The majority of the accumulation of DON varied between the ear or stalk parts for each hybrid by year. We found higher DON levels in the 2018 F2F627 ear samples compared to the stalk samples for all treatments tested (*data not shown*). In the 2018 P0956AMX samples, DON accumulated in the stalk to a higher level than the ear. In 2019, again likely due to environmental conditions, there were lower levels of DON overall with the highest being found in the non-treated stalk samples for both hybrids. *F. graminearum* fungal accumulation in 2018 followed a similar trend to DON accumulation in F2F627. However, in P0956AMX, the location of *F. graminearum* fungal accumulation did not correspond with DON accumulation with more fungal DNA being detected in the ear parts and more DON being detected in the stalks.

This work shows that there are differential responses between BMR hybrids to fungicide treatments. Environmental conditions can contribute greatly to disease development and DON accumulation and impact where DON is found in silage corn plants. The work also demonstrates that DON can be found in all parts of the corn plant. While more work is needed to understand how DON accumulates in both the ear and stalk, breeding efforts should focus on slowing the growth of *F. graminearum* and accumulation of DON in both stalks and ears.

Table 2. Northern corn leaf blight severity, tar spot severity, ear rot severity, dry matter yield, TTNDFD, and deoxynivalenol (DON) for P0956AMX BMR corn hybrid treated with fungicide or not treated with fungicide in Wisconsin, 2018.

Treatment and rate/A (growth stage at application)	Northern Corn Leaf Blight Severity(%)[z, u]	Tar Spot Severity (%)[y, u]	Ear Rot Severity (%)[x]	Yield (tons dry matter/a)	TTNDFD (%)[w]	DON (ppm)[v]
Non-Treated Check	25.0 a	3.8 a	2.1	12.9	34.9	9.4
Miravis Neo 2.5SE 13.7 fl oz (V12)	16.3 bc	2.1 b-d	2.9	13.6	36.2	7.7
Miravis Neo 2.5SE 13.7 fl oz (V6)[t]	17.5 c-e	1.8 b-d	1.4	12.6	37.3	8.4
Topguard 1.04SC 10 fl oz (R1)	6.1 e	1.4 b-d	4.9	11.9	38.5	12.9
Proline 480SC 5.7 fl oz (R1)	14.3 b-d	1.2 b-d	3.1	11.8	36.8	8.5
Miravis Neo 2.5SE 13.7 fl oz (R2)	8.1 de	1.2 b-d	1.6	12.1	36.7	9.8
Miravis Ace 5.2SC 13.7 fl oz (R1)	11.3 c-e	1.0 cd	3.3	12.2	37.8	9.8
Proline 480SC 5.7 fl oz (R2)	11.3 c-e	1.0 cd	1.4	12.8	36.3	10.0
Delaro 325SC 8 fl oz (R1)	11.8 c-e	1.0 cd	2.1	11.9	36.7	10.5
Lucento 4.17SC 5 fl oz (R1)	8.0 de	0.8 cd	1.5	11.8	37.1	8.5
Headline AMP 1.68SC 14.4 fl oz (R1)	14.3 b-d	0.8 cd	1.4	13.0	35.9	11.9
Delaro 325SC 8 fl oz (R2)	10.5 c-e	0.6 d	2.1	11.7	38.5	8.2
Headline AMP 1.68SC 14.4 fl oz (R2)	13.0 c-e	0.6 d	1.0	12.0	37.1	11.9
Miravis Neo 2.5SE 13.7 fl oz (R1)	9.8 b-e	0.6 d	1.0	12.5	36.4	17.9
Fisher's LSD (α=0.05)	7.4	1.1	ns[s]	ns[s]	ns[s]	ns[s]

[z]Northern corn leaf blight severity was visually assessed as the average % ear leaf symptomatic per plot with the aid of a standard area diagram; means for each plot were used in the analysis
[y]Tar spot severity was visually assessed as the average % ear leaf symptomatic per plot with the aid of a standard area diagram; means for each plot were used in the analysis
[x]Ear rot severity assessed visually on 5 ears per plot
[w]Total-Tract Neutral Detergent Fiber Digestibility
[v]Deoxynivalenol (DON) content were analyzed for each plot; means for each plot were used in the analysis
[u]Means followed by the same letter are not significantly different based on Fisher's Least Significant Difference (LSD; α=0.05)
[t]Treatments including the non-ionic surfactant Induce 90SL at 0.25 %v/v
[s]ns = not significant (α=0.05)

Table 3. Northern corn leaf blight severity, tar spot severity, ear rot severity, dry matter yield, TTNDFD, and deoxynivalenol (DON) for F2F627 BMR corn hybrid treated with fungicide or not treated with fungicide in Wisconsin in 2018.

Treatment and rate/A (growth stage at application)	Northern Corn Leaf Blight Severity (%)[z, u]	Tar Spot Severity (%)[y, u]	Ear Rot Severity (%)[x]	Yield (tons dry matter/a)	TTNDFD (%)[w]	DON (ppm)[v]
Miravis Neo 2.5SE 13.7 fl oz (V12)	27.5 c-e	11.3 a	4.6	11.6	36.2	18.6
Non-Treated Check	62.5 a	10.5 ab	8.8	11.0	38.7	21.2
Proline 480SC 5.7 fl oz (R2)	27.5 c-e	8.6 a-c	6.5	10.4	39.4	10.7
Proline 480SC 5.7 fl oz (R1)	31.3 c-f	7.4 a-d	10.4	11.0	38.5	13.2
Miravis Neo 2.5SE 13.7 fl oz (R1)	21.3 de	6.9 a-d	11.1	11.1	39.5	17.2
Miravis Ace 5.2SC 13.7 fl oz (R1)	42.5 bc	6.3 b-f	7.7	11.7	39.7	15.7
Lucento 4.17SC 5 fl oz (R1)	18.8 ef	5.8 b-e	4.5	12.2	37.5	18.0
Topguard 1.04SC 10 fl oz (R1)	23.8 de	5.6 c-e	4.8	10.7	38.1	15.1
Miravis Neo 2.5SE 13.7 fl oz (R2)	15.0 e	5.5 c-e	7.9	10.7	39.9	30.3
Miravis Neo 2.5SE 13.7 fl oz (V6)[t]	50.0 ab	4.9 c-e	10.0	11.0	37.0	12.0
Delaro 325SC 8 fl oz (R1)	22.5 de	4.3 c-e	12.9	11.2	37.8	17.7
Headline AMP 1.68SC 14.4 fl oz (R1)	36.3 b-d	2.8 d-f	14.2	10.6	38.7	18.7
Delaro 325SC 8 fl oz (R2)	28.8 c-e	2.0 ef	9.7	10.5	37.1	12.7
Headline AMP 1.68SC 14.4 fl oz (R2)	17.5 ef	1.4 e	18.4	11.5	40.9	14.9
Fisher's LSD (α=0.05)	15.9	4.8	ns[s]	ns[s]	ns[s]	ns[s]

[z]Northern corn leaf blight severity was visually assessed as the average % ear leaf symptomatic per plot with the aid of a standard area diagram; means for each plot were used in the analysis
[y]Tar spot severity was visually assessed as the average % ear leaf symptomatic per plot with the aid of a standard area diagram; means for each plot were used in the analysis
[x]Ear rot severity assessed visually on 5 ears per plot
[w]Total-Tract Neutral Detergent Fiber Digestibility
[v]Deoxynivalenol (DON) content were analyzed for each plot; means for each plot were used in the analysis
[u]Means followed by the same letter are not significantly different based on Fisher's Least Significant Difference (LSD; α=0.05)
[t]Treatments including the non-ionic surfactant Induce 90SL at 0.25 %v/v
[s]ns = not significant (α=0.05)

Table 4. Southern rust severity, tar spot severity, ear rot severity, dry matter yield, TTNDFD, and deoxynivalenol (DON) for P0956AMX BMR corn hybrid treated with fungicide or not treated with fungicide in Wisconsin, 2019.

Treatment and rate/A (growth stage at application)	Southern Rust Severity (%)[z, u]	Tar Spot Severity (%)[y, u]	Ear Rot Severity (%)[x]	Yield (tons dry matter/a)	TTNDFD (%)[w]	DON (ppm)[v,u]
Non-Treated Check	2.8 a	0.8 b	1.5	10.0	43.6	1.6 a
Miravis Neo 2.5SE 13.7 fl oz (V6)[t]	1.4 bc	2.2 a	10.3	9.1	46.1	1.3 ab
Miravis Neo 2.5SE 13.7 fl oz (V6)[t] Miravis Neo 2.5SE 13.7 fl oz (R1)	2.1 ab	0.9 b	1.2	10.3	45.3	2.2 a
Miravis Neo 2.5SE 13.7 fl oz (V14)	2.2 ab	0.9 b	3.3	9.0	47.0	0.2 d
Proline 480SC 5.7 fl oz (R1)	1.9 ab	0.6 b	0.3	9.7	47.1	0.5 a-d
Topguard 1.04SC 10 fl oz (R1)	2.9 a	0.8 b	1.1	10.2	46.3	1.3 ab
Delaro 325SC 8.0 fl oz (R1)	1.2 bc	0.7 b	1.5	10.2	44.0	0.3 b-d
Headline AMP 1.68SC 14.4 fl oz (R1)	2.4 ab	0.7 b	0.7	10.5	46.1	0.2 cd
Lucento 4.17SC 5.0 fl oz (R1)	0.8 c	0.6 b	0.6	9.4	46.4	1.0 a-c
Miravis Ace 5.2SC 13.7 fl oz (R1)	1.8 ab	1.0 b	1.3	9.5	45.1	0.6 a-d
Miravis Neo 2.5SE 13.7 fl oz (R1)	2.1 ab	0.8 b	2.7	10.3	46.1	0.6 a-d
Miravis Neo 2.5SE 13.7 fl oz (R2)	2.0 ab	0.6 b	1.1	9.8	45.8	1.6 a
P-value	<0.05	<0.05	ns[s]	ns[s]	ns[s]	<0.05

[z]Southern rust severity was visually assessed as the average % ear leaf symptomatic per plot with the aid of a standard area diagram; means for each plot were used in the analysis.
[y]Tar spot severity was visually assessed as the average % ear leaf symptomatic per plot with the aid of a standard area diagram; means for each plot were used in the analysis.
[x]Ear rot severity assessed visually on 5 ears per plot.
[w]Total-Tract Neutral Detergent Fiber Digestibility
[v]Deoxynivalenol (DON) content were analyzed for each plot; means for each plot were used in the analysis.
[u]Means followed by the same letter are not significantly different based on Fisher's Least Significant Difference (LSD; α=0.05).
[t]Treatments including the non-ionic surfactant Induce 90SL at 0.25 %v/v
[s]ns = not significant (α=0.05)

Table 5. Southern rust severity, tar spot severity, ear rot severity, dry matter yield, TTNDFD, and deoxynivalenol (DON) for F2F627 BMR corn hybrid treated with fungicide or not treated with fungicide in Wisconsin, 2019.

Treatment and rate/A (growth stage at application)	Southern Rust Severity (%)[z, u]	Tar Spot Severity (%)[y]	Ear Rot Severity (%)[x]	Yield (tons dry matter/a)	TTNDFD (%)[w]	DON (ppm)[v]
Non-Treated Check	9.25 ab	0.91	0.05	9.09	47.32	0.12
Miravis Neo 2.5SE 13.7 fl oz (V6)[t]	7.60 a-c	0.82	0.05	8.24	46.37	0.20
Miravis Neo 2.5SE 13.7 fl oz (V6)[t] Miravis Neo 2.5SE 13.7 fl oz (R1)	4.61 b-d	0.83	0.05	8.80	47.77	0.08
Miravis Neo 2.5SE 13.7 fl oz (V14)	3.08 d	0.85	0.00	8.79	47.88	0.02
Miravis Neo 2.5SE 13.7 fl oz (R1)	2.94 d	0.99	0.25	9.24	45.72	0.08
Miravis Ace 5.2SC 13.7 fl oz (R1)	6.58 a-c	0.79	0.00	9.05	48.22	0.07
Lucento 4.17SC 5.0 fl oz (R1)	0.84 e	0.87	0.50	8.75	48.37	0.22
Topguard 1.04SC 10 fl oz (R1)	9.72 a	0.65	0.05	8.57	47.21	0.09
Proline 480SC 5.7 fl oz (R1)	3.97 cd	1.08	0.25	8.67	48.96	0.05
Headline AMP 1.68SC 14.4 fl oz (R1)	5.10 a-d	0.79	0.30	9.70	47.02	0.02
Delaro 325SC 8.0 fl oz (R1)	3.91 cd	0.95	0.30	7.91	49.46	0.01
Miravis Neo 2.5SE 13.7 fl oz (R2)	5.24 a-d	0.67	0.50	8.58	48.94	0.08
P-value	<0.0001	ns[s]	ns[s]	ns[s]	ns[s]	ns[s]

[z]Southern rust severity was visually assessed as the average % ear leaf symptomatic per plot with the aid of a standard area diagram; means for each plot were used in the analysis.
[y]Tar spot severity was visually assessed as the average % ear leaf symptomatic per plot with the aid of a standard area diagram; means for each plot were used in the analysis.
[x]Ear rot severity assessed visually on 5 ears per plot.
[w]Total-Tract Neutral Detergent Fiber Digestibility
[v]Deoxynivalenol (DON) content were analyzed for each plot; means for each plot were used in the analysis.
[u]Means followed by the same letter are not significantly different based on Fisher's Least Significant Difference (LSD; α=0.05).
[t]Treatments including the non-ionic surfactant Induce 90SL at 0.25 %v/v
[s]ns = not significant (α=0.05)

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IMPROVING SOYBEAN WHITE MOLD CONTROL: INTEGRATED MANAGEMENT AND BREEDING FOR RESISTANCE

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Introduction

White mold of soybean is caused by the fungal pathogen, *Sclerotinia sclerotiorum*, and is a devastating disease in the Great Lakes growing region of the United States. The integrated management techniques used to control this disease are multi-level including the manipulation of row spacing, adjusting planting population, and using fungicides along with genetically resistant cultivars. Previously, it had been shown that widening rows to 30" resulted in lower disease levels when compared to narrower row spacings of 10" and 15" (Grau and Radke 1984), and increasing planting populations to over 175,000 seeds/acre resulted in higher disease compared to lower planting populations (Lee et al. 2005). Fungicide programs have also been shown to significantly reduce white mold of soybean (Willbur et al. 2019). With the work presented here, we hoped to identify the most influential management practices for decreasing the incidence of disease while also maintaining high yields.

In addition to the agronomic controls, breeding for genetic resistance is also being performed in hopes of creating new elite cultivars with physiological resistance to white mold while still retaining high agronomic traits such as lateral branching and high yields. Currently there are 3 groups of breeding lines in the "pipeline" at the Univ. of Wisconsin-Madison, with the most recent having initial crosses occurring in summer of 2018. So far out of this whole endeavor, one line high in white mold resistance has gone public, "Dane," and is commercially available. Any lines developed from this work hopefully can also be used in future breeding plans to further improve commercial germplasm.

There is a significant need to test all combinations of control strategies together to measure the full effect on white mold control. Thus, the objective of our current work are as follows:

Objectives

1. Improve management of white mold by determining the greatest methods for reducing disease pressure
2. Develop soybean lines with high white mold resistance while also retaining favorable agronomic traits

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Materials and Methods

The integrated management trial occurred over the years 2017, 2018, and 2019 at 10 different locations across the upper Midwest. Plots were planted with a white mold moderately susceptible cultivar into either 15- or 30-inch rows and were planted at one of four planting populations; 110,000, 140,000, 170,000, or 200,000 plants/acre. Each plot was then designated one of three fungicide treatments, either non-treated control, applications at the R1 and R3 growth stages, or applications following the disease risk prediction model developed by Willbur et al. (2018a, 2018b). The fungicide Aproach→ was used for all fungicide treatments. Beginning around the R5 growth stage, plots were scouted for disease. A total of 10 - 1 m pushes were made within the inner rows and disease incidence was taken by counting the total number of disease plants in all pushes. Disease severity was scored on a scale of 0-3 as described by Grau et al. (1982).

Currently there are 3 groups of breeding lines in the pipeline. As aforementioned, a newly released cultivar, Dane, has been released out of the first group of breeding lines. This work was previously described by McCaghey and Willbur et al. (2017). The second group of lines were crossed in 2016 with the help of Dr. Asheesh Singh at Iowa State and included crosses between 51-23 and 52-82B and between SSR51-70 and 51-23. With the use of a Chilean winter nursery, these lines have been able to progress through generations quickly. In 2019, the F:6 generation was planted at the Arlington Research Station and final agronomic selections (lodging, branching, plant height) were made. The third group of breeding lines were initially developed in the summer of 2018 by crossing four lines exhibiting favorable agronomics and disease resistance (Savoy, 42-136, SSR51-70, and 91-38). These lines were progressed through greenhouse increases in the spring of 2019 and field-planted in summer of 2019. Initial selections were made within each family by selecting for agronomics.

Results and Discussion

A total of 19 site years have been accumulated in the integrated management study. For analysis, locations were separated based on disease level in the non-treated check. Two levels were established, low (DIX<20) and high (DIX<20). Separate analyses were then performed for the low and high disease level sets. In the high disease locations, fungicide application (P<0.01) and the interaction of row spacing and planting population (P<0.05) influenced yield (shown in Figures 1 and 2). The main effects of row spacing, planting population, and fungicide application significantly (P<0.05) influenced DIX (shown in Figures 3, 4, and 5). In the low disease locations, fungicide application (P<0.0001) and the interaction of row spacing and planting population (P<0.001) influenced yield. Fungicide application (P<0.1) and the interaction of row spacing and planting population (P<0.1) also influenced DIX in low disease environments.

Of the second group of breeding lines, greenhouse disease screenings will begin in the spring of 2020 and preliminary yield trials will follow in 2020 field season. After initial selections, the third group of breeding lines are currently being grown out in Chile over the 2019-2020 winter months and will be planted back in Wisconsin during the summer of 2020 for more selections to occur.

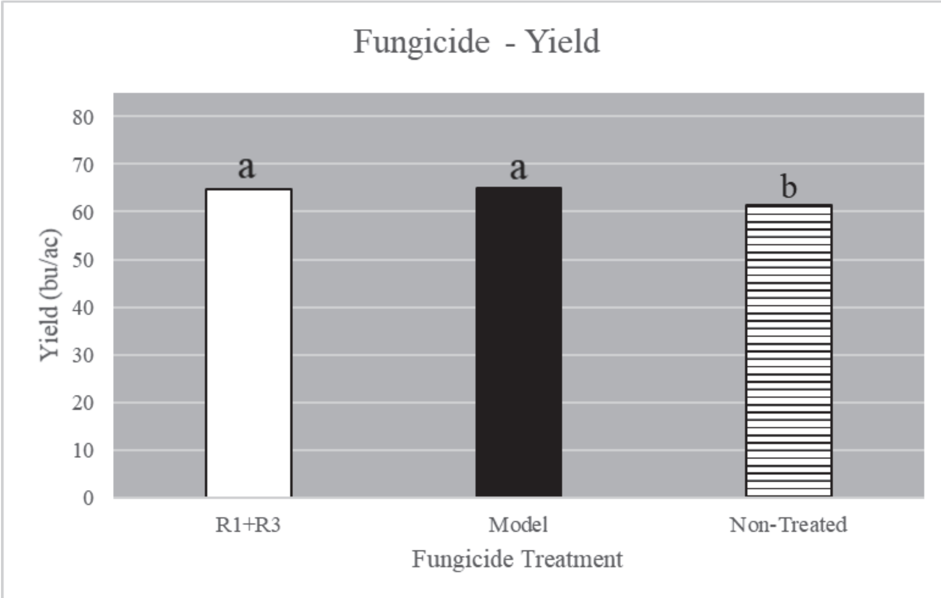

Figure 1. Fungicide application effect on yield in high disease environments across 2017, 2018, and 2019. Locations were pooled and the mean yields were examined using Fischer's least significant difference. Bars assigned the same letter are not significantly different at the α = 0.05 significance level.

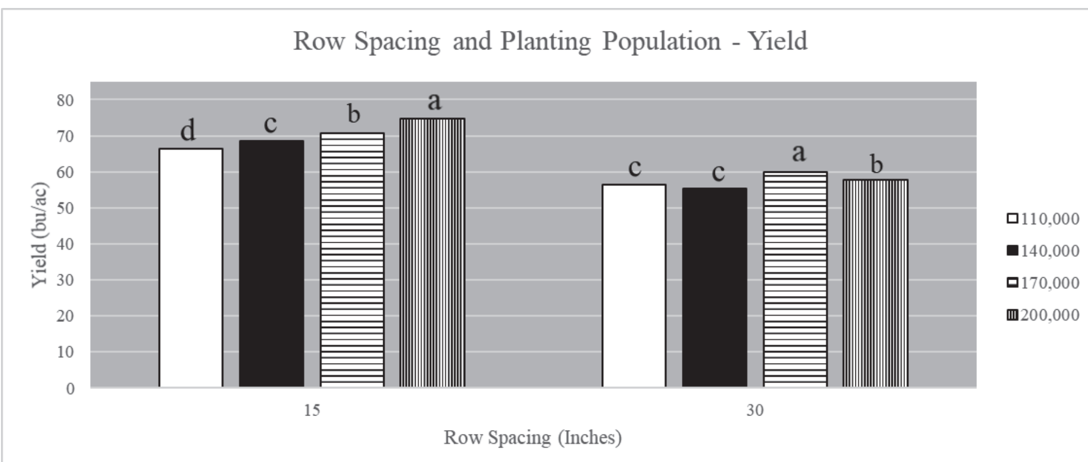

Figure 2. Row spacing and planting population effect on yield in high disease environments across 2017, 2018, and 2019. Locations were pooled and the mean yields were examined using Fischer's least significant difference. Bars assigned the same letter are not significantly different at the α = 0.05 significance level.

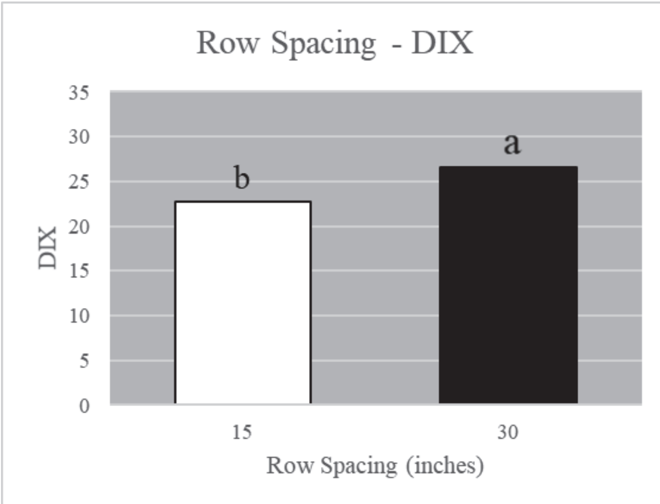

Figure 3. Row spacing effect on DIX in high disease environments across 2017, 2018, and 2019. Locations were pooled and the mean DIX were examined using Fischer's least significant difference. Bars assigned the same letter are not significantly different at the α = 0.05 significance level.

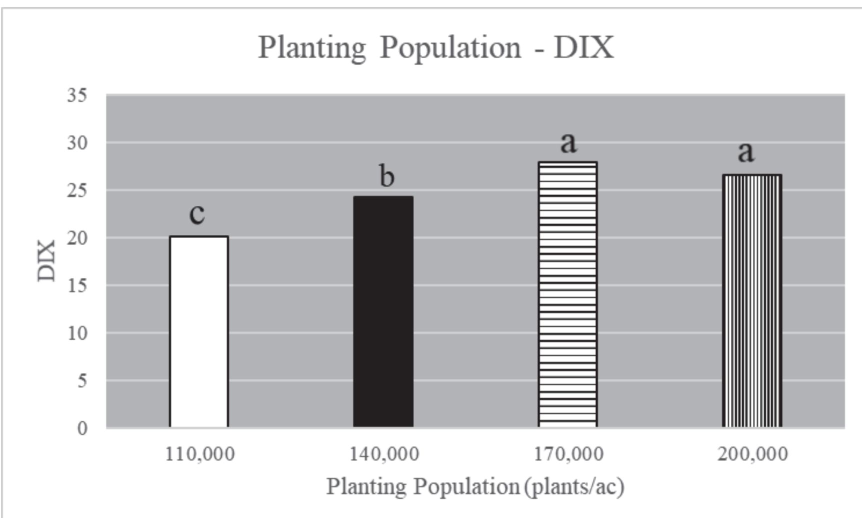

Figure 4. Planting population effect on DIX in high disease environments across 2017, 2018, and 2019. Locations were pooled and the mean DIX were examined using Fischer's least significant difference. Bars assigned the same letter are not significantly different at the α = 0.05 significance level.

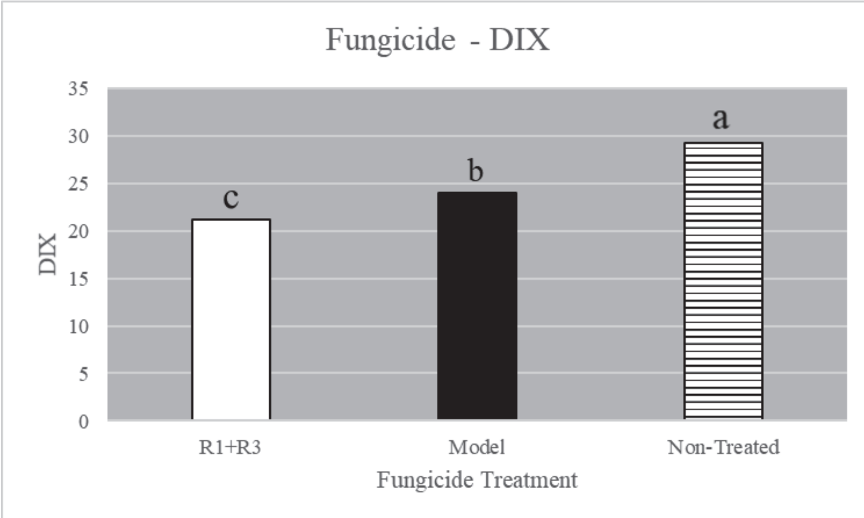

Figure 5. Fungicide application effect on DIX in high disease environments across 2017, 2018, and 2019. Locations were pooled and the mean DIX were examined using Fischer's least significant difference. Bars assigned the same letter are not significantly different at the α = 0/05 significance level.

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CLIMATE CHANGE'S IMPACT ON FIELD CROP DISEASES

Daren Mueller [1/]

Abstract

Weather patterns not only affect crop growth and development, but also the plant pathogens, beneficial and harmful insects, and weed species present in the agro-ecosystem. In recent years, there have been disease outbreaks directly related to extreme weather events including white mold and sudden death. Researchers predict that leaf and root pathogens will be more problematic because of an overall increase in humidity and frequency of heavy rainfall events projected for many parts of the United States. However, other extreme weather events such as drought, hail events, and high winds also will affect diseases from year-to-year and region to region.

Farming practices are modified continually for a variety of reasons, including in response to changing weather patterns. Changes in farming practices can also affect diseases and pests in fields. This presentation will outline how climate and changing farming practices may affect diseases in the Midwest.

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SEED-TRANSMITTED VIRUSES: NEW AND RE-EMERGING THREATS TO WISCONSIN SOYBEAN

Cristina Zambrana-Echevarría and Damon Smith [1/]

Introduction

Viral infections in soybean can affect the health and quality of the seed in a number of ways, but especially when they are transmitted to the plant's progeny. *Alfalfa mosaic virus*, *Soybean mosaic virus*, *Tobacco streak virus*, and *Tobacco ringspot virus* are viruses that infect soybean and transmitted by seed. *Soybean vein necrosis virus* (SVNV) is an emerging virus that causes soybean vein necrosis. SVNV infection in soybean can affect seed health and quality. It is transmitted by seed and has been shown to change protein and oil content (Groves et al., 2016; Anderson et al., 2017). After its first report in Tennessee in 2008, SVNV has spread into major soybean growing regions in the U.S. and Canada (Zhou and Tzanetakis, 2019). Three species of thrips (Thysanoptera: Thripidae) transmit the virus into soybean fields (Keough et al., 2016). These are *Neohydatothrips variabilis* (soybean thrips), *Frankliniella tritici* (eastern flower thrips), and *Frankliniella fusca* (tobacco thrips). Soybean thrips is the primary and most efficient vector of SVNV (Keough et al., 2016). Soybean vein necrosis symptoms start as vein-associated chlorosis that later become reddish-brown necrotic lesions as they expand through the veins and can continue to progress throughout the season. The symptoms are typically observed in soybean late in the season and have been observed after an increase of captures of thrips populations (Bloomindale et al., 2016; Keough et al., 2018).

Tobacco streak virus (TSV) is another seed-transmitted virus of soybean first reported in Iowa (Fagbenle and Ford, 1970). The virus has re-emerged in Oklahoma, Iowa, Wisconsin, among other states (Irizarry et al., 2016). It is considered an understudied virus of soybean that causes yield reductions (Rabedeaux et al., 2005). Thrips have been reported as transmitting the virus by the physical movement of infected pollen (Sdoodee and Teakle, 1993). Tobacco Streak symptoms on soybean include stunting, shepherd's crook, poor pod production, necrotic streaks in the stem, bud blight, and bud proliferation. These symptoms are likely noticed around harvest due to plants with green stems from delayed maturity. Between 2017-2019, we have detected TSV in Columbus, Rusk, and Lafayette counties in Wisconsin. The re-emergence of TSV and emergence of SVNV as pathogens of soybean poses a threat to soybean seed health and quality.

Objectives

1) Survey of variety trials in Wisconsin to assess the occurrence of SVNV and TSV infections.
2) Monitor populations of thrips that transmit SVNV, using sentinel crops, to determine the timing of arrival of viruliferous thrips.

Materials and Methods

Variety Trials

Conventional variety trials were established by Dr. Shawn Conley's lab from the Department of Agronomy at UW-Madison in three counties: Chippewa, Columbia, and Lafayette or Grant. These trials were scouted for viral symptoms in 2018 and 2019. Plants with or without viral symptoms were sampled for each location. SVNV and TSV were detected using nested RT-PCR and gene specific primers for the nucleoprotein gene and coat protein gene, respectively.

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Thrips Monitoring
A field trial of sentinel plots was established from 2017 to 2019 at the Arlington Agricultural Experiment Station (AARS). Eight replicated plots measuring 20 x 20 ft consisted of eight rows with four rows of cowpea (California Blackeye #5; the sentinel crop) in the center with two outer rows with soybean (Dwight). Yellow sticky traps were placed in an east to west transect at the center of each plot and changed weekly. Twenty squares per trap were randomly selected to identify the thrips that transmit SVNV: soybean thrips, eastern flower thrips, and tobacco thrips. The number of thrips captured per card were determined based on the counts from the randomly sampled cells and extrapolated to the total number of squares in the trap. Asymptomatic and virus-like symptomatic plants were collected weekly for virus detection using nested RT-PCR to correlate with the seasonal patterns of thrips population.

Results and Discussion

Variety trials were scouted for SVNV and TSV in 2018 and 2019. A total of 20 symptomatic plants were sampled among the trials in 2018. Out of the 20 samples, 15 were positive for SVNV only and 5 were positive for SVNV and TSV. These finding suggests naturally occurring SVNV and TSV mixed infections. In 2019, 64 samples (symptomatic and asymptomatic) were collected from all three locations. Incidence of soybean vein necrosis symptoms (Fig. 1A) was higher in 2018 (2%) in Lafayette County and in 2019 (4.2%) in Grant county, compared to Chippewa and Columbia on both years. Plant with delayed maturity and TSV-like symptoms were observed in 2019 (Fig. 1B). The virus was detected in Columbia county in at least 2 plants. While the effect of SVNV and TSV infections on seed health and seed quality were not evaluated in this study, these results show that these viruses continue to occur in Wisconsin. The presence of these seed-transmitted viruses in single and mixed infections can have detrimental effects to soybean production.

Figure 1. Symptoms caused by *Soybean vein necrosis virus* (A) and *Tobacco streak virus* (B) on soybean plants from the variety trials.

Thrips populations that transmit SVNV were monitored in the growing season from 2017 to 2019 using sentinel plots. In all three years, eastern flower thrips comprised the majority of captures (Fig. 2). During the 2017 season, there was a dispersal event (i.e., peak) of eastern flower thrips early in the season (June-July) but the population declined after that. Soybean thrips showed two dispersal events (Fig. 2A) late in the season. Tobacco thrips had one dispersal event before soybean thrips (Fig. 2A). SVNV was detected in September and TSV was detected mid-season

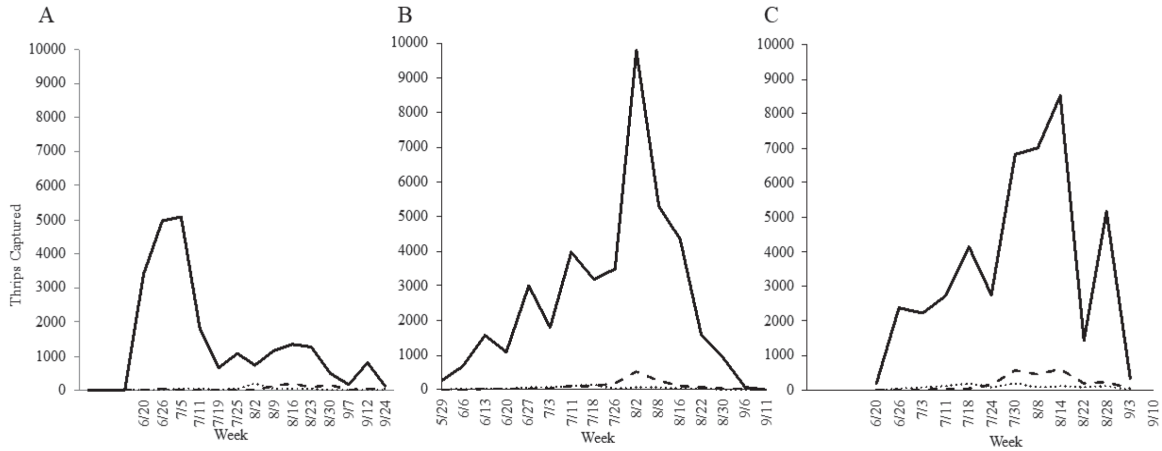

Figure2. Weekly captures of thrips that transmit SVNV in 2017 (A), 2018 (B), and 2019 (C). Eastern flower thrips (black line), soybean thrips (dashed line), and tobacco thrips (dotted line).

(July). In 2018, the dispersal patterns were different than in 2017. Overall, the dispersal events occurred mid to late in the season. Eastern flower thrips had 4 dispersal events starting from early (June) to late (August) in the season and quickly declined. Soybean thrips had one dispersal event in late August (Fig. 2B) that was followed by the detection of SVNV in the trial. Similar to 2017, tobacco thrips had one dispersal event, but there was a second peak at the same time as eastern flower thrips and soybean thrips in 2018 (Fig. 2B). TSV was detected in the trial in mid-July in both 2017 and 2018. In 2019, thrips populations increased around mid-season. Eastern flower thrips had three dispersal events from July-August, soybean thrips had two in early August, and tobacco thrips in July-August. SVNV and TSV were detected in late August of 2019. TSV was detected in mid-season most of the years with no relationship with the seasonal patterns of the thrips species studied here. TSV is transmitted by many different species of thrips (Sdoodee and Teakle, 1993) and it is possible that there were other thrips species responsible for its transmission. In all three years of captures, SVNV was detected following an increase in soybean thrips around early August (Fig. 2). Precipitation and temperature can have a variable effect on thrips populations (Keough et al., 2018). Weather patterns during the years of captures cannot be discarded as factors that contributed to these seasonal dynamics. The data from thrips captures, along with weather data, will be used to develop a model for describing the arrival of viruliferous thrips for 2017-2019.

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FOLIAR FUNGICIDE CONSIDERATIONS FOR CORN AND SOYBEAN

Daren Mueller [1/]

Abstract

Fungicide-resistant strains of the pathogen that causes frogeye leaf spot was first found in Iowa in 2017 and Septoria brown spot in 2018. These findings have changed the efficacy of fungicide products used in the Midwest. We conducted a state-wide survey of strains of the fungus in 2019 and found that EVERY isolate of the pathogen was resistant to the QoI (sometimes called strobilurins) fungicides. Similar findings have been reported in several other Midwestern states. This confirms that the resistant strain of the pathogen is widespread and this should affect your decision on which fungicides to use moving forward. One place to gather information on fungicide efficacy is the Crop Protection Network webpage. Started in 2015, the CPN now serves as the infrastructure for corn, soybean, and small grain Extension outputs from a diverse set of collaborators across the United States. This network is primarily made up of individuals in land grant universities in the United States and closely related organizations in Canada, but includes other entities that contribute to agricultural Extension. Before deciding about using foliar fungicides, be sure to visit www.cropprotectionnetwork.org.

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MANURE, PHOSPHORUS, AND 125 SITE-YEARS OF EDGE-OF-FIELD RUNOFF MEASUREMENTS

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Abstract

Phosphorus export from agricultural fields continues to create water quality concerns in Wisconsin. The UW Discovery Farms program, along with Discovery Farms Minnesota have collected 125 site-years of edge-of-field monitoring data which can be used to better understand the relative effects of inherent soil properties (slope, drainage class, texture), management practices (manure application, tillage, crop rotation, cover cropping), and soil test P values on seasonal (frozen and non-frozen conditions) losses of dissolved P (DP) and total P (TP). The objectives of this study were to: (1) determine the seasonal controls of DP and TP loss, (2) determine the effect of manure application, tillage, and soil test P on DP and TP loss, and (3) evaluate the relative contribution of inherent soil properties and management practices on seasonal DP and TP loss. The relationship between DP and TP concentration was very strong during frozen conditions, but quite weak during non-frozen conditions. Manure application had a greater effect on DP and TP flow weighted mean concentration (FWMC) during frozen conditions compared to non-frozen. During non-frozen, pasture had greater FWMC compared to other manure applications. Tillage practices led to inconsistent effects, sometimes increasing and sometimes decreasing FWMC relative to no-till. The relationship between STP and FWMCs during frozen or non-frozen conditions was generally weak, with R^2 values less than 0.27. Regression tree analysis identified soil test P (0-2”) as the most influential factor for DP FWMC during non-frozen conditions and TP and DP FWMC during frozen conditions. Tillage was the most influential factor for TP FWMC for non-frozen conditions. Collectively, this work, along with future analysis can lead to a greater understanding of the relative influence of factors that drive P loss. This analysis would suggest that reducing soil test P would be the first step to reduce P loss for most conditions, although tillage reduction should be the first step to reduce TP during non-frozen conditions.

Justification

Controlling phosphorus loss from farm fields in Wisconsin continues to be a challenge. The Wisconsin Department of Natural Resources has identified more than 5,400 miles of streams and 230 lakes as “impaired” based on total concentrations (WDNR, 2015). However, improve-ments can be made at a watershed scale through targeted implementation on high-export fields (Carvin et al., 2018). Agricultural management practices such as no-tillage, conducting nutrient management plans reduce STP and manage manure, and increasing vegetative cover (of both managed lands and field boundaries) as well as engineering practices such as grade-stabilization structures and stream bank stabilization, have been promoted as conservation practices to help mitigated P loss. While P loss is estimated through process models or through

P indexes (e.g., Wisconsin phosphorus Index), what is often lacking is empirical data of edge-of-field losses. The UW Discovery Farms program. While classic experimental design limitations prevent direct comparison of individual management practices through reductionist research, other statistical approaches can be used to understand the relevance and the magnitude of inherent soil properties and management practices on P loss. The objectives of this study were to: (1) determine

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the seasonal controls of DP and TP loss, (2) determine the effect of manure application, tillage, and soil test P on DP and TP loss, and (3) evaluate the relative contribution of inherent soil properties and management practices on seasonal DP and TP loss.

Materials and Methods

UW Discovery Farms and Discovery Farm Minnesota Dataset

The field scale edge-of-field runoff monitoring data presented in this study were generated by UW Discovery Farms and Discovery Farms Minnesota (hereby collective referred to as Discovery Farms), which in partnership with agricultural producers has fostered this on-farm research. The producers within this dataset represent a broad spectrum of current farm management practices and environmental conditions across the Wisconsin and Minnesota. Edge-of-field runoff measurements were installed in collaboration with the USGS (USGS, 2008). The Discovery Farms annual edge-of-field runoff monitoring dataset was evaluated in a series of screening layers to ensure the validity of the resultant dataset and narrow its focus to represent common agricultural practices. The first screening layer omitted sites that were not in an agricultural land use or reflected a non-representative agricultural land use. The second layer removed sites or site years that contained incomplete data or data that could not be validated. The third layer evaluated the subsequent dataset for outlier sites or site years using a simple linear regression model. The linear regression evaluation was conducted in R and screened dependent nutrient variables against input variables known to have a significant relationship (runoff depth and precipitation) for normality. Sites and site years that were believed to be non-normal underwent further evaluation to determine the integrity of the data prior to retaining or omitting the data. The resultant dataset is comprised of 26 individual agricultural sites (Figure 1), in two states (MN, WI), and over the course of 14 water years spanning from 2004 to 2017.

The resultant dataset, was originally established on a hydrologic year set between (October 1st to September 30th). In order to narrow the focus of the study and investigate the effects of field-level management practice on edge-of-field phosphorus loses under frozen conditions the dataset was divided into two sub-datasets based on soils' thermal phase of (1) non-frozen soil and (2) frozen soil. The soil temperature used to separate the two sub-datasets was monitored on site at depths ranging from 2 to 80 cm in WI (USGS 2008-1015, 2008) and 5 to 60 cm in MN (Discovery Farms SOP, 2011). If the soil temperature profile contained any temperature below 32°F the soil was considered frozen.

The agricultural land use variable was comprised of two categories: annual cropping (including beans, beet, corn, mix, soy, wheat) and perennial cropping (alfalfa-based rotations and pasture). Crop rotation was also simplified into four categories: (1) continuous corn, (2) corn-soybean (which may contain other small grains), (3) pasture, and (4) perennial legumes (where alfalfa was the dominant crop in rotation. Tillage practices were narrowed into four categories: (1) pasture, (2) no-till, (3) minimal-till (including vertical and strip tillage) and (4) conventional (including disk, chisel, moldboard plow, cultivator, injection, and rip tillage). Manure practices were separated in five categories based on field practices and the soil thermal phases: (1) no manure, (2) applied non-frozen soil, (3) applied early frozen soil approximately December and January, (4) applied late frozen soil approximately February and March, and (5) pasture fields receiving manure year-round from grazing animals. The dependent variables TP and DP flow weighted mean concentrations (FWMC) were derived from the Discovery Farms edge-of-field monitoring stations. TP and DRP loads were calculated by multiplying the composite sample TP and DP concentration by their respective flow volume and reported on a per-hectare basis. TP and DP FWMC were determined by dividing loads, irrespective of unit area, by their respective flow volumes.

Statistical Analysis

Statistical data analysis and graphing were conducted in the R statistical environment version 3.5.1 (R Core Team, 2018). Univariate analysis of the input and dependent continuous variable was conducted with the "summary" function, while skewness and kurtosis were determined with the package "moments". Regression analyses were used to determine the relationships between TP FWMC and DP FWMC, as well as, TP FWMC or DP FWMC and soil test phosphorus with their respective soil thermal phase. Field-level manure and tillage management practices were separately analyzed for treatment effects on TP FWMC and DP FWMC using a Tukey Honest Significance Difference one-way ANOVA ($\alpha = 0.05$) with a general linear fit model using the package "agricolae". The relationships between field-level manure as well as tillage management practices and the dependent nutrients were determined to behave non-normal and potentially impact results, thus the data were log(x+1) transformed prior to analysis. The predictive models developed in this study were constructed from the regression tree analysis packages "rpart" and "rpart.plot." Regression tree analysis can evaluate relationships or make predictions based on a wide array of input variables and is utilized broadly across ecological, agronomic, and hydrologic scientific disciplines (e.g., Jakubowski et al., 2010; Smidt et al., 2016). A regression tree initiates with single root node that contains the entire data set. The root node is analyzed and partitioned by a predictor variable resulting in the greatest reduction in variability within the two descendant nodes. The process of node splitting continues until the tree reaches a limiting factor such as the complexity parameter (CP) or a minimum observation limit required to split a node is reached.

Surface runoff TP and DP FWMC or TP and DP loads were the primary response variables in the regression trees and the entire list categorical and continuous input variables is described in Zopp et al. (2019). Regression trees in this study were grown so that each node had at least 20 observations, each leaf had seven observations, and a CP = 0.001. The most parsimonious tree was selected through the application of the 1-SE rule as the smallest tree within one standard deviation of the minimum standard error. The 1-SE rule was applied in this study to locate the lowest number splits, by taking the sum of the smallest 10-fold cross validation error (xerror) and its corresponding standard error (xstd); the sum is then used to determine the cross-validation error and corresponding CP value via linear interpolation. The selected CP value is then used to prune the most parsimonious tree with the lowest number of splits. The variables of importance and top five completing splits for the primary node were reported by the "summary" function and the R^2 for the regression tree was determined the equation: $R^2 = 1 -$ relative error.

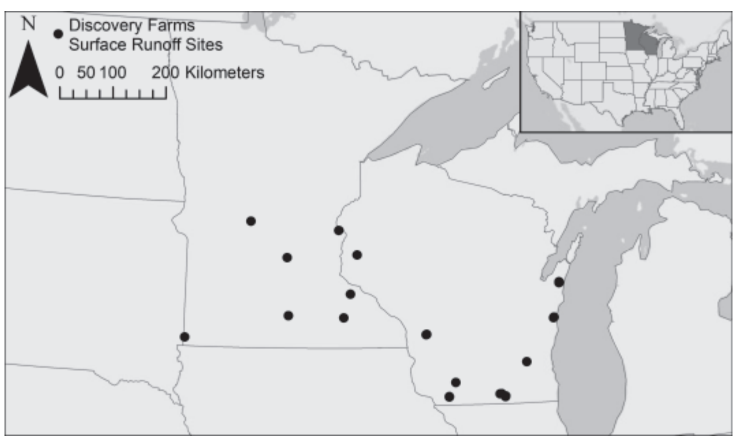


Figure 1. Location of the 26 farm fields used in this study.
Fields within 10 miles of each other are represented with one dot.

<u>Flow-weighted Mean Concentrations</u>
The TP and DP FWMC relationships for the non-frozen and frozen soil phases, seen in Figure 2, were both found to be significant ($P < 0.001$). However, only the frozen phase TP and DP FWMC relationship was determined to behave linearly with an adjusted $R^2 = 0.96$, while the non-frozen relationship was determined to behave non-linearly with an adjusted $R^2 = 0.11$.

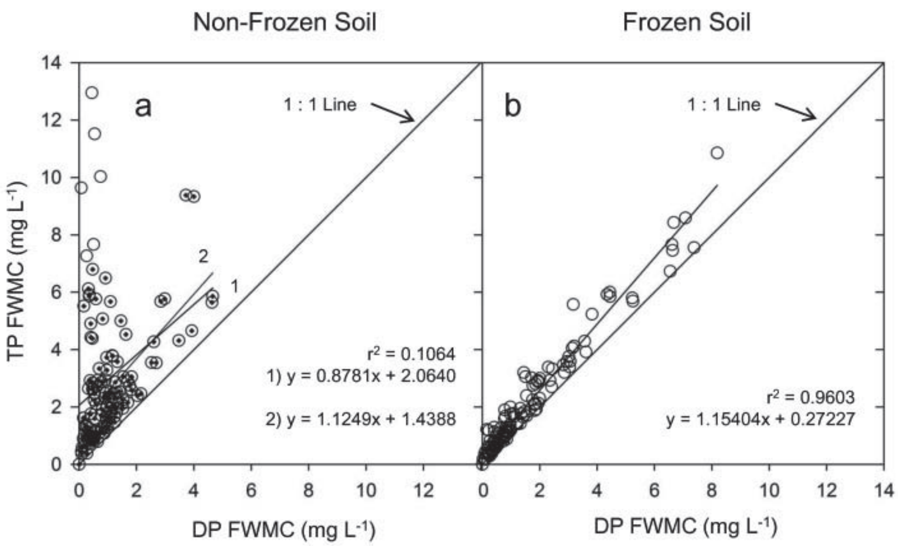


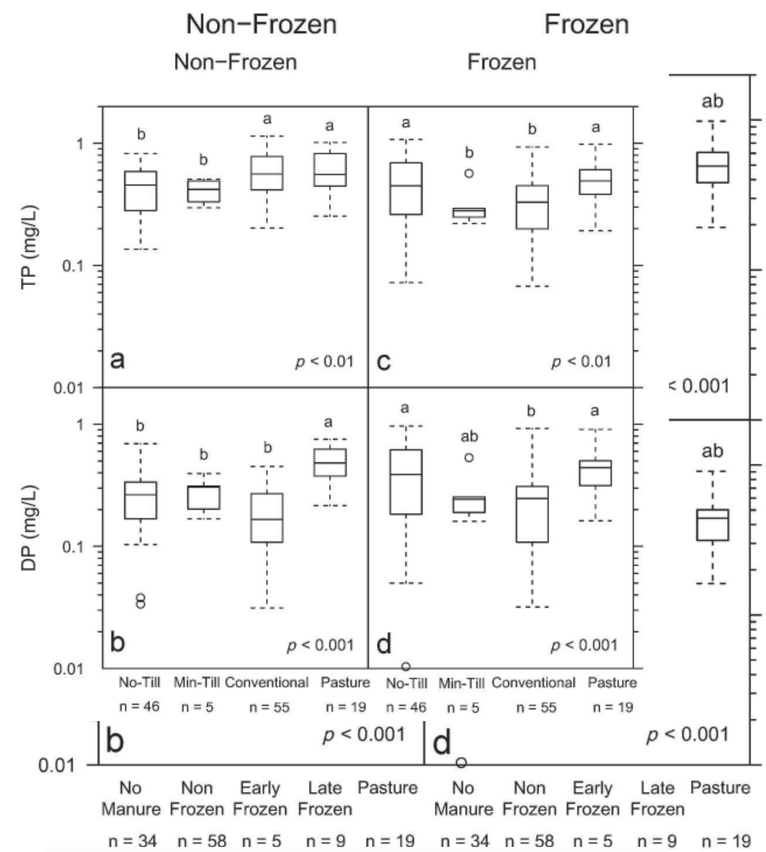
Figure 2. Relationships between total P (TP) flow weighted mean concentration (FWMC) and dissolved P (DP) FWMC during non-frozen soil conditions or frozen soil conditions (n = 125).

The slope ($b = 1.15$) of the frozen TP and DP FWMC linear regression indicates that potentially 87.7% of TP was comprised by DP; while the non-frozen was relationship too weak ($R^2 = 0.11$) to make such an estimate. Alternatively, the TP/DP ratio can also estimate the amount of TP comprised of DP. Based on the TP/DP ratio, DP FWMC on average accounted for 17.5% of TP during non-frozen phases and 60.1% of TP during frozen phases.

<u>Management Practice Dynamics</u>
Field-level manure practices, using a significance level ($\alpha = 0.05$) were shown to influence TP and DP FWMCs (Figure 3). The influence of field-level manure practices was predominately observed during the frozen soil phase. Seen in Figure 3c, the application of manure during the late frozen phase yields significantly ($P < 0.001$) higher TP FWMC as compared to a no manure or non-frozen manure application practices. The early frozen phase were similar to all other practices.

The application of manure during the late frozen phase was observed to result in significantly higher ($P < 0.001$) DP FWMC, as compared to the no manure and non-frozen manure application practices (Figure 3d). Pasture yielded significantly higher DP FWMC during frozen as compared to the no manure practice, but was similar to all other practices. The comparison of manure practices during the non-frozen soil phase showed no significant ($P < 0.05$) treatment difference in TP FWMC across all groups, even though individual comparisons of manure practices may have differed (Figure 3a). However, pastured fields produced significantly ($P < 0.001$) higher DP FWMC as compared to any other manure practice (Figure 3b).

Figure 3. Box plots of manure application timing and TP or DP flow weighted mean concentration (FWMC) during non-frozen (n = 125) or frozen soil condi-tions (n = 125). Relationships are log(x+1) – log(x+1) transformed. Results from a one-way ANOVA (Tukey) in R (α = 0.05) are indicated by letters above the 90th percentile whisker.



Field-level tillage practices, using a significance level (α = 0.05) were shown to impact log(x+1) transformed TP and DP FWMC for every soil phase (Figure 4).

Figure 4. Box plots of tillage practices TP or DP flow weighted mean concentration (FWMC) during non-frozen (n = 125) or frozen soil conditions (n = 125). Relationships are log(x+1) – log(x+1) transformed. Results from a one-way ANOVA (Tukey) in R (α = 0.05) are indicated by letters above the 90th percentile whisker.

The comparison of tillage practices during the non-frozen soil phase indicated that both conventional tillage and pasture "tillage" (bovine animals continuously roaming) practices yielded significantly ($P < 0.01$) higher TP FWMC as compared to no-till and minimum tillage practices (Figure 4a). Furthermore, pastured fields produced significantly ($P < 0.001$) greater DP FWMC as compared to any other tillage practice (Figure 4b).

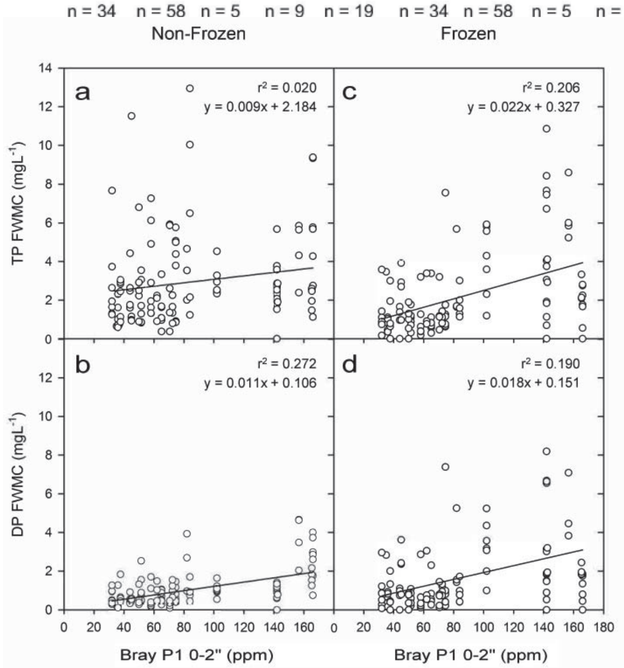


Figure 5. Relationships between 0 – 6 inch depth soil test Bray 1 phosphorus and total P (TP) or dissolved P (DP) flow weighted mean concentration (FWMC) during non-frozen or frozen soil conditions (n = 122).

Comparisons of tillage practices during the frozen soil phase reveal a slightly different set of influences. As seen in Figure 4c, both the no-till and pasture tillage practice yield significantly ($P < 0.01$) greater TP FWMC as compared to minimum tillage and conventional. No-till and pasture tillage practices again result in significantly ($P < 0.001$) higher DP FWMC as compared to conventional tillage, with minimum tillage being similar to all practices. In contrast to tillage and manure applica-tions, the relationship between TP or DP FWMC and soil test P (0-6") was weak with R^2 values less than 0.272, although positively associated (Figure 5).

Regression Tree Analysis

Regression tree analysis, within the bounds of the 1-SE rule, did result in reportable trees for TP and DP FWMC across the non-frozen and frozen soil phases. The TP FWMC non-frozen soil was only split by tillage practice (1.9 mg L^{-1} for minimum tillage and no-till; 3.6 mg L^{-1} for conventional and pasture) and only explained 11.6% of the variation. The DP FWMC non-frozen was only split by 2" soil test P (Bray-P) (0.76 mg L^{-1} if less than 150 ppm and 2.7 mg L^{-1} if greater than 150 ppm), but it explained 45.2% of the variation. The trees for TP frozen and DP frozen both had the 2" soil test P as the first split (Figure 6 and 7).

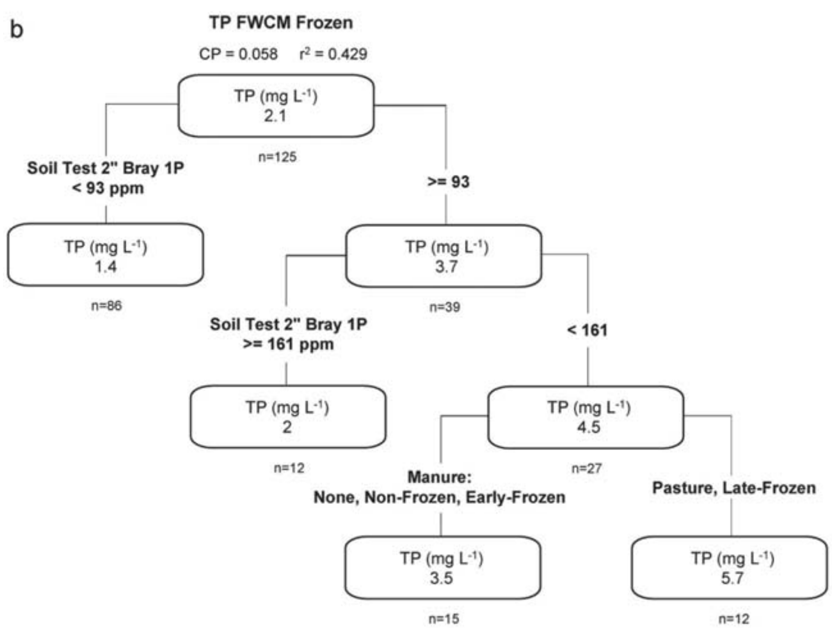


Figure 6. Regression tree results for TP FWMC under frozen conditions.

For TP frozen, additional splits under >93 ppm STP were an additional STP split of 161 ppm and manure application (with pasture and late-frozen having greater TP FWMC than other manure applications). For DP frozen, there was an additional split under >93 ppm STP of 161 ppm STP (Figure 7).

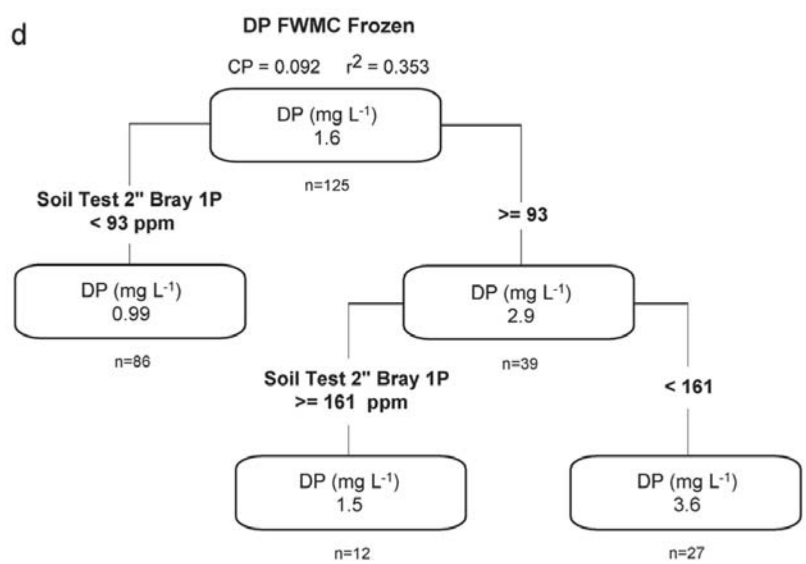


Figure 7. Regression tree results for DP FWMC under non-frozen conditions.

Conclusions

Clearly the relationship between TP and DP FWMC differs by environmental condition (frozen or unfrozen). Tillage, soil test P, and manure application were all influential aspects of TP and DP loss, but the magnitude of the influence differed between frozen and non-frozen conditions. Interestingly, inherent soil factors such as slope, texture, and drainage class were not influential based on regression tree analysis. These results confirm the conventional wisdom related to tillage, manure application, and soil test P, although no-till did not result in lower P losses during frozen conditions. Pasture also had much higher P losses than expected. More work is needed to understand that effect. But collectively, this work, along with further analysis, can lead to a greater understanding of the relative influence of factors that drive P loss. This analysis would suggest that reducing soil test P would be the first step to reduce P loss, followed by reduction in tillage.

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DOES IMPROVED SOIL HEALTH ALWAYS RESULT IN BETTER WATER QUALITY?

Francisco J. Arriaga [1/]

The hydrologic cycle is closely associated with soil. Soil purifies and stores water. These are important functions that soils provide for plants and are essential components of soil health. Soil health is defined as "The capacity of a soil to function within ecosystem boundaries to sustain biological productivity, maintain environmental quality, and promote plant and animal health" (Soil Science Society of America, 2008). Although the relationship between soil health and water quality is known, often it is difficult to observe their direct connections. For example, cover crops can enhance soil health by increasing soil organic matter, improve aggregation, increase water infiltration, cycle nutrients, reduce evaporative losses, and reduce erosion, among others. The value of cover crops for improving soil health and water quality is obvious, but the benefits of other practices are not as clear. Manure applications to soil can help improve soil quality by increasing soil organic matter and providing nutrients, but manure application on the landscape has the potential to impair water quality when not done properly. Therefore, it is important to understand that crop and soil management decisions can have an impact on other parts of the environment. The concept of soil health recognizes these connections and provides a framework that can be used to build upon. However, soil health and water quality might not always be compatible. During this talk links between soil health and water quality as they relate to agricultural production will be reviewed

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HOW CAN SOIL HEALTH MEASURES BE USED TO INFORM FARM MANAGEMENT?

Steve Culman [1/]

Soil health has enjoyed a meteoric rise over the past decade, and it appears that interest is only continuing to increase. But despite all of the attention, how much progress has actually been made? Do we know more about soil health today than we did 20 years ago? Are our laboratories more capable of quantifying soil health in meaningful ways? Do we know which farm practices help maximize soil health? In order for soil health to become cemented as a widespread and useful framework, farmers need to find soil health measurements useful in making on-farm decisions. This talk will highlight recent Midwest work in active organic matter measurements and how they reflect soil and crop function.

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COVER CROP MANAGEMENT IS KEY TO REDUCE RUNOFF AND PHOSPHORUS LOSSES

Francisco J. Arriaga and Matthew D. Ruark [1/]

Cover crop can provide important ecosystem services in agricultural systems by reducing the risks of nutrient losses to the environment. Reducing nutrient losses from farmland should also help improve agricultural viability by reducing the amount of nutrients that need to be imported back to the farm. A study was established to determine the impact of cereal rye (*Secale cereale* L.) and dairy liquid manure application method (surface, low-disturbance and deep injection) on phosphorus losses from soil under corn silage production. Manure was applied in the fall at 8,000 gal/acre rate to a cover crop that was drill seeded three weeks prior. A rainfall simulator was used to compare water runoff volume and phosphorus losses between management schemes. Rainfall simulations were conducted 2 weeks after manure application in the fall, in the spring, and early summer (corn at V3 stage). There were significant differences in phosphorus losses between the different simulation timings, with more phosphorus lost in the fall. Cover crop had a less important role relative to method of manure application for phosphorus losses, especially in the fall. This can be attributed to low biomass present at the time of the fall simulation. Runoff losses were lower with the cover crop in the spring. This study's results underline the importance of establishing a cover crop early to maximize fall biomass production and that the method of manure application plays an important role. Future work includes comparing other rye cover crop and manure application combinations, and investigating nitrogen availability to the following corn crop.

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NITRATE: AN ION FOR ALL SEASONS

Kevin C. Masarik[1] and Christopher J. Kucharik[2]

Nitrogen fertilizers and other nutrient sources (e.g., manure, bio-solids, legume credits, etc.) are critical for maintaining the productivity of agricultural systems, however a portion of nitrogen applied with these methods leaches to groundwater as nitrate. Nitrate is generally considered Wisconsin's most widespread groundwater contaminant and occurs at levels considered unsuitable for drinking water in an estimated 8.2% of private wells throughout the state (DATCP, 2017). Agricultural systems represent the most significant contribution of nitrate to Wisconsin's groundwater.

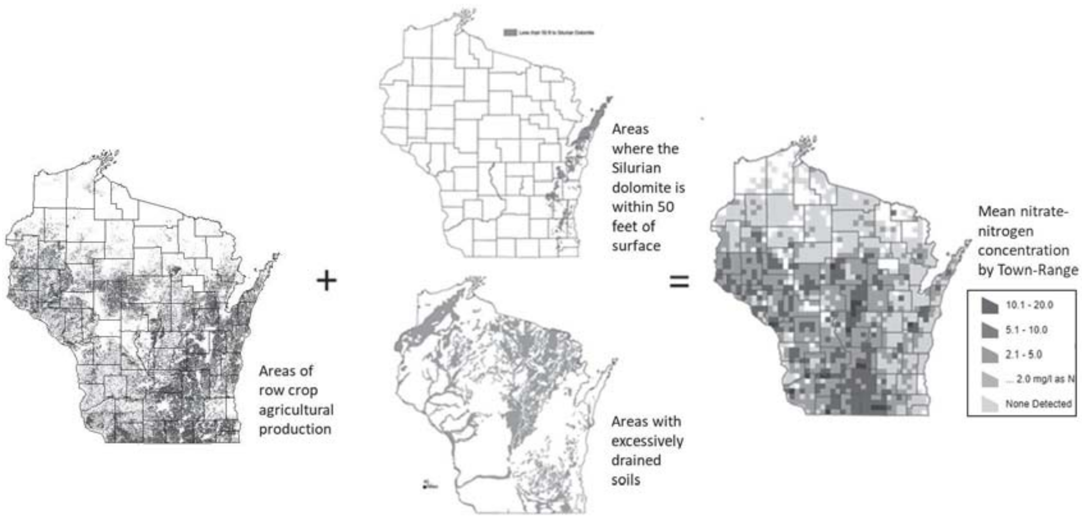

Figure 1. Nitrate in groundwater is generally greater in agricultural areas. Soils and other geologic concerns can help limit or exacerbate how much nitrate reaches groundwater.

While significant research has been performed in Wisconsin investigating how to best manage nitrogen for optimizing crop productivity (Laboski and Peters, 2012); less research has been performed investigating various management practices and impacts to groundwater. Even under optimal nitrogen recommendations, agricultural systems result in some nitrate loss to groundwater (Masarik et al., 2014).

From 2016-2019, a study was conducted to quantify nitrate leaching losses below an irrigated field in the central sands region of Wisconsin. Lysimeters were used to measure year-round water drainage and nitrate leaching losses. Results showed nitrate losses to be variable from year to year; significant nitrate losses occurred outside the growing season in some of the years.

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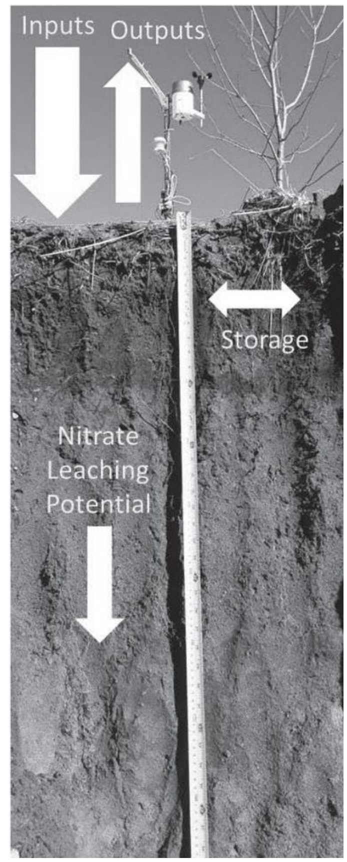
Crop type is a good predictor for understanding why leaching losses were higher in some years compared to others. However, variability in precipitation patterns and soil temperature can be important factors, particularly for understanding when during the year nitrate leaching is likely to occur. Understanding the timing of leaching losses is useful for understanding where additional improvements to groundwater quality can be made.

A simple nitrogen budget calculator was then used to estimate potential nitrogen leaching losses. The calculator utilizes a mass balance approach to calculate the leachable nitrogen once all the major inputs (fertilizer, manure, irrigation water, etc.) and outputs (nitrogen removed via harvested portion of crop) are accounted for (Meisinger and Randall, 1991).

Nitrate Leaching Potential = Nitrogen Inputs – Nitrogen Outputs – Change in Nitrogen Storage



The annual nitrate losses estimated with the simple nitrogen budget calculator compare well with lysimeter measurements of nitrate leaching. This simple method for quantifying leachable nitrogen may help growers better understand where improvements could be made for improving groundwater quality.

There is no one size fits all solution to improving groundwater quality with respect to nitrate. A combination of strategies and techniques that considers a year-round approach to managing nitrate will be required. Meaningful progress requires creativity, experimentation, and collaboration from both the agricultural community and water quality researchers to develop a range of solutions to a complicated problem.

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TALKING PLANTS: THE SCIENCE BEHIND GOOD WEED MANAGEMENT

C. Swanton [1/]

Understanding how plants can talk provides us with an opportunity to "eves drop" into their conversation and explore how this exchange of information is affecting plant health. I will illustrate using research examples, how quickly crop plants are able to detect and respond to the presence of neighbouring weeds. I will attempt to prove that crop plants such as corn and soybeans growing in the presence of weeds are in a state of constant communication. This communication results in molecular, physiological and morphological changes that help explain crop yield loss caused by weeds. These results also provide a scientific bases for the importance of early season weed control.

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PALMER AMARANTH: IT COMES HERBICIDE PROOF AND ADAPTS WELL TO WISCONSIN

Rodrigo Werle, Maxwel Oliveira, Felipe Faleco, and Nick Arneson[1]

Palmer amaranth is ranked as the most troublesome weed species in the southern US. In recent years, Palmer amaranth has become more predominant in the southern part of the Midwest, further increasing the complexity of weed management in corn and soybean production systems in the region. Having similar biological characteristics as waterhemp (male and female plants, prolific seed producer, wide emergence window, and vigorous growth), Palmer amaranth can be difficult to control and capable of rapidly evolving resistance to herbicides. Populations from across the US have been documented to have evolved resistance to 8 herbicide sites of action (SOAs) including groups 2 (ALS-inhibitors), 3 (Microtubule inhibitors), 4 (synthetic auxins), 5 (PSII-inhibitors), 9 (EPSPS-inhibitors), 14 (PPO-inhibitors), 15 (VLCFA-inhibitors), and/or 27 (HPPD-inhibitors). Of these, populations identified in Wisconsin have been confirmed resistant to groups 2, 9, and/or 27 (Heap, 2019). Separate individual populations from Kansas and Arkansas have been documented to have evolved resistance to 5 different SOAs.

Greenhouse experiments were conducted to determine herbicide-resistance level of a Palmer amaranth population from southern Wisconsin identified in August of 2018. Two Palmer amaranth populations from Nebraska were included for comparison. The populations were screened to preemergence (PRE) and postemergence (POST) herbicides commonly used in corn and soybean production. PRE treatments included atrazine, mesotrione, metribuzin, sulfentrazone, and S-metolachlor at 0.5x, 1x, and 3x label rate. POST treatments included glyphosate, imazethapyr, atrazine, lactofen, mesotrione, glufosinate, and dicamba at 1x and 3x label rates. PRE treatments were applied at planting of Palmer amaranth and POST treatments were applied when plants reached 2-4 inches tall. For the PRE experiment, number of established plants was determined at 25 days after treatment (DAT). For the POST experiment, a visual evaluation was taken on a scale from 1 (dead) to 10 (healthy) at 21 DAT. Palmer amaranth populations were considered resistant to each POST treatment if more than 50% of treated plants across both experimental runs had VE $\geq$ 7. Atrazine did not provide satisfactory control in PRE emergence applications. Reduced PRE rates (0.5X) resulted in lower Palmer amaranth control for some herbicides. All populations tested in the POST emergence screenings were found to be resistant to imazethapyr (1x and 3x), two populations to glyphosate and atrazine (1x), and one population to atrazine (3x). The Wisconsin population was resistant to these three herbicides. Glufosinate resulted in the most satisfactory POST control. The results from these studies indicate that novel infestations of Palmer amaranth are likely to be resistant to herbicides.

Research investigating Palmer amaranth adaptation across a range of US Midwest climates was conducted in 2018 and 2019 in Wisconsin (1 location), Nebraska (3 locations), and Illinois (1 location) to evaluate the adaptation of Palmer amaranth to different cropping systems (corn, soybeans, and fallow). At each location a block of corn and soybean on 30 in row spacing were planted in May and a fallow block was established as well. Palmer amaranth plants were transplanted to the field at the 2-3 leaf stage at two timings (early June and early July). Palmer amaranth growth was influenced by location, crop emergence time

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and crop canopy type. Overall, Palmer amaranth plants transplanted in June produced higher biomass in fallow compared to corn and soybeans. When growing in corn and soybeans, Palmer amaranth produced higher biomass if transplanted in June compared to July. Palmer amaranth produced more biomass at the two westernmost Nebraska locations, center of origin of the population used herein, but it was also able to reach reproductive stages and produce a significant amount of biomass in the northernmost site (Arlington, Wis.). Results of this study indicate that if seeds are introduced and proper management is not adopted immediately, Palmer amaranth will likely establish and thrive in the upper Midwest cropping systems.

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WATERHEMP MANAGEMENT WITH RESIDUAL HERBICIDES IN ESTABLISHED ALFALFA

J.L.C.D. Dias[1], M.J. Renz[1], E. Burns[2], R. Becker[3], and J. Wallace[4]

Introduction

Alfalfa (*Medicago sativa* L.) is one of the most important perennial forages in Northern regions of the USA. It provides a high yielding and quality forage as well as key ecosystems services as part of a rotation with annual crops. In addition, one of the under-valued services is weed-control as it has been documented that alfalfa stands can reduce weed populations if managed correctly (Clay and Aguilar, 1998; Goplen et al., 2017). However, waterhemp (*Amaranthus tuberculatus* (Moq.) J. D. Sauer), one of the most troublesome weed species in the Midwestern United States, appears to be able to thrive within alfalfa production systems as established alfalfa fields are currently being invaded by this weed.

While waterhemp has been present in Wisconsin for over 150 years, it has only recently expanded its range in Wisconsin. At present, it can be found in over 80% of our counties, with 40% of the observations being reported in the last 4 years (Renz, 2018). Several factors are likely responsible for its rapid spread, including its biology (e.g. high fecundity, rapid growth rate), ecology (e.g,. discontinuous emergence pattern) and high propensity to develop resistance to herbicides. Currently, some of the waterhemp herbicide resistant populations found throughout the Midwest include resistance to glyphosate, acetolactate synthase-, photosystem II-, 2,4-D, protoporphyrinogen (PPO), or 4-hydroxyphenylpyruvate dioxygenase (HPPD)-inhibiting herbicides (Heap 2018). Furthermore, several multiple-herbicide resistant populations have been reported in the Midwest (Schultz et al., 2015).

Although it has been reported that waterhemp can germinate under established plant canopies (Steckel et al., 2003) and produce viable seed (Wu and Owen, 2014), there is a lack of information on these patterns in established alfalfa fields. Additionally, it is not known what the impact of waterhemp invasions have on forage quality, productivity and resulting milk production from established alfalfa fields. Weeds harvested often increase yields and can be utilized as a forage, but reduce forage quality (Cosgrove and Barrett, 1987). While recent research suggests the level of reduction can be offset by the added biomass in milk production, weed biomass must be a minor component (<15%) of the total forage biomass (Renz et al., 2018). Moreover, water-hemp may impact alfalfa stand density which could reduce long-term alfalfa stand life.

Even though several herbicides registered for use in established alfalfa (e.g. acetochlor, flumioxazin, metribuzin, and pendimethalin) have been documented to have success in controlling waterhemp in other crops, it is not clear when to apply each product to maximize season-long control of waterhemp in established alfalfa. Given that

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little is known about the impacts and control of this species in established alfalfa, the objectives of this study were to determine the impacts of waterhemp on alfalfa productivity and quality; the effectiveness of management strategies based on residual herbicides applied at different timings; and (iii) waterhemp's emergence patterns and ability to produce seeds in established alfalfa cropping systems.

Material and Methods

The trial was conducted on a commercial established second-year alfalfa field, located in Omro, Wis. from June to September 2019. The experimental design was a randomized complete block design with four replications. Plots were three meters wide and nine meters long. Treatments consisted of all possible combinations of two application timings (after the first [06/03] or second cut [07/07] of the growing season); and three residual herbicide treatments (acetochlor at 1.7 kg ai ha^{-1}, flumioxazin at 140 g ai ha^{-1} and pendimethalin at 2.13 kg ha^{-1}). A sequential application of acetochlor at 1.7 kg ha^{-1} (after first cut) followed by flumioxazin at 140 g ha^{-1} (after second cut) was also included, resulting in 7 different herbicide treatments plus an untreated control. Rates were based on soil type and on the maximum rate provided on the labels. Treatments were applied with a CO_2-pressurized backpack boom sprayer equipped with eight 11002 flat-fan nozzles at a pressure of 276 kPa and an application volume of 187 L ha^{-1}.

Waterhemp control and alfalfa selectivity were determined quantitatively at the second, third, and fourth harvest of the season by randomly tossing three 0.5 m^2 quadrats in each plot and harvesting all above ground plant material within the quadrat. Forage was combined into one sample and separated into waterhemp, other weeds, and alfalfa. Samples were dried until constant mass was achieved and weighed. In addition, alfalfa stem density was measured by randomly placing three 0.25 m^2 quadrats within each plot in the fall after the last harvest. Measurements occurred when alfalfa stems were between 15 and 25 cm tall following methods summarized by Undersander et al. (2011). Furthermore, waterhemp control was also determined qualitatively by visually estimating the percentage of waterhemp at different phenological stages (i.e. vegetative, flowering, or with fruit present) at each harvest interval. Finally, forage quality was estimated for each plot at each harvest interval. Plant categories were combined for each plot at each harvest, ground and then sent to UW USDA Laboratory for Near-Infared Reflectance Spectroscopy (NIRS) analysis.

Statistical analyses were performed using the open-source statistical software R 3.4.3 (R Core Team 2014). All response variables were subjected to ANOVA to test for herbicide treatment effects. Treatments were considered different when $P \leq 0.05$. Means were separated using Fisher's LSD test ($\alpha = 0.05$) when appropriate. When necessary, data were square root transformed to stabilize error variances; however, original values are reported.

Results

Results indicated that herbicide treatments had no impact on alfalfa biomass at any harvest interval or when summed across all three (Table 3-4). Additionally, while no waterhemp biomass was observed in the second cut, all treatments decreased waterhemp biomass during the third harvest (Table 3). Acetochlor applied on 6/3 and flumioxazin applied on both timings provided ≥ 90% biomass reduction (Table 3). At the fourth harvest, acetochlor (6/3) and the sequential application of acetochlor (6/3) followed by flumioxazin (7/7) were the only treatments that continued to provide >90% waterhemp biomass suppression as all herbicides applied on 7/7 provided ≤ 77% waterhemp suppression (Table 4). The most effective treatments for total season waterhemp biomass production were acetochlor applied on 6/3 (94% reduction) and acetochlor + flumioxazin (94% reduction). These were followed by flumixazin and acetochlor (86 and 82% reduction, respectively) both applied on 7/7 (Table 4). Moreover, despite the herbicides and frequent harvests, waterhemp plants were able to produce viable seeds after the fourth harvest in all treatments (September) (Table 5).

Initial Conclusions

Alfalfa yields were not affected, by the waterhemp populations at any time throughout the study. While large germination events occurred (> 100 plants/m^2), many of the plants died or were not able to compete with the established alfalfa plants. It is not known if higher densities and different conditions would result in reduced alfalfa biomass, and further research is required to confirm these results. While alfalfa forage biomass may not be impacted reductions in forage quality may occur, especially in the 4^{th} harvest when waterhemp plants are mature and consist of mostly stems. The amount of waterhemp required to reduce forage quality is currently under investigation. While successful control of waterhemp (> 90% biomass reduction) was observed with select treatments, seeds were still produced in these treatments. Thus, alternative approaches will be required to assure waterhemp seed bank reductions. Knowledge of the resistance status of waterhemp populations will be critical in developing these strategies as few herbicides exist that do not have resistant waterhemp populations in the United States. Additional research at different sites is needed to validate these findings.

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Table 1. Treatment information.

TRT	Trade name	Active ingredient	Rate (kg ai ha^{-1})	Application timing	MOA	Manufacturer
1	Untreated	-	-	-	-	-
2	Warrant	acetochlor 359 g ai L^{-1}	1.70	06/03	Group 15; VLCFA synthesis inhibitors	Bayer
3	Chateau	flumioxazin 51%	0.14	06/03	Group 14; PPO inhibitor	Valent
4	Prowl H_2O	pendimethalin 455 g ai L^{-1}	2.13	06/03	Group 3; Microtubule assembly inhibition	BASF
5	Warrant	acetochlor 359 g ai L^{-1}	1.70	07/07	Group 15; VLCFA synthesis inhibitors	Bayer
6	Chateau	flumioxazin 51%	0.14	07/07	Group 14; PPO inhibitor	Valent
7	Prowl H_2O	pendimethalin 455 g ai L^{-1}	2.13	07/07	Group 3; Microtubule assembly inhibition	BASF
8	Warrant[1] + Chateau[2]	Acetochlor[1] + flumioxazin[2]	1.7 + 0.14	Both	Group 15 + Group 14	-

[1] Applied at 06/03; [2] Applied at 07/7

Table 2. Period between herbicides application (both timings) and study assessments.

TRT	Active ingredient	Rate (kg ai ha^{-1})	Application timing	Second cut	Third cut	Fourth cut	Alfalfa stand count
1	-	-	-	-	-	-	-
2	acetochlor 359 g ai L^{-1}	1.70	06/03	24 DAT	53 DAT	88 DAT	115 DAT
3	flumioxazin 51%	0.14	06/03	24 DAT	53 DAT	88 DAT	115 DAT
4	pendimethalin 455 g ai L^{-1}	2.13	06/03	24 DAT	53 DAT	88 DAT	115 DAT
5	acetochlor 359 g ai L^{-1}	1.70	07/07	-	19 DAT	54 DAT	81 DAT
6	flumioxazin 51%	0.14	07/07	-	19 DAT	54 DAT	81 DAT
7	pendimethalin 455 g ai L^{-1}	2.13	07/07	-	19 DAT	54 DAT	81 DAT
8	acetochlor + flumioxazin	1.7 + 0.14	Acetochlor (6/3) + flumioxazin (7/7)	-	-	-	-

Table 3. Herbicide effects for alfalfa, waterhemp and other weeds biomass prior to the second and third cut of the season in an established alfalfa field located at Omro, Wis., 2019.

Treatments	Second cut			Third cut		
	Alfalfa	Waterhemp	Other weeds[1]	Alfalfa	Waterhemp[3]	Other weeds[1]
	……………… kg DM ha^{-1} ………………					
Untreated	1,987.8	0	7.5	1,852.7	55.6 a	1.8
acetochlor (06/03)	1,952.5	0	0	1,839.7	3.9 def	1.3
flumioxazin (06/03)	1,728.7	0	0	1,687.6	3.0 ef	1.7
pendimethalin (06/03)	1,954.1	0	13.1	1,910.6	6.4 c	6.5
acetochlor (07/07)	-	-	-	1,520.4	5.6 cd	8.6
flumioxazin (07/07)	-	-	-	1,533.4	2.0 f	28.4
pendimethalin (07/07)	-	-	-	1,652.1	47.2 b	2.5
acetochlor + flumioxazin	-	-	-	1,188.4	4.3 cde	10.9
P-value	0.450	-	0.242	0.376	<0.001	0.301

[1] Mainly fall panicum and dandelion; [2] Means within alfalfa cuts, plant classes and columns followed by the same lowercase letter are not significantly different according to Fisher's LSD test at $P \leq 0.05$. [3]Data were square root transformed for mean separation, but raw means are presented for easier clarification.

Conclusions

Clearly the relationship between TP and DP FWMC differs by environmental condition (frozen or unfrozen). Tillage, soil test P, and manure application were all influential aspects of TP and DP loss, but the magnitude of the influence differed between frozen and non-frozen conditions. Interestingly, inherent soil factors such as slope, texture, and drainage class were not influential based on regression tree analysis. These results confirm the conventional wisdom related to tillage, manure application, and soil test P, although no-till did not result in lower P losses during frozen conditions. Pasture also had much higher P losses than expected. More work is needed to understand that effect. But collectively, this work, along with further analysis, can lead to a greater understanding of the relative influence of factors that drive P loss. This analysis would suggest that reducing soil test P would be the first step to reduce P loss, followed by reduction in tillage.

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WEED CONTROL, CLOVER INJURY, AND RESULTING YIELD FROM GF-3731 IN ROTATIONALLY GRAZED PASTURES

J.L.C.S. Dias*[1], M.J. Renz[1]; and S. Flynn[2]

Introduction

Adding legumes to grass pastures can result in multiple benefits including increased forage nutritive value (Sleugh et al., 2000), extended grazing season (Gibson and Cope, 1985; Sleugh et al., 2000) and increased grass yield due to N fixation (Sanderson et al., 2005). White clover (*Trifolium repens* L.), a short-lived perennial with prostrate growth habit, is one of the most important and widely adopted legume in grass-legume mixtures worldwide (Ball and Lacefield, 2000). In addition, red clover (*Ttifolium pretense* L.), another short-lived perennial, is widely grown in grass-clover mixtures in Wisconsin.

However, one long-lasting management problem that often limits adoption of mixed swards by producers is selective broadleaf weed control. Previous research has demonstrated that most legumes are highly sensitive to herbicides (e.g., triclopyr, fluroxypyr, dicamba and aminopyralid) commonly used for weed-management in pastures (Beeler et al., 2003; Payne et al., 2010). Ways of which desirable legumes may be negatively impacted include direct herbicide injury, or injury from soil residual activity, leaving producers with few weed-management tools for broadleaf weed control in these production systems (Enloe et al., 2014).

With the goal to address this weed management challenge, Corteva Agriscience is developing a new product currently designated as GF-3731 (florpyrauxifen-benzyl and 2,4-D). This product, if released, will contain the first new active ingredient introduced in the Range and Pasture market in nearly 15 years (i.e. florpyrauxifen-benzyl). It has been shown to provide broadleaf weed control in pastures with limited injury to select clover species. The possibility of effective broadleaf weed control without significant negative impacts on clover may help producers to optimize forage productivity and quality while at the same time decrease fertilizer and reseeding costs (Enloe et al., 2014). Given that little information is available on GF-3731 safety to white and red clover species, efficacy on common pasture weeds and resulting yield under rotationally grazed pastures, our objective was to evaluate these parameters in rotationally grazed cool-season grass-clover mixed swards located in the Midwestern United States.

Material and Methods

Experiments were conducted from June 2019 through September 2019 in pastures located near Lancaster (LARS) and Prairie Du Sac (PDS), Wis. The main clover species present at LARS and PDS were white clover (*Trifolium repens* L.) and red clover (*Trifolium pretense* L). Other main plant species present at both locations included tall

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fescue (*Festuca arundinaceae),* orchard grass (*Dactylis glomerate L.*) and smooth brome (*inermis Leyss*) (Tables 1 and 2). Overall, broadleaf weeds at the time of herbicide application was 25 and 10% at PDS and LARS, respectively. The predominant weed species are described in Tables 1 and 2.

Treatments included GF-3731 at 24.0 Fl oz acre^{-1} (1.75 L ha^{-1}) and a control, in a randomized complete block design with four replications at each site. Plot size was 33 by 33 m (100 by 100 ft). Herbicide treatment was applied after emergence of weeds (first week of May and June at PDS and LARS, respectively). Grazing was implemented approximately 30 d after herbicide application to a residual height of 10.0 cm (4.0 inches). There was a total of three grazing events at both locations.

The percentage of vegetative cover was estimated prior to each grazing event using a line-intercept method. Plant species that intersected points at 90-cm intervals along a 33-m transect were recorded along three transects (100 points per plot) in each plot. Cover data was separated into four plant classes (clover, perennial grasses, annual grasses, and broadleaf weeds) for statistical analyses. Aboveground biomass was measured just prior to every grazing event by clipping three representative 0.25-m^2 quadrats per plot. After biomass collection, biomass samples were sorted into the same four plant classes used for vegetative cover data. Biomass was summed across all grazing events.

Statistical analyses were performed using the open-source statistical software R 3.6.1 (R Core Team, 2014). All response variables were analyzed by fitting mixed-effects models using the package "*lme4*" and function "*lmer*" in R. The model statement for all response variables included treatment (herbicide vs control) as a fixed effect; whereas block and location were considered random effects. Treatments (herbicide vs control) were considered different when $P \leq 0.05$. All reported means are least squares means. To satisfy the assumptions of analysis of variance, data were square root or arcsine square root transformed when necessary, but nontransformed means were reported.

Results

Results from this study indicate that GF-3731 provided effective control of broadleaf weeds at both sites (Table 1-2). Broadleaf weed cover was 3.6, 4.1 and 5.8-fold lower on GF-3731 treated pastures compared to controls at 30, 60 and 90 DAT, respectively (Table 3). This resulted in a 5.0-fold lower broadleaf weed biomass production on treated pastures (104 vs 518 kg DM ha^{-1} for GF-3731 and control, respectively) (Table 5). White clover cover was not negatively impacted by GF-3731 as it was similar to untreated controls at 30, 60 and 90 DAT. However, red clover was nearly eliminated from the treated pastures as its cover was reduced to ≤ 2.0% throughout 90 DAT. Clover biomass (white plus red clover) was three-fold greater on untreated pastures at 30 DAT but no differences were detected at 60 and 90 DAT. This resulted in lower clover biomass on GF-3731 treated pastures (729 kg DM ha^{-1}) compared to untreated pastures (1,282 kg DM ha^{-1}). In contrast, perennial forage grass cover was greater on GF-3731 treated pastures at 30 DAT, but no differences were detected 60 or 90 DAT in cover or total season perennial grass biomass.

Conclusion

The use of GF-3731 appears to be a promising tool for broadleaf weed management in cool season grass-clover mixed swards in the Midwestern United States. Although clover suppression was observed on GF-3731, pastures maintained significant white clover cover and biomass while reducing broadleaf weeds compared to untreated plots. Results also suggest clover tolerance to GF-3731 is species dependent as white and red clover exhibited different tolerance levels. Future research should investigate the susceptibility of different clover species to GF-3731 and management practices to limit injury of susceptible clovers.

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Table 1. List of plant species found at Lancaster throughout the experiment.

Common name	Scientific name	Plant family	Plant class
Red clover	*Trifolium pretense L.*	Fabaceae	Clover
White clover	*Trifolium repens L.*	Fabaceae	Clover
Kentucky bluegrass	*Poa pratensis L.*	Poaceae	Perennial grass
Orchard grass	*Dactylis glomerate L.*	Poaceae	Perennial grass
Quackgrass	*Elymus repens (L.) Gould*	Poaceae	Perennial grass
Reed canarygrass	*Phalaris arundinacea L.*	Poaceae	Perennial grass
Tall fescue	*Festuca arundinaceae*	Poaceae	Perennial grass
Timothy	*Phleum pratense L.*	Poaceae	Perennial grass
Smooth brome	*Bromus inermis Leyss.*	Poaceae	Perennial grass
Foxtail spp.	*Setaria* spp.	Poaceae	Annual grass
Common burdock	*Arctium minus (Hill) Bernh.*	Asteraceae	Broadleaf weed
Canada thistle	*Cirsium arvense (L.) Scop.*	Asteraceae	Broadleaf weed
Dandelion	*Taraxacum officinale F. H. Wigg.*	Asteraceae	Broadleaf weed
Giant chickweed	*Cerastium fontanum Baumg.*	Caryophyllaceae	Broadleaf weed
Smartweed spp.	*Persicaria* spp.	Polygonaceae	Broadleaf weed

Table 2. List of plant species found at PDS throughout the experiment.

Common name	Scientific name	Plant family	Plant class
Red clover	*Trifolium pretense L.*	Fabaceae	Clover
White clover	*Trifolium repens L.*	Fabaceae	Clover
Kentucky bluegrass	*Poa pratensis L.*	Poaceae	Perennial grass
Orchard grass	*Dactylis glomerate L.*	Poaceae	Perennial grass
Quackgrass	*Elymus repens (L.) Gould*	Poaceae	Perennial grass
Tall fescue	*Festuca arundinaceae*	Poaceae	Perennial grass
Large crabgrass	*Digitaria sanguinalis (L.) Scop.*	Poaceae	Annual grass
Dandelion	*Taraxacum officinale F. H. Wigg.*	Asteraceae	Broadleaf weed
Giant chickweed	*Cerastium fontanum Baumg.*	Caryophyllaceae	Broadleaf weed
Speedwell spp.	*Veronica spp.*	Plantaginaceae	Broadleaf weed
Smartweed spp.	*Persicaria* spp.	Polygonaceae	Broadleaf weed
Bull thistle	*Cirsium vulgare (Savi) Ten.*	Asteraceae	Broadleaf weed
Plumeless thistle	*Carduus acanthoides L.*	Asteraceae	Broadleaf weed

3. White clover, red clover and broadleaf weeds vegetative cover at 30, 60 and 90 d after treatment as affected by herbicide treatment. Values represent means (± standard error) pooled across locations.

picide	White clover[1]			Red clover[1]			Broadleaf weeds[1]		
tment	30 DAT	60 DAT	90 DAT	30 DAT	60 DAT	90 DAT	30 DAT	60 DAT	90 DAT
	… vegetative cover (%) …			… vegetative cover (%) …			… vegetative cover (%) …		
ol	56 (±12)	61 (±10)	70 (±11)	16* (±6.5)	13* (±5)	8* (±2.5)	40* (±7)	33* (±6)	35* (±5)
731	51 (±9)	51 (±8)	61 (±9)	1 (±0.3)	2 (±1)	1 (±0.4)	11 (±2)	8 (±3)	6 (±2)
value	0.441	0.145	0.055	<0.001	0.025	0.010	0.003	0.002	<0.001

within plant classes and evaluation timings (columns) with followed by * were significantly greater at P ≤ 0.05.

4. Perennial and annual grasses vegetative cover at 30, 60 and 90 d after treatment as affected by herbicide treatment. Values represent means (± standard error) pooled locations.

picide	Perennial grasses[1]			Annual grasses[1]		
tment	30 DAT	60 DAT	90 DAT	30 DAT	60 DAT	90 DAT
	… vegetative cover (%) …			… vegetative cover (%) …		
ol	97 (±0.7)	90 (±2.6)	90 (±4.3)	0	7 (±)	10 (±2.4)
731	99* (±0.2)	95 (±1.4)	94 (±2.7)	0	12 (±)	20 (±5.8)
value	0.010	0.071	0.184	-	0.090	0.120

within plant classes and evaluation timings (columns) with followed by * were cantly greater at P ≤ 0.05.

5a. Clovers (white and red) and broadleaf weeds pre-graze biomass (kg DM ha^{-1}) at 30, 60, and 90 d after ent (DAT), and total season production (sum across months), as affected by herbicide treatment. represent means (± standard error) pooled across locations.

picide	Clovers (white and red)[1]				Broadleaf weeds[1]			
tment	30 DAT	60 DAT	90 DAT	Season	30 DAT	60 DAT	90 DAT	Season
	… Biomass (kg DM ha^{-1}) …				… Biomass (kg DM ha^{-1}) …			
ol	558* (±131)	350 (±82)	374 (±147)	1,282* (±332)	237* (±60)	144* (±55)	137* (±54)	518* (±120)
731	163 (±61)	249 (±75)	317 (±128)	729 (±223)	69 (±40)	23 (±20)	12 (±6)	104 (±39)
value	<0.001	0.204	0.312	0.016	0.025	0.009	0.003	0.003

Table 5b. Perennial grasses and annual grasses pre-graze biomass (kg DM ha^{-1}) at 30, 60, and 90 d after treatment (DAT), and total season production (sum across months), as affected by herbicide treatment. Values represent means (± standard error) pooled across locations.

Herbicide	Perennial grasses[1]				Annual grasses[1]			
Treatment	30 DAT	60 DAT	90 DAT	Season	30 DAT	60 DAT	90 DAT	Season
	… Biomass (kg DM ha^{-1}) …				… Biomass (kg DM ha^{-1}) …			
Control	1,796 (±265)	903 (±224)	639 (±97)	3,339 (±477)	0	5 (±)	7 (±3)	12 (±5)
GF-3731	2,136 (±226)	754 (±137)	811 (± 122)	3,700 (±264)	0	11 (±)	6 (±10)	18 (±12)
P-value	0.143	0.352	0.233	0.334	-	0.530	0.935	0.639

[1]Mean within plant classes and evaluation timings (columns) with followed by * were significantly greater at $P \leq 0.05$.

Table 6. Total season production (sum across months) as affected by herbicide treatment. Values represent means (± standard error) pooled across locations.

Herbicide	Sum of all classes (total biomass)[1]			
Treatment	30 DAT	60 DAT	90 DAT	Season
	… Biomass (kg DM ha^{-1}) …			
Control	2,592 (±146)	1,402 (±185)	1,158 (±)	5,151 (±172)
GF-3731	2,368 (±225)	1,037 (±131)	1,147 (±)	4,551 (±217)
P-value	0.336	0.059	0.925	0.057

[1]Mean within plant classes and evaluation timings (columns) with followed by * were significantly greater at $P \leq 0.05$.

KEYS TO ALFALFA ESTABLISHMENT IN HIGH-YIELDING SILAGE CORN

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Alfalfa has often been replaced in rotations by corn silage, in part because corn produces greater forage dry matter yield than alfalfa. First year yields of spring-seeded alfalfa are particularly low, often being one-half that of subsequent full production years. Planting small grain, grass, or legume companion crops with alfalfa can modestly improve forage yields in the establishment year, but seeding companion crops with alfalfa often reduces forage quality. Thus, new approaches are needed to increase the yield of alfalfa, especially during its first year of production.

One way to bypass the low yielding establishment year would be to interseed alfalfa into corn to jumpstart full production of alfalfa the following year. When successfully established, first year dry matter yields of interseeded alfalfa are 1.6- to 2.25-fold greater than conventionally spring-seeded alfalfa. During and after establishment, interseeded alfalfa also serves as a cover crop to reduce soil and nutrient loss from cropland. Unfortunately, this system has been unworkable because traditional intercropping methods require producers to plant corn at low density (sacrificing high silage yields) to allow reliable establishment of alfalfa.

Therefore, scientists at the USDA-Agricultural Research Service, the University of Wisconsin and other institutions are working to develop reliable methods for establishing alfalfa in high yielding silage corn. During the course of this work in Wisconsin, it has become apparent that successful establishment of alfalfa in corn can be greatly improved by applying growth altering and protective agrichemicals on alfalfa seedlings. Good alfalfa establishment and high yields of corn silage can also be ensured by proper field selection and preparation and by using good weed control, adequate nitrogen fertilization, adapted alfalfa varieties, suitable seeding rates, and appropriate planting and harvest dates. In ongoing work, we will identify corn hybrids that are best suited for interseeding and will further refine management practices to ensure interseeded alfalfa production systems will be reliable, high yielding, and profitable for farmers.

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ALFALFA COMPACTION FROM WHEEL TRAFFIC: HOW DOES MACHINERY TRAFFIC EFFECT YIELD AND SOIL COMPACTION

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Alfalfa harvest requires multiple machinery passes over the field to complete. Harvesting alfalfa for hay production requires mowing, raking, and baling; while silage harvest requires mowing, merging, and chopping passes. Each harvest practice impacts the plants on re-growth as well as the soil due to ground pressure applied by the tires of harvest machines. A research project at the Univ. of Wisconsin-Madison is aiming to simulate these traffic patterns to assess the impact of wheel traffic on alfalfa yield and quality while monitoring impacts on the compaction incurred by the soil. This project is also assessing the machinery used during alfalfa silage harvest at a commercial dairy to quantify the area of the field impacted by wheel traffic and using remote sensing technology to help model and predict alfalfa yield impacts due to wheel traffic.

To assess the impact of wheel traffic, plots were established at the Univ. of Wisconsin Arlington Agricultural Research Station. These plots were blocked into four different tillage treatments: 1) fall and spring tilled, 2) spring tilled, 3) no-till, and 4) established alfalfa (2nd year of production). Replicated treatments were randomized within each of these blocks to test different harvest methodologies and the wheel traffic each of these apply. These treatments are listed below.

1. Single Pass Silage: One application of compaction immediately after harvest covering the entire plot.
2. Three Pass Silage: Three applications of compaction. One immediately after harvest, one 24 hours after harvest and one 26 hours after harvest. Full plot application.
3. Five Pass Silage: Five applications of compaction. One immediately after harvest, two passes 24 hours after harvest, and two passes 26 hours after harvest. Full plot application.
4. Simulated Silage: Two wheel tracks applied within the plot. One pass immediately after harvest, one pass 24 hours after harvest, and two passes 26 hour after harvest.
5. Three Pass Hay: Three applications of compaction. One immediately after harvest, one 48 hours after harvest and one 72 hours after harvest. Full plot application.
6. Five Pass Hay: Five applications of compaction. One immediately after harvest, two passes 48 hours after harvest, and two passes 72 hours after harvest. Full plot application.
7. Zero Compaction (control): No machine traffic applied.

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The newly seeded alfalfa plots were harvested three times in 2019 and the standing alfalfa plots were harvested four times over the growing season. A small walk-behind plot harvester was used to harvest the plots and any compaction applied by this machine was considered negligible. Four ~400g samples were taken from each plot and dried to determine moisture content of the harvested material and yield results were corrected to dry matter weights based on these values. Statistical analysis shows that the compaction treatments (P-value < 0.0001), tillage treatments (P-value = 0.0005), harvest date (P-value < 0.0001) were all significant. Interactions between harvest date and compaction treatment (P-value = 0.0262), harvest date and tillage treatment (P-value < 0.0001), and harvest date, tillage treatment, and compaction treatment (P-value = 0.0002) were all significant as well. Table 1 shows the effect of compaction treatments on alfalfa yield over all harvest dates and tillage treatments. The no-compaction control was the only statistically different treatment (Table 1).

Table 1: Dry matter yield results (ton/ac) for seven different compaction treatments applied to the alfalfa plots in 2019.

Treatment	Dry matter yield (ton/ac)	Standard error (ton/ac)
Zero Compaction (control)	1.89[a]	0.09
Three Pass Silage	1.44[b]	0.09
Three Pass Hay	1.41[b]	0.09
Five Pass Silage	1.38[b]	0.09
Five Pass Hay	1.34[b]	0.09
Single Pass Silage	1.33[b]	0.09
Simulated Silage	1.33[b]	0.09

*Letter differences indicate statistical differences at alpha = 0.05.

The tillage treatment results showed that the standing alfalfa (1.87 ton/ac) and the no-till alfalfa (1.71 ton/ac) had higher yields over the growing season than the tilled new seeding. The spring tillage treatment yielded 1.26 ton/ac and the fall and spring tilled treatment yielded 0.94 ton/ac over all harvests. Interaction between harvest date and compaction treatment showed, not unexpectedly, that first harvest yielded higher than second, third, and fourth harvest. Within each of these harvests the no compaction treatment yielded numerically higher than the other compaction treatments, but the difference was not always statistically significant.

In summary, wheel traffic influences alfalfa dry matter yield. One single pass over the plant at harvest can show a dry matter yield reduction between 0.45 and 0.56 ton/ac. This work is continuing to look at alfalfa quality and quantify the area of the field impacted by wheel traffic in an alfalfa silage harvest system.

NUTRITIVE VALUE AND YIELD OF EMERGENCY FORAGES

Yoana C. Newman [1/]

Introduction

Summer annual forages are chosen by many farmers to fill the summer slump experienced by cool-season perennial forages or when needing an emergency forage if facing a challenging year with winterkilled fields. Whichever the case, the need is for the combination of high yield and nutritive value in addition to rapid growth, drought tolerance and quick response to fertilizer because of the short window for summer production. Two of these promising forages for sandy soils have been tested in recent years and they include warm-season annuals teffgrass and crabgrass. The yield and nutritive value of these grasses was compared against orchardgrass and bluegrass (perennial cool-season and native grasses, respectively) which are commonly grown in areas of sandy soils in Wisconsin. During summer teff and crabgrass yields were comparable or exceeded those of orchardgrass or bluegrass.

Teffgrass

This annual bunchgrass originated in the highlands of Ethiopia in northern Africa. It does not tolerate frost and is adapted to temperatures ranging from 50 to 80°F and soil pH from 4.5 to 7.0. Plants have quick germination of three to five days, and fast growth allows to cut it six to nine weeks after planting. Dry matter yield at first harvest ranges from 1500 to 2400 lb/acre with a second cutting after 30-days at 50% of the initial one for a total yield of 2,400 to 3,600 lb/acre. In grazing trials in southern Wisconsin planted in 7.5" rows resulted in 2,900 lb DM/acre. It is a high-quality grass with high digestibility and palatability, high crude protein (22% in current trial) and excellent amino acid composition. It has been used in the last decade as a mite-free alternative to timothy and orchardgrass for the summer slump.

Large Crabgrass

This sod-forming grass is highly palatable and well adapted to sandy loam-clay soils ranging in pH from 5.5 to 7.0. It is a true summer annual with no cold and frost tolerance. It responds well to fertilization and dry matter yield at first harvest ranges from 1,300 to 2,100 lb/acre with a second cutting after 20 to 30-days at 46% of first cutting for total yield of ~3,500 lb/acre. This grass is excellent for grazing and soil conservation, and also makes top quality leafy hay with crude protein around 15% and digestibility near 60%.

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GRAZING DAIRY HEIFERS ON MEADOW FESCUE OR ORCHARDGRASS

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Background

Rearing dairy heifers for optimal body weight gains (1.8-2.2 lb/day for Holstein breed) is needed to allow for breeding at 13 months of age and reaching an ideal weight by calving. Heifer rearing costs are significant for a dairy farm ($2.50-3.00/day) with feed costs being about 50% of these costs. Grazing high yielding, high quality pastures has potential to meet these heifer growth goals while possibly reducing feeding costs, but there has been minimal evaluation of heifer growth when grazing different grass species. With the increased interest in meadow fescue for grazing due to its improved quality, this project's objective was to evaluate heifer growth, forage yield, and forage quality when grazing either meadow fescue or orchardgrass.

Methods

Six pastures (2.5 acres each) at the Marshfield Agricultural Research Station (Stratford, Wis.) were established in 2015 to either orchardgrass (variety Haymaster) or meadow fescue (variety Hidden Valley) with 3 pasture replications per species. 24 dairy heifers (5-6 months of age) grazed the pastures (4 heifers per pasture) starting in late-May or early June and ending in mid-October to early November depending on pasture conditions. No grain or forage supplementation was provided during the study. Grazing was repeated for 3 years (2016-2018) using different heifers each year. Managed grazing was used with 10 paddocks (0.25 acres) per pastures and heifers moved to a new paddock twice weekly (every 3-4 days) to allow paddocks a 31 day rest period between grazing events. Heifers were weighed and measured before and after the grazing season. Pasture forage availability was measured pre- and post-grazing using a rising plate meter. Weekly clippings of forage (3-inch residue height) were made to calculate forage availability from the plate meter data and to asses forage quality. Forage quality was estimated using NIRS with calibrations developed from grazing forage samples.

Results

Data are presented in Table 1. Grazing began in mid-May each year with orchardgrass having more rapid early growth, so heifers were placed on orchardgrass pastures one week before meadow fescue pastures. Pre-grazing forage availability was greater for meadow fescue during two of the three years. Overall utilization of forage was similar between the species, but was affected by year. In 2017, excessive precipitation did not allow for management of grass residue to remove reproductive stems and re-initiate vegetative growth. Orchardgrass was more affected by this as the stems are coarser and heifers refused to

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consume the stemmy material. Similar to other work, forage quality was better for meadow fescue with lower neutral detergent fiber (NDF) concentration and greater digestibility of NDF (NDFD). Heifer growth was not significantly different between species across any of the years. In 2017, heifers grazing orchardgrass had numerically lower gains due to reduced forage availability and quality caused by not being able to remove the reproductive stems and less vegetative high-quality forage growth in mid-summer. Meadow fescue did not seem to have the degree of reduced quality and growth, which helped maintain heifer growth.

Conclusions

Overall, meadow fescue had improved growth and quality compared to orchardgrass. Heifer growth was not impacted significantly by species, but the heifers grazing meadow fescue had a more consistent average daily gain each year (1.72 to 1.81 lb/day) compared to orchardgrass (1.50 to 1.70 lb/day). This is likely due to a reduced effect of delayed clipping of mature stems on meadow fescue quality and palatability. In addition, this study shows the importance of pasture management to maintain high-quality vegetative growth, which leads to better animal productivity.

Table 1. Forage availability and quality of meadow fescue or orchardgrass grazed by dairy heifers

	Meadow Fescue				Orchardgrass			
	Mean	2016	2017	2018	Mean	2016	2017	2018
Pre-grazing forage availability, lb DM/acre	1348	1031	1345	1664	1211	1005	1141	1488
Forage utilization, lb DM/acre/year	2671	2874	2432	2709	2703	3393	2432	2362
NDF[1], % DM	53.3	51.6	54.8	53.7	56.0	55.2	57.9	54.9
NDFD[2], % of NDF	66.9	69.4	61.3	70.0	64.0	64.7	58.8	68.9
CP[3], % of DM	14.8	16.4	12.8	15.1	14.1	15.4	12.2	14.7
Heifer growth								
Start weight, lb	529	538	562	494	531	527	575	482
End wt, kg	798	851	836	716	781	818	803	718
Total gain, kg	269	313	274	222	250	291	228	236
Daily gain, kg/d	1.72	1.81	1.79	1.59	1.61	1.70	1.50	1.63

[1] Neutral detergent fiber
[2] In-vitro neutral detergent fiber digestibility after 48 hour incubation
[3] Crude protein

WEED CONTROL, CLOVER INJURY, AND RESULTING YIELD FROM GF-3731 IN ROTATIONALLY GRAZED PASTURES

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Introduction

Adding legumes to grass pastures can result in multiple benefits including increased forage nutritive value (Sleugh et al., 2000), extended grazing season (Gibson and Cope, 1985; Sleugh et al., 2000) and increased grass yield due to N fixation (Sanderson et al., 2005). White clover (*Trifolium repens* L.), a short-lived perennial with prostrate growth habit, is one of the most important and widely adopted legume in grass-legume mixtures worldwide (Ball and Lacefield, 2000). In addition, red clover (*Ttifolium pretense* L.), another short-lived perennial, is widely grown in grass-clover mixtures in Wisconsin.

However, one long-lasting management problem that often limits adoption of mixed swards by producers is selective broadleaf weed control. Previous research has demonstrated that most legumes are highly sensitive to herbicides (e.g., triclopyr, fluroxypyr, dicamba and aminopyralid) commonly used for weed-management in pastures (Beeler et al., 2003; Payne et al., 2010). Ways of which desirable legumes may be negatively impacted include direct herbicide injury, or injury from soil residual activity, leaving producers with few weed-management tools for broadleaf weed control in these production systems (Enloe et al., 2014).

With the goal to address this weed management challenge, Corteva Agriscience is developing a new product currently designated as GF-3731 (florpyrauxifen-benzyl and 2,4-D). This product, if released, will contain the first new active ingredient introduced in the Range and Pasture market in nearly 15 years (i.e. florpyrauxifen-benzyl). It has been shown to provide broadleaf weed control in pastures with limited injury to select clover species. The possibility of effective broadleaf weed control without significant negative impacts on clover may help producers to optimize forage productivity and quality while at the same time decrease fertilizer and reseeding costs (Enloe et al., 2014). Given that little information is available on GF-3731 safety to white and red clover species, efficacy on common pasture weeds and resulting yield under rotationally grazed pastures, our objective was to evaluate these parameters in rotationally grazed cool-season grass-clover mixed swards located in the Midwestern United States.

Material and Methods

Experiments were conducted from June 2019 through September 2019 in pastures located near Lancaster (LARS) and Prairie Du Sac (PDS), Wis. The main clover species present at LARS and PDS were white clover (*Trifolium repens* L.) and red clover (*Trifolium pretense* L). Other main plant species present at both locations included tall

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fescue (*Festuca arundinaceae),* orchard grass (*Dactylis glomerate L.*) and smooth brome (*inermis Leyss*) (Tables 1 and 2). Overall, broadleaf weeds at the time of herbicide application was 25 and 10% at PDS and LARS, respectively. The predominant weed species are described in Tables 1 and 2.

Treatments included GF-3731 at 24.0 Fl oz acre^{-1} (1.75 L ha^{-1}) and a control, in a randomized complete block design with four replications at each site. Plot size was 33 by 33 m (100 by 100 ft). Herbicide treatment was applied after emergence of weeds (first week of May and June at PDS and LARS, respectively). Grazing was implemented approximately 30 d after herbicide application to a residual height of 10.0 cm (4.0 inches). There was a total of three grazing events at both locations.

The percentage of vegetative cover was estimated prior to each grazing event using a line-intercept method. Plant species that intersected points at 90-cm intervals along a 33-m transect were recorded along three transects (100 points per plot) in each plot. Cover data was separated into four plant classes (clover, perennial grasses, annual grasses, and broadleaf weeds) for statistical analyses. Aboveground biomass was measured just prior to every grazing event by clipping three representative 0.25-m^2 quadrats per plot. After biomass collection, biomass samples were sorted into the same four plant classes used for vegetative cover data. Biomass was summed across all grazing events.

Statistical analyses were performed using the open-source statistical software R 3.6.1 (R Core Team, 2014). All response variables were analyzed by fitting mixed-effects models using the package "*lme4*" and function "*lmer*" in R. The model statement for all response variables included treatment (herbicide vs control) as a fixed effect; whereas block and location were considered random effects. Treatments (herbicide vs control) were considered different when P ≤ 0.05. All reported means are least squares means. To satisfy the assumptions of analysis of variance, data were square root or arcsine square root transformed when necessary, but nontransformed means were reported.

Results

Results from this study indicate that GF-3731 provided effective control of broadleaf weeds at both sites (Table 1-2). Broadleaf weed cover was 3.6, 4.1 and 5.8-fold lower on GF-3731 treated pastures compared to controls at 30, 60 and 90 DAT, respectively (Table 3). This resulted in a 5.0-fold lower broadleaf weed biomass production on treated pastures (104 vs 518 kg DM ha^{-1} for GF-3731 and control, respectively) (Table 5). White clover cover was not negatively impacted by GF-3731 as it was similar to untreated controls at 30, 60 and 90 DAT. However, red clover was nearly eliminated from the treated pastures as its cover was reduced to ≤ 2.0% throughout 90 DAT. Clover biomass (white plus red clover) was three-fold greater on untreated pastures at 30 DAT but no differences were detected at 60 and 90 DAT. This resulted in lower clover biomass on GF-3731 treated pastures (729 kg DM ha^{-1}) compared to untreated pastures (1,282 kg DM ha^{-1}). In contrast, perennial forage grass cover was greater on GF-3731 treated pastures at 30 DAT, but no differences were detected 60 or 90 DAT in cover or total season perennial grass biomass.

Conclusion

The use of GF-3731 appears to be a promising tool for broadleaf weed management in cool season grass-clover mixed swards in the Midwestern United States. Although clover suppression was observed on GF-3731, pastures maintained significant white clover cover and biomass while reducing broadleaf weeds compared to untreated plots. Results also suggest clover tolerance to GF-3731 is species dependent as white and red clover exhibited different tolerance levels. Future research should investigate the susceptibility of different clover species to GF-3731 and management practices to limit injury of susceptible clovers.

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Table 1. List of plant species found at Lancaster throughout the experiment.

Common name	Scientific name	Plant family	Plant class
Red clover	*Trifolium pretense L.*	Fabaceae	Clover
White clover	*Trifolium repens L.*	Fabaceae	Clover
Kentucky bluegrass	*Poa pratensis L.*	Poaceae	Perennial grass
Orchard grass	*Dactylis glomerate L.*	Poaceae	Perennial grass
Quackgrass	*Elymus repens (L.) Gould*	Poaceae	Perennial grass
Reed canarygrass	*Phalaris arundinacea L.*	Poaceae	Perennial grass
Tall fescue	*Festuca arundinaceae*	Poaceae	Perennial grass
Timothy	*Phleum pratense L.*	Poaceae	Perennial grass
Smooth brome	*Bromus inermis Leyss.*	Poaceae	Perennial grass
Foxtail spp.	*Setaria* spp.	Poaceae	Annual grass
Common burdock	*Arctium minus (Hill) Bernh.*	Asteraceae	Broadleaf weed
Canada thistle	*Cirsium arvense (L.) Scop.*	Asteraceae	Broadleaf weed
Dandelion	*Taraxacum officinale F. H. Wigg.*	Asteraceae	Broadleaf weed
Giant chickweed	*Cerastium fontanum Baumg.*	Caryophyllaceae	Broadleaf weed
Smartweed spp.	*Persicaria* spp.	Polygonaceae	Broadleaf weed

Table 2. List of plant species found at PDS throughout the experiment.

Common name	Scientific name	Plant family	Plant class
Red clover	*Trifolium pretense L.*	Fabaceae	Clover
White clover	*Trifolium repens L.*	Fabaceae	Clover
Kentucky bluegrass	*Poa pratensis L.*	Poaceae	Perennial grass
Orchard grass	*Dactylis glomerate L.*	Poaceae	Perennial grass
Quackgrass	*Elymus repens (L.) Gould*	Poaceae	Perennial grass
Tall fescue	*Festuca arundinaceae*	Poaceae	Perennial grass
Large crabgrass	*Digitaria sanguinalis (L.) Scop.*	Poaceae	Annual grass
Dandelion	*Taraxacum officinale F. H. Wigg.*	Asteraceae	Broadleaf weed
Giant chickweed	*Cerastium fontanum Baumg.*	Caryophyllaceae	Broadleaf weed
Speedwell spp.	*Veronica spp.*	Plantaginaceae	Broadleaf weed
Smartweed spp.	*Persicaria* spp.	Polygonaceae	Broadleaf weed
Bull thistle	*Cirsium vulgare (Savi) Ten.*	Asteraceae	Broadleaf weed
Plumeless thistle	*Carduus acanthoides L.*	Asteraceae	Broadleaf weed

Table 3. White clover, red clover and broadleaf weeds vegetative cover at 30, 60 and 90 d after treatment (DAT) as affected by herbicide treatment. Values represent means (± standard error) pooled across locations.

Herbicide	White clover[1]			Red clover[1]			Broadleaf weeds[1]		
Treatment	30 DAT	60 DAT	90 DAT	30 DAT	60 DAT	90 DAT	30 DAT	60 DAT	90 DAT
	… vegetative cover (%) …			… vegetative cover (%) …			… vegetative cover (%) …		
Control	56 (±12)	61 (±10)	70 (±11)	16* (±6.5)	13* (±5)	8* (±2.5)	40* (±7)	33* (±6)	35* (±5)
GF-3731	51 (±9)	51 (±8)	61 (±9)	1 (±0.3)	2 (±1)	1 (±0.4)	11 (±2)	8 (±3)	6 (±2)
P-value	0.441	0.145	0.055	<0.001	0.025	0.010	0.003	0.002	<0.001

[1]Mean within plant classes and evaluation timings (columns) with followed by * were significantly greater at $P \leq 0.05$.

Table 4. Perennial and annual grasses vegetative cover at 30, 60 and 90 d after treatment (DAT) as affected by herbicide treatment. Values represent means (± standard error) pooled across locations.

Herbicide	Perennial grasses[1]			Annual grasses[1]		
Treatment	30 DAT	60 DAT	90 DAT	30 DAT	60 DAT	90 DAT
	… vegetative cover (%) …			… vegetative cover (%) …		
Control	97 (±0.7)	90 (±2.6)	90 (±4.3)	0	7 (±)	10 (±2.4)
GF-3731	99* (±0.2)	95 (±1.4)	94 (±2.7)	0	12 (±)	20 (±5.8)
P-value	0.010	0.071	0.184	-	0.090	0.120

[1]Mean within plant classes and evaluation timings (columns) with followed by * were significantly greater at $P \leq 0.05$.

Table 5a. Clovers (white and red) and broadleaf weeds pre-graze biomass (kg DM ha^{-1}) at 30, 60, and 90 d after treatment (DAT), and total season production (sum across months), as affected by herbicide treatment. Values represent means (± standard error) pooled across locations.

Herbicide	Clovers (white and red)[1]				Broadleaf weeds[1]			
Treatment	30 DAT	60 DAT	90 DAT	Season	30 DAT	60 DAT	90 DAT	Season
	… Biomass (kg DM ha^{-1}) …				… Biomass (kg DM ha^{-1}) …			
Control	558* (±131)	350 (±82)	374 (±147)	1,282* (±332)	237* (±60)	144* (±55)	137* (±54)	518* (±120)
GF-3731	163 (±61)	249 (±75)	317 (±128)	729 (±223)	69 (±40)	23 (±20)	12 (±6)	104 (±39)
P-value	<0.001	0.204	0.312	0.016	0.025	0.009	0.003	0.003

[1]Mean within plant classes and evaluation timings (columns) with followed by * were significantly greater at $P \leq 0.05$.

Table 5b. Perennial grasses and annual grasses pre-graze biomass (kg DM ha^{-1}) at 30, 60, and 90 d after treatment (DAT), and total season production (sum across months), as affected by herbicide treatment. Values represent means (± standard error) pooled across locations.

Herbicide	Perennial grasses[1]				Annual grasses[1]			
Treatment	30 DAT	60 DAT	90 DAT	Season	30 DAT	60 DAT	90 DAT	Season
	… Biomass (kg DM ha^{-1}) …				… Biomass (kg DM ha^{-1}) …			
Control	1,796 (±265)	903 (±224)	639 (±97)	3,339 (±477)	0	5 (±)	7 (±3)	12 (±5)
GF-3731	2,136 (±226)	754 (±137)	811 (± 122)	3,700 (±264)	0	11 (±)	6 (±10)	18 (±12)
P-value	0.143	0.352	0.233	0.334	-	0.530	0.935	0.639

[1]Mean within plant classes and evaluation timings (columns) with followed by * were significantly greater at $P \leq 0.05$.

Table 6. Total season production (sum across months) as affected by herbicide treatment. Values represent means (± standard error) pooled across locations.

Herbicide	Sum of all classes (total biomass)[1]			
Treatment	30 DAT	60 DAT	90 DAT	Season
	… Biomass (kg DM ha^{-1}) …			
Control	2,592 (±146)	1,402 (±185)	1,158 (±)	5,151 (±172)
GF-3731	2,368 (±225)	1,037 (±131)	1,147 (±)	4,551 (±217)
P-value	0.336	0.059	0.925	0.057

[1]Mean within plant classes and evaluation timings (columns) with followed by * were significantly greater at $P \leq 0.05$.

PREDICTING YIELD BEFORE HARVEST: HOW DOES THE USDA NASS FORECAST CORN AND SOYBEAN YIELD AND PRODUCTION?

Introduction

The USDA National Agricultural Statistics Service (NASS) crop production forecasts have two components--acres to be harvested and expected yield per acre. Preliminary corn and soybean acreage estimates are made using data obtained from a survey of farmers conducted during the first two weeks in June. Expected corn and soybean yields are obtained monthly, August through November, from two different types of yield surveys. Data from the yield surveys reflect conditions as of the first of the month, as data are collected during the last week of the previous month and the first two or three days of the current month.

Crop production forecasts are based on conditions as of the survey reference date and projected assuming normal conditions for the remainder of the season. For example, the assumption of "normal conditions" is that temperatures and precipitation will be at historic averages for the remainder of the season. It is assumed that the first killing frost will occur on the historic average date. The crop maturity and conditions at the reference date are evaluated against the time remaining until the expected frost--if one third of the crop will not reach maturity until the frost date has passed; it is assumed that some frost damage will result. Long-range weather projections are not used as an indicator for final yield.

The reference point for crop forecast surveys is the first of the month, which is also usually close to the mid-point of data collection. Both grower-reported average yields and objective-measurement modeled yields contain a measurable forecast error based on the historic difference between these survey estimates and the final end-of-season yield. The review process followed to develop the monthly yield forecasts involves evaluating the relative ranges of the forecast errors of the grower yields and the objective measurement yields and the degree to which they overlap. When NASS states as policy that it is forecasting based on conditions as of the first of the month, it is saying that it will establish yields within the range of the survey estimates.

When forecasting crop yields, NASS does not attempt to predict future weather conditions. Long-range weather forecasts are not used in any forecast models. To the extent that conditions depart from normal, the forecasts also will fluctuate. Procedures used to prepare acreage estimates and yield forecasts are discussed in the following sections.

Base for Acreage Planted and To Be Harvested

The largest single survey NASS conducts each year is the June Agricultural Survey. During the first 2 weeks in June, about 2,400 interviewers contact over 100,000 farmers nationwide, either by telephone or in person, to obtain information on crop acreages, grain stocks, and livestock inventories. These producers are asked to report the acreage, by crop, that has either been planted or that they intend to plant, and the acreage they expect to harvest as grain. Data from this survey are used to estimate, among other things, total acres planted to corn, soybeans, and other crops regardless of the intended uses. Preliminary projections of acres to be harvested for grain or soybeans, including seed, are also made using these data.

The sample design for this survey utilizes two different sampling frames. The area frame, which is essentially the entire land mass of the United States, ensures complete coverage of the U.S. farm population. The list frame, a list of known farmers and ranchers, does not provide complete coverage of all farms, but allows the use of more efficient data collection methods.

Sampling from the area frame is a multi-step process. First, all land in each State is classified into land use categories by intensity of cultivation using a variety of map products, satellite imagery, and computer software packages. These land use classifications range from intensively cultivated areas to marginally cultivated grazing areas to urban areas. The land in each use category is then divided into segments ranging from about 1 square mile in cultivated areas to 0.1 square mile in urban areas. This allows intensively cultivated land segments to be selected with a greater frequency than those in less intensively cultivated areas. Segments representing cultivated areas are selected at a rate of about 1 out of 125. Sample segments in land use classifications with decreasing amounts of cultivated land are selected at rates ranging from 1 out of 250 to 1 out of 500.

About 9,000 area segments are selected nationwide for the survey conducted each June with 136 of these segments located in Wisconsin. Using maps and aerial photos showing the exact location and boundaries of each sample segment, interviewers locate and interview every operator with land inside the segment boundaries to identify crops planted in each field, and to obtain livestock inventory information, and quantities of grain in storage.

Before sampling from the list, each farm is classified by various characteristics such as number of acres by crop. Large farms are sampled at high rates. For example, Wisconsin farms on the list with over 5,000 acres of cropland, or grain storage capacity exceeding 1.0 million bushels, are selected with certainty. Smaller farms are selected at rates of 1 out of 10 to 1 out of 50.

About 68,000 farms across the United States are selected from the list to be surveyed during the same time period in June with about 2,200 of these farms located in Wisconsin. Farmers on the list sample are asked to provide total acres planted for each crop on all the land they operate, and quantities of grain stored on their operation. Data from this sample are collected mainly by mail and telephone interviewers.

Data from the area and list samples are combined using multiple-frame statistical methodology developed jointly by NASS and Iowa State University, which ensures that all land areas in the United States can be accounted for once and only once.

Generally, estimates of planted acres for corn and soybeans from the June Agricultural Survey are not re-evaluated and updated until October. However, occasionally the planting season runs late and many fields are not yet planted with the intended crops at the time the June survey is conducted. When this happens, adjustments to planted area estimates may be made at the time of the first yield forecast in August. If a significant portion of the crops are not planted by the time the June Agricultural Survey is completed, NASS may re-interview the June survey respondents during July to determine what was actually planted and also use satellite based acreage estimates and Farm Service Agency (FSA) data, if available. The preliminary projections for harvested acres may also be adjusted using data from the August yield surveys or in extreme cases from a special July re-interview survey. Any necessary changes to planted and harvested acreage estimates will be published in the August *Crop Production* report.

In October, NASS will review several data sources for corn and soybeans, including the farmer reported surveys, satellite imagery, and acreage data reported by producers to the Farm Service Agency (FSA) and may update the area planted and expected acres for harvest in the October *Crop Production* report.

Yield Forecasts

A subsample of farmers who respond to the list portion of the June Agricultural Survey is selected to provide monthly crop yield forecasts. This provides a way to screen farmers so that only those currently growing the commodities of interest are contacted during the monthly surveys. This monthly Agricultural Yield Survey asks the sampled farmers to report what they expect their crops to yield before harvest and actual yields are obtained at harvest. All yield data for an individual report are weighted by the farm's crop acres for harvest.

Objective Yield Surveys are conducted monthly beginning with the September 1 forecast in States that contribute most heavily to total U.S. production of corn and soybeans. These surveys provide information for making forecasts and estimates of crop yields based on counts, measurements, and weights obtained from small plots in a random sample of fields. Sample corn and soybean fields are selected from those identified in the area-frame sample portion of the June Agricultural Survey. In Wisconsin, 60 corn fields are selected. A total of 1,015 corn fields are sampled across the ten largest corn-producing states and 1,050 soybean fields are sampled across the 11 largest soybean states. Observations within each selected field are made in two randomly located plots. Each plot include two adjacent rows of predetermined length.

Harvested yield can be thought of as biological or gross yield minus harvest loss. Counts, measurements, and other observations from each sample plot are input to statistical models based on historical data to predict final number of fruit and final weight per fruit. A forecast of gross yield is calculated by multiplying these two components together and dividing by land area. Figure 1 shows the forecast variables used to predict the gross yield components for each crop.

Figure 1: Objective Yield Forecast Variables for Number of Fruit and Fruit Weight

Crop	Component	Forecast Variable[1]
Corn	Ears	- stalks - ears & ear shoots - ears with kernels
	ear weight	- historic average - kernel row length - ear volume - grain weight per ear
Soybeans	Plants pods per plant	- plants - main stem nodes - lateral branches - blooms, dried flowers & pods -pods with beans
	pod weight	- historical average - weight of pods with beans

[1] Variables measured are determined by stage of maturity.

Plant characteristics used as prediction variables change as the crop maturity progresses. At an early stage, plant counts may be the only data available for forecasting the number of mature fruit. As the crop matures, actual fruit counts can be used, and weights and measurements of the immature fruit are used to predict final weight per fruit.

The same plots are revisited each month until the crop is mature. At that time, the plots are harvested and final counts and weights are obtained. After the entire field has been harvested by the farmer, one-fourth of the sample fields are revisited and two more plots are laid out. Any grain left unharvested by the producer or grain on the ground in these plots is picked up and weighed to provide a measure of harvest loss.

Corn objective yield survey forecasts are based on estimates of number of ears and average ear weight. The ear count forecasts are accurate early in the season. When the crop is late developing, the projection of ears is based on a model using plant population. Historical average ear weights are used until ears are present to measure. Kernel row length and ear volume models are then used to project ear weight until crop maturity.

The estimate of number of soybean pods per acre from the Objective Yield Survey is usually very consistent from month to month and accurate when the bloom period has ended. Pod count forecasts usually stabilize with the September survey. Average pod weights prior to crop maturity are based on historical averages. In normal years, much of the soybean crop has matured by the October survey, so current-year pod weights are used at that time.

Potential accuracy of each month's forecast for these crops is dependent on the crop maturity at the time of the forecast and future weather. When maturity lags normal patterns, number of pods, ears, etc., is based on number of plants and fruiting positions rather than actual number of fruit. Thus, when maturity lags, the forecasts become more variable because the expected number of fruit can differ from the final. However, the primary source of forecast error occurs when final end of season fruit weights differ from the historic average because fruit weight cannot be fully determined until crop maturity. A comparison of the August and November yield forecast to the final NASS estimate for Wisconsin corn and soybeans is shown in Figures 2 and 3, respectively.

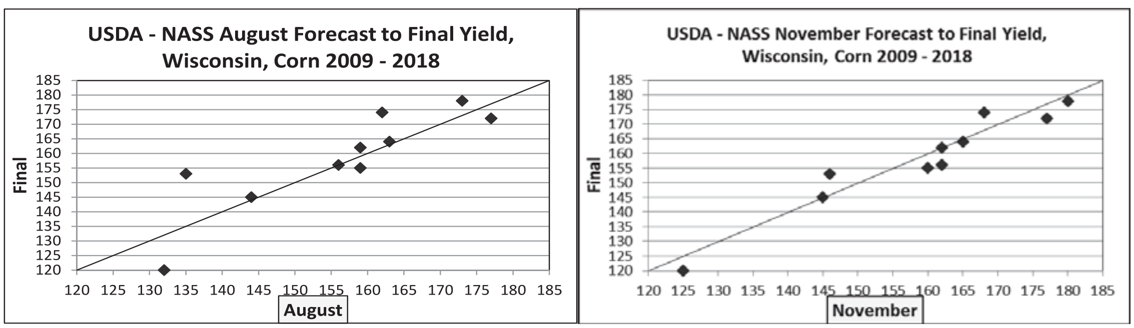


Figure 2

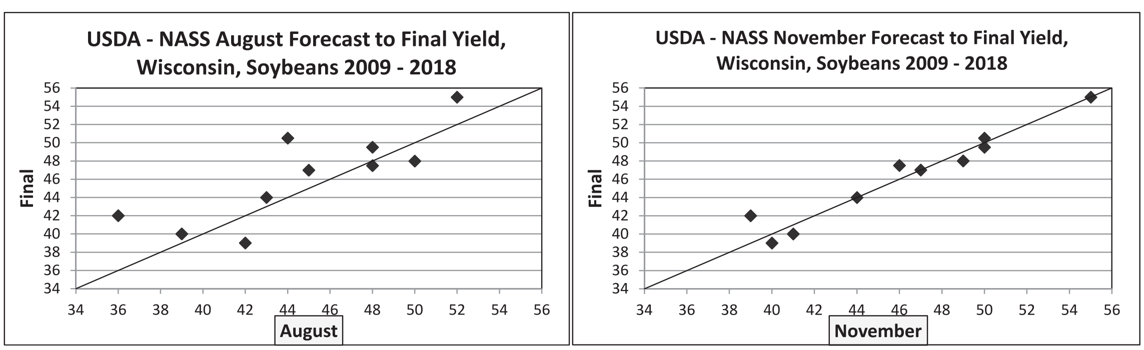
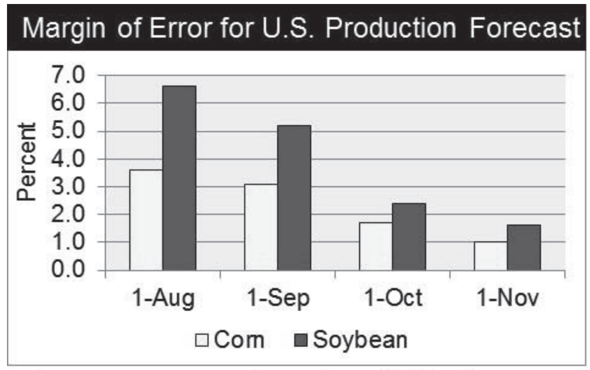


Figure 3

To assist users in evaluating the reliability of the production forecasts, the "Root Mean Square Error," a statistical measure based on past performance, is computed using the latest 20-year period. This margin of error, which is published in each *Crop Production* report and represents the deviation between the monthly U.S. production forecast and the final estimate, is expressed as a percentage of the final estimate. For example, the "Root Mean Square Error" for the September 1 corn for grain production forecast is 3.1 percent (see chart).



As crops progress toward maturity and NASS collects new survey data each month, the forecast error declines.

NASS will revise estimates of harvested acres if necessary during the forecast season when extreme weather events (flood, drought, hurricane) warrant and supporting data from a survey is available. Again, the goal is to make the production forecasts as accurate as possible. The production forecasts are based on projecting the acres that will be harvested and the final yield per harvested acre. If acres are lost during the forecast season because of weather or disease problems, those yields drop to zero, the acres are classified as planted but abandoned, and acres for harvest are reduced. For this reason, it is possible for the production forecast to be reduced without a corresponding drop in forecast yield per acre. It is also possible for the yield per acre to increase during adverse periods if acres for harvest are abandoned and classified as not for harvest. Data on which to base changes in harvested acres come from the yield forecast surveys when sample fields are taken out of production or the operator reports acres no longer being considered for harvest.

Final Estimates

During the first 2 weeks of December, an end-of-season multiple frame survey of about 82,000 producers across the country is conducted with approximately 2,300 of those producers located in Wisconsin. With harvest complete or nearly complete, farmers responding to this survey provide their actual numbers for planted and harvested acres as well as the actual yields realized on their farm. This information along with satellite imagery, acreage data reported by producers to FSA, and the final objective yield survey data are used to estimate the final acreage and production for the year.

Conclusion

NASS strives to provide the agricultural community with estimates and forecasts that are accurate, objective, reliable, and timely. The yield and production forecasts are meant to remove speculation about the size of this year's crops and are the unbiased source of information used by many market analysts to help provide their market outlook and advice to farmers and agribusinesses. NASS provides the information to everyone at the same time which helps level the playing field between buyers and sellers allowing more equal bargaining since neither has an unfair advantage by collecting his own facts. Up-to-date agricultural statistics also help to develop a stable economic atmosphere to reduce risk in production, marketing, and distribution operations.

The information provided by NASS is only possible with the voluntary cooperation of farmers on surveys throughout the growing season and after harvest. All information collected from farmers is kept completely confidential, as required by law. NASS safeguards the privacy of all respondents and only publishes aggregate totals, ensuring that no individual person or business can be identified. Strict security measures are followed to prevent leaks of this market-sensitive information that is published in the *Crop Production* report each month and is available on the NASS website at www.nass.usda.gov.

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ENLIST E3 – WHAT APPLICATORS SHOULD KNOW ABOUT THIS NEW TRAIT

Rodrigo Werle and Nick Arneson[1]

With the rise of herbicide-resistant weeds in row crop production throughout the US, there is need for new tools to be incorporated into POST-emergence weed management programs. Novel soybean herbicide-tolerant traits have been emerging in recent years allowing POST applications of glufosinate (Liberty Link, Liberty Link GT27, BASF Corporation) or dicamba (Roundup Ready Xtend, Bayer CropScience). In 2019, an additional tolerance trait was released allowing for POST applications of both glufosinate and 2,4-D choline (Enlist E3, Corteva Agriscience). The Enlist E3 trait technology was limited in its availability in 2019; however, it is expected to be adopted by many in the 2020 growing season. The adoption of Enlist E3 soybeans will allow for POST applications of glyphosate and glufosinate as well as new products containing 2,4-D choline such as Enlist One (2,4-D choline) and Enlist Duo (2,4-D choline and glyphosate). With the opportunity to apply these herbicides comes additional responsibilities in understanding the necessary measures for proper application.

Extension colleagues from other states have reported potential compatibility concerns with tank-mixing Enlist One with potassium salt of glyphosate formulations such as Roundup PowerMAX. Dr. Joe Ikley, Extension Weed Specialist at North Dakota State University, performed a jar test to evaluate compatibility of Enlist One with potassium salt of glyphosate (Roundup PowerMAX) and dimethylamine salt of glyphosate (Durango DMA) at 3 different carrier volumes (1, 3, and 15 gallons/acre). Ikley (2019) found that at the lower carrier volumes (1 and 3 gallons/acre) Enlist One + Roundup PowerMAX separated quickly and resulted in white chalky residue on the container walls. The same mixture at 15 gallons/acre carrier volume stayed in solution. This is important if applicators are considering tank mixing glyphosate with Enlist One. It is always a good idea to perform a jar test before tank mixing products to ensure adequate compatibility.

A large-scale trial evaluating potential drift of 2,4-D was established near Sun Prairie, Wis. in 2019. The field area was established by planting a 7-acre block of Enlist E3 soybeans in the center of a 40-acre soybean field. The acres surrounding the Enlist E3 block (total of 33 acres) were planted with 2,4-D sensitive soybeans. An application of Enlist Duo was made following label requirements in late July over the top of the Enlist E3 soybeans. Only slight injury was observed infrequently in the adjacent sensitive areas surrounding the trial indicating minimal drift of 2,4-D. It is important to pay attention to environmental conditions and follow all label requirements when applying 2,4-D to limit drift potential while optimizing weed control in Enlist E3 systems.

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EXPLORING TOOLS TO MONITOR IN-SEASON CROP NITROGEN STATUS

Mack Naber and Yi Wang [1/]

Nitrogen management on sandy soils is challenging by limited nutrient capacity coupled with rain events exceeding the water storage capacity of the crop root zone, which can quickly change plant available nitrogen. The findings presented here are from the first two years of a three-year study with two objectives: firstly, to compare in-season plant tissue samples, petiole, whole leaf and whole vine NO_3-N and total nitrogen for determining plant nitrogen status and correlation with final yield; secondly, to compare optimum applied nitrogen rates of developing varieties to varieties widely grown in Wisconsin.

The trial uses four varieties, Snowden, Hodag, Silverton, and W9433-1rus; five rates applied nitrogen (40, 180, 240, 300 and 360 pounds of nitrogen per acre over) were replicated four times for each variety-rate combination. W9433-1rus is compared with Silverton; Hodag with Snowden.

As this study is continuing, some data sets are incomplete at this writing, presented data is preliminary. In both 2018 and 2019, observed petiole NO_3-N concentrations are lower than the optimum concentrations outlined by Univ. of Wisconsin Extension (UWEX) recommendations. The rate, timing, and nitrogen source made in the study are comparable to the recommendations outlined UWEX guidelines for potato. The reason for this discrepancy is unclear. Comparisons of tissue sample types indicate petiole NO3-N concentrations were the most responsive to changes in plant available nitrogen. Petiole NO_3-N increased following nitrogen application and decreased following leaching events. Whole leaf and whole vine samples show a similar trend but lower in magnitude. Trends in total nitrogen content were similar in trend and comparable to observed changes to concentration of NO_3-N for each of the tissue times. In terms effort and time to collect samples, petiole and whole leaf samples collection required less resources than whole vine sampling. It is not apparent from two years of data that whole vine samples provide data greater value in than petiole or whole leaf, and it is difficult to justify the additional time and effort required for sample collection.

Trends between tissue nitrogen content and final yield were mixed. Total marketable yield of Silverton and W9433-1rus show a strong correlation between marketable yield with petiole nitrate content at 25 and 35 days after emergence (DAE) in 2018; there is weak or no correlation between yield and petioles nitrogen concentration for later

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collection dates during 2018 or 2019. The general correlation between marketable yield and applied nitrogen is positive, although weak. Total marketable yield for all varieties and treatments was lower in 2019 than 2018; cumulative growing degree days were also lower in 2019 than 2018. The yield response curve to applied nitrogen is not the expected smooth curve. While the correlation between applied nitrogen and total marketable yield was positive, yield from the 240-unit rate was the same or less than yield of the 180-unit rate in 2018 and 2019. This provides the evidence for splitting side-dress application if there is a chance rain capable of causing a leaching event within a week of the application, but more data is required.

The properties of sandy soils provide challenges to nitrogen management of irrigated crops. Sandy soils have high infiltration and fast draining, and low nutrient holding capacity and low water holding capacity. Weather is likely the most significant confounding variable in nitrogen response studies on sandy soils. Future nitrogen management tools may benefit from tools that incorporate probabilities of future rainfall event totals when determining application amount and timing.

WISCONSIN POTATO AND VEGETABLE WEED MANAGEMENT UPDATE

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

At the risk of gloom-and-doom, let's cut to the chase: traditional weed management as we've known it has been significantly challenged in recent years and the future isn't looking much brighter.

So why the dark clouds on the horizon? There are several reasons but for the sake of driving the situation home, let's focus on the top three:

1) Herbicide resistance among weeds is out of control. Globally, herbicide resistance has now been documented in 259 weed species and with 23 of 26 herbicide sites of action (Heap, 2019, www.weedscience.org). This year University of Illinois colleagues documented waterhemp resistance to the site of action that includes s-metolachlor, the active ingredient in Dual and several other herbicide trade names commonly used in potato and vegetable production. Why is this noteworthy? This is the first time where a broadleaf weed has been found to be resistant to that important herbicide group, and to make matters much worse, waterhemp has now been found to be resistant to seven herbicide sites of action.
2) Weed species that are almost always found with herbicide resistance have spread at an amazing pace across Wisconsin. Waterhemp is the unfortunate poster child for the spread of herbicide resistant weeds. My colleagues in the UW-Madison Agronomy Department have now found waterhemp in 61 of Wisconsin's 72 counties with glyphosate and other herbicide resistance traits common across those populations.
3) We haven't seen a new herbicide site of action since 1988 and that won't change soon. Hence the "recycling" of some of the first commercial herbicides from the 1940's with 2,4-D and dicamba in herbicide-resistant soybean and other crops to address weed resistance. Even if a new herbicide site of action were to be discovered, it takes at least 10 years and hundreds of millions of dollars to get from the lab bench to a label.

Without new herbicides on the way and the potential to lose control with our existing tools, where do we go? Our solutions are going to be vastly different and creative, and hopefully practically integrated into current management programs in smooth transition and without significant economic impact.

We're focused on strategies that require few if any additional inputs, including grower time, but instead focus on overemphasizing inherent crop traits that improve competitiveness with weeds. In contrast, most integrated weed management work to date has included adding inputs, like cultivation, cover crops, or more herbicides. So, what traits are valuable in our potato and vegetable crops in terms of competitiveness with weeds? We're looking for:

- Rapid and uniform crop emergence. This not only gives the crop a head start in the race against weeds but also decreases the time needed to get to a point where post-emergent herbicides and cultivation are less injurious. In our current situation crops like carrot and potato emerge slowly and rather inconsistently. We're changing that equation by adding very low doses of natural plant growth regulators that stimulate growth as either seed

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treatments or applied to young crop foliage. These plant hormones already occur in all plants – we're just tweaking them.

- Planting timing that not only optimizes yield but also early crop canopy closure. Each crop has a "sweet spot" for temperature and photoperiod that enhances early-season growth. Our recent work with carrot is a great example – shifting the planting timing two weeks later enhanced early carrot emergence and growth so much that very few weeds survived, and yield wasn't compromised compared to earlier plantings.
- Planting populations and configurations that lead to earlier canopy closure while maintaining or increasing crop yield. If you could increase your marketable crop yield by 10 to 20% without increasing water, fertilizer, pest management, time or other inputs, would you take it? Probably so if there weren't significant side effects. We've been able to do that in crops like carrot by adding two rows to each bed, in essence filling in areas that are still fertilized, water and sprayed to get to a competitive closed canopy earlier. Side effects could include increased risk of foliar diseases with less air movement in the canopy, and most significantly, equipment changes for the seeder and harvester. These significant changes will need to be balanced with the need to control herbicide resistant weeds with fewer tools – we're right up against that breaking point.
- Competitive crop varieties. From the standpoint of added energy and time, it can't get more efficient than just filling the planter with a more competitive variety that still has suitable end use characteristics. We've evaluated this extensively in potato with varieties dating back to some of the original Russet Burbanks from the late 1800's to recent introductions. The general trend was that older varieties tended to have faster developing and more complete plant canopies, likely a result of breeding for many years for higher yield at the cost (intentional or unintentional) of above-ground growth. In related work in carrot, breeders are now doing both – selecting for disease-resistant heavy top growth that outcompetes weeds as well as high yield and quality.

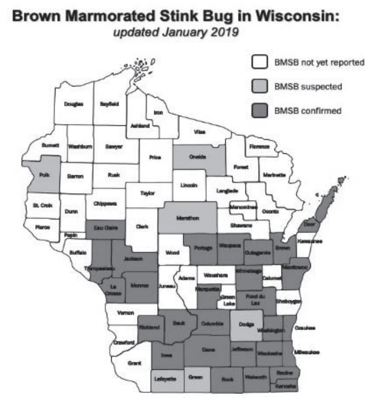
Our work "recycling" traditional herbicides from agronomic crops to specialty crop continues in addition to the work outlined above. In the past few years, we've conducted herbicide research on over two dozen crops. And, we've had some successes, such as new registrations for Zidua and Sonalan in potato, and we expect more in the near future. However, we also need to be prepared to integrate some of the more innovative strategies outlined above for a long-term solution.

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

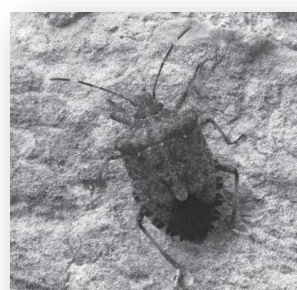
RECENT AND ANTICIPATED INSECT ARRIVALS IN PROCESSING VEGETABLES

Russell L. Groves[1/]

In the 2019 crop season, only a few insect populations were larger than expected, and even a few were regarded as the lowest on record. But as has been reported in past years, we have several new, and potentially a few anticipated exotic and invasive insects that could affect processing vegetables in Wisconsin. One of these is the Brown Marmorated Stink Bug (BMSB), a relatively recent arrival that has continued its statewide range expansion and increase across the state. Recall, this pest species was initially detected in the state nearly nine years ago, with new reports over many counties in the west central and southcentral parts of the state by January 2019, and established, reproducing populations throughout many portions of central and southern Wisconsin. This insect is now established as a serious pests of fruit, vegetables and field and forage crops in the Mid-Atlantic region and it is very likely these insects will become serious issues once populations increase in localized areas. In the upper Midwest, processing vegetable and potato production regions containing crops such as pepper, green bean, sweet corn, tomato and even potato, could be affected if populations become large and sufficiently damaging in the years to come. BMSB activity seems to be concentrated in two principle regions of Wisconsin: the Highway 41 corridor from Fond du Lac up to Green Bay and southern Wisconsin from Dane and Rock Counties east to the Milwaukee metro area. These two areas have the longest history of BMSB in the state and account for the majority of reports thus far. Populations of BMSB population are expected to build to a point where nuisance problems around structures are more prevalent, and reports of potential plant damage will become more commonplace.



Distribution of the brown marmorated stink bug in Wisconsin as of early 2019. BMSB has been confirmed in 28 counties. Map Credit: PJ Liesch, UW Insect Diagnostic Lab (http://labs.russell.wisc.edu/insectlab/files/2018/11/BMSB-Map-January-2019.jpg).



Brown marmorated stink bug adult on the side of a building in fall. Photo Credit: PJ Liesch, UW Insect Diagnostic Lab.

Native to Europe and southwestern Asia, the swede midge, *Contarinia nasturtii* (Kieffer) Diptera: Cecidomyiidae, was identified on pheromone trap samples from Dane and Milwaukee counties this summer in 2019. Specifically, officials with the USDA APHIS confirmed two samples as positive for the presence of swede midge, using traps baited with pheromone lure, and set in broccoli as part of a USDA Farm Bill, 'Pathways Survey'. The two records were collected on 06/17/2019 in Madison, WI (Dane Co.), and on 07/01/2019 in Wauwatosa, WI (Milwaukee Co.), and following definitive identifications, this information was released to the Wisconsin Department of Agriculture, Trade and Consumer Protection (DATCP) on Tuesday, September 10, 2019. An additional four trapping locations (located

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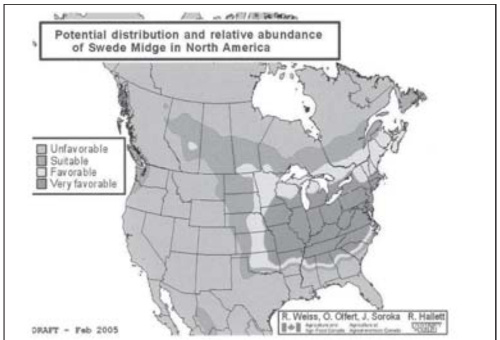
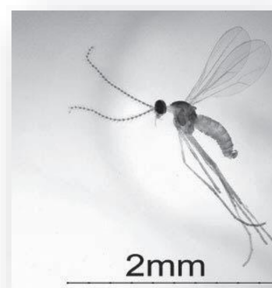
in Dane, Sauk, Columbia counties) did not find any swede midge through the 2019 survey season. Reports were initially provided by the USDA APHIS to Mr. Brian Kuhn, State Plant Regulatory Bureau Director, and Ms. Krista Hamilton, Entomologist with the Bureau.
This is regarded as the first Wisconsin detection of the insect which was originally identified in North America in 2000, where it was detected in Ontario, Canada. In 2004, the first detection in the US occurred in Niagara County, New York. The insect was later detected in Michigan in 2015, and in Minnesota in 2016, and appears to have been spreading across NE states and Canadian provinces since this time. Climatic projections suggest that the insect can easily become established in production areas within and around the State of Wisconsin.



Potential distribution of Swede midge populations in areas of the US and Canada as determined by climate projections (photo credit: Olfert et al. 2006).

In areas of Europe where the swede midge is endemic, the insect is regarded as a pest of cruciferous vegetable crops, such as broccoli, cabbage, cauliflower, Brussels sprouts, kale, collards and rutabagas. The insect can also be found infesting many cruciferous weed species to include wild mustard, wild radish, shepherd's-purse, field pennycress, common pepper grass and yellow rocket. The swede midge adult is a very small, light-brown fly or midge (1-2 mm), and can be very difficult to distinguish from other closely related midge species. New occurrences in uninfested areas require confirmation by a qualified insect taxonomist. Suspected samples can initially be directed to the Insect Diagnostic Laboratory in the Department of Entomology (http://labs.russell.wisc.edu/insectlab/). Over-wintered adults emerge in the spring from mid-May through mid-June, with peak emergence usually occurring around June 1. After emergence, mated females will begin to lay eggs on the youngest, actively growing vegetative tissue of susceptible cruciferous crops (and weeds), typically near the growing point (apical meristem). Larvae hatch from eggs in about 3 days and begin to feed (as maggots) as groups of individuals on succulent plant tissue, completing their development in about 12-20 days (temperature dependent). Larvae complete development and drop from affected plants onto the soil where they pupate for 5-7 days re-emerging as adults ready to initiate as many as four to five overlapping generations in a season. Larvae of the swede midge damage crops through their oral secretions (saliva) that break down plant cell walls, allowing larvae to feed on the cellular contents. The saliva interacts with the plant tissues to produce swollen, distorted and twisted leaves and meristems. Significant damage to the terminal leader (meristem) can result in the formation of a blind head. Damage symptoms can be easily confused with other common problems. Check suspected plants carefully for the presence of larvae, examining the new growth more carefully.



Swede midge adult fly. Photo credit: Susan Ellis, Bugwood.org (#1253047).


Swede midge damage in a terminal leader (meristem). Yellow circles indicate larval infestations. Photo credit: K. Hoepting, (http://web.entomology.cornell.edu/swede-

Detailed information discussing the impact of the pest, and associated management and control of the pest can be found:
http://web.entomology.cornell.edu/shelton/swede-midge/index.html
http://www.omafra.gov.on.ca/english/crops/facts/08-007.htm

https://www.canr.msu.edu/news/swede_midge_biology_and_management

EVALUATING EFFICACY OF 590 FALL MANURE MANAGEMENT PRACTICES TO IMPROVE CORN N UTILIZATION?[1]

Anna O. Teeter, Todd W. Andraski, and C.A.M Laboski[2]

Abstract

Fall applications of manure have the potential for high nitrogen (N) losses. Cereal/grass cover crops have been shown to take up fall applied N. Similarly, using nitrapyrin (Instinct®) has been shown to prevent loss of fall applied N. No studies have been conducted to evaluate combining these tools to prevent N loss. This experiment was performed in 2016 and 2017 on a well-drained and somewhat poorly drained silt loam soils. This study was conducted to determine if using Instinct® and spring wheat (*Triticum aestivum)* with fall applied manure could improve nitrogen availability to corn (*Zea mays*) due to a synergistic effect. Dairy slurry was broadcast and incorporated in the fall either with or without Instinct® and with or without cover crop. Fertilizer N treatments were split (40 lbs/a at plant and sidedressed at growth stage V6) applied in 40 lb N/a increments up to 240 lb N/a. The amount of soil nitrate in the upper 12 inches of soil was reduced up to 41% in the first four weeks after application. Eight weeks after manure application the cover crop reduced soil nitrate concentration up to 68%. Instinct® did not have any significant effect on soil nitrate concentration. At the V6 corn growth stage cover crop increased soil nitrate concentration 31% compared to manure only plots. Cover crop significantly reduced grain yield by as much as 38 bu/a. At one site year in 2017, cover crop with Instinct® significantly decreased grain yield compared to manure only, manure with cover, and manure with Instinct®. In the fall Instinct® does not perform in long warm periods before the soil cools and may also be affected by manure organic matter cover crop effectively takes up soil N.

Introduction

There is rising concern for the high rates of N loss in agricultural crop production. These N losses transport through the soil via leaching and contaminate local drinking water and run off the soil surface where it eventually flows to the Mississippi river, and collects in the Gulf of Mexico (Kladivko et al., 2014). Losses of nitrate can denitrify in anerobic, wet, conditions contributing to greenhouse gas emissions and reducing air quality. Even with this concern there is still some preference for growers to apply their fertilizer or manure in the fall. In the Midwest soils in the fall are drier and provide a better surface for application equipment compared to spring soils that can be very wet. Emptying manure pits in the fall also gives growers a chance to lower their manure levels before winter ensuring they prevent overflow. In addition, there is more time in the fall to apply fertilizer as there is no competition from planting crops.

Because of this need for fall application, mitigation techniques must be employed to prevent as much N loss as possible. Cover crops are a tool which recently have been shown to be an effective means of N uptake in fall applied manure and are labeled as catch crops. Catch

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crops are typically grasses; rye or winter wheat are the most popular, as their growth before frost will take up N (Dabney et al., 2001; Strock et al., 2004; Snapp et al., 2005a; b; Lacey and Armstrong, 2015). There is strong evidence that these practices reduce nitrate losses during winter months with fall manure applications, but there are mixed results on the impact on yield (Thilakarathna et al., 2015). After the winter season the cover crop is intended to mineralize N during the cash crop growing season, although results are inconsistent (Ketterings et al., 2015). Overall cover crops are a potentially useful tool for preventing N losses.

Nitrification inhibitors are another tool used to mitigate N losses. After the hydrolysis of urea to ammonium from manure fertilizers, the ammonium is relatively quickly converted to nitrate where it is easily lost because it has a weak negative charge (Beeckman et al., 2018). Nitrification inhibitors are designed to prevent the first step of nitrification, the conversion of ammonium to nitrite by *Nitrosomonas spp.* Instinct® (nitrapyrin) is a commonly used nitrification inhibitor in the USA. Instinct® is a bacteriostatic compound as it inhibits enzymatic activity, and is not a broad spectrum bactericide (McCarty, 1999; Beeckman et al., 2018). In studies with high soil organic matter Instinct®'s efficacy decreased, compared to soils with low organic matter (McCarty and Bremner, 1989). High temperatures also tend to reduce longevity of Instinct® (Touchton et al., 1979). Vetsch et al. (2017), has demonstrated the use of Instinct® to successfully increase N availability of fall applied swine manure to corn and increased yields.

The objective of this study was to determine if there is a synergistic effect of cover crop and Instinct® on availability of N from fall applied dairy slurry.

Material and Methods

Site Conditions and Plot Setup

Research was conducted in 2016 and 2017 at two locations, Arlington Agricultural Research Station and Marshfield Agricultural Research Station. Arlington Agricultural Research Station is on a well drained Plano silt loam soil (fine-silty, mixed, mesic Typic Agriudolls). Marshfield Agricultural Research Station is on a somewhat poorly drained Withee silt loam soil (fine-loamy, mixed Aquic Glossoboralfs) (NRCS USDA, 2017).

Treatments

The experimental design was a randomized complete block with 11 treatments and 4 replications, totaling 44 plots. The plots were 10 feet wide (four rows of corn with 30 inch-spacing) and 40 ft long. There were four fall treatments that had 7,000 gal/a of dairy slurry broadcast and incorporated either with or without 78 oz/a Instinct® and either with or without a fall cover crop. There were seven synthetic split fertilizer treatments (40 lbs N/a at plant plus sidedress at growth stage V6) applied in 40 lb N/a increments up to 240 lb N/a. The previous crop was corn silate. Hard-red spring wheat was planted in the fall after manure application at a population of 2.5 bu/a in 7.5-inch rows. The reason for using spring wheat as the cover crop are several fold: 1) Instinct® is only registered for use on corn or wheat in Wisconsin; 2) spring wheat has greater fall biomass production than winter wheat; 3) spring wheat winter kills so it is unnecessary to terminate in the spring and can speed up spring field operations; and 4) the fall growth can be used as a forage if needed. Corn was planted in May at a population of 35,000 seeds/a. Each plot had an initial starter fertilizer of 110 lb/a of 9-23-30 placed 2x2. Corn was managed using the University of Wisconsin recommendations, including preplant and post emergence herbicide application.

Soil, Plant and Manure Sampling

Manure samples collected during application were analyzed for dry matter, total C, total N, NH_4^+-N, total P, total K, pH, and ash (Peters et al., 2003). Manure total N for Arlington 2016 was 126 lb/a and 49.6% was NH_4^+, for 2017 total N was 116 lb/a and 50.9% was NH_4^+. For Marshfield 2016 total N was 58 lb/a and 44.8% was NH_4^+, and for 2017 total N was 69 lb/a and 44.9% was NH_4^+.

In the fall, a soil sample from the control treatment was collected in each replicate and comprised of 6 cores collected to a depth of 6 inches and was analyzed for Bray 1 P and K (Bray and Kurtz, 1945). Weight loss on ignition (Schulte and Hopkins, 1996) was used to analyze organic matter, and 1:1 soil to water was used to analyze pH. In treatments where manure was applied, as well as the control treatment, soil samples were collected to 12 inches in the fall at 4 and 8 weeks after manure application as well as in the spring at the V6 corn growth stage. Samples were oven dried then ground and passed through a 2 mm sieve before analysis. All samples analyzed for nitrate and ammonium were extracted with 2*N* KCL with a 1:10 soil to solution mixture and shaken for one hour (Bundy and Meisinger, 1994) and then analyzed with Flow Injection Analysis (Růžička and Hansen, 1984).

Just prior to winter kill spring wheat biomass samples were collected from 15 inch sections from 5 rows and then analyzed for total N concentration. Grain was harvested from each replicate and analyzed for total N concentration. All grain and plant samples were oven dried then ground and passed through a 1 mm sieve before analysis. Total N concentrations were measured using a Kjeldahl digestion for all plant and grain samples (Nelson and Sommers, 1973).

Statistical Analysis

Corn grain response to N was analyzed using SAS 9.4 (SAS Institute, 2004), PROC REG was used to analyze linear and quadratic regressions. PROC NLIN was used to analyze linear plateau regression and quadratic plateau regression. All four sites used the quadratic plateau regression except for Arlington 2016 because there was no response to N fertilization.

PROC MIXED was used to analyze means of data for plant and soil samples, and a p-value of 0.10 was used to establish significant differences between means.

Results and Discussion

At both Arlington and Marshfield 2016 soil samples collected 4 and 8 weeks after manure application in the fall had significantly lower soil nitrate concentrations when the cover crop was planted compared to manure without cover crop (Table 1). Cover crop reduced soil nitrate at Arlington 29 and 60% after 4 and 8 weeks, respectively. At Marshfield cover crop reduced soil nitrate 41 and 68% after 4 and 8 weeks, respectively. In 2016, V6 soil nitrate concentrations were 31% greater with cover crop compared to no cover crop at Arlington suggesting the cover crop helped retain N. In contrast, cover crop had significantly lower soil nitrate than without cover at Marshfield (Table 1). Wildlife grazed the cover crop approximately 7 weeks after manure application (Table 2) and removed N from the system which likely explains the reduced soil nitrate concentrations at V6. Due to excellent growing conditions and high soil N mineralization, there was no yield response to spring applied N fertilizer (Table 3); the control treatment yielded 265 bu/a. No yield differences were found between fall manure treatments (Table 4). At Marshfield the cover crop significantly reduced corn grain yield compared to no cover crop (Table 3). This is likely due to the wildlife grazing mentioned previously. The data demonstrate that if a fall cover is used for late fall forage or grazing, N taken up by the cover crop would be removed from the system and would be unavailable for the following crop.

At Marshfield 2017, 4 weeks after manure application there was no significant differences in soil nitrate concentrations. Eight weeks after manure application, soil nitrate concentrations were significantly lower with cover compared to without (Table 2), a 21% reduction. Differences in soil nitrate concentrations occurring later in the fall coupled with generally lower cover crop N uptake are evidence of the slow growth of the cover crop. Use of Instinct® did not affect cover crop biomass yield (Table 2) or biomass N uptake. In the spring, V6 soil nitrate concentrations were not significantly different from each other. In April, May, and June the precipitation was 3.2, 2.0, and 2.4 inches, respectively, above the 30 year average (Figure 1) providing conditions conducive to N loss. Grain yield from the various manure treatments were not significantly different from each other and yields from manure treatments (Table 1) were equivalent to the 0 lb N/a treatment (Table 3). This indicates all N from manure application was lost.

At Arlington in 2017, 4 weeks after manure application there was not a significant difference in soil nitrate concentration between treatments. Eight weeks after manure application cover crop significantly reduced soil nitrate concentrations compared to no cover crop (Table 1). Due to lower cover crop yields in 2017 compared to 2016, less soil N was taken up by the cover crop until later in the fall (Table 2). There was no significant difference between cover crop biomass with Instinct® and cover crop without Instinct®; however cover crop N uptake with Instinct® was significantly greater than cover crop without Instinct® (Table 2). Spring V6 soil nitrate concentrations for any fall manure treatment was not significantly different than the control. Cover crop with Instinct® grain yield was significantly lower than manure only, manure with cover crop or manure with Instinct® (Table 3). It is unknown as to why cover crop with Instinct® is 32 bu/a lower than manure only, but it may be due to higher N uptake by cover crop with Instinct® (Table 2).

Use of Instinct® with manure did not change soil nitrate concentrations whether used in conjunction with cover crop or not for all four site years. It is likely that with warmer than average November temperatures (Figure 1) and above average precipitation following manure application, Instinct® degraded quickly in the soil and could not preserve ammonium for the following crop.

Summary

Although there are positive impacts of both grass cover crop and Instinct® on N uptake from fall applied manure, there was no strong evidence that they worked synergistically to improve N availability to the corn crop. The use of spring wheat as a cover crop did reduce soil nitrate 4 and 8 weeks after fall dairy slurry application, but this was not converted into available

N during the growing season. It may be more practical to recover the growing cover crop as a forage and eliminate the possibility of N escaping during the growing season, and fertilize the cash crop accordingly. In this study Instinct®'s efficacy was challenged with at least two months of warm weather before the soil froze and slowed biological activity. In addition, Instinct® was applied with manure, which contains high levels of organic matter which may bind compound lowering it's efficacy.

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Table 1. Soil nitrate concentrations at 4 and 8 weeks after fall manure application and in the spring at V6 at Arlington and Marshfield in 2016 and 2017.

	2016			2017		
	Post fall manure			Post fall manure		
Treatments	4 weeks	8 weeks	V6	4 weeks	8 weeks	V6
	-------------------------------lb N/a------------------------------					
Arlington						
Control	61 c †	24 b	70 b	43	35 a	51
Slurry	128 a	58 a	74 b	39	33 a	49
Slurry + Instinct®	124 a	57 a	79 b	38	38 a	55
Slurry + Cover crop	91 b	23 b	97 a	35	20 b	51
Slurry + Cover crop + Instinct®	87 b	22 b	95 a	38	17 b	46
p-value	<0.01	<0.01	<0.01	0.95	<0.01	0.70
Marshfield						
Control	42 bc	33 b	66 ab	17	19 a	14
Slurry	59 a	45 a	82 a	15	19 a	17
Slurry + Instinct	51 ab	51 a	85 a	15	19 a	13
Slurry + CC	35 c	17 c	60 b	16	15 b	13
Slurry + CC + Instinct®	37 c	15 c	56 b	15	15 b	15
p-value	0.03	<0.01	0.09	0.68	<0.01	0.27

† For a given location, values within each column followed by the same letter are not significantly different ($p<0.1$).

Table 2. Fall sampled spring wheat biomass yield and biomass N uptake at Arlington and Marshfield in 2016 and 2017, 8 weeks after manure application.

	2016		2017	
Treatment	Arlington	Marshfield	Arlington	Marshfield
	-----------------------lb/a-----------------------			
Biomass yield				
No Instinct®	1664	307†	498	350
Instinct®	1407	221	528	320
p-value	0.08	0.03	0.14	0.52
Biomass N uptake				
No Instinct®	70	13	18	10
Instinct®	64	9	20	9
p-value	0.03	0.06	0.07	0.24

† Grazed by wildlife between 4 and 8 weeks after manure application, 1 to 5 inches in height.

Table 3. Corn grain response to split N applications at Arlington and Marshfield in 2016 and 2017.

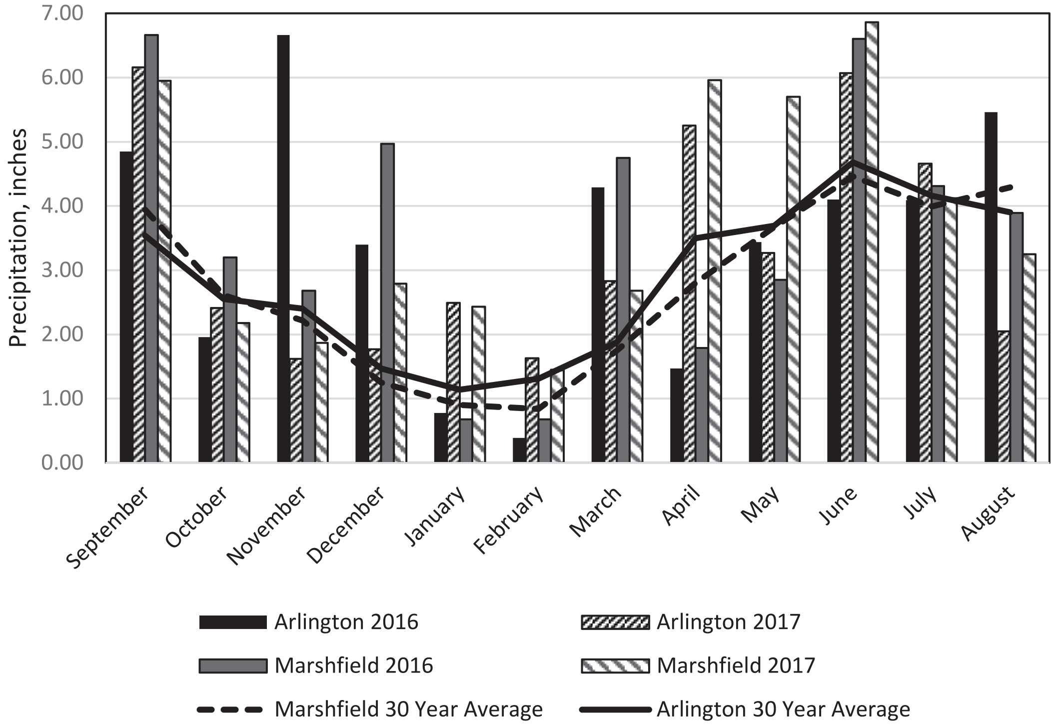
	2016		2017	
Treatment	Arlington	Marshfield	Arlington	Marshfield
	--------------------------------bu/a----------------------			
0	265	160 c †	186 d	74 e
40	266	201 b	199 cd	90 d
80	274	220 a	216 bc	134 c
120	272	231 a	219 b	155 b
160	268	234 a	228 ab	170 a
200	273	222 a	237 a	175 a
240	276	230 a	233 ab	181 a

† Values within each column followed by the same letter are not significantly different (p<0.1).

Table 4. Corn grain response to various dairy slurry treatments at Arlington and Marshfield in 2016 and 2017.

	2016		2017	
Treatment	Arlington	Marshfield	Arlington	Marshfield
	----------------------bu/a---------------------			
Slurry	259	192	185 a†	78
Slurry + Instinct®	267	184	191 a	77
Slurry + Cover Crop	261	154	180 a	75
Slurry + Instinct® + Cover Crop	260	164	153 b	72
p-value				
Instinct®	0.46	0.95	0.07	0.35
Cover crop	0.61	0.02	<0.01	0.56
Instinct® x Cover crop	0.36	0.41	<0.01	0.74

† Values within each column followed by the same letter are not significantly different (p<0.01).



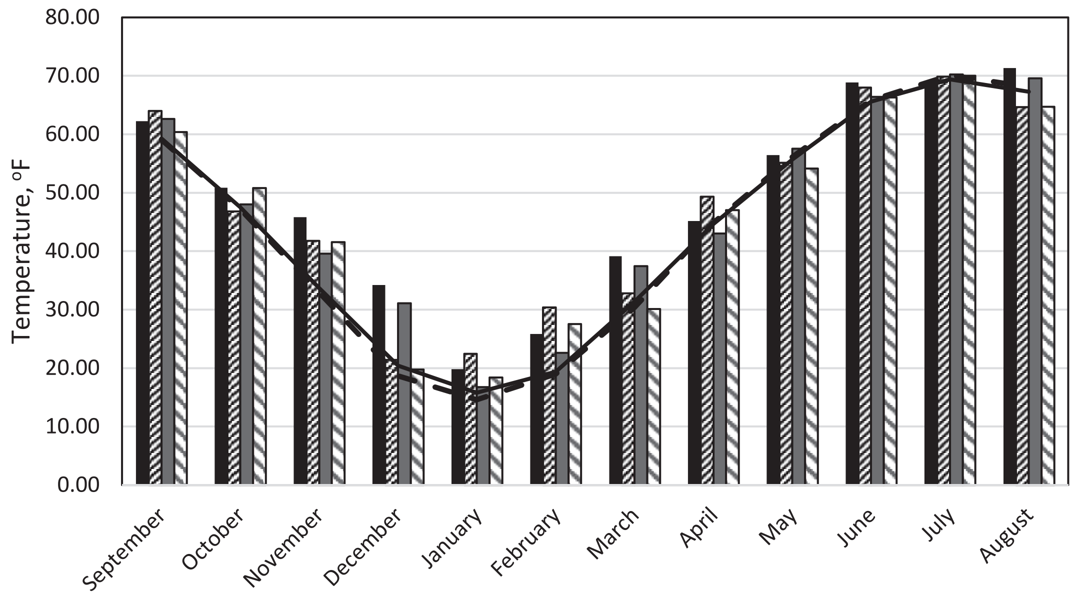


Figure 1. Mean monthly air temperature in ^{o}F of all four site years, and thirty year averages (upper graph). Monthly sum of precipitation in inches over all four site years and 30-year averages (lower graph).

UTILIZING P AND K FERTILIZER RECOMMENDATIONS IN OHIO WITH ON-FARM STRIP TRIALS

Steve Culman [1/]

In Ohio, phosphorus (P) and potassium (K) recommendations for corn and soybean were last updated in 1995 with the Tri-State Fertilizer Recommendations. Water quality and nutrient management issues in the state have stimulated interest in re-evaluating these recommendations after more than 2 decades. From 2014-2018, we conducted 102 on-farm trials in P in corn and soybean and 84 trials in K for corn and soybean in Ohio. All trials were replicated and randomized and employed both large strip trials and small plot trials formats. Soil test P and K, leaf tissue concentrations at R1, grain nutrient concentrations at harvest and grain yields were measured on all trials. Soil tests values ranged greatly, with most fields falling above the current critical levels. Overall, grain yield responses to P or K fertilization were rarely observed with < 5% of trials for both P and K demonstrating statistically significant responses. Overall, our results suggest that current fertilizer recommendations in Ohio are not too low and that current critical levels for soil test P and K provide a very conservative range for corn and soybean.

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Sue Porter [1/]

Implementing a nutrient management (NM) plan is one of the best practices farmers can use to protect their soil and water resources and farm profitability. The Wisconsin Department of Agriculture, Trade and Consumer Protection (DATCP) annually tracks NM plans on farms through NM plan checklists submitted from farmers, agronomists, and agency staff. A NM plan follows the USDA Natural Resources Conservation Service's (NRCS) WI 2015-590 NM Standard. A NM plan is prepared by a qualified planner. The planner is the farm's owner, operator, or a certified crop advisor.

2019 NM by the Numbers

- 8,399 NM plans reported by Wisconsin farmers
- 3.4 million acres under a plan
- 36.9% of Wisconsin's 9 million acres of cropland covered by a plan
- 6,245 farmers hired 322 agronomists to assist with plan development *(up 2% from 2018)*
- 74% of all plans are produced by agronomists *(up 2% from 2018)*
- 2,154 farmers wrote their own plans on 620,238 acres *(up 8% from 2018)*
- 26% of all plans are produced by farmers

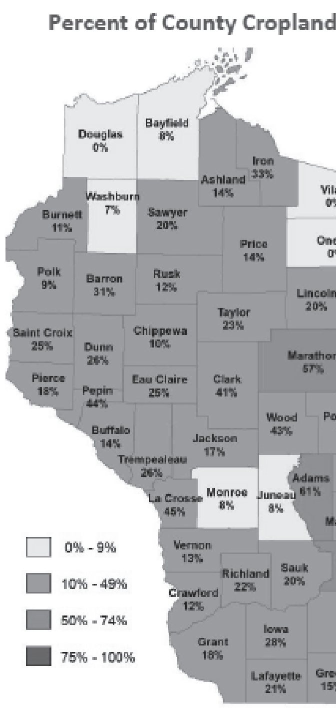


Figure 1 Harvested cropland acres are derived from National Agricultural Statistics Service, Census of Agriculture, 2017. The 2012 census reported 9,148,876 harvested cropland acres; the 2017 census reported 9,234,611 harvested cropland acres.

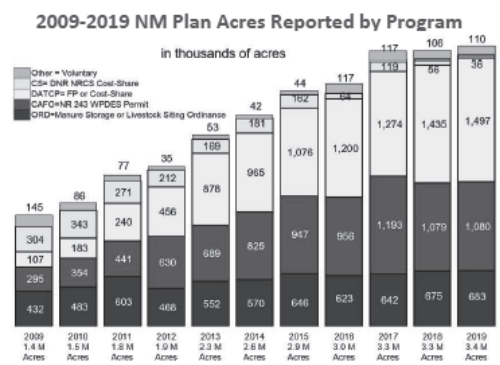


Figure 2 NM plan acres derived from NM plan checklists reported to WDATCP. The Farmland Preservation (FP) program is the major reason for developing and maintaining a NM plan.

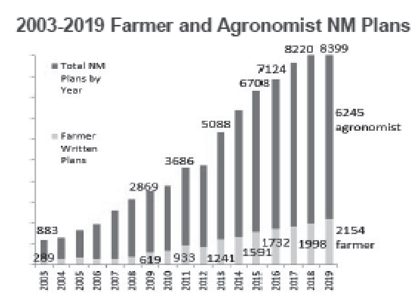


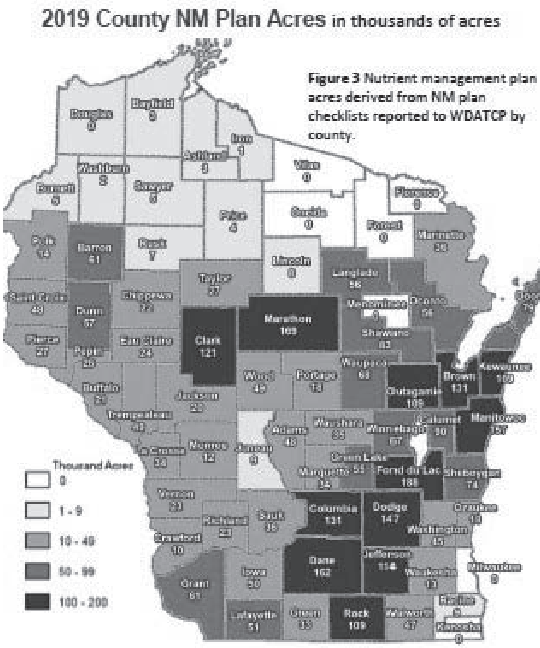
Figure 5 Farmers write more NM plans every year.

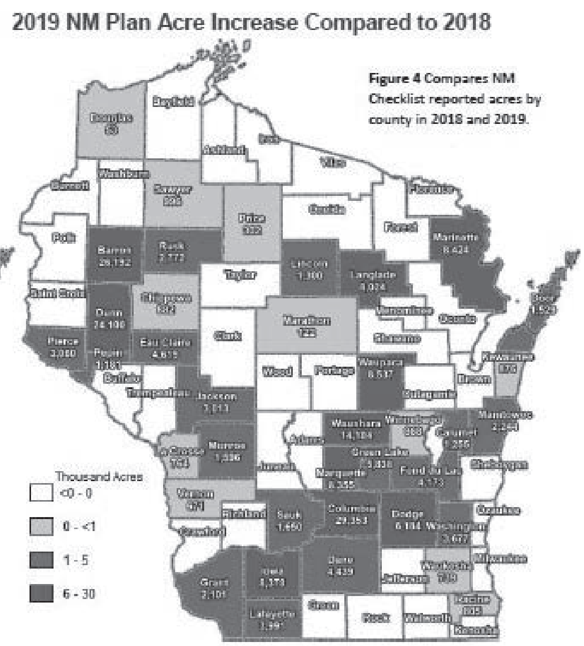
County conservation staff and programs are a major driver for NM plan implementation. They offer education, provide cost-sharing, provide technical support, assist with conservation compliance, and issue permits under ordinances. Other DNR and NRCS staff and programs also have roles in implementation, Figures 1 and 2. See Figure 3 for NM plan acres, Figure 4 for acres increased from 2018 by county, and Figure 5 for who wrote plans.

[1/] Nutrient management specialist, Wisconsin Department of Agriculture, Trade, and Consumer Protection, 2811 Agriculture Drive, Madison WI 53718

Who needs a NM plan? All farms: Some farms voluntarily plan, others are required to have a plan when applying nutrients to any pasture or field if:

- Offered cost-share for NM or manure storage
- Participating in the FP program
- Regulated under a county ordinance for manure storage or livestock siting
- Regulated under a Wi DNR Pollutant Discharge Elimination System (WPDES) permit
- Found causing a significant discharge





Planning and Resources

A NM plan is a planning tool that is annually reviewed and updated to reflect actual crop management practices. As of February 1, 2018, chapter ATCP 50 Wis. Admin. Code requires that farmers follow the 590 standard adopted by NRCS in 2015. To help farmers and planners follow the 2015-590 NM Standard, SnapPlus software is continually being improved by the SnapPlus team led by Dr. Laura Ward Good of the University of Wisconsin's Soil Science Department. The rest of the team consists of Joe Wolter, Jim Beaudoin, Rick Wayne, Sarah Sebrosky, and Mimi Broeske of the UW Nutrient and Pest Management Program. Without these people coordinating with the agencies and incorporating the soil databases, models, map layers, and educational materials, Wisconsin farmers would not be implementing NM at the current level.

Planning and Resources
SnapPlus Software and Training Opportunities

- Farmers or their agronomist can use SnapPlus computer software to develop a farm database that uses the farm's soil tests, field maps, crops, and tillage systems to plan applications for manure and fertilizer. Download the free software at: https://snapplus.wisc.edu/

- Contact your county land and water conservation department or DATCP NM staff. Learn about Nutrient Management and Farmer Education grants, which can reimburse farmers

for soil testing when part of a class to write a plan. Information at:
https://datcp.wi.gov/Pages/Programs_Services/NutrientManagement.aspx.

NM plans begin with soil tests from DATCP's Certified Soil Testing Labs

A & L Great Lakes Labs (Fort Wayne IN) AgSource Labs (Bonduel WI) Dairyland Labs (Stratford WI) Minnesota Valley Testing Labs (New Ulm MN) Midwest Labs Inc. (Omaha NE) Rock River Lab (Watertown WI) UW Soil & Forage Analysis Lab (SFAL Marshfield WI)	UW - SFAL and DATCP operate a robust quality assurance program to ensure the certification process facilitates confidence in commercial laboratories' ability to effectively deliver precise and accurate results.

Performance Standard Implementation
WI NM laws have been set up to provide education, outreach, and compliance. WI is implementing more NM every year and showing our system can work. ATCP 50 Wis. Admin. Code explains how NM is to be implemented using the 2015-590 standard.

A team of DATCP, DNR, NRCS, UW NPM and UW SnapPlus staff reviewed 78 plans covering 33,090 acres while testing the next SnapPlus2 ver.19. Fifteen of these plans were farmer written, and 63 written by Certified Crop Advisers (CCAs) for the farmer. All of these plans were prepared with SnapPlus software. The team's plan reviews looked at 26 components of the NM plan noted on the 2015-590 Nutrient Management Checklist. Reviews showed 20 of these components to be correctly planned on all fields in 90% or more of the plans reviewed. We found the 6 components, noted in Figure 6 needed the most improvement. The three brightly colored items relate to new 2015-590 standard requirements for manure applications.

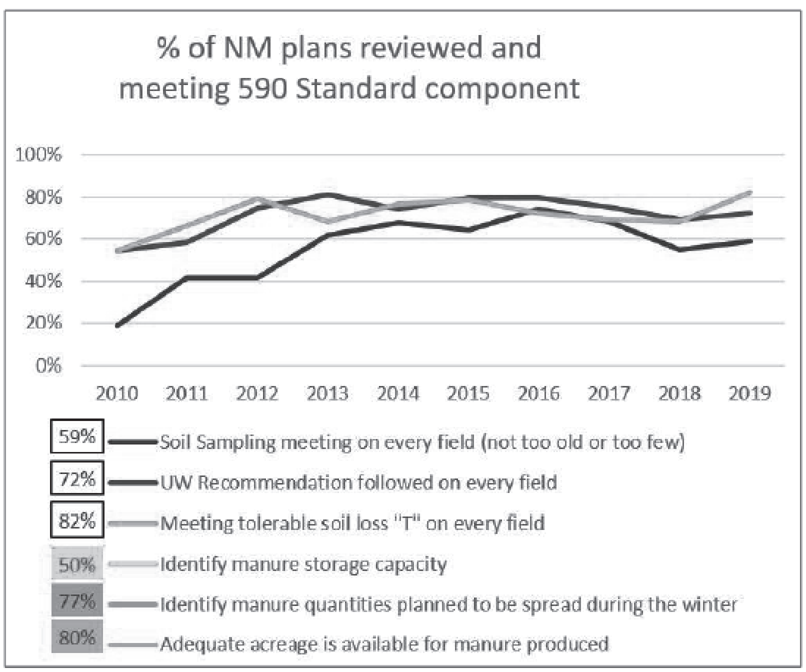


Figure 6 NM plans show improvement over last year in meeting soil testing, University of WI nutrient recommendations, and meeting tolerable soil loss. Requirements for identifying winter manure volume stored, winter manure applied, and adequate acreage for manure produced started being required for all NM plans in 2019 with the promulgation of ATCP 50 Wis. Admin. Code in 2018.

SOIL BALANCING: SHOULD WE MANAGE SOILS FOR Ca:Mg RATIOS?

Steve Culman [1/]

There is a large divide among university researchers and crop consultants and farmers about the usefulness of managing soils based on calcium (Ca) and magnesium (Mg) base saturation. Researchers will tell you that managing Ca and Mg does not work and this was shown decades ago. Many consultants and farmers will tell you that gypsum is a valuable amendment that helps with soil tilth. But how much do we really know? And is there any consensus we can draw from these divergent views? This talk will highlight the research in Ohio over the past 5 years that has looked at how Ca and Mg ratios influence soil health, crop productivity, and weed communities.

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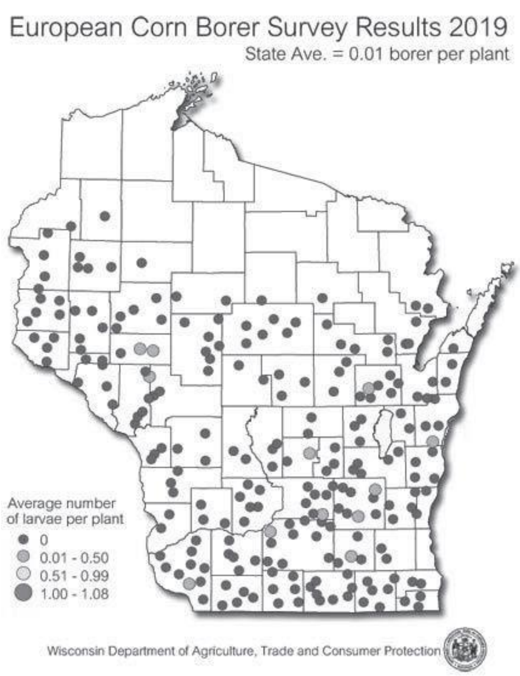
A REVIEW OF DATCP'S INSECT SURVEY RESULTS FROM 2019

Krista L. Hamilton[1/]

European Corn Borer

Larval populations remained historically low for the second consecutive season. The 2019 fall European corn borer survey found a state average count of 0.01 borer per plant, tying 2018 for the lowest population in 78 years. Seven of the state's nine agricultural districts showed averages less than or equal to 2018 levels, while negligible increases were noted in the southwest and south-central areas. Larvae were absent from 89% of the 229 sampled fields in September and October.

The exceptionally low European corn borer (ECB) pressure documented by the fall survey should provide reassurance to growers who planted non-trait corn seed in 2019, though conventional acreage will continue to require a higher level of scouting and management to address local variability in seasonal ECB abundance.



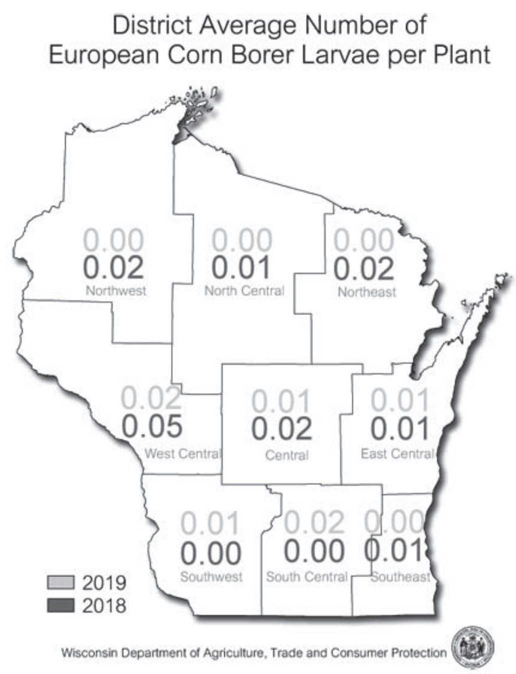


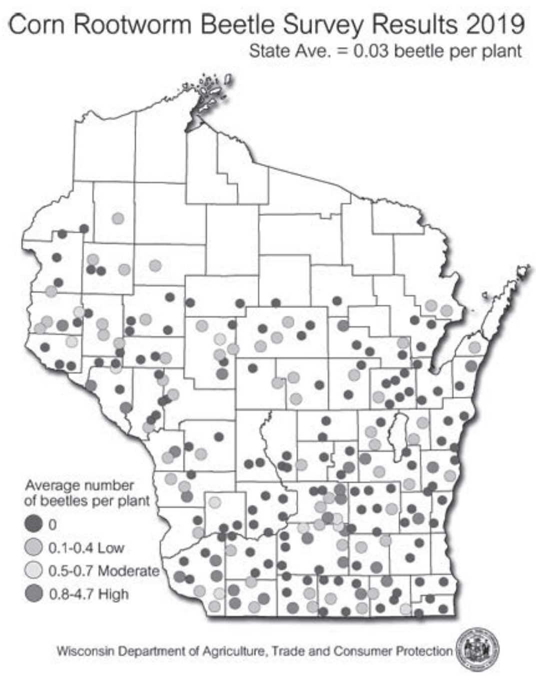
Table 1. European corn borer fall survey results 2010-2019 (Average no. borers per plant).

District	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	10-Yr
NW	0.08	0.15	0.04	0.07	0.06	0.03	0.13	0.09	0.02	0.00	0.07
NC	0.02	0.07	0.01	0.02	0.04	0.00	0.08	0.04	0.01	0.01	0.04
NE	0.19	0.13	0.05	0.02	0.01	0.04	0.00	0.00	0.02	0.01	0.06
WC	0.08	0.12	0.09	0.06	0.12	0.03	0.15	0.01	0.05	0.02	0.08
C	0.06	0.05	0.01	0.01	0.00	0.01	0.24	0.02	0.02	0.01	0.05
EC	0.01	0.03	0.01	0.01	0.01	0.04	0.00	0.01	0.01	0.01	0.02
SW	0.12	0.03	0.03	0.06	0.00	0.03	0.14	0.04	0.00	0.01	0.05
SC	0.07	0.20	0.01	0.08	0.01	0.02	0.14	0.06	0.00	0.02	0.06
SE	0.00	0.01	0.00	0.01	0.00	0.00	0.04	0.04	0.01	0.00	0.01
WI Ave.	**0.07**	**0.09**	**0.03**	**0.04**	**0.03**	**0.02**	**0.11**	**0.03**	**0.01**	**0.01**	**0.05**

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

Beetle counts increased from record-low levels in 2017-2018, but remained low overall. The state average count in 229 cornfields sampled in August was 0.3 beetle per plant, which is only marginally higher than the all-time low average of 0.2 per plant found during the two preceding seasons. For the third year in a row, average counts stayed at or below 0.3 beetles per plant across all six central and northern crop districts and the southeast region, while increases were limited to the south-central and southwest districts. Averages in these two districts rose from 0.3 beetle per plant last year to 0.5 per plant in 2019.

Above-threshold populations of 0.75 or more beetles per plant were found in 27 of 229 (12%) fields surveyed this season, compared to last year’s 20 fields (9%). No beetles were observed in 120 (52%) of the sites. The 2019 total count of 711 beetles was 26% higher than the 566 beetles recorded in 2018.



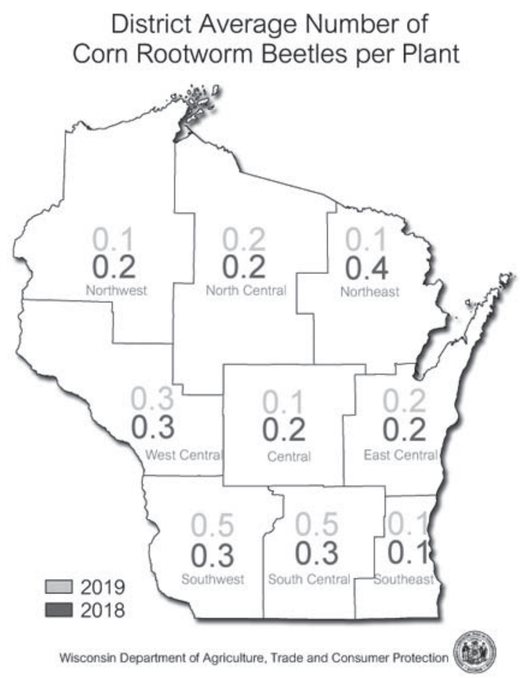


Table 2. Corn rootworm beetle survey results 20010-2019 (Average no. beetles per plant).

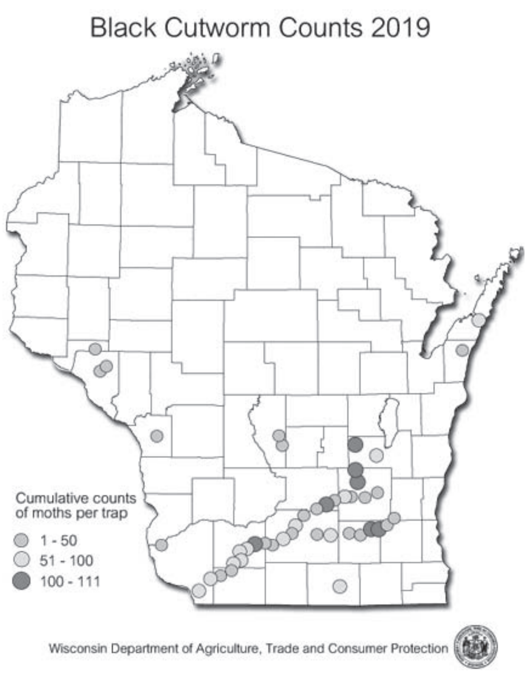
District	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	10-Yr
NW	0.3	0.1	0.5	0.7	0.5	0.2	0.5	0.2	0.2	0.1	0.3
NC	0.1	0.1	0.3	0.2	0.2	0.5	0.7	0.2	0.2	0.2	0.3
NE	0.1	0.3	0.6	0.2	0.1	0.2	0.7	0.2	0.4	0.1	0.3
WC	0.4	0.6	0.4	0.4	0.6	0.3	0.6	0.2	0.3	0.3	0.4
C	0.4	0.8	0.5	0.2	0.2	0.5	0.3	0.3	0.2	0.1	0.4
EC	0.3	0.5	0.4	0.3	0.3	0.8	0.4	0.2	0.2	0.2	0.4
SW	0.3	1.1	0.8	0.6	0.9	0.8	0.7	0.3	0.3	0.5	0.6
SC	0.3	1.4	0.9	0.5	0.3	0.8	0.4	0.3	0.3	0.5	0.6
SE	0.2	0.7	0.9	0.8	0.4	0.7	0.2	0.1	0.1	0.1	0.4
WI Ave.	**0.3**	**0.7**	**0.6**	**0.5**	**0.4**	**0.6**	**0.5**	**0.2**	**0.2**	**0.3**	**0.4**

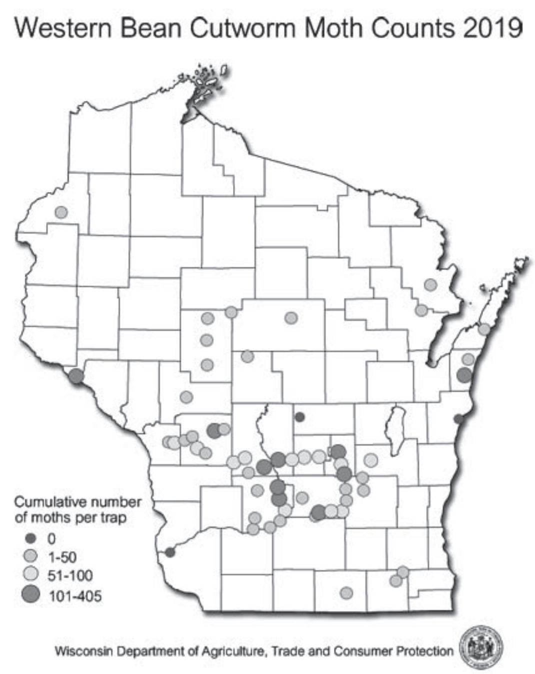
Corn Earworm

Pheromone traps captured a cumulative total of 3,495 moths (15 traps) during the late-season monitoring program, with the largest flights recorded during the last two weeks of September. The highest individual pheromone count was 589 moths at Mayville in Dodge County from September 19-25, while the Janesville black light trap registered its highest weekly total of 932 moths from September 26-October 2. Compared to 2018 when 7,905 moths were collected in 15 pheromone traps, this year's total count was markedly lower. Although this would suggest the risk to late sweet corn from migrating corn earworm moths was also much lower in 2019, the September CEW flights produced localized larval damage to apples, corn and tomatoes throughout fall.

Black Cutworm

Unprecedented planting delays and wet, weedy field conditions contributed to an elevated threat of cutworm damage this spring. Moths appeared by April 4 and substantial migration flights occurred throughout May. The April-June trapping survey captured 1,271 moths in 44 traps, with an individual high count of 111 moths near Waupun in Dodge County. In 2018, the survey collected 2,217 moths in 47 traps. Late corn planting resulted in a protracted primary larval damage period that extended throughout June, but contrary to expectations, black cutworm damage to emerging corn was not prevalent this spring.





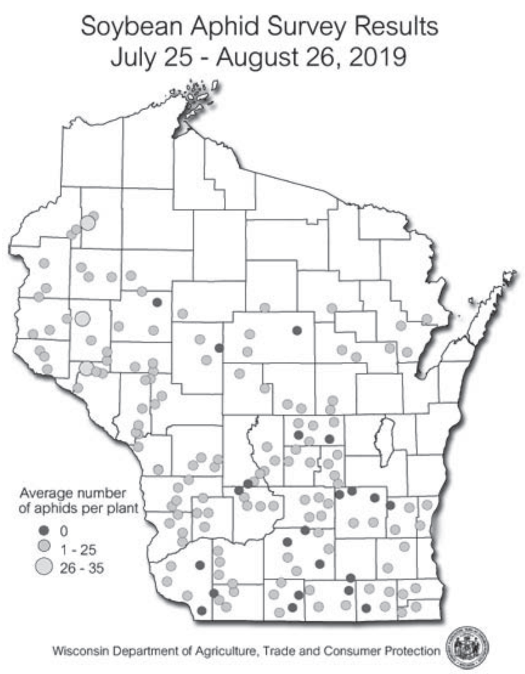
Western Bean Cutworm

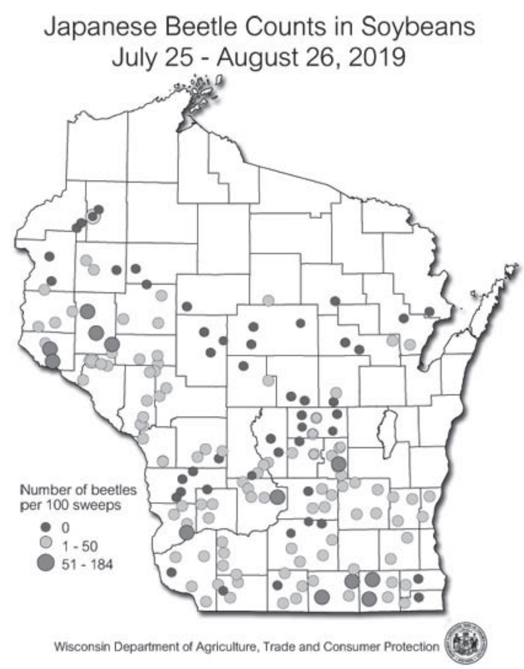
Moth counts and larval injury to corn increased in 2019 compared to the year before. The annual trapping program from June-August registered an average of 65 moths per trap (3,600 moths in 55 traps), the second highest average in 15 years. The survey record of 79 moths per trap (10,807 moths total) was set in 2010. The highest individual count for the 10-week monitoring period was 405 moths at Princeton in Green Lake County. This season's relatively large flight generated larval infestations in central and southern areas of the state that traditionally experience western bean cutworm problems, though widespread damage not observed during fall corn pest surveys.

Soybean Aphid

Populations recorded during the annual survey were very low, aside from a few western Wisconsin fields with moderate pressure. The state average count in 160 fields sampled from July 26-August 26 was only five aphids per plant. For comparison, the 2018 survey found an average of 14 aphids per plant, the 2017 average was six aphids per plant, and surveys from 2010-2016 documented counts of 7-55 aphids per plant. This season's state average was the lowest in the 18-year history of Wisconsin soybean aphid surveys. In addition, no cases of pyrethroid insecticide failure were reported in the state in 2019.

Results of the survey suggest that while aphid pressure was slightly higher in 2018 than in the previous two years, most sampled soybean fields did not meet treatment guidelines during the survey timeframe. In addition, no cases of pyrethroid insecticide failure were reported or confirmed in the state.





White Mold Gall Midge

This new gall midge was found for the first time in Wisconsin this year. The white mold gall midge (WGM) *Karshomyia caulicola* (Diptera: Cecidomyiidae) was collected by a seed company representative from a Pierce County soybean field in August and identified by a USDA ARS entomologist on October 2. The species is similar morphologically to the soybean gall midge (SGM) *Resseliella maxima*, but there are important differences between the two. First, the WGM is a fungus feeder and, unlike the SGM, is not considered a significant crop pest. Second, the larvae appear later in the season (after flowering) and can be found throughout white mold-infected fields. By contrast, SCM infestations can develop by the V3 stage and show an edge effect. Although the WGM is associated with soybean white mold, it does not spread or promote infection.

Soybean producers are advised to be alert for both this species and the soybean gall midge next season. The SGM has not yet been found in Wisconsin.

Japanese Beetle

Defoliation was observed in 75% of the soybean fields examined in August. Counts taken during the soybean aphid survey ranged from 1-184 beetles per 100 sweeps, with a state average of 14 per 100 sweeps (the 2018 average was 8 per sweep). The highest counts of 50 or more beetles per 100 sweeps were noted in the southern and west-central districts for the second year in a row (see table 3 page 159). The prevalence of Japanese beetles documented by the survey signals that this invasive pest is becoming an increasingly significant defoliator threat to the state's soybean crop.

Table 3. Soybean pest survey results 2019 (Average no. insects per 100 sweeps).

District	Bean leaf beetle	Japanese beetle	Northern CRW	Southern CRW	Western CRW	Green Cloverworm	Grass-hopper	Stink Bug
NW	0.3	1.5	0.1	0	0	5.2	3.5	0.7
NC	0	0.6	0.1	0.4	0	3	5.8	0.6
NE	1.3	2.7	0	0	0	2	2.6	1
WC	0.1	27	0.9	0.1	0.2	12.8	3.3	1.3
C	1.1	7.9	1.9	0	1.5	2.8	7.2	1.2
EC	NA	NA	NA	NA	NA	NA	NA	NA
SW	0.3	17.3	1.7	0.1	1	1	4.5	1.5
SC	0.2	14.9	1.8	0.1	0	7.1	1.7	0.4
SE	0.1	18.3	7.7	0.1	0.5	16.3	1.1	0.3
WI Ave.	**0.4**	**14.4**	**1.8**	**0.1**	**0.5**	**6.6**	**3.8**	**1.0**

NEONICOTINOID INSECTICIDE SEED TREATMENTS AND SOYBEAN YIELDS IN THE MIDWEST

Christian Krupke [1/]

Neonicotinoids are the most widely used insecticides worldwide and are typically deployed as seed treatments (hereafter NST) in many grain and oilseed crops, including soybeans. However, there is a surprising lack of information regarding NST effectiveness in increasing soybean seed yield, and most published data suggest weak, or inconsistent yield benefit. The US is the key soybean-producing nation worldwide and Dr. Krupke will present the results of a collaborative project that includes soybean yield data from 194 randomized and replicated field studies conducted specifically to evaluate the effect of NSTs on soybean seed yield at sites within 14 states from 2006 through 2017. We show that across the principal soybean-growing region of the country, there are negligible and management-specific yield benefits attributed to NSTs. Across the entire region, the maximum observed yield benefits due to fungicide (FST = fungicide seed treatment) + neonicotinoid use (FST + NST) reached 2 bu/acre. However, when we account for the cost of seed treatments, we find that this practice appears to have little benefit for most soybean producers under current economic conditions - across the entire region, a partial economic analysis showed inconsistent evidence of a break-even cost of FST or FST + NST. These results demonstrate that the current widespread prophylactic use of NST in the key soybean-producing areas of the US should be re-evaluated and potential cost-savings may be realized by regionally, without reductions in yield.

For full paper, please see: https://www.nature.com/articles/s41598-019-47442-8

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SOYBEAN GALL MIDGE

Bryan Jensen[1]

Introduction

Soybean gall midge, *Resseliella maxima*, is a relatively new insect pest of soybean found in Nebraska, Iowa, South Dakota, Minnesota, and Missouri. To date, it has not been found in Wisconsin.

Origins of this insect are unknown. There were a few reports of damage from this insect dating back to 2011. However, these reports were sporadic and damage more of a curiosity than widespread or economic. Beginning with the 2018 growing season, reports of damage were reported from approximately 66 counties in a core area of Nebraska, Iowa, South Dakota, and Minnesota. The infested area expanded to Missouri in 2019 and a total of over 90 counties.

Identification

Soybean gall midge was only recently described as *Resseliella maxima*. It is unknown whether it is native or invasive. Adults are about ¼ inch long, have light colored banding on their legs and antennae and can be described as "mosquito-like." Larvae cause damage to soybean and are small and maggot-like. Small maggots are likely to be translucent white older, more mature larvae are orange.

Life Cycle

Many aspects of the soybean gall midge life cycle are unknown at this point in time. Likely, they overwinter as pupae and adults begin flying in June. There are two if not three generations/year.

Damage

After hatch, maggots will feed on stems near the soil line. Stems will start to turn black at the feeding site and can be swollen and brittle. Note: not all black stems at the soil line are the result of soybean gall midge feeding. After prolonged feeding the entire plant may wilt or turn necrotic. Several maggots may be found at each feeding site.

Scouting

Adult soybean gall midges are considered weak fliers. Therefore, damage is more common along field edges which include roadsides, ditches, and grassy waterways. For initial detection, walk field edges looking for individual plants which are wilted or dead. Inspect damaged plants for blackened areas at the soil line and for larvae. If orange maggots are found, please confirm the identification by contacting your local extension agent.

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RADIO-TAGGED BEES AND RADIOACTIVE PLANTS: NEW APPROACHES TO TRACK HONEY BEE MOVEMENT IN AG ENVIRONMENTS

Christian Krupke and Sebastian Shepherd [1/]

Abstract

Honey bees and other pollinators often forage within and near agricultural environments. A recent research focus has been investigating how and where bees may encounter agricultural pesticides, in order to minimize their exposure by moving bees out of harm's way, changing practices, or a combination of the two approaches. This presentation will summarize the work being conducted in my laboratory by postdoctoral researcher Dr. Sebastian Shepherd. These studies use a combination of technologies, both in the open field and in semi-field environments (high tunnels) to assess insect movement and behavior following typical levels of pesticide exposure, including results of preliminary work that highlight the complex nature of these questions.

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INDUSTRIAL HEMP (GRAIN, FIBER AND CBD) RESEARCH IN WISCONSIN: LESSONS FROM YEAR 1

Haleigh Ortmeier-Clarke, Nick Arneson, Shelby Ellison, Shawn Conley and Rodrigo Werle[1]

In the early 1900s, Wisconsin emerged as a leading producer of industrial hemp (*Cannabis sativa* L.) as a fiber crop (Wright 1918). There were several pushes to regulate hemp production and Wisconsin harvested its last hemp crop in 1957 (LeCloux 2019). Cannabis was banned under the Controlled Substances Act in the 1970s (LeCloux 2019). Under the Controlled Substances Act cannabis was listed as a Schedule I drug, the most restrictive category. The 2014 Farm Bill identified industrial hemp as *Cannabis sativa* L. with < 0.3% tetrahydrocannabinols (THC), separating it out from *Cannabis sativa* L. with > 0.3 % THC (otherwise known as marijuana) (Agricultural Act of 2014). The 2018 Farm Bill further identified hemp as an agricultural commodity and de-scheduled it as a Schedule 1 drug (Agricultural Act of 2018).

Farmers can again legally cultivate industrial hemp, which has led to many questions including best management practices, especially surrounding variety selection as well as weed and nutrient management. Most research surrounding these questions is outdated or geographically irrelevant (Sandler et al. 2019). Researchers within the UW system have been investigating various aspects of hemp cultivation ranging from agronomic practices to economics and markets. This talk will provide an update on projects in the following areas:

- Grain Variety Response to Seeding and Nitrogen Rate
- Grain Variety Selection
- Herbicide Tolerance
- Double Cropping
- CBD Production

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