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Kerry G. Denson [1/]

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[1/] Brigadier General (retired), Applied Leadership.

WHEN IT HITS THE FAN: PATHOGENS FROM HUMAN AND BOVINE SOURCES IN THE ENVIRONMENT

Mark A. Borchardt[1]

Manure from livestock and fecal wastes from humans are economically and environmentally valuable. Applied to agricultural crops, fecal wastes contribute macro and micronutrients, enhance soil tilth, and aid soil carbon sequestration. Manure spreading, and the on-farm nutrient recycling it facilitates, is the quintessential practice of sustainability. However, these benefits can only be fully realized when the wastes are managed to avoid contamination of non-target sites. Best management practices primarily focus on nutrients. Pathogens are also found in fecal wastes, but research and development are limited in identifying those practices that help avoid pathogen contamination issues that can lead to disease transmission.

This presentation will focus on fecal pathogens in the environment: their release, transport, and potential for disease transmission, or in other words, the consequences of "when it hits the fan." These concepts will be illustrated by presenting two research studies. The first will report the rate of acute gastrointestinal illness in Wisconsin communities that drink non-disinfected groundwater contaminated with human viruses. The role of human sanitation in disease transmission is well established, and this study provides a good example of the same research steps that can be applied to investigate and solve problems related to manure-borne pathogens. Such steps include pathogen detection, exposure assessment, and measuring risk. In addition, because the study resulted in changes to Wisconsin's drinking water code that were later rescinded by legislation, it provides an excellent starting point for a discussion on the role government has in fecal sanitation issues.

The second study to be presented is being conducted at the new Institute for Environmentally Integrated Dairy Management. A research unit of the Dairy Forage Research Center of the USDA Agricultural Research Service, the Institute's mission is to conduct research that addresses comprehensive nutrient management, atmospheric emissions, water quality, and pathogen transfer within dairy production systems.

The study is quantifying runoff losses of bovine pathogens from dairy manure applied to corn silage fields under different manure/crop/tillage management systems. The site is in central Wisconsin and is designed as a paired watershed study consisting of four 1.6 hectare adjacent fields, each equipped with H-flumes, flow meters, and automated runoff samplers. During runoff pathogens are sampled continuously, and the samples are analyzed for bovine pathogenic protozoa, bacteria, and viruses. Manure is applied to the fields in autumn (three fields) or spring (one field) at a rate of 56,000 liters/hectare. The practices being investigated include: 1) Control, autumn applied dairy manure with same day chisel plow; 2) Spring manure/chisel plowing with autumn seeded rye cover crop; 3) Autumn surface-applied manure with spring chisel plowing; 4) Autumn manure/chisel plowing with permanent vegetative buffer strips.

So far we have learned the types of pathogens and their concentrations in the field runoff are highly variable. Runoff may contain pathogens many months after manure application. For example, some viruses detected in the manure applied in the fall were still present in the runoff

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the following summer. However, the virus concentrations are low and it appears from preliminary data that fall-applied manure with same day chisel plowing will reduce pathogens exported from the field by 99.9%. The problem is if the manure has high pathogen concentrations to begin with, despite a 99.9 % reduction, the concentration in runoff can remain above the dose that will cause infections. Importantly, we also have learned that measurements of the standard indicator bacteria *E. coli* in runoff are not correlated with pathogen measurements. *E. coli* is easy to measure and is a common parameter in runoff studies. However, microorganisms can differ in their transport behavior, and making runoff measurements on just one could lead to erroneous conclusions.

Understanding the potential for disease transmission from fecal wastes in the environment and finding solutions for minimizing disease risk are important to the economic and environmental value of these materials to agricultural production. In the case of manure, such knowledge will help protect the health of wildlife, livestock, and people.

THE ECONOMIC IMPORTANCE OF ATRAZINE IN THE USA

Paul D. Mitchell[1/]

U.S. crop producers derive substantial economic benefits from atrazine and the other triazine herbicides (simazine and propazine). These herbicides generate yield gains for U.S. crop farmers, and in many cases, also reduce total costs for herbicides. Atrazine, the most widely used triazine herbicide, is the keystone of herbicide-based weed control in corn and other regionally important crops in the U.S. Corn acreage, yields and prices have increased over time so that the 3-year average value of corn produced in the U.S. has increased more than 2.7 times, from $18.6 billion in 1990 to 1992 to $54.3 billion in 2008 to 2010. Over this same period, crop production practices also evolved, including the widespread adoption of transgenic crops and reduced tillage systems. Given these and other changes since previous economic assessments of the producer benefits from triazine herbicides, an updated economic assessment of the benefits of atrazine and the other triazine herbicides seemed warranted.

The primary benefit of atrazine and the other triazine herbicides to farmers is improved weed control that increases harvested yields and usually reduces costs, as alternative herbicides are less effective and/or more expensive. Based on yield loss and herbicide cost changes estimated using models, the economic value of the yield losses prevented by the triazine herbicides are estimated to range between $3.0 billion and $3.3 billion per year for U.S. corn, sorghum, sweet corn, and sugarcane farmers. Most of these benefits accrue to Midwestern field corn farmers using atrazine, but farmers in other regions and growing these other crops also derive substantial benefits. The annual yield benefits and net herbicide cost savings from triazine herbicides are worth an estimated $2.36 billion to $2.65 billion for U.S. field corn growers, $341 million for U.S. sorghum growers, $210 million for U.S. sweet corn growers, and between $60 and $120 million for U.S. sugarcane growers.

Longer term, if atrazine were not available, these yield losses and cost changes would imply price changes and crop acreage reallocations as the supply effects worked their way through the U.S. farm economy. As a result, estimated corn prices would increase between $0.25/bu to $0.30/bu and sorghum prices by about $0.65/bu. These price increases imply losses to consumers estimated to range between $3.6 billion to $4.4 billion per year. In addition, based on model estimates, U.S. corn acres would expand by around one million acres and sorghum acres decrease by about 450,000, with small increases in total wheat and soybean acres as well. However, the largest single source for these increased acres would come from land currently enrolled in the Conservation Reserve Program (CRP) – CRP acres estimated to decrease between 620,000 to 880,000 acres, or about 2%.

Atrazine and the other triazine herbicides generate other types of benefits for farmers not accounted for in these values. Atrazine works well with other herbicides, often enhancing the value of less efficacious herbicides. Atrazine also increases the value of crop rotations by reducing weed populations and weed seed banks in crops commonly rotated with atrazine-treated crops. Atrazine also serves as an important tool for managing herbicide resistance, helping to preserve future weed control benefits for other herbicides. Finally, atrazine provides effective

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weed control that has aided adoption of conservation tillage and no-till systems in corn and other crops. Reducing or eliminating tillage reduces soil erosion and associated negative environmental impacts of agriculture, which improves water quality and further enhances the sustainability of U.S. crop production.

The longer-term adjustments in crop acreage and tillage practices that would occur if atrazine were not available to U.S farmers are estimated to increase total soil erosion from U.S. crop land between 56 million to 85 million tons per year, a 9 to 13% increase. About half of this increased erosion would occur because of the shift in crop acreage, especially conversion of CRP acres to crop production, and about half would occur because of shifting land from no-till and into conventional and conservation tillage to address problems with controlling herbicide resistant weeds. The cost of this increased soil erosion to U.S. society ranges between $210 million and $350 million per year.

Combining the consumer surplus estimates and the values of the soil erosion benefits, the longer-term benefits of atrazine are between $3.8 billion and $4.8 billion per year, with most of these benefits accruing to consumers.

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The presentation will be based on the following two AAE Staff Papers:

Mitchell, P.D. 2011. Economic assessment of the benefits of chloro-s-triazine herbicides to U.S. corn, sorghum, and sugarcane producers. Univ. of Wisconsin Agricultural and Applied Economics Staff Paper No. 564, November. 2011, 51 p. Online: http://www.aae.wisc.edu/pubs/sps/pdf/stpap564.pdf.

Mitchell, P.D. 2011. Estimating soil erosion and fuel use changes and their monetary values with AGSIM: A case study for triazine herbicides. Univ. of Wisconsin Agricultural and Applied Economics Staff Paper No. 563, November 2011, 97 p. Online: http://www.aae.wisc.edu/pubs/sps/pdf/stpap563.pdf.

WATER QUALITY BEENFITS OF REMOVING TILE SURFACE INLETS

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DRAINAGE LAW AND DRAINAGE DISTRICTS: ADVANTAGES OF PUBLIC DRAIN SYSTEMS

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NITROGEN LOSS FROM TILE DRAINS

Eric T Cooley [1] and Dennis Frame [2]

Nitrogen contributions to the Gulf of Mexico have increased hypoxia issues in recent years. Numerous efforts have targeted the reduction of nitrogen loads to the Mississippi River drainage basin to control the hypoxic zone. Agricultural tile drainage is a major contributor to nitrogen loads in the Mississippi River.

Research performed by the University of Wisconsin - Discovery Farms Program in collaboration with the United States Geologic Survey has established the importance of nitrogen fertilizer and manure application rate and timing with potential loss of nitrogen to tile drains. Manure applied to fields soon after corn silage was harvested resulted in a high conversion to nitrate and subsequent loss to tile drains in late fall through early spring. Abnormally high fall soil temperatures allowed for conversion of ammonium and organic nitrogen to nitrate and subsequent late fall and early spring precipitation carried nitrate to tile drains.

Under specific frozen ground conditions, elevated ammonium levels were observed in both surface runoff and tile drainage flow. A manure application on frozen ground, just prior to a runoff event, resulted in a high percentage of total nitrogen lost as ammonium. Ammonium comprised 97% of surface runoff and 84% of tile flow from a January rain on frozen ground event.

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PHOSPHORUS LOSS FROM TILE DRAINS: SHOULD WE BE CONCERNED?

Matt Ruark, Allison Madison [1/], Eric Cooley[2/], Todd Stuntebeck, and Matt Komiskey[3/]

Introduction

Subsurface P loss is of greatest concern in areas with P-rich flat, clayey soils and P-rich tile-drained soils (Beauchemin et al., 1998). Eastern Wisconsin farmland fits the criteria for high subsurface P emitting soils. Soil tests conducted between 1995 and 1999 indicated that the average soil P levels in eastern Wisconsin counties were in excess of the recommended levels for most crops (Laboski et al, 2006). Additionally, considerable portions of eastern Wisconsin's cultivated acres are tile-drained. The highest concentration of tile drainage is along the shore of Lake Michigan. The 1992 United States Census of Agriculture estimates the portion of cultivated acres that are tile drained to range from 20 to 60% among all of Wisconsin's far-eastern counties (Kewaunee, Manitowoc, Sheboygan, Ozaukee, Milwaukee, Racine, and Kenosha).

Current tile drainage systems provide no filtration of intercepted water. If nutrient-rich soil solution enters the tile drain, nutrient-rich water is discharged. While tile drain P concentrations are typically lower than surface P concentrations, annual P loads from drains have exceeded loads from surface pathways (Algoazany et al., 2007). Areas of active hydrological connectivity where natural preferential flow channels connect to artificial drainage systems may be P loss hotspots (Beauchemin et al., 1998; Sharpley et al., 2009).

The possibility of P leaching was discounted historically because orthophosphate, the biologically active form of P, rapidly sorbs onto soil surfaces. It was thus assumed that P would be held by the soil as long as P amendments were incorporated (such that P was allowed to interact with the soil) and P-enriched soils were not eroded away. Work by Beauchemin et al. (1998) on P-saturated soils revealed that P loss via subsurface pathways was a reality. The objectives of this study were to quantify P losses and concentrations in tile drainage in Wisconcin and to evaluate P loss dynamics after manure applications.

Materials and Methods

The study was conducted between 2005 and 2009 on four tile-drained, in-field basins at three farmsteads in eastern Wisconsin. All farms are working dairies that participated in the UW-Extension Discovery Farms program during the monitoring period. Two of the sites were located 1 km apart on a farm in Kewaunee County and were managed as chisel-plow continuous corn cropping systems. The third site was managed as a no tillage corn-soybean cropping system and located in Waukesha County. The fourth site, located in Manitowoc County, was managed as a grazed pasture. The sites will be referred to according to their management type: chisel-plowed (CP1 and CP2), no-till (NT), and grazed pasture (GP). Slopes ranged from 1 to 3% at NT and 2 to

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6% across the CP and GP study sites. The CP1, CP2 and NT sites were within the Lake Michigan watershed and the NT site was located within the watershed of the Rock River, a tributary of the Mississippi River (Fig. 1). According to state nutrient requirement guidelines, all sites were excessively high in P (Laboski et al., 2006) (Table 1).

Drain tile at CP1 and CP2 was installed underneath grassed waterways. Drain placement at the NT site includes both parallel and randomly-spaced drains. The GP site has a randomly-spaced drainage system. Drains were installed at the CP and GP sites between prior to 1990; the NT drains were installed prior to 2000. The drain lines are 0.15 m (6-inch) diameter ceramic tile at CP1 and CP2, 0.15 m diameter PVC tile at NT, and 0.3 m (12-inch) diameter concrete tile at GP. All drains are installed to a depth of approximately 1 m. Surface and subsurface basin boundaries were determined by the United States Geological Survey (USGS).

Permanent monitoring stations were installed by the USGS to continuously quantify and sample edge-of-basin surface runoff and tile drainflow at each site. The following description of field equipment and sampling procedures used at the Discovery Farm sites was condensed from Stuntebeck et al (2008). Surface runoff and tile drainflow were monitored with non-submersible pressure transducers, coupled with nitrogen bubbler systems. All sampling data were organized annually by hydrologic year beginning on 1 October and ending on 30 September (e.g., water year 2005 is from 1 Oct 2004 to 30 Sept 2005). Surface runoff and tile drainflow data were collected at sites CP1 and CP2 from 2005-2008 and sub-surface data only were collected in 2009. Surface runoff and tile drainflow data were collected at NT and GP during 2006-2008 and 2007-2009, respectively.

Surface runoff and tile drainflow sub-samples were flow-weighted by volume into composite samples that represented discrete drainage events. All surface and tile samples were collected by an automated, refrigerated, 24-bottle ISCO 3700R sampler; samples were retrieved within 24 hours of runoff events, placed in coolers, and transported to the University of Wisconsin-Stevens Point Water and Environmental Analysis Laboratory (UWSP-WEAL). All samples were held at 4°C until analysis by the UWSP-WEAL. Samples were shaken vigorously before discharge-weighted portions of the discrete samples were combined into one composite sample for each runoff event. Dissolved reactive P (DRP) was measured after filtering through a 0.45 µm filter and analyzed using the ascorbic acid colorimetry method as described by Murphy and Riley (1962). Total P (TP) samples were digested with mercuric sulfate prior to colorimetry analysis. Surface and tile event DP and TP loads were determined by multiplying the event DP and TP concentration by the respective event volume. Event loads were aggregated into monthly and annual loads. Monthly and annual P loads were divided by their respective flow volumes, to give monthly and annual flow-weighted (FW) concentrations.

Results and Discussion

Across all sites, both surface and tile drainflow TP and DRP loads were characterized by high inter-annual variability across all sites (Table 1, Table 2). Like annual variability, monthly variability in loading was largely influenced by the volume of water moving through these pathways. Overall, tile drainflow contributed 17 to 41% of cumulative TP loads. Tile contributions to DRP loads were slightly higher and ranged from 16 to 58% of total loads. In 2006 and 2008, annual tile DRP loads at the CP sites exceeded respective annual surface DRP loads.

The highest annual surface FW-TP concentrations were consistently measured at the GP site (Table 3). At all sites, surface FW-TP and FW-DRP concentrations were greater, and demonstrated more inter-annual variability, than tile FW-TP and FW-DRP concentrations (Tables 3 and 4). Average annual tile FW-TP concentrations were 1.2 to 1.8 times greater than average annual tile FW-DRP concentrations. The relative ratio of DRP to TP was lowest at the CP indicating that a greater amount of TP was held in the particulate fraction at the CP sites. The NT site consistently exhibited the lowest tile FW-TP concentrations as well as the greatest disparity between surface and tile FW-TP concentrations. The lowest surface and tile FW-P concentrations at this site were measured in 2007, the year that no manure was applied (Tables 3 and 4).

Surface runoff, with much higher P concentrations than those measured in tile discharge, was the dominant P loss pathway at each site. In NR151, the Wisconsin Department of Natural Resources set an eight-year average maximum delivery limit of P from agricultural fields at 6 lb a^{-1} yr^{-1}, as predicted by the Wisconsin Phosphorus Index. Tile drainage can reduce surface P losses by diverting surface runoff into subsurface pathways; however, on these P-rich soils, it is evident that tile drainage is not a sufficient to remove their risk to neighboring freshwater ecosystems.

Annual tile P loads, although lower than surface loads, were consistently higher than those previously reported in many tile drainage studies. Unfortunate for comparison, many studies that monitored subsurface P losses from tile-drained soils did not measure annual P loads from surface runoff (Grant et al., 1996; Brye et al., 2002; Macrae et al., 2007; Oquist et al., 2007). Field studies that monitored both surface runoff and tile P loads reported lower average annual surface losses than those measured at the Discovery Farm sites. Eastman et al. (2010) reported average annual surface TP loads of 0.50 and 1.35 kg ha^{-1} on two fields with tile drainage that received inorganic P additions. In Illinois, measurements of average annual soluble P surface loads ranged from 0.04 to 0.12 lb ac^{-1} across six fields (Algoazany et al., 2007).

Excessively high STP levels at the Discovery Farm sites likely contributed to the high P loads at these sites. A study that compiled annual P load data from forty studies reported significant positive relations between STP and annual dissolved P (DP), PP, and TP surface runoff loads (Harmel et al., 2006). Measures of STP in column and plot studies have repeatedly been found to correlate with concen-trations of DRP in leachate and annual TP- and DRP-FW (Andraski and Bundy, 2003; Chapman et al., 2003; Maguire and Sims, 2002; Matula, 2009). Tile FW-P concentrations at the Discovery Farm sites were high relative to literature values. Tile TP concentrations repeatedly exceeded 1 mg L^{-1}; this is 10 times the concentration that the USEPA recommends for freshwater streams and lakes (USEPA, 1986). Across all study sites, the percent of tile samples that were greater than 1 mg L^{-1} ranged from 11-55% (CP1: 32/129 (25%); CP2: 13/107 (12%); NT: 10/95 (11%); GP: 42/76 (55%)).

Conclusion

Tile drain P loads contribute considerably to total basin loads and may respond negatively to the practices designed to reduce surface P losses. Minimizing preferential flow transport or controlling tile drainage may be investigated as methods to reduce tile P loading. Once P reaches the tile, tile drains are direct conduits to surface water bodies.

It is clear that extrapolations from studied systems to all tile-drained fields must acknowledge the large degree of variability among drainage systems in eastern Wisconsin. Within farm differences in tile system behavior underscore the unpredictability of tile systems.

Parallels in soil, precipitation, and management led CP1 and CP2 to perform more similarly to each other than to the other sites. Yet even between CP1 and CP2, annual tile contributions to total basin drainage and P load varied extensively. It is possible that the loading behavior of the irregular and randomly-spaced tile systems common in Wisconsin will be more difficult to predict than the parallel grid tile designs present in other artificially-drained regions of the United States.

In the tile drainage study, the GP site highlights the risk of excessive manure application. Phosphorus additions at this site were on the order of five to ten times greater than those at the other study sites. The landowner's decision to till and re-seed this pasture during the study period was partially in response to the high P losses. This management act was an attempt to improve the quality of the pasture, reduce P stratification, and decrease soil and nutrient losses. The actions of this farmer demonstrate the potential for education to prompt behavioral change. After seeing the field monitoring data, the farmer was compelled to take action to reduce the amount of P that his farm was releasing into local waterways. Providing farmers with a report of actual field nutrient losses for a given year is extremely powerful. While widespread monitoring is not practical, but widespread modeling is both practical and possible. The incorporation of tile drainage losses into the WPI, the next step of this research, will enable producers to make decisions based on more complete knowledge of the impacts of their management practices.

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Table 1. Annual total phosphorus loads in tile flow and surface runoff.

	2005		2006		2007		2008		2009	
	Tile	Surface	Tile	Surface	Tile	Surface	Tile	Surface	Tile	Surface
	--- lb ac^{-1} ---									
CP1	1.28	1.49	1.31	2.24	0.41	0.54	1.26	2.00		
CP2	0.21	1.04	1.31	4.06	0.44	1.88	1.37	1.27		
NT			0.44	2.03	0.47	0.94	2.44	6.19		
GP					1.12	3.70	2.35	8.69	0.24	3.87

Table 2. Annual dissolved reactive phosphorus loads in tile flow and surface runoff.

	2005		2006		2007		2008		2009	
	Tile	Surface	Tile	Surface	Tile	Surface	Tile	Surface	Tile	Surface
	--- lb ac^{-1} ---									
CP1	0.70	0.85	0.77	0.37	0.24	0.20	0.72	0.34		
CP2	0.14	0.68	0.56	0.30	0.19	0.78	0.76	0.36		
NT			0.32	1.83	0.43	0.46	1.88	5.23		
GP					0.83	2.96	1.86	7.00	0.12	2.96

Table 3. Annual flow-weighted total phosphorus concentrations in tile flow and surface runoff.

	2005		2006		2007		2008		2009	
	Tile	Surface	Tile	Surface	Tile	Surface	Tile	Surface	Tile	Surface
	-- mg L^{-1} (ppm) --									
CP1	1.76	3.09	0.61	5.38	0.55	1.14	0.60	5.27		
CP2	0.61	1.17	0.54	4.10	0.58	3.25	0.55	2.03		
NT			0.19	5.28	0.08	2.00	0.37	4.45		
GP					0.84	6.32	1.78	6.64	1.34	5.83

Table 4. Annual flow-weighted dissolved reactive phosphorus concentrations in tile flow and surface runoff.

	2005		2006		2007		2008		2009	
	Tile	Surface	Tile	Surface	Tile	Surface	Tile	Surface	Tile	Surface
	-- mg L^{-1} (ppm) --									
CP1	0.85	1.57	0.32	0.79	0.29	0.38	0.30	0.79		
CP2	0.36	0.68	0.21	0.27	0.28	1.23	0.28	0.51		
NT			0.13	4.26	0.06	0.87	0.26	3.36		
GP					0.56	4.53	1.26	4.78	0.56	3.99

DAIRY HEIFER DIETS, MANURE MANAGEMENT, AND RUNOFF PHOSPHORUS.

Bill Jokela[1], Wayne Coblentz[1], and Pat Hoffman[2]

Livestock manure is considered a waste product from the perspective of the animal operation, but it can be an important resource for crop production by providing valuable nutrients and enhancing soil quality. However, manure application to cropland can also have adverse environmental effects, in particular ammonia and greenhouse gas emissions and impairment of surface and ground water quality. The benefits of manure can be enhanced and the potential environmental risks minimized by employing improved manure and soil management practices (Sharpley et al., 1994; Jokela et al., 2004). In this article we discuss the results of integrated research to evaluate several of these "best management practices" for their effect on runoff P losses: a) prompt incorporation of manure, aimed at controlling N losses by ammonia volatilization and protecting manure from runoff losses of P and N, b) application of manure at rates that do not exceed crop nutrient need (typically N or P, depending on crop needs and soil P test level), c) avoiding build-up of soil test P to excessive levels can contribute to runoff P losses even if manure and fertilizer are not applied, and d) eliminating unnecessary P supplementation of dairy diets, a practice that can have economic benefits and can help balance whole-farm P budget, thereby helping prevent soil P build-up.

Studies in Wisconsin and elsewhere have shown that dietary P levels fed to lactating dairy cattle can be reduced substantially without negatively affecting animal health or production, with a resultant decrease in manure P (Wu et al., 2000; Morse et al., 1992). More recent research in Wisconsin has shown that P supplementation for dairy heifers does not result in growth, reproductive, or lactation benefits (Bjelland et al., 2011). Other research has shown that application of manure from lactating cows fed diets over-supplemented with P led to increased losses of dissolved and total P in runoff (Ebeling et al., 2002; Hanrahan et al., 2009). We found no similar studies for heifer manure.

We conducted a series of three rainfall simulation experiments to assess the effects of dairy heifer dietary P, manure incorporation, manure application rate, and soil test P (in various combinations) on runoff P losses from successive rains.

Materials and Methods

Manure used in these experiments was from dairy heifers (average weight=1000 lb) at the UW Marshfield Agricultural Research Station. Pens of dairy heifers containing eight heifers per pen bedded with sawdust were offered diets with (0.38% P) or without (0.32% P) supplemental P. This resulted in manure with 18 to 21% dry matter and differing P levels. Manure from heifers fed non-supplemented diets had 16 to 20% lower total P and 35 to 50% lower water-extractable P than manure from heifers fed diets supplemented with P.

To evaluate runoff effects, soil from the surface layer of a Withee silt loam was put in 40 x 8-inch sheet metal pans to a 2-inch depth and packed to approximate the bulk density of a field

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soil (about 1.2 g/cm^3). Pans with soil (10 or 12 for each run) were placed under a rainfall simulator (Joerns, Inc., West Lafayette, IN; Humphrey et al., 2002) at a slope of 5%. Rain generated through a single nozzle 10 feet above the pans provided a uniform rain intensity of 2.75 inches per hour. Runoff was collected from each pan for 30 minutes after the start of runoff (2 to 6 minutes in most cases). This is a rainfall of relatively high intensity, equivalent to a storm with an approximate recurrence interval of 10 years in Wisconsin (Huff and Angel, 1992). Two successive rain/runoff events were generated in each experiment, the first about 24 hours after manure application and the second three or four days later. We measured runoff volume, total and dissolved P, and total and volatile solids from both runoff events. We also calculated runoff loads of solids and P (concentration x runoff volume), but only concentrations are reported here. Treatments had little or no effect on runoff volumes, so treatment effects on loads of P and solids were similar to those on concentrations.

In Experiment 1, manure was applied at a rate equivalent to 20 tons per acre from heifers fed either non-supplemented or P-supplemented diets, which supplied P at rates of 88 or 112 lb P_2O_5/acre. Each manure type was applied either on the surface or incorporated by mixing manure with the soil and was compared to a no-manure control. In Experiment 2, manure produced from each of the two dietary P levels was surface-applied at two rates (equivalent to 15 and 30 tons/acre), which supplied a range of 75 to 180 lb P_2O_5 per acre for different manure P-level and application-rate combinations. Experiment 3 consisted of soils from the surface horizon of a Withee silt loam without manure with Bray P1-extractable P levels of 11, 29, 51, and 75 ppm.

Results and Discussion

The concentration of total solids in runoff was lower (about 50%) from surface-applied manure than from incorporated manure in both runoff events (Experiment 1; data not shown), reflecting a mulching effect of surface manure that protected the mineral soil from erosion. However, the concentration of volatile solids, which is a measure of the organic, primarily manure-derived, solids, was about three times greater from surface-applied than from incorporated manure in runoff from both rains. Incorporation of manure reduced total and dissolved P concentration and load by 85 to 90% compared to surface application (Fig. 1). As a result, P concentrations from incorporated manure treatments were not different from those with no manure applied (except total P in Rain 1). So, despite the reduction in erosion of total solids by the surface manure, the P-rich manure left on the surface dominated effects on runoff P because runoff interacts primarily with the immediate surface layer of the soil. Doubling the rate of surface-applied manure increased runoff dissolved and total P concentrations an average of 35% (Experiment 2; Fig. 2), which is a function of more manure P being available for release to runoff from the higher application rate.

Phosphorus diet supplementation resulted in twice the concentrations of dissolved and total P in runoff from surface-applied manure in Experiment 2 (Fig. 2) and smaller but significant increases of dissolved P in Experiment 1. Alternatively, eliminating supplemental P from the diet, which has been shown to have no adverse effect on dairy heifer performance (Bjelland et al., 2011), lowered runoff P concentration by approximately 50%. Thus, avoiding over-supplementation of P in dairy heifer diets can have both environmental and economic benefits.

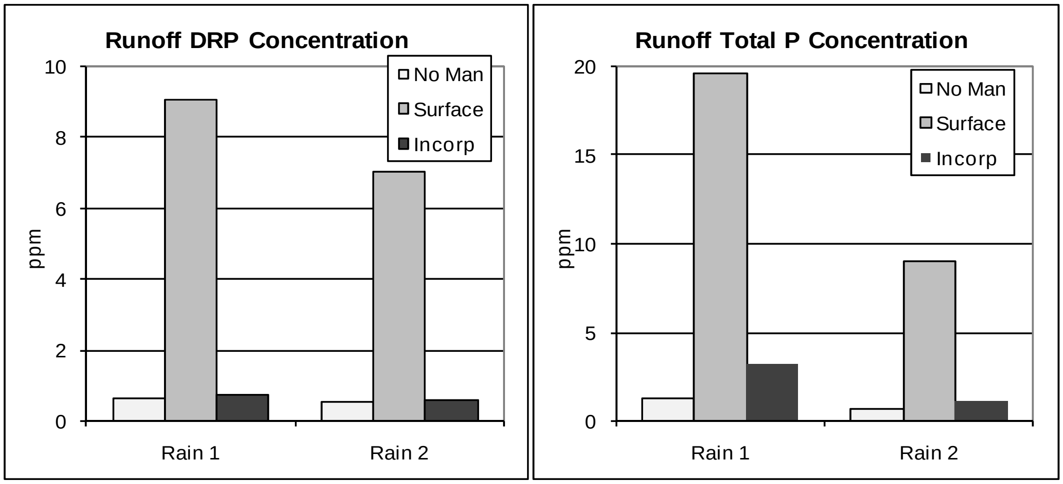

Figure 1. Dissolved reactive P (DRP) and total P concentrations for Rains 1 and 2, Experiment 1. P concentrations for manure treatments were averaged across dietary P levels.

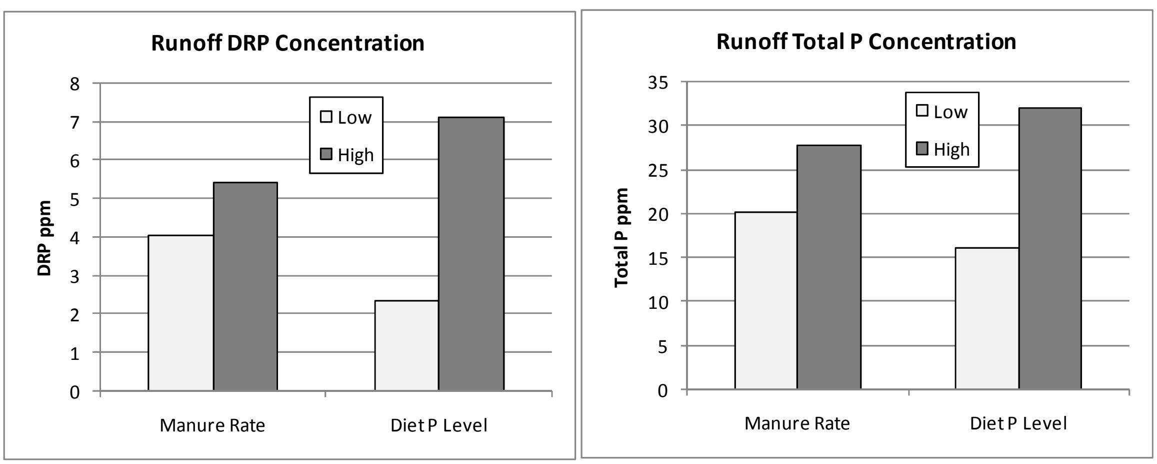

Figure 2. Dissolved reactive P (DRP) and total P in runoff from Rain 1, Experiment 2. P concentrations for each manure rate were averaged across dietary P levels, and those for each dietary P level were averaged across manure rates.

Evaluation of the effect of soil test P without manure application (Experiment 3) showed that runoff dissolved P increased with increasing soil test P, particularly at excessive (above optimum) levels (Fig. 3). Note that soils testing in the optimum range (16 to 23 ppm for alfalfa and corn silage on a Withee soil; Laboski et al., 2006) resulted in quite low concentrations of dissolved P in runoff, but that P concentrations increased rapidly at excessive (> 30 ppm) or higher levels. While manure, especially when surface applied, has a much greater effect on runoff P than high soil test P, avoiding buildup of soil test P to excessive levels is also important. Applying higher manure rates than needed, as in the high rate in Experiment 2, not only contributes directly to increasing runoff P, but also increases soil test P to levels that will continue to contribute to P loading even if manure is no longer being applied.

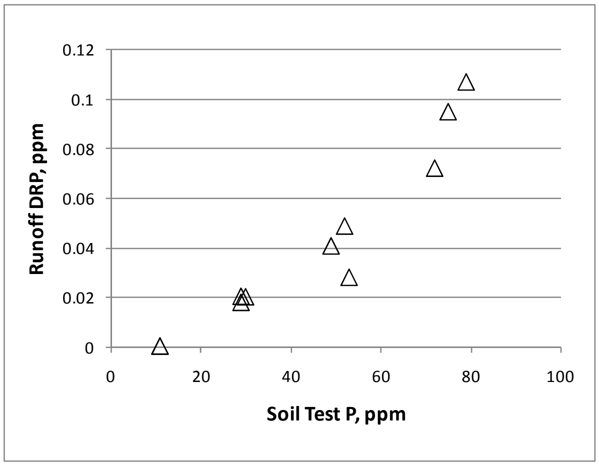

Figure 3. Runoff dissolved reactive P (DRP) concentration vs. soil test P for Rain 1, Exp. 3.

All three experiments involved two rain/runoff events, an initial one and a second one three or four days later. In most cases, concentrations of solids and total and dissolved P in runoff from the second event were 25 to 75% lower than from the first one, as illustrated by P data from Experiment 1 (Fig. 1). This suggests that the first runoff-producing rain event soon after manure application has the potential to produce the greatest P runoff, but the degree will depend on the weather and resulting soil and manure conditions in the intervening period.

Results from this research demonstrate that large reductions in P runoff losses can be achieved by incorporation of manure, avoiding unnecessary dietary P supplementation, limiting manure application rate, and managing soils to prevent excessive soil test P.

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INDUSTRY TRAIT PIPELINE: 2012 AND BEYOND

Panel

{This page provided for notes}

TESTING VERSUS TESTIMONIALS: HOW DO YOU TELL THE DIFFERENCE? HOW AND WHY DO WE DO RESEARCH?

Joe Lauer[1]

Research is a systematic investigation, including research development, testing and evaluation, designed to develop or contribute to generalized knowledge. So, research can lead to knowledge, but only if it's done well. Done "well" means using accepted scientific methods, which often include statistics. If we "just don't like" research outcomes, that does not mean it isn't science!

Applied agronomic research is a set of **planned comparisons** carried out over an **adequate** number of fields and years (sets of weather), with results accumulated, and analyzed to allow us to **predict** the response from tested inputs or practices when we use them in the future. Usually includes economics. We might think of this as a "branch" of science, in which probabilities of certain outcomes suggest whether to use certain inputs.

Planned comparisons are careful choices and placement of treatments to establish two or more (crop) inputs under the same (neutral) conditions, with results (yield, quality) from each input carefully measured. An "unplanned" comparison can become a planned one, but only if it meets the "same conditions" test.

An **adequate** number of fields and years depends on the expected variability of response, from none to some; depends on the frequency and cost of yield loss from using an input; depends on the cost of the product. Before we do the research, this obviously requires some guesswork.

A **prediction** is a statement of likelihood of expected results from use of a particular input: Usually includes an "average" expected result: "Product X increases yield by 3.4 bushels on average." It should include an economic assessment: "The average return to using Product X is $3.50 per acre, after subtracting its cost of $2.20 per acre." It should include some measure of uncertainty: "Product X is expected to provide a positive return 70 percent of the time, and net return is expected to range from -$2.20 (product cost, with no effect on yield) to +$10.50 per acre." If appropriate, "condition" statements should be included: "There is little return to use of this product under poor drainage conditions."

Knowing *what we want to say* when the work has been completed should be a critical precondition for undertaking on-farm, applied research. If you can't even guess what such a statement might look like, you might want to hold off. If you are "required" to reach a certain conclusion, is there any real point to the whole exercise?

But still, a certain percentage of all on-farm research projects are wasted effort or even harmful. The research may suggest the use of harmful inputs; it may suggest the use of useless inputs, or it may fail to predict (accurately) the benefit of a useful input. We want to reduce the frequency that this happens.

Farmers today have an increasing number of tools for managing crops. New developments in precision farming technologies, biotechnology, and advancements in pesticides, equipment, and other ag inputs are converging and arriving at the farm-gate at an unprecedented rate. Sifting

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through the overwhelming milieu of technologies to find the tools that really work is a challenge for farmers and the consultants and agronomists that serve and support production agriculture.

Often farmers use technologies with little or no evaluation prior to use. Industry heavily invests in technology research and development, thus, “ramp-up” is fast and products are often marketed and distributed quickly in an attempt to recover investments in the early phases of technology adoption. Often farmers, usually at great expense, must learn and re-learn management of these technologies as new and improved versions are released.

In general, there are two major categories of on-farm research trials. The first is **replicated trials** that try to account for field variability with repeated comparisons. Examples include trials conducted by universities and by public and private plant breeders. The other type is **non-replicated demonstrations** such as yield contests, on-farm yield claims, demonstration trials and farmer observation and experience.

The advent of effective tools for collecting data related to crop production such as weigh wagons, on farm scales and yield monitors have removed many of the traditional barriers of on-farm trials. The next phase in the development of agriculture is necessary coordination of multi-site trials that will require collaborative specialists for data collection and analysis.

Randomization: Randomization prevents bias of any one treatment in any way (intended or unintended). To randomize a trial, randomly assign replicated check plots and treatments (Fig. 1) by drawing numbers out of a hat or flipping a coin as you assign treatments to plots.

Replication: Replication is used to determine whether the difference between plots is due to chance variation or treatment variation. Chance variation is caused by differences in weather, soil and other factors. These factors change significantly in space (field to field) and time (year to year). Through replication in both space and time, average treatment effect values can be obtained. Replication in space means that several plots of each treatment are grown in the field (field replication) or that single plots of each treatment are placed in several fields across the farm (farm replication). Replication in time is repeating the trial over several years. Comparisons between average values are more accurate than those between single plots. Replicating your check and treatment plots at least three or more times will give you much greater confidence in your results and final conclusions about a new practice if it is made only after being evaluated over several years and/or at several locations.

Replicate 1	Replicate 2	Replicate 3
Treatment 1	Check	Treatment 2
Check	Treatment 3	Treatment 3
Treatment 2	Treatment 1	Check
Treatment 3	Treatment 2	Treatment 1

Low ----------------------------------- High
Soil Fertility Gradient (or yield potential, organic matter, pH, etc.)

Fig. 1. An example of a plot design, with a check plot and treated plots arranged in three replications. The entire trial area should be kept within a uniform soil condition. Other plot arrangements are possible.

Check (Control) Plots: Your current practice is represented in the check or control plot. It does not receive the new technology being tested; rather it represents your current management style where your tillage practice, applied fertilizer, variety and/or applied fungicide is used in the usual manner. The check plot and the treated plot differ only in the specific treatment comparison being made. Aside from this treatment, plots are managed exactly the same to avoid biasing results.

In some trials, the new technology incorporates several practices. Avoid these if possible. For example, consider a trial that compares a farmer's current planting operation with another planting operation using different tillage, fertilization and row spacing systems. A fair comparison can only be made between the two complete systems, not any given part of either system. This kind of trial is difficult to interpret because of all the confounding interactions that may occur among the parts.

Selection of treatments to be tested: Keep treatments simple. Limit the number of treatments to no more than four, including one well-known treatment as a check (control) plot. As the number of treatments increase so does the complexity of the on-farm trial. Choose treatments that you expect to be significantly different. With experience you will gain confidence in your on-farm testing abilities and you can move on to testing treatments involving minor impact, difficult to test production practices. It is very important that production inputs remain constant, except for the tested treatments.

Plot size: Optimum plot size for on-farm tests may vary greatly with the size of uniform land area, number of treatments and size of equipment. Adjust plot lengths so that each treatment is within a reasonably uniform area or so that each uniformly covers the field variation as discussed above. Plots should be similar in size. Avoid using field edges in plots. Field edges should be left as borders. Plot width is determined by the width of equipment used to apply treatments (e.g., planter, sprayer, etc.) and/or harvest plots. The width of the established treatment should be larger than the harvest width. This way there will be a uniform harvest width and errors in harvesting will not affect side by side treatments. Typical treatment plots are between 1/10 and 1/2 acre.

Management: Each plot should be managed exactly the same and as close as possible to the conditions which normally occur on your farm.

Measurements: Depending on the test, take stand counts of the crop, ratings of weed control, disease or insects. Weigh the yield of each plot, take a moisture sample, and adjust yields to the same moisture content. Yield estimates are needed to make production and economic comparisons between treatments. Measure the size of the harvest area using a measuring tape or before or immediately after you harvest each plot. These distances are then multiplied by the width of the combine head to arrive at the harvested area and yield per acre.

Harvest the middle area of each treatment plot so that border effects do not bias the results. Yields can be measured with a local truck scale, a weigh wagon, or a properly calibrated yield monitor. Harvest equipment must be completely empty and clean before each treatment is harvested. Save a sample from each treatment to determine moisture content at harvest and any other quality factors that may be important such as test weight and protein content. If moisture contents differ between the treatments, you must be corrected to constant moisture.

Data analysis and Statistics

Data analysis largely depends on how the project was designed and conducted. Simple statistical software packages are available. Microsoft Excel has a very good analysis of variance procedure.

Economics: Use a partial budget analysis where

Grower return = (Yield*Price) - [Yield * (Handling+ Hauling+ Storage+ Drying+ Trucking)]

- Price = Weighted Price per Bushel = 50% November 15 Average Cash price + 25% March CBOT Futures price ($0.15 basis) + 25% July CBOT Futures price ($0.10 basis). November 15 Average Cash price derived from Wisconsin Ag Statistics; CBOT Futures prices derived from closing price on first business day in December.
- Handling costs = $0.02 per bushel
- Hauling costs = $0.04 per bushel
- Storage costs = $0.02 per bushel for 30 days
- Drying costs = $0.02 per bushel per point of moisture
- Trucking costs = $0.11 per bushel for 100 miles

Analysis: Use averages over replicates to compare treatments. A well-conducted test will have small differences among plots of the same treatment and some large difference between treatment averages. Consider all-important traits and not just yield.

Variations in yield and other measurements because of variations in soil and other growing conditions lower the precision of the results. Statistical analysis makes it possible to determine, with known probabilities of error, whether a difference is real or whether it might have occurred by chance.

Means are often separated using a number labeled "LSD" which stands for least significant difference. LSD's at an appropriate level of confidence (usually 10%) are used. Where the difference between two selected treatments within a column is equal to or greater than the LSD value at the bottom of the column, you can be sure that in nine out of ten chances that there is a real difference between the two treatment averages. If the difference is less than the LSD value, the difference may still be real, but the experiment has produced no evidence of real differences.

Statistics are only a tool to help prevent us from deceiving ourselves and others. Growing conditions in any particular year can have large effects on certain practices. Two years of replicated data are a minimum for supporting most practices. Statistics, as commonly used, often describe better than they predict. But, stats used over a lot of site-years can provide a measure of the usefulness of a prediction based on data. And yet, statistical statements always involve probability, and this is not always easy to "apply" when it comes to inputs. Statistics do NOT substitute for the large amount of data (site-years) that good on-farm testing always requires.

Time: Data from one field in one year may be misleading. About two to three years of your own tests in conjunction with other reliable information should be adequate to select treatments to be practiced on larger acreage. One year's data may be adequate to discard poor treatments from the test. Replace discarded treatments with new treatments in any tests conducted next year.

Adjustments in the number site-years should be considered if expected variability due to soil type is high (then you need more soil types), if expected variability due to years (weather) is high (then you need more years), and/or if variability is expected to be high over both soils and years, (then you will need a lot of sites and years). If variability is expected to be high over varieties/hybrids, you have a problem.

ASSESSING TRAIT BY MANAGEMENT INTERACTION: "NO UNITARDS ALLOWED"

Shawn P. Conley, John Gaska, Mark Martinka, and Paul Esker [1/]

Though growers across WI enjoyed record soybean yields (50.5 bu/a, Source: USDA-NASS) in 2010, questions continue to be asked about the small incremental yield gain observed over time. As the WI Soybean Research program continues to investigate the main yield limiting factors affecting soybean (SCN, white mold, SDS, BSR, soybean aphid, stress, etc), it is also clear that we must also address the question of input interactions.

Currently there is no published University data that supports claims that the perceived soybean yield plateau can simply be overcome through intensive management (high/multiple input) and/or adoption of new yield/input responsive traits (i.e., RR2Y® soybean). For example, in testing fungicide alone, Swoboda and Pedersen (2009) found that fungicides applied in the absence of foliar disease did not produce non-fungicidal physiological effect or associated yield improvement. Similarly, Cooper (1989) found a fungicide yield response only in cultivars where diseases were controlled. Our own data from fungicide efficacy trials have shown that response to foliar fungicide has been greatest when disease is being controlled and also that the use of tank mixes of fungicides and insecticides is not a warranted or cost-effective approach to increasing grower profitability.

When comparing multiple input systems, Lentz et al. (1985) found that combinations of metribuzin (herbicide), insecticides, and nematicides increased plant height, however, also increased the risk of soybean injury and yield loss. In an irrigated system, Slater et al. (1991) found variable response to additional N, P, and fungicide only in an early maturity cultivar where *Phomopsis spp*. was controlled. Lastly, Bradley and Sweets (2008) also reported inconsistent yield response when combining glyphosate with multiple fungicides and fungicide application timings. The paucity of published data coupled with the lack of consistent positive responses emphasizes the need for this research.

The need to address questions about multiple inputs will continue to increase given the projected releases of multiple new traits [DHT (Dow Herbicide Tolerance® 2,4-D resistance) and dicamba-resistant soybean] and input releases (novel foliar and seed treatment fungicide, nematicide, insecticide active ingredients as well as new biological compounds) in the near future. It is critical that we begin to quantify these complex interactions and ask "do synergies actually exist?" so WI growers are provided with accurate, unbiased recommendations that allow them to choose those technologies that increase both yield and profitability and avoid those inputs that are unresponsive and unprofitable. Therefore, the objectives of our experiments are to:

1. Characterize the effect of multiple input interactions on soybean yield and grower profitability;
2. Quantify soybean trait response to intensive management.

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Materials and Methods

Objective 1. Characterize the effect of multiple input interactions on soybean yield and grower profitability: The experimental design was a factorial (2^5) design with site serving as the replication (Cochran and Cox, 1957). The advantage of this design was to limit the total number of plots per site to 32 (1 block of 32 units) versus a traditional 128 plot design (32 treatment combinations x 4 reps if all factors were considered and replicated at a site). This design, with its manageable number of plots, will allow for expansion to multiple locations and allow for more intensive data collection. In Year One (2011), these experiments were located at our Arlington, Janesville, and Fond du Lac Variety Trial locations. The main factors of interest were trait (RR1 vs. RR2Y), seed treatment (ApronMaxx plus Optimize 400) (yes or no), foliar fertilization (3 gallons of 3-18-18) @ V6 (yes or no), foliar insecticide @ R2/3 (yes or no), and foliar fungicide @ R2/3 (yes or no).

Objective 2. Quantify soybean trait response to intensive management: Due to our design limitation on the number of traits/varieties we can compare in Objective 1, as well as the difficulty in testing the influence of multiple inputs on soybean yield, we also conducted a second set of experiments. The experimental design was a randomized complete block split-split-plot design with 4 replications (Cochran and Cox, 1957). The main plot effect was intensive management (+ or -), the sub-plot was trait, and the sub-sub-plot was variety. The intensive management treatment combined all the inputs used in Objective 1: no treatment (-) vs. (seed treatment + foliar fertilization @ V6 + foliar insecticide @ R2/3 + foliar fungicide @ R2/3) (+). The trait treatment tested was RR1 vs. RR2Y. The variety treatment consisted of 5 varieties of each trait. One each of the RR1 and RR2Y varieties tested was the same as those in Objective 1 to allow for comparisons among experiments and to increase our level of inference.

Data collection for both sets of experiments:

- Stand counts at V3 and R8
- Leaf tissue analysis for (N, P, K) @ V6 and R3 (objective 1 only)
- Disease incidence and severity at R3 and R5
- Soybean aphid counts at R3 and R5
- Reflectance measurements using a crop canopy sensor @ V6, R3
- Grain yield and quality

Data analysis: Initial analyses focused on comparing the effect of different treatments using standard methods of ANOVA and LSD values.

Results and Discussion

Preliminary results from 2011 of this multi-year experiment suggested that variety selection and foliar fungicide were the primary contributors to yield in 2011 ($P < 0.05$) (Table 1). No yield differences were observed between RR1 and RR2Y traits in Objective 2 (Table 2). Furthermore, we did not observe any trait by input interactions (Tables 1 and 2). Given the lack of interactions in objective one and the similar yield increases between the fungicide only treatment in objective one and the overall yield increase in the intensive management treatment in objective two, we can speculate that this yield response was also likely due to the fungicide application. These preliminary results suggest that no "synergies" were attained by adding or deleting inputs in these experiments. These results further emphasize our recom-mendations that variety selection is the most valuable tool in increasing soybean yield followed by scouting and timely application of a pesticide when needed to control soybean pests.

Table 1. Main effect and interactions for soybean seed yield from objective one.

Main effect	Grain yield	P-value
Trait (variety)		0.0043
Pioneer 92Y30 (RR1)	70.0	
Dairyland DSR-2375/R2Y (RR2Y)	66.7	
Seed treatment		0.57
UTC	68.1	
ApronMaxx (1.5 fl oz/cwt) + Optimize 400 (2.4 fl oz/cwt)	68.6	
Foliar fertilizer		0.54
UTC	68.0	
3-18-18 (3 gal/a @ V6)	68.7	
Foliar insecticide		0.86
UTC	68.5	
Warrior w/Zenon (3.0 fl oz @ R2/3)	68.3	
Foliar fungicide		0.03
UTC	67.1	
Quilt Xcel (14 fl oz @ R2/3)	69.6	

† No interactions were significant at the 0.05 probability level.

Table 2. Main effect and interactions for soybean seed yield from objective two.

Main effect	Grain yield	P-value
Trait†		0.56
RR1	73.0	
RR2Y	74.1	
Management ‡		0.01
UTC	72.2	
Intensive	75.0	
Trait by management		0.12

† (RR1 varieties: Pioneer 92Y30 and 92Y51, NK Brand S21-N6 and S19-A6, Dairyland DSR-2011; RR2Y varieties: FS HiSoy HS24A01, Dairyland DSR-2375/R2Y, Renk RS241R2, Asgrow AG2631 and AG2431)
‡ Intensive management = ApronMaxx (1.5 fl oz/cwt) + Optimize 400 (2.4 fl oz/cwt) + 3-18-18 (3 gal/a @ V6) + Warrior w/Zenon (3.0 fl oz/a @ R2/3) + Quilt Xcel (14 fl oz/a @ R2/3)

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MANAGING RISK USING TRANSGENIC CROPS

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Abstract

Farmers have adopted biotechnology and genetically engineered (GE) crop technologies quickly. Yield data were analyzed from field experiments over the period 1990-2010 to test the hypothesis that GE corn technologies reduces production risk. GE technology can increase yield, but it also decreases yield for some GE traits. A significant part of the benefits of GE technology comes from protecting corn yield and reducing risk exposure. Gene interactions affect corn productivity through "yield lag" and "yield drag" effects. Often 3 to 4 years are required for new technologies to be equivalent to yields of conventional hybrids.

Corn yield progress has increased dramatically over the last century. Average U.S. corn grain yields have increased from 119 to 153 bushels per acre between 1990 and 2010 (*1*). Over the last 15 years, biotechnology has been rapidly adopted in U.S. agriculture (*2, 3*). Quick adoption of genetically engineered (GE) corn by farmers indicates that farmers benefit from biotechnology. Yet, documenting the nature and sources of these benefits has been challenging (*2, 3*). By analyzing yield data from field experiments over the period 1990-2010 in Wisconsin, we show how transgenes affect corn yield, with a special focus on possible gene interactions and their effects on corn productivity. We test the hypothesis that GE crops can reduce production risk, as measured by the variance, skewness and kurtosis of corn yield. GE crops contribute to lowering yield loss and reducing risk exposure. This helps support lower crop insurance premiums offered to farmers who plant GE crops (*3*, p. 145). In addition, farmers often perceive a delayed yield increase due to "yield lag" and "yield drag" associated with GE genes (*3*, p. 142). This analysis documents the presence of such effects.

In general, reducing variance and increasing skewness are seen as desirable: it means a reduction in risk exposure (from a lower variance), and a decreased exposure to downside risk (from a higher skewness). Also decreasing kurtosis may be desirable to the extent that it means a lower exposure to rare events located in the tails of the yield distribution. In general, the mean, variance, skewness and kurtosis of yield vary with management choices, including GE genes that could lower yield loss and reduce risk exposure.

The data used for the analysis is derived from field experiments conducted through the University of Wisconsin Corn Hybrid Performance Evaluation program from 1990 to 2010. The field experiments are conducted annually at 12-15 location across Wisconsin. Management practices were typical of those utilized on Corn Belt farms practicing rainfed agriculture. The seedbed at each location was usually prepared by fall plowing followed by spring roller harrowing. Fertilizer was applied as recommended by soil tests. Herbicides were applied for weed control and supplemented with cultivation when necessary. Insecticide was applied when the infestation level is above a certain level (that a typical farmer would find it economically reasonable to apply insecticides). Between Two-row plots, twenty-five foot long, were planted at all locations. The experimental design was a randomized complete block where each hybrid was grown in at least three separate plots (replicates)

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at each location to account for field variability. Two-row plots were harvested with a self-propelled corn combine. Lodged plants and/or broken stalks were counted, plot grain weights, moisture content and test weight were measured and yields were calculated and adjusted to 15.5% moisture. A total of 4748 hybrids have been tested in the past 21 years, of which 2653 are conventional hybrids and 2095 are GE hybrids. Some hybrids are tested in multiple sites and/or for multiple years, yielding 31799 usable observations for the analysis.

The cost of risk is defined as the number of bushels of corn per acre a farmer is willing to give up to replace a risky yield with a mean yield. As such, it is expressed in bushels per acre. The cost of risk depends on the farmer's degree of risk aversion.

Results and Discussion

The analysis showed strong evidence of gene interactions among GE traits when they are stacked. Both significant negative and positive interaction effects were found. While the identification of gene interactions in corn is not new (*4, 5*), the evidence of negative interaction effects among GE genes indicates that the performance of GE hybrids can be lower than conventional hybrids. Yet, such gene interactions are subject to management by geneticists and plant breeders (depending on where the GE genes are inserted in the germplasm as well as the quality of the germplasm used). It is a challenge to GE technology to manage such gene interactions in a productive way.

Lower performance may also be due to a time lag in the development of hybrids and the "rush to market" with GE gene technologies. These lags are measured by the number of years since the first introduction of a given event for each specific trait or system of traits (stacks). Such effects may develop if GE genes interact with the genetic material in the germplasm and where the GE genes are inserted in the germplasm, as well as the quality of the germplasm and success of the transfer of the GE gene(s). The analysis finds evidence of event lag effects, although such effects vary with each trait as well as their stacking. The effects of GE genes on corn yield in general depend upon the underlying germplasm. Plant breeders try to minimize over time any adverse interaction effects between GE genes and the germplasm. Yet, such gene interactions are found to vary with each GE gene.

GE hybrids were found to have significant effects on yield risk. First, GE technology affects the variance of corn yield. These effects are in general negative (implying that GE hybrids lower yield variance), although they vary with the system of GE hybrids (e.g., with GE stacking). For the lag effects, the longer the GT and ECB single-trait events have been introduced, the lower the yield variance. However, the quadratic term time lag effect for ECB single-trait event is positive, suggesting that variance will eventually increase for that type of hybrid. This indicates that ECB does reduce yield variance in the short term, although such effects seem to decline in the longer term. The event lag effect on yield variance for the ECB and RW stacked event is also negative.

The estimation of the skewness and kurtosis of corn yield shows that GE traits do affect the distribution of corn yield (beyond their effects on variance). This indicates a need to go beyond mean-variance in the analysis of yield risk. In general, yield skewness is found to be negative, meaning that the yield distribution tends to be skewed to the left (implying a greater exposure to losses and downside risk). And yield kurtosis is found to be large: the "excess kurtosis" tends to be positive and statistically significant. This suggests that the distribution of corn yield has "fat tails". It means that the probability of rare events located in the tail of the distribution is higher than would be predicted from a normal distribution. Importantly, both GE and management are found to have significant effects on both skewness and kurtosis. Some of the GE effects are positive for skewness, indicating that GE hybrids contribute to reducing exposure to downside risk. And some of the GE effects are negative for kurtosis, showing that GE hybrids reduce the thickness of the tails of the corn yield distribution. These effects are somewhat complex as they vary with the system of GE traits (e.g., with GE stacking).

In general, the total cost of risk amounts to 2 to 4 percent of expected production. While such percentages are not very large, they do provide useful information on the extent of risk exposure in corn production. First, most of the cost of risk comes from the variance component. For example, the total cost of risk for conventional hybrids is 6.36 bushels per acre; the variance component accounts for 90 percent of it (5.72 bushels per acre); and the skewness and kurtosis components account for about 5 percent each.

All GE hybrids decrease the cost of risk compared to conventional hybrids. These effects come from reductions in all three components of risk: variance, skewness and kurtosis. The reduction in variance is found to be the dominant factor. But the reduction in downside risk (the skewness effect) and the reduction in the probability of facing rare events (the kurtosis effect) also contribute to reducing the cost of risk. This documents that GE hybrids do help reduce farmers' exposure to risk. However, these effects vary with the GE hybrids. In general, the stacking of traits within hybrids reduces risks further than the single-trait GE hybrids. This shows that multiple genes reinforce their effects on risk reduction, thus giving an advantage to stacked hybrids (compared to single-trait hybrids) in reducing risk.

What does all this mean for farmers in Wisconsin? Buying corn hybrids is more confusing than ever. For years we have recommended to growers to choose hybrids by using comparative yield performance data. We do this by selecting hybrids with high average yield that is consistent across many environments and management situations. In the last few years these two basic principles have expanded to the following five principles:

1) Use multi-location averages to compare hybrids
2) Evaluate consistency of performance
3) Pay attention to seed costs
4) Every hybrid must stand on its own
5) Buy the traits you need

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INVESTIGATING GIANT RAGWEED RESISTANCE TO GLYPHOSATE IN WISCONSIN

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Abstract

Giant ragweed resistance to glyphosate has been confirmed in several Midwest states, including the neighboring states of Minnesota and Iowa. In Minnesota as well as Ohio, giant ragweed has developed resistance to more than one herbicide mode of action (glyphosate and ALS inhibitors). In Wisconsin, we've identified three giant ragweed populations that are suspected of being resistant to glyphosate. Results of preliminary experiments on a giant ragweed population from southwest Wisconsin (Grant County) and a second population from southeast Wisconsin (Rock County) were reported at the 2011 Wisconsin Crop Management Conference. A third population of giant ragweed with suspected resistance to glyphosate was identified in south-central Wisconsin (Columbia County) in 2011. Seeds were collected from this giant ragweed population for investigation of resistance to glyphosate and other herbicide modes of action. The results of greenhouse experiments conducted over the last 12 months to more fully characterize the whole-plant response of the Grant County and Rock County populations to glyphosate will be presented.

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CONTROLLING FIELD HORSETAIL AND OTHER ODD WEEDS

Vince M. Davis[1]

Introduction

Field horsetail (*Equisetum arvense*) is in the *Equisetaceae* family which was comprised by over 30 species some 230 million years ago. The horsetail family was the dominant plant group in that time period. Currently, two surviving species from the family which many of us today call weeds are *E. arvense* and *E. hyemale*, or scouring rush. Therefore, these ‘weeds’ have been around a long time so it’s obvious they have a tremendous ability to adapt to their environment. Field horsetail is a perennial weed that vegetatively re-propagates by spreading rhizomes. It is additionally unique because it is a non-flowering plant so it does not reproduce my seed, but rather, it reproduces by spores. The reproduction by spores occurs early in the spring when a single, fertile brownish stalk emerges and produces a ‘cone-like’ structure which releases the spores at the top of the main stalk. This early growth is followed by a single, sterile green stalk and then branched, green plants as shown in Figure 1.


Figure 1 on left, Branched field horsetail among field corn. Figure 2 on right, field horsetail extending from the roadside into a no-till field of corn. Both images were taken in 2011 at a field research site in Green Lake, WI.

Field horsetail populations often start in ditch banks or other adjoining natural areas and spread inward from the field edges (Figure 2). Like many perennials, field horsetail is favored by reduced tillage. Moreover, very few herbicides are effective at controlling field horsetail, and common no-till herbicides, namely glyphosate and 2,4-D, offer essentially no control. Despite few control options, this weed has not been studied a lot because while it is difficult to control, it traditionally occupies few acres. However, with the popularity of reduced tillage and subsequent increased reliance on glyphosate in Roundup Ready crops, it is increasing in several geographies.

Dr. Chris Boerboom wrote an article in the Wisconsin Crop Manager in May of 2009, *Field Horsetail ID and Management in Field Corn* that addressed the increasing concern a couple years ago. They established field research trials in 2009 and 2010. Tim Trower reported on those trials at the Wisconsin Crop Management conference in 2011. Results in those trials were extremely variable among locations and between years (results not shown). In 2010, no

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differences in field horsetail control were observed among the soil-applied herbicide programs they examined. Postemergence applications of Steadfast plus Hornet and Steadfast plus Status seemed to be the most consistent postemergence programs. According to research in Ontario Canada and other Midwest states, flumetsulam, the active ingredient in Python and one of the active ingredients in Hornet and Surestart herbicides, provides the most consistent control when applied preemergence. However, as Boerboom noted in 2009, growers often still report inadequate control.

Research continued in 2011 in a field site in Green Lake county Wisconsin. This was a long-term no-till field where horseweed completely infested approximately 10% of 60 acres. The objective in 2011 was to compare postemergence herbicide combinations focusing on combinations of acetolactate synthase (ALS) inhibitor and dicamba herbicide combinations presented in Table 1. All treatments were broadcast at 15 gal/a on June 9, 2011 when the corn was at the V4 growth stage and the field horsetail was 6 to 14 inches tall. All herbicide treatments contained the addition of ammonium sulfate at 3.4 lb/a.

Table 1. Visual control ratings for field horsetail following postemergence herbicide applications in corn on June 9, 2011; where 0 is no control and 100 is complete control.

			Percent control rating		
Herbicide treatment	Rate	Unit	6/24/2011	7/28/2011	10/5/2011
Roundup PowerMax	22	fl oz/a	0 b	0 b	0 c
Roundup PowerMax +	22	fl oz/a	25 ab	37 a	47 b
Surestart	1.5	pt/a			
Roundup PowerMax +	22	fl oz/a	37 ab	45 a	67 ab
Yukon +	4	oz/a			
NIS	0.25	% v/v			
Steadfast +	0.75	oz/a	34 ab	59 a	95 a
Yukon +	4	oz/a			
COC	1	% v/v			
Steadfast +	0.75	oz/a	53 a	74 a	95 a
Status +	5	oz/a			
COC	1	% v/v			
Steadfast +	0.75	oz/a	35 ab	58 a	77 a
Hornet +	4	oz/a			
COC	1	% v/v			
Roundup PowerMax +	22	fl oz/a	36 ab	61 a	88 a
Status +	5	oz/a			
COC	1	% v/v			
Steadfast +	0.75	oz/a	48 a	71 a	95 a
Northstar +	5	oz/a			
COC	1	% v/v			
LSD (P=.05)			24	26	22
Standard deviation			16	17	15
CV			48	34	21

2011 Field Horsetail Summary

Field horsetail control was again very inconsistent among treatments and the experimental variability was quite large. Roundup Powermax plus Surestart applied postemergence provided the least horsetail control, despite having flumetsulam as one of the active ingredients. However, in a normal field use rate of surestart, the concentration of flumetsulam is much lower than can be applied as Python or Hornet in preemergence applications. Conversely, Steadfast + Status again performed among the best (albeit numerically) and was the most consistent across timings. Steadfast + Northstar also performed equally well in this trial. As evidenced in Table 1, none of the postemergence herbicide options were highly effective, and there is still no clear answer or easy solution for horsetail control. A multipronged approach, and repeated applications are needed and ideas for successful integrated approaches will be discussed in more detail.

Other 'ODD' Weeds

In addition to the continued pursuit of investigating control options for field horsetail, a few other weeds which are less common to Wisconsin crop production fields came to our attention this year. Namely common pokeweed (*Phytolacca americana*) and Palmer amaranth (*Amaranthus palmeri*). We will discuss identification of these weeds and potential implications and control strategies.

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MANAGEMENT OF CANADA THISTLE IN GRASS BASED SYSTEMS

Mark J. Renz[1]

Since its introduction into the United States in the late 1700s, Canada thistle (*Cirsium arvense*) has spread dramatically, causing greater crop losses than any other perennial broadleaf weed in the north central region of the United States. In Wisconsin, it continues to be a major pest identified by growers, land managers, and consultants. In pastures studies indicate that, while highly variable, forage loss from Canada thistle can result in an average of 22% yield loss. While forage quality remains high for Canada thistle, its palatability can be extremely low due to the spiny nature of the leaves. This can result in partial-use (40%) or complete rejection by animals. In addition to these costs animals do not utilize the forage nearby effectively when Canada thistle is present. This can result in <50% utilization of desirable forage. Finally, spines present on the leaves can aggravate animals often resulting in reduced performance. Clearly Canada thistle is not a desirable plant.

Information on the biology of Canada thistle will be presented, followed by detailed information on how to develop an integrated management plans. Mechanical, physical, biological, and chemical methods will be discussed. While emphasis will be places in grass based systems, information will be applicable to other cropping systems.

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INTEGRATING 2,4-D AND DICAMBA RESISTANT SOYBEAN INTO WISCONSIN CROPPING SYSTEMS

Vince M. Davis[1]

Introduction

Glyphosate resistant crops, first released in 1996, have been the most rapidly adopted agriculture technology by the farming community in the U.S. The technology was rapidly adopted because weed management systems were drastically simplified. Weed management was simplified because glyphosate is a highly efficacious, non-selective postemergence herbicide for control of annual and perennial weed species, and when used in conjunction with glyphosate-resistant crops, a high-level of crop safety was ensured. Additionally, glyphosate is also safer for the environment, safer for humans and animals, cheaper, and slower to develop resistance in comparison to many other herbicide options. All of those reasons have contributed to make glyphosate an herbicide that growers and applicators prefer to use.

Unfortunately, in part due to its' own superior postemergence weed control efficacy and low cost, glyphosate has been relied upon too much in many glyphosate-resistant cropping systems. This 'over-reliance' on a single weed control strategy has created a 'shift' in the problematic weeds in many fields to become dominated by species where glyphosate is less efficacious, as well as infested with weed biotypes which are resistant to glyphosate. Currently, there are 21 weed species Worldwide documented with biotypes that are resistant to postemergence glyphosate. Some of these weeds like horseweed, giant ragweed, common ragweed, waterhemp, Palmer amaranth, and johnsongrass (just to name a few) infest millions of acres of corn, soybean, and cotton across the U.S. Additional management, additional herbicides, and subsequently additional costs have been the result of this progression.

One additional result of the increased glyphosate-resistant weeds in glyphosate-resistant cropping systems Worldwide has been the need for newer technologies to aid in weed control to ensure sustainability of our primary commodity crop production across the U.S. A couple of those developed technologies are crops with genetically modified traits which will allow them to be resistant to growth regulator herbicides in addition to glyphosate. The growth regulating herbicides of primary utility for these crop traits are 2,4-D and dicamba.

Dicamba-resistant Soybean

Monsanto Company, St. Louis, MO, is developing the addition of dicamba tolerance to the Genuity™ Roundup Ready 2 Yield™ Soybean platform which will offer growers an additional tool for flexible and effective weed management along with the increased yield opportunity of Roundup Ready 2 Yield™. Once approved, the dicamba tolerant technology will enable the use of dicamba and glyphosate tank-mixes for preplant burndown, at planting, and in-season applications adding considerable weed control value to the well-established and effective Roundup Ready® system. Monsanto and BASF are working together to develop innovative dicamba formulations for use with these herbicide-tolerant cropping systems, and both companies are working together to develop robust Best Management Practices for the use of dicamba over Dicamba tolerant soybeans. Dicamba tolerant soybeans are projected to

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be commercialized in the middle of this decade, pending global regulatory approvals with initial product launches in the U.S. and Canada.

2,4-D-resistant Crops

Dow AgroSciences has developed traits conferring herbicide tolerance in plants. This technology was originally referred to as Dow AgroSciences Herbicide Tolerance (DHT) traits, and is now referred to as Enlist™ Weed Control System. In soybean, the trait will provide tolerance to pre-emergence and post-emergence applications of 2,4-D. In corn, the trait will provide tolerance to pre-emergence and post-emergence applications of 2,4-D and post-emergence applications of quizalofop, an ACCase – inhibitor grass herbicide. In conjunction with the Enlist crop traits, Dow AgroSciences is also developing new and novel proprietary technology that will significantly reduce the physical drift and volatility of 2,4-D relative to current DMA and ester 2,4-D herbicide formulations in the market. This new technology will be used to create proprietary pre-mix formulations of 2,4-D + glyphosate having improved compatibility and cold storage stability characteristics. Dow AgroSciences is also committed to providing comprehensive stewardship guidance for deploying this technology. Enlist technologies are also projected to be commercialized in the middle of this decade, pending global regulatory approvals.

Thoughts about Growth Regulator Resistant Crop Adoption in Wisconsin

I agree these growth regulator resistant technologies will offer many plausible and important weed control benefits. However, the adoption and acceptance of these technologies may once again stretch the entire crop production community to revolutionize. The benefits with these pending technologies will include increasing broad-spectrum postemergence weed control options, particularly for broadleaf weeds. Similar to glyphosate, the growth regulating herbicides are also relatively cheap, and weeds are slow to develop biotypes with resistance. However, growth regulator resistant weeds have been documented in a couple unique situations, so like glyphosate, it can happen when the herbicide is used too often.

The adoption of these technologies also bring much concern about the potential for these herbicides to be used more often, and as a result, find their way to sensitive vegetation which was not an intended target. Growth regulating herbicides cause plant symptoms that are highly visible which can lead to easy detection of off-site movement. There are three common ways these herbicides will move off-target including failure to properly clean spray equipment (which is very difficult in relation to other herbicides), particle drift during herbicide applications, and volatilization, or movement of vapor off the target after spray has deposited on the target surface. In summary, these technologies bring with them both opportunity and challenges for weed management systems which will be discussed.

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CROP ROTATION, TILLAGE, AND WEED MANAGEMENT EFFECTS ON WEED COMMUNITIES AFTER 12 YEARS

Dave Stoltenberg [1]

Abstract

Research was conducted from 1998 through 2009 to determine the effects of crop sequence, tillage system, and glyphosate use frequency on weed community composition and management risks in glyphosate-resistant corn and soybean. Weed communities tended to be dominated by a few highly abundant weed species. Common lambsquarters, giant foxtail, and redroot pigweed were abundant across cropping sequence and tillage treatments over time. In contrast, giant ragweed was not observed in 1998, but increased over time, particularly in chisel plow and no-tillage systems, to become the most abundant weed species in most treatments by 2009. Giant ragweed abundance was similar between continuous corn and corn-soybean rotation after 12 years, but there were fewer instances over time of high densities of giant ragweed and crop yield loss in corn-soybean rotation than continuous corn. In both continuous corn and corn-soybean rotation, giant ragweed increased over time in treatments that did not provide adequate control, particularly control of later flushes of giant ragweed (e.g., those that emerged after the typical postemergence application timing). Giant ragweed abundance was affected greatly by tillage system. In the moldboard plow system, total weed densities (including giant ragweed) were very low over time across cropping sequence and weed management treatments. In contrast, giant ragweed abundance increased over time in chisel plow and no-tillage systems, particularly in treatments that did not provide adequate control of late flushes as noted above. However, the greatest crop yield losses associated with crop-weed competition occurred in the continuous corn, chisel plow system. Weed management treatments that effectively targeted the range of giant ragweed emergence (from early to late flushes) were associated with the lowest total weed densities and lowest crop yield loss risks across cropping sequence and tillage systems over time.

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SULFUR FERTILIZATION RESPONSE IN IOWA CORN AND SOYBEAN PRODUCTION

John E. Sawyer, Brian Lang, and Daniel W. Barker[1]

Sulfur (S) is often classified as a "secondary" plant essential element, mainly due to a smaller plant requirement but also because it is less frequently applied as a fertilizer compared to other nutrients like the "macronutrients" nitrogen (N), phosphorus (P), and potassium (K). This has certainly been the case in Iowa where research for many years had not documented S deficiency or fertilization need for optimal corn or soybean production. However, if deficient, S can have a dramatic effect on plant growth and crop productivity – more than the classification "secondary" would imply.

In Iowa, before 2005 more than forty years of field research with corn and soybean conducted at many locations across the state had measured a yield response to S fertilizer application only three times out of approximately 200 trials – an indication of adequate available S supply and limited deficiency. This began to change in the early 2000's as producers in northeast Iowa noticed yellow plant foliage and reduced growth in areas of alfalfa fields. After investigating several potential reasons for the growth problems, such as plant diseases, research in multiple fields documented improved alfalfa plant coloration, growth, and forage yield with S fertilizer application (Lang et al., 2006). These responses, as well as questions about deficiency symptoms in corn, led to investigation of potential response to S application in corn and soybean.

Response in Corn Fields with Suspected S Deficiency

Initial S response trials were started in 2006 corn fields where early plant growth was exhibiting dramatic S deficiency symptoms or where there was expectation of S deficiency based on research conducted with alfalfa. Calcium sulfate (gypsum) was surface broadcast applied after early corn growth at 40 lb S/acre, with a control treatment for comparison. The 40 lb S/acre rate was chosen as a non-limiting S rate to maximize any potential yield increase.

Corn yield was increased with the S application at five of six sites (Table 1). The yield increases were large, especially considering the surface side-dress application. However, the sites were chosen based on expected S deficiency, with many sites showing severe plant yellowing. With rainfall after application, plant response (increase in greenness) was observed in a short time period. Across all sites, the yield increase from S application was 38 bu/acre. These results indicate that a substantial corn yield increase to S application is possible when soil conditions are conducive to low S supply and severe S deficiency exists. In this study, those conditions were coarse textured soils and a soil/landscape position similar to that with documented S deficiency in alfalfa.

Corn Response to Sulfur Fertilization Rate

An expanded set of trials was conducted in 2007 to 2009 at 47 sites in north-central to northeast Iowa to determine corn response to S rate. The sites were selected to represent major soils, cropping systems, and a range in potential S response. Sites had no recent or known manure application history. Calcium sulfate was surface broadcast applied with no incorporation shortly after planting at 0, 10, 20, and 40 lb S/acre. Individual site S response was determined by grain yield comparison of the no S control vs. applied S. Corn yields were averaged across responsive

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sites by fine and coarse soil textural grouping, with response models fit to the yield response. Economic optimum S rate was determined with S fertilizer at $0.50/lb S and corn grain at $4.00/bu.

Corn grain yield was increased with S fertilizer application at 17 of 20 sites in 2007, 11 of 25 sites in 2008, and no response at two sites in 2009. Ear leaf S concentration was increased at 16 sites each year in 2007-2008. Across all sites, the average yield increase was 11 bu/acre. When grouped by soil texture just for responsive sites (Figure 1), the yield increase was 15 bu/acre for the fine-textured soils (loam, silt loam, silty clay loam, and clay loam) and 28 bu/acre for the coarse-textured soils (fine sandy loam, loamy fine sand, and sandy loam). Grain yields increased with S application at 21 of 36 (58%) fine-textured soil sites and 7 of 11 (64%) coarse-textured soil sites. These are frequent and large yield increases to S fertilization. However, sites located more toward the north-central geographic area of Iowa had a lower frequency of yield response to S application, indicating soil or other factors affecting potential need for S fertilization that are different from the northeast area of Iowa.

When analyzed by the responsive sites, the maximum S response rate for the 21 fine-textured soil sites was 17 lb S/acre, with an economic optimum rate at 16 lb S/acre (Figure 1). For the 7 coarse-textured soil sites, the maximum response rate was 25 lb S/acre, with an economic optimum rate at 23 lb S/acre.

One test for evaluating potential S deficiency is plant analysis for ear leaf S concentration. There is a wide range in published minimum sufficiency concentrations for corn ear leaves at the silking stage, 0.10 to 0.21% S (Jones et al., 1990; Dick et al., 2008). The current study does not confirm or refute these minimum levels. Across measured leaf S concentrations there was no clear relationship between ear leaf S and yield response (Figure 2), with the leaf S concentration below 0.21% S at all but one site. Therefore, it is not possible to define a critical level from this study. Sulfur application increased leaf S concentration, but was not a large increase; across sites, an increase of 0.02% S with the 40 lb S/acre rate.

Another test for evaluating potential S deficiency is soil testing for extractable sulfate-S in the surface soil. Concentrations (-0 to 6-inch depth) were not related to yield response (Figure 3). Also, several sites had concentrations above the 10 ppm S level considered sufficient (Hoeft et al., 1973), but responded to S application. This has been found in other studies where the sulfate-S soil test has not been reliable for predicting crop response to S application on soils in the Midwest USA. Supply of crop-available S is related to more than the sulfate-S concentration in the top six inches of soil, thus the poor relationship between yield response and soil test. Soil organic matter has a somewhat better relationship to yield response, but for similar reasons does not clearly differentiate between responsive and non-responsive sites (Figure 4). These results highlight the complex combination of environment, soil, and crop factors that result in deficient or adequate season-long supply of available S. Visual observation of deficiency symptoms can lead to correct determination of S response (Figure 5), however, in research since 2000, there has been five times that early in the season corn plants have exhibited S deficiency symptoms, but no grain yield response was measured. Also, hidden hunger can exist where the corn plant does not exhibit deficiency symptoms but yield increase may occur (Figure 5).

Field-Scale Sulfur Evaluation in Corn

In 2009, replicated field-length strip trials were conducted in 11 fields in central and northeast Iowa with spring preplant broadcast calcium sulfate compared to no S application. One rate of S was used in each field, but the rate varied between sites (Table 2). These strip trials are considered a survey of potential field-scale S response in corn.

Six of the eleven fields had a corn yield increase from S application (9 bu/acre average, with a range of 5 to 13 bu/acre), with the other five fields having no S response (Table 2). This is a 55% response rate to S application, which is similar to the recent small plot research conducted in central to northeast Iowa. The yield increases were large enough to more than pay for a field-wide S application. This strip trial work confirms that field-scale S deficiency is occurring across a wide geographic area of Iowa from central to northeast Iowa.

Sulfur Fertilizer Product Evaluation in Corn

Field trials were conducted in 2006 (northeast Iowa, two sites), 2008 (northern Iowa, one site), and 2009-2010 (central to northern Iowa, two sites each year) on producer fields with loamy fine sand, silt loam, and loam soils to evaluate phosphorus-sulfur fertilizer combination products. The fertilizer sources varied somewhat, but were consistent in the product makeup. In 2006, the first year of this work, the product evaluated was a Simplot 13-33-0-15S fertilizer (SEF). No studies were conducted in 2007. In 2008, the Mosaic 13-33-0-15S (MicroEssentials MES15) product was evaluated, and in 2009-2010 the Mosaic 12-40-0-10S (MES10) product. These products are comprised of monoammonium phosphate (MAP), with S as sulfate and elemental S in approximate equal proportions. Since these products were similar in nutrient makeup, a combined analysis was performed across site years.

The following P and S treatment combinations were used at all locations. The product rates were set by the desired rate of S application, 10 and 30 lb S/acre. The P application rate was set by the highest rate of the combination product at 30 lb S/acre (66 lb P_2O_5/acre with SEF and MES15 evaluation, and 120 lb P_2O_5/acre with MES10 evaluation). For correct comparisons, rates of P were equalized when required by the specific treatment with triple superphosphate (TSP). The P rate was constant for all treatments except the S & P control where no S or P was applied. The N rate was constant across all treatments as needed for the rotation, and K was applied at 60 lb K_2O/acre as potassium chloride to all plots. Fertilizer treatments were broadcast applied in the spring, prior to tillage and/or planting depending on the tillage system.

- SP-CON: S & P control, zero P and zero S (equalize N).
- S-CON: S control, zero S (equalize N; add P at the highest P rate).
- MES/SEF-10: 10 lb S/acre from the MES/SEF product (equalize N; equalize P to highest P rate).
- AMS-10: 10 lb S/acre from ammonium sulfate (AMS) (equalize N; equalize P to highest P rate).
- MES/SEF-30: 30 lb S/acre from the MES/SEF product (equalize N; no additional P as this is the highest P rate).
- AMS-30: 30 lb S/acre from AMS (equalize N; equalize P to highest P rate).
- MAP-30: P rate used in the MES/SEF 30 lb S/acre rate applied from MAP (equalize N; apply AMS at highest S rate).

The across-site (all seven sites) combined analysis for P and S response evaluation is given in Table 3. Ear leaf P concentration was increased with all P fertilizers. The SP-CON did not have any P applied (true control), and all other treatments (including the S-CON) had P fertilizer applied. The increase in ear leaf P concentration indicates that all P fertilizers (SEF, MES, MAP, TSP) were equally effective in supplying plant available P. Ear leaf S concentration was increased with S application from all fertilizer products. This indicates all S fertilizers (SEF, MES, AMS) were equally effective in supplying plant available S. The form of S in the SEF and MES was half sulfate and half elemental. That mix did not appear to detract from supplying plant available S. The SP-CON and S-CON treatments did not have S fertilizer applied, and therefore had the lowest S concentrations. The higher rate of S resulted in greater ear leaf S concentration, reflecting the higher application rate. The ear leaf S concentration was increased slightly with P application in the S-CON (compared to the SP-CON treatment). The P source used in that treatment was TSP. The S concentration in TSP is expected to be low; therefore, that ear leaf S increase could be due a small amount of S applied in the TSP or to enhanced uptake due to response from the applied P.

The corn grain yield was increased with all P fertilizer product applications. Along with the leaf P concentration increase, this yield response indicates an overall response to P application. The uniformity in yield response also indicates all P fertilizers were equally effective in supplying plant available P. The S-CON treatment did not have S applied, and the yield with that treatment was the same as treatments where P and S was applied. Therefore, the across-site yield response appears to be due to P and not S.

Soybean Response to Sulfur Application

Recent research trials with S application to soybean have been limited. In 2000 and 2001 there were no yield increases to S application rate each year at six Iowa State University research farms across Iowa. In 2008, there were two rate trials, one at central Iowa and one in northeast Iowa. The trial in northeast Iowa had a yield increase at one S rate, but not others. In 2011, there was one trial on a sandy soil in southeast Iowa, with no yield response to S application. Additional research is needed with direct S application to soybean, and to study potential residual response in the year after application to corn.

Summary

Corn grain yield increase to S fertilization has occurred with high frequency. Also, the magnitude of yield increase has been large. Across the small plot S rate studies, 60% of the sites had a statistically significant yield increase to applied S fertilizer: 68% of sites with loam, silt loam, fine sandy loam, loamy fine sand, and sandy loam textural classes; and 14% of sites with silty clay loam or clay loam textural classes. The across-site yield increase averaged 19 bu/acre for the responsive sites. Analyzed across S rate, the economic optimum S rate was 16 lb S/acre for fine-textured soils and 23 lb S/acre for coarse-textured soils.

This research indicates a change in need for S fertilization, especially in northeast Iowa and the associated soils, and that S application is an economically viable fertilization practice on soils in areas neighboring northeast Iowa. However, the research also shows that corn does not respond to S application in all fields. It has been frustrating that a single test has not been found to be reliable for detecting potential for S response in corn and soybean. Plant tissue testing has worked well in alfalfa, but nothing similar in corn. The difficulty in determining consistency of yield response is that there are multiple sources of plant-available S, including surface soil, subsoil, and atmospheric. And, a marginal deficiency can be overcome in-season by a change in organic matter mineralization, rooting depth, precipitation, or co-application with fertilizers. In addition, the amount of S uptake in corn is not large (in recent research, at 200 bu/acre, 8 lb S/acre in grain and 13 lb S/acre total aboveground), and can be easily met by a small change in supply from multiple sources. Research continues to evaluate potential tools for determining S deficiencies and application requirement, including tools like an index of sufficiency.

Suggestions for Managing Sulfur Applications in Corn

- The extractable sulfate-S concentration in the 0- to 6-inch soil depth is not reliable for indicating potential S deficiency or need for S application.
- The S concentration in ear leaves collected at silking can indicate low S supply, but a specific critical concentration with modern hybrids could not be established in this research.
- For confirmed S deficiencies, on fine-textured soils apply approximately 15 lb S/acre and on coarse-textured soils 25 lb S/acre.
- Sulfur deficiencies have been documented and large crop yield response measured in some fields. However, we are uncertain about the geographic extent of S deficient soils across Iowa. Soil and field conditions increasing chance of S deficiency include: low organic matter soils, side-slope landscape position, eroded soils, coarse-textured soils, low subsoil sulfate content, alfalfa previous crop, no manure application, and no S applied in fertilizers. With reduced- and no-till systems, reduced or lack of soil mixing and cooler soils reduce mineralization which slows release of S from organic materials, a main source of plant-available S.
- Research to date has not fully documented the variability of deficiency within corn fields. Site-specific response is possible, but inexpensive and reliable methods are needed to "map" S deficiency. This is especially problematic in corn and soybean as symptoms are not always present or obvious, especially with minor S deficiency and small but economic yield response (Figure 5). Research and development is needed to provide tools for reliable S deficiency detection.

Acknowledgments

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Table 1. Effect of S fertilizer application on corn grain yield in fields with high probability of S deficiency (showing early plant deficiency symptoms or expectation of S deficiency based on research conducted with alfalfa), 2006.

County	Previous crop	Soil type†	Soil SO_4-S‡	Grain yield – S	Grain yield + S§
			ppm	- - - - bu/acre - - - -	
Buchanan	soybean	Sparta lfs	6	123	151*
Buchanan	soybean	Sparta lfs	7	154	198*
Delaware	soybean	Chelsa lfs	9	88	108*
Delaware	soybean	Kenyon l	13	196	204^{NS}
Allamakee	alfalfa	Fayette sil	3	96	172*
Allamakee	alfalfa	Fayette sil	--	118	171*
Across sites				129	167*

† lfs, loamy fine sand; l, loam; sil, silt loam.
‡ Extractable sulfate-S in the 0-6 inch soil depth.
§ Sulfur applied at 40 lb S/acre after planting. Symbol indicates statistically significant (*) or non-significant (^{NS}) yield increase with S application, $p \leq 0.10$.

Table 2. Sulfur strip trials conducted in central and northeast Iowa corn fields, 2009.

Site	County	Previous crop	Special remarks†	S rate	Corn yield – S	Corn yield + S
				lb S/acre	- - - bu/acre - - -	
3	Greene	corn	a	40	225	229
4	Greene	corn	a	40	210	215*
5	Greene	corn	b	40	217	228*
6	Dallas	soybean	--	40	201	200
9	Dallas	corn	c	40	147	152*
10	Dallas	corn	a, d	40	135	134
1	Fayette	soybean	--	15	224	236*
2	Howard	soybean	--	20	186	192*
7	Dubuque	soybean	--	30	216	229*
8	Floyd	---	e	20	199	203
11	Winneshiek	soybean	--	30	215	212

† Special remarks
a) Planter split with two hybrids.
b) Sixteen of twenty four rows cultivated.
c) Visual S deficiency symptoms on June 17, corn at V6-V7 growth stage.
d) Field had manure history.
e) Only two replications and considerable yield data missing from two strips.
* Significantly different yield than with no S applied, $p \leq 0.10$. If no symbol, then yields are not statistically different.

Table 3. Evaluation of combination P and S fertilizers, mean response across seven sites, 2006-2010.

Treatment[†]	Ear leaf P	Ear leaf S	Grain yield
	%	%	bu/acre
SP-CON	0.24b[‡]	0.14d	194b
S-CON	0.28a	0.15c	209a
MES/SEF-10	0.28a	0.17b	213a
AMS-10	0.28a	0.16b	211a
MES/SEF-30	0.28a	0.19a	208a
AMS-30	0.28a	0.18a	212a
MAP-30	0.28a	0.18a	212a

[†] See the text for a description of the specific treatments. The number behind the treatment code indicates the S rate.

[‡] Letters indicate significant difference at $p \leq 0.05$.

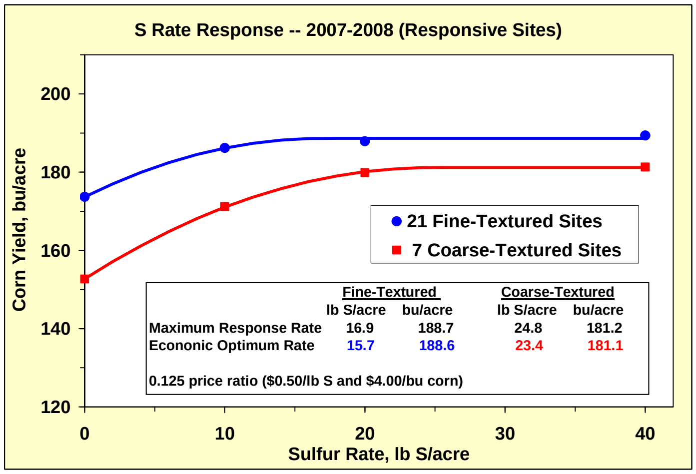

Figure 1. Corn grain yield response to S application rate at responsive sites.

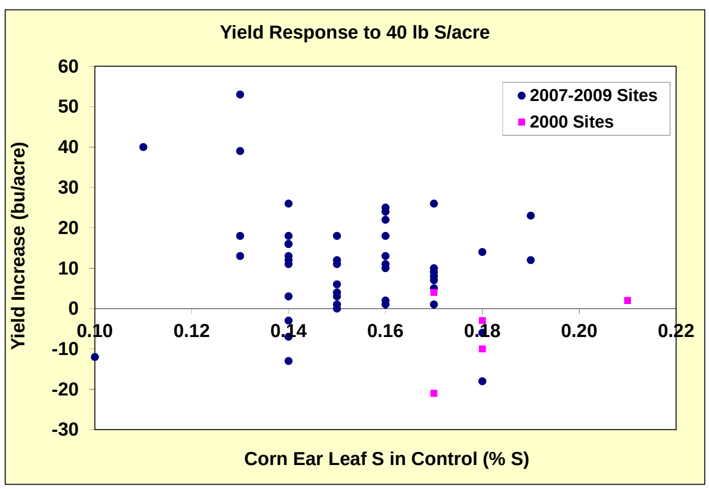

Figure 2. Corn grain yield response to S application as related to ear leaf S concentration in the no-S control.

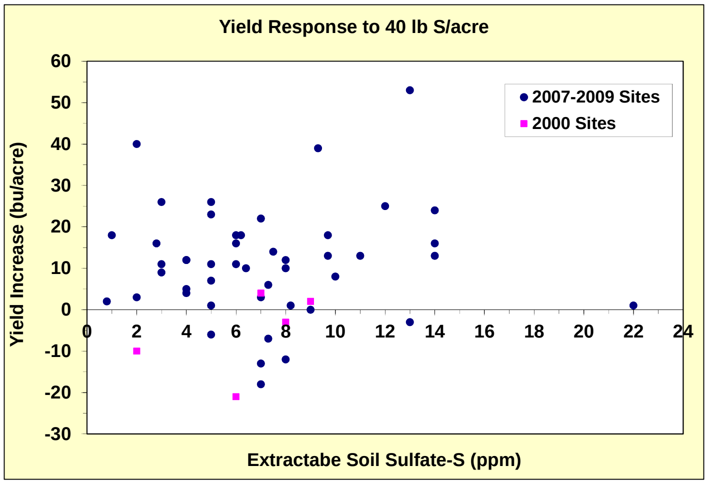

Figure 3. Corn grain yield response to S application as related to extractable soil sulfate-S concentration, 0- to 6-inch soil depth in the no-S control.

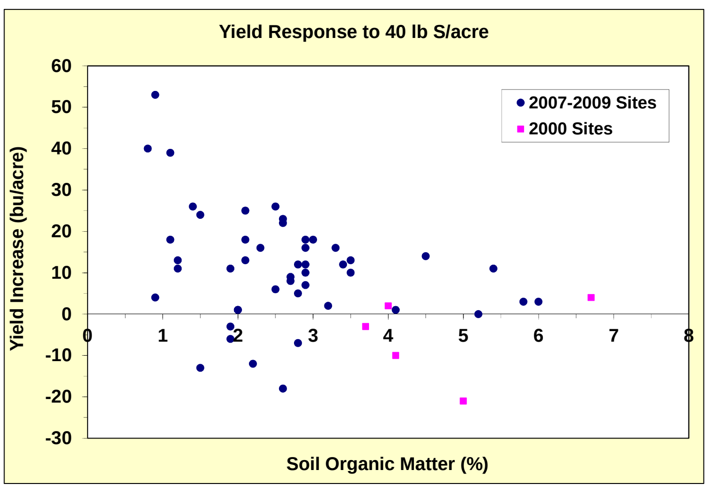

Figure 4. Corn grain yield response to S application as related to soil organic matter, 0-6 inch soil depth in the no-S control.

Figure 5. Corn expressing dramatic S deficiency symptoms and having large yield increase from S application (photo grouping A), and corn not showing deficiency symptoms and either having a yield increase or no increase from S application (photo grouping B).

EFFECT OF SOYBEAN VARIETY, GLYPHOSATE USE, AND MANGANESE APPLICATION ON SOYBEAN YIELD

Carrie A.M. Laboski[1], Todd Andraski[1], Shawn Conley[2], and John Gaska[2]

Introduction

Manganese (Mn) deficiency in crops has occasionally been noted in Wisconsin and is most common on soils with high pH (>7.0) and/or high organic matter (>6.0 %). Soils that meet these criteria are typically, but not exclusively, found in Eastern Wisconsin. Soybean has a relatively high requirement for Mn. Current University of Wisconsin nutrient application guidelines (Laboski et al., 2006) for Mn are based on research conducted in the early 1970s (Randall et al., 1975) when soybean was gaining popularity as a crop in Wisconsin. These guidelines indicate that for soils with OM ≤ 6.0% a soil test for Mn coupled with the relative crop need for Mn should be considered to determine fertilizer Mn needs. For crops with a high relative need for Mn, like soybean, grown on soils with OM > 6.0%, starter fertilizer containing Mn or foliar Mn application is recommended.

Randall et al. (1975) assessed the effectiveness of various rates of broadcast, row (starter), and foliar applications of $MnSO_4$ along with row and foliar applications of MnEDTA on improving soybean yield on soils with OM >6.0% and average soil pH of 6.3. They found that soil applied MnEDTA decreased yield slightly. All methods of $MnSO_4$ application and foliar application of MnEDTA were effective in supplying Mn to the plant. Starter fertilizer applications containing 4.5 to 19.5 lb Mn/a as $MnSO_4$ were the most effective in increasing yield. Foliar applications of Mn were most effective when applied at early blossom (R1) or early pod set (R3), or at multiple application timings during these growth stages. On soils with moderate to severe Mn deficiency, 4.5 to 10 lb Mn/a as $MnSO_4$ in starter fertilizer was suggested. If Mn deficiency appeared after the canopy was large enough, then a foliar Mn application could be made (Randall et al., 1975).

Soybean acreage in Wisconsin has increased from 216,000 acres in 1975 to 1,670,000 acres in 2011with significantly higher yields due to improved management and varieties with higher yield potential. The percentage of total soybean acreage planted to herbicide tolerant soybean varieties (primarily glyphosate resistant) in the United States has increased from 7% in 1996 to 94% in 2011 (USDA-ERS, 2011). Likewise, nearly 90% of soybean planted in Wisconsin in 2010 was herbicide tolerant varieties (USDA-NASS, 2010).

Recent soybean research in Indiana and Kansas have suggested that one of the most limiting factors to high yield in glyphosate resistant soybean systems is a suspected micronutrient deficiency resulting from applications of glyphosate to soil, weeds, and

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directly to glyphosate resistant soybean. Manganese concentration in soybean plants is frequently lower than optimum, particularly in the week or two following post-emergence glyphosate application. It has been hypothesized that glyphosate reduces the uptake and translocation of Mn via physiological immobilization of Mn in soybean plants, and that glyphosate is toxic to soil microbes that reduce soil Mn into a form that is available for plant uptake (Huber, 2007). Glyphosate exuded by roots of resistant soybean plants, as well as by weeds surrounding the soybean plants, is particularly likely to immobilize available Mn in the rhizosphere of soybean roots. Both root Mn uptake, and translocation of Mn to the shoot, are lower when glyphosate residues are present in soil.

Huber et al. (2007) reported that glyphosate resistant (GR) soybean varieties were less efficient at manganese (Mn) uptake compared with non-GR varieties. In 2006, results from a one-year study in Indiana by Huber (2007) showed that where glyphosate was applied to a GR soybean variety, yields increased from 57 bu/a without Mn to an average of 72 bu/a where Mn was applied. Research in Kansas by Gordon (2006) showed that a $MnSO_4$ application to a GR soybean variety at planting more than doubled leaf tissue Mn concentration and increased yield by about 13 bu/acre. These results also showed that a non-GR soybean variety had greater Mn uptake efficiency compared with the GR variety, and that yields declined as Mn rate increased suggesting Mn toxicity.

The most extensive study evaluating the relationship between GR soybean response to Mn following glyphosate application was conducted at five Kansas locations in 2006 to 2008 and was recently published (Loecker et al., 2010). A significant yield increase occurred where Mn was added at three of the locations; however, it was not consistent whether the soybean variety was GR or non-GR. The authors concluded that soybean genetics likely influenced Mn uptake and yield response to Mn, but that these responses were not conclusively related to GR in soybean. Due to the limited research on this topic and the potential economic impact this may have on soybean growers in Wisconsin, a three-year research study was conducted with the following objectives: i) to quantify the effect of glyphosate on Mn availability in GR soybean systems; and ii) to evaluate soybean response to starter and/or foliar Mn applications.

Materials and Methods

Field research studies were established at six on-farm locations in the spring of the 2008 to 2010 growing seasons. Two of the locations (Jefferson County near Hubbleton in 2008 and Outagamie County east of New London in 2010) were not completed due to excessive rainfall resulting in flooded conditions. The four locations which were completed included Walworth County near East Troy in 2008, Dodge County near Hubbleton and Jefferson County near Watertown in 2009, and a second site in Outagamie County north of New London in 2010 (Table 1).

Treatments consisted of: i) three soybean variety/herbicide combinations including a non-glyphosate resistant (Non-GR) soybean variety (Dairyland DSR2118) with conventional herbicide, a glyphosate resistant (GR) variety (Asgro AG2204) with conventional herbicide, and a GR variety with glyphosate herbicide; ii) two rates of Mn (as $MnSO_4$) in a 2 x 2 starter fertilizer band including 0 and 5 lb Mn/a; and iii) four levels of foliar Mn (as $MnSO_4$) rate and timing including none, 1.25 lb Mn/a at the R1 growth stage, 1.25 lb Mn/a at the R3 growth stage, and 1.25 lb Mn/a at the R1 and R3 growth stages. The experiment was a split-split-plot in a randomized complete block design with four replications. Soybean variety/herbicide was the main plot, starter Mn rate was the sub-plot, and foliar Mn rate and timing was the sub-sub-plot.

Soybean was planted at a 1-inch soil depth on 30-inch row spacing at a rate of 155,500 seeds/acre on 19 or 20 May at each location. For the treatments receiving 5 lb Mn/acre as starter fertilizer, $MnSO_4$ (ManGro DF; 31% Mn and 15% S) was dissolved in water and the solution was applied at a rate of 8.6 gal/acre using a 4-nozzle CO_2 sprayer connected with polyethylene tubing to each of the four granular starter fertilizer applicator tubes on the planter and placed in a band 2-in. below and 2-in. laterally from the seed at planting. The initial plot size was four-rows wide (10 ft.) and 30-ft long and was trimmed to 25-ft long at the V1-V2 stage of growth.

All treatments received either a preplant incorporated or preemergence herbicide application to control weeds prior to the postemergence herbicide treatment (conventional or glyphosate) application. Glyphosate herbicide was applied at a 0.75 lb ae/acre around 1 July (29 June to 2 July) to the GR/Glyphosate treatment. Non-glyphosate containing herbicides were applied, if needed, at this time to the Non-GR/Conventional and GR/Conventional variety/herbicide treatments. Postemergence herbicides included First Rate (0.6 oz/a) at Walworth County in 2008, and a tank mix of Assure II (10 fl oz/a) and Harmony GT (1/24 oz/a) at Dodge and Jefferson counties in 2009. No postemergence herbicides were applied to the Non-GR/Conventional and GR/Conventional variety/herbicide treatments at Outagamie County in 2010 due to negligible weed pressure.

Foliar Mn treatment applications were made about 10 and 25 days following postemergence herbicide treatment applications, specifically at the R1 (10-13 July) and R3 (25-29 July) growth stages, respectively. The foliar Mn treatments were applied using dissolved $MnSO_4$ (in water) with a non-ionic surfactant (0.32 oz/gal) at a rate of 20 gal/acre using a CO_2 sprayer using flat fan spray tips.

Soybean leaf samples were collected from select treatments at several times throughout the season including: i) at the R1 growth stage just prior to R1 foliar application; ii) about 10-days post R1 foliar application; iii) at the R3 growth stage just prior to R3 foliar application; and iv) about 10-days post R3 foliar application. Samples consisted of collecting 10 leaves (uppermost fully-developed trifoliate and petiole) from the center two rows within the plot. Leaf samples were dried at 160^oF, ground to pass a 1-mm mesh screen, digested, and analyzed for Mn using an inductively coupled plasma (ICP) emission spectrophotometer. Soybean grain yield was determined by harvesting the middle two rows from each plot using a plot combine in early- to mid-October. Soybean grain yields are reported at 13% moisture.

Soybean leaf Mn concentration and grain yield data were analyzed using the PROC MIXED procedure for a balanced split-split-plot design with the whole plots arranged in a randomized complete-block design (SAS Institute, 2002). The variety/herbicide, starter Mn, and foliar Mn treatments were fixed effects and replication and replication x variety/herbicide x starter Mn were random effects. Significant mean treatment differences were evaluated using Fisher's protected LSD test at the 0.10 probability level. The relationship between soybean leaf Mn concentration 10-days post R3 foliar Mn application and grain yield was determined using linear regression analysis (PROC REG).

Results and Discussion

Site Background

Soil characteristics and site background information are provided in Table 1. The Mn soil test was optimum at Walworth and Outagamie, and low at Dodge. At Jefferson the soil organic matter (OM) content was greater than 6.0% and thus out of the interpretative range for the Mn soil test (Laboski et al., 2006). The pH at Jefferson was 7.8 and in combination with an OM of 6.1%, suggests that soil Mn may be low for soybean production.

Growing season rainfall and temperature at each location are provided in Table 2. Of particular note are the relatively dry and cool conditions at both locations in 2009 (Dodge and Jefferson) and wet conditions at Outagamie in 2010. At Walworth, brown stem rot set in late in the growing season and limited yields.

No visual Mn deficiency symptoms were observed throughout the growing season at any location.

Tissue Manganese Concentrations

At all locations tissue Mn concentrations at the R1 growth stage were less than current UW sufficiency range (54 to 300 ppm) (Schulte et al. 2000) (Tables 3 though 6); thus a response to Mn application would be expected. There was no significant effect of starter Mn application or soybean variety/herbicide on R1 tissue Mn concentrations.

Ten days after 1.25 lb Mn/a was applied foliarly at R1, tissue Mn concentrations were greater compared to R1 at all locations. There was a significant effect of variety/herbicide on tissue Mn concentrations 10 days post R1 application at all locations except Walworth. At Dodge and Jefferson, the non-glyphosate resistant variety with conventional weed management (Non-GR/Conv) had significantly lower tissue Mn concentrations compared to the glyphosate resistant variety with either conventional (GR/Conv) or glyphosate (GR/glyphosate) weed management. The opposite trend occurred at Outagamie where the Non-GR/Conv had significantly greater tissue Mn compared to GR/Conv or GR/glyphosate.

Tissue Mn concentrations at the R3 growth stage were generally less than at R1 for plots that had not received any foliar Mn application at R1 at all locations except Outagamie (Tables 3 through 6). At Outagamie, tissue Mn increased from R1 to R3. Where Mn was applied foliarly at R1, tissue Mn was lower at R3 compared to 10 days post R1 application at all locations except Outagamie where R3 tissue Mn was greater. Tissue Mn concentrations at Outagamie were about double the concentrations at the other locations at the R3 sampling time. Plots that received foliar Mn at R1 had significantly greater tissue Mn at R3 compared to plot that had not received foliar Mn at all locations except Walworth. At the R3 sampling time there were some significant differences between variety/herbicide at Jefferson and Outagamie where GR/Conv and Non-GR/Conv had significantly greater tissue Mn, respectively.

At all locations, tissue Mn concentrations 10 days post R3 were significantly affected by foliar Mn application. No foliar application and application of Mn at R1 only had significantly lower tissue Mn concentrations compared to foliar applications at R3, and R1 + R3. Non-GR/Conv had significantly greater tissue Mn at 10 days post R3 compared to GR/Conv or GR/glyphosate at Walworth and Outagamie only.

Where no foliar Mn was applied tissue Mn concentrations decreased slightly or remained steady from R1 until 10 days post R3 at all locations except Outagamie where tissue Mn generally increased through the growing season. Application of foliar Mn at R1 resulted in tissue Mn concentrations initially increasing through 10 days post R1 and then decreasing at Walworth and Dodge. At Jefferson, foliar application of Mn at R1 resulted in tissue Mn initially increasing to 10 days post R1, then decreasing to R3 and then remaining steady or slightly increasing through 10 days post R3.

Outagamie often showed trends in tissue Mn data that was not consistent with other locations. This may be the result of soil test Mn being optimum and the soil being somewhat poorly drained compared to other sites which were poorly or very poorly drained.

Effect of Manganese Application on Yield

Soybean yields were the greatest at Outagamie and ranged from 53 to 59 bu/a (Table 10). Yields at the other locations were 43 to 52 bu/a at Jefferson; 45 to 52 bu/a at Dodge; and 27 to 43 bu/a at Walworth (Tables 7 through 9). Manganese application and variety/weed management had minimal effects on soybean yield over all locations. At Walworth, which had the largest range in yields, there were no significant differences between any treatments. This was caused by the large variability between plots within the same treatment and was likely a result of brown stem rot that set in late in the growing season.

The glyphosate resistant variety had significantly greater yield compared to the non-glyphosate resistant variety regardless of whether or not glyphosate was applied (Table 10). At Jefferson, there was an interaction between foliar Mn applications and variety/herbicide management. Foliar applications of Mn at R1 significantly increased yield compared to foliar applications at R3 and no foliar application for the GR/Conv only; there were no differences between foliar Mn treatments in Non-GR/Conv and GR/glyphosate variety/herbicide treatments.

At Dodge and Jefferson there was a significant three-way interaction between variety/herbicide, starter, and foliar treatments. Interactions like this are difficult to understand. At both of these locations, when starter Mn was applied to the GR/glyphosate, yields were greater than foliar Mn was applied at R1 + R3 (51 and 52 bu/a) compared to no foliar application (45 and 48 bu/a). However when no starter Mn was applied to this variety/herbicide treatment, the trend was reversed; yields were lower where Mn was applied at R1 + R3 (46 and 43 bu/a) compared to no foliar application (52 and 51 bu/a). These trends for the GR/glyphosate treatment were not observed for the other variety/herbicide treatments.

There was no correlation between yields achieved and tissue Mn concentrations 10 days post R3 at any locations. This is not surprising because there were generally no significant yield differences.

Summary and Conclusions

Application of Mn in starter or as foliar at R1, R3, or R1 + R3 did not increase soybean yield at locations where Mn was expected to be a problem based on low soil test levels or at locations with optimum soil test levels. At all of these locations, R1 tissue Mn concentrations were considered low based on current UW plant analysis interpretation guidelines; however there were no visual Mn deficiency symptoms. It should be noted that some Mn treatments at some locations may have increased yield by a couple bushels, yield reductions with Mn application were also observed.

At some tissue sampling times in Outagamie and Walworth, the non-glyphosate resistant variety had greater tissue Mn concentrations compared to the glyphosate resistant variety with either conventional herbicides or glyphosate. The opposite of this was true at Dodge and Jefferson. Overall, these data do not suggest that glyphosate resistant soybean varieties are more sensitive to Mn, or benefit from foliar applications after glyphosate application.

These data suggest that a tissue Mn sufficiency concentration range of 54 to 300 ppm may be too high because all sites had R1 tissue Mn concentrations below this range but did not respond to Mn applications. These data also suggest that even on soils where Mn deficiency has the potential to be a problem (low Mn soil test or pH over 6.9 on soils with OM greater than 6.0%), if no visual deficiency symptoms are apparent, then application of Mn is likely not economical.

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Table 1. Experimental conditions at four locations.

Information	County and year			
	Walworth 2008	Dodge 2009	Jefferson 2009	Outagamie 2010
Soil name and texture	Sebewa silt loam	Granby fine sandy loam	Wacousta silty clay loam	Shiocton silt loam
Soil parent material	Loamy outwash over calcareous sandy and gravelly outwash.	Sandy outwash or glaciolacustrine deposits on outwash or lake plains.	Silty stratified lacustrine deposits.	Silty lacustrine deposits over stratified sandy and silty lacustrine deposits.
Soil drainage	Poorly drained	Poorly drained	Very poorly drained	Somewhat poorly drained
Soil group	B	E	B	D
Soil test:				
pH	7.2	8.1	7.8	7.2
Organic matter, %	3.1	5.2	6.1	2.6
Bray 1 P, ppm	123 (EH)†	2 (13 ppm Olsen)‡	12 (H)	19 (H)
Bray 1 K, ppm	189 (EH)	68 (O)	109 (O)	73 (L)
Mn, ppm	16 (O)	2 (L)	4 (L: organic matter >6% and pH > 6.9)	14 (O)
Previous crop	Corn grain	Corn grain	Corn grain	Corn grain
Fertilizer (non-treatment)	0-0-0 lb/a $N-P_2O_5-K_2O$	5-64-60 lb/a $N-P_2O_5-K_2O$	0-0-60 lb/a $N-P_2O_5-K_2O$	0-0-90 lb/a $N-P_2O_5-K_2O$
Tillage	No-till	No-till	Spring chisel plow	Spring chisel plow

† Soil test category: L, low; O, optimum; H, high; and EH, excessively high.
‡ The soil test P level using the Bray 1 P extract was very low (2 ppm) due to the high soil calcium carbonate content. The Olsen soil P extract (commonly used in regions with alkaline or highly calcareous soils) was 13 ppm would be considered to be in the optimum to high category in Iowa.

Table 2. Monthly precipitation and average air temperature departure from the 30-yr average at four locations†, 2008 to 2010. Source NOAA.

	Walworth 2008		Dodge 2009		Jefferson 2009		Outagamie 2010	
Month	Precip.	Average air temp.	Precip.	Average air temp.	Precip.	Average air temp.	Precip.	Average air temp.
	in.	^oF	in.	^oF	in.	^oF	in.	^oF
May	-0.65	-5.4	0.56	0.9	0.18	-0.1	1.11	1.4
June	2.59	0.3	0.01	0.1	1.55	-0.8	2.82	-0.4
July	1.28	-1.6	-2.27	-6.1	-2.99	-6.2	8.44	1.4
Aug	-2.98	-1.1	-1.62	-0.6	-2.46	-3.3	0.96	3.7
Sept	1.05	1.8	-0.61	3.6	-2.35	1.4	1.60	-1.3
Oct	0.20	-0.6	1.64	-1.2	1.27	-4.6	0.64	2.7

† NOAA sites include Burlington (Walworth County), Waterloo, departures from Watertown (Dodge County), Watertown (Jefferson County), and New London (Outagamie County).

Table 3. Effect of soybean variety/herbicide, starter Mn, and foliar Mn on soybean leaf Mn concentration at four sampling times at Walworth County, 2008.

Variety/ herbicide	Starter Mn	Foliar Mn rate and time of application	Time of sampling † R1	10-d post R1	R3	10-d post R3
	------------- lb/a -------------		--------- leaf Mn concentration, ppm --------			
Non-GR/ Conventional	0	0				29
		1.25 @ R1	33	38		30
		1.25 @ R3			31	54
		1.25 @ R1+R3			34	63
	5	0				28
		1.25 @ R1	35	43		34
		1.25 @ R3			31	56
		1.25 @ R1+R3			35	57
GR/ Conventional	0	0				25
		1.25 @ R1	27	36		26
		1.25 @ R3			28	34
		1.25 @ R1+R3			34	47
	5	0				28
		1.25 @ R1	29	37		29
		1.25 @ R3			32	46
		1.25 @ R1+R3			32	47
GR/ Glyphosate	0	0				26
		1.25 @ R1	36	38		31
		1.25 @ R3			30	38
		1.25 @ R1+R3			33	37
	5	0				32
		1.25 @ R1	34	41		33
		1.25 @ R3			32	36
		1.25 @ R1+R3			29	36

ANOVA

Source of variation:	R1	10-d post R1	R3	10-d post R3
	------------------------ *p* ------------------------			
Variety/herbicide(V)	0.19	0.29	0.62	<0.01
Starter Mn (S)	0.74	0.06	0.93	0.51
V x S	0.82	0.73	0.87	0.74
Foliar Mn (F)			0.11	<0.01
V x F			0.51	0.13
S x F			0.13	0.86
V x S x F			0.45	0.99

† R1, 10 July; 10-day post R1, 21 July; R3, 25 July; 10-d post R3, 4 August. Samples obtained prior to foliar Mn application at the R1 and R3 stage of growth.

Table 4. Effect of soybean variety/herbicide, starter Mn, and foliar Mn on soybean leaf Mn concentration at four sampling times at Dodge County, 2009.

Variety/ herbicide	Starter Mn	Foliar Mn rate and time of application	Time of sampling † R1	10-d post R1	R3	10-d post R3
	------------- lb/a -------------		--------- leaf Mn concentration, ppm --------			
Non-GR/ Conventional	0	0				36
		1.25 @ R1	40	62		38
		1.25 @ R3			32	63
		1.25 @ R1+R3			39	69
	5	0				37
		1.25 @ R1	35	55		36
		1.25 @ R3			35	73
		1.25 @ R1+R3			37	77
GR/ Conventional	0	0				37
		1.25 @ R1	37	63		32
		1.25 @ R3			36	74
		1.25 @ R1+R3			40	68
	5	0				39
		1.25 @ R1	51	77		38
		1.25 @ R3			38	69
		1.25 @ R1+R3			39	63
GR/ Glyphosate	0	0				32
		1.25 @ R1	58	68		41
		1.25 @ R3			35	60
		1.25 @ R1+R3			45	62
	5	0				38
		1.25 @ R1	46	81		41
		1.25 @ R3			41	75
		1.25 @ R1+R3			38	61

ANOVA

Source of variation:	------------------------ *p* ------------------------			
Variety/herbicide(V)	0.15	0.02	0.44	0.79
Starter Mn (S)	0.86	0.15	0.96	0.12
V x S	0.13	0.11	0.89	0.44
Foliar Mn (F)			0.02	<0.01
V x F			0.87	0.23
S x F			0.02	0.67
V x S x F			0.42	0.36

† R1, 13 July; 10-day post R1, 23 July; R3, 29 July; 10-d post R3, 6 August. Samples obtained prior to foliar Mn application at the R1 and R3 stage of growth.

Table 5. Effect of soybean variety/herbicide, starter Mn, and foliar Mn on soybean leaf Mn concentration at four sampling times at Jefferson County, 2009.

Variety/ herbicide	Starter Mn	Foliar Mn rate and time of application	Time of sampling † R1	10-d post R1	R3	10-d post R3
	------------- lb/a -------------		--------- leaf Mn concentration, ppm --------			
Non-GR/ Conventional	0	0				31
		1.25 @ R1	34	61		35
		1.25 @ R3			27	110
		1.25 @ R1+R3			30	118
	5	0				31
		1.25 @ R1	30	51		35
		1.25 @ R3			26	125
		1.25 @ R1+R3			32	115
GR/ Conventional	0	0				33
		1.25 @ R1	33	57		36
		1.25 @ R3			28	83
		1.25 @ R1+R3			36	98
	5	0				34
		1.25 @ R1	33	67		36
		1.25 @ R3			32	103
		1.25 @ R1+R3			30	93
GR/ Glyphosate	0	0				33
		1.25 @ R1	34	70		38
		1.25 @ R3			27	101
		1.25 @ R1+R3			32	100
	5	0				36
		1.25 @ R1	33	67		38
		1.25 @ R3			25	110
		1.25 @ R1+R3			32	109

ANOVA

Source of variation:	R1	10-d post R1	R3	10-d post R3
	------------------------ *p* ------------------------			
Variety/herbicide (V)	0.65	0.04	0.01	0.20
Starter Mn (S)	0.20	0.75	0.47	0.23
V x S	0.40	0.12	0.66	0.96
Foliar Mn (F)			<0.01	<0.01
V x F			0.44	0.18
S x F			0.22	0.37
V x S x F			0.01	0.98

† R1, 13 July; 10-day post R1, 23 July; R3, 29 July; 10-d post R3, 6 August. Samples obtained prior to foliar Mn application at the R1 and R3 stage of growth.

Table 6. Effect of soybean variety/herbicide, starter Mn, and foliar Mn on soybean leaf Mn concentration at four sampling times at Outagamie County, 2010.

			Time of sampling †			
Variety/ herbicide	Starter Mn	Foliar Mn rate and time of application	R1	10-d post R1	R3	10-d post R3
	------------- lb/a -------------		--------- leaf Mn concentration, ppm --------			
Non-GR/ Conventional	0	0				83
		1.25 @ R1	44	71		76
		1.25 @ R3			79	311
		1.25 @ R1+R3			96	286
	5	0				79
		1.25 @ R1	49	75		81
		1.25 @ R3			72	222
		1.25 @ R1+R3			85	361
GR/ Conventional	0	0				60
		1.25 @ R1	49	71		66
		1.25 @ R3			63	132
		1.25 @ R1+R3			77	171
	5	0				70
		1.25 @ R1	42	63		67
		1.25 @ R3			64	166
		1.25 @ R1+R3			64	149
GR/ Glyphosate	0	0				64
		1.25 @ R1	49	63		77
		1.25 @ R3			66	141
		1.25 @ R1+R3			67	139
	5	0				72
		1.25 @ R1	45	68		64
		1.25 @ R3			60	155
		1.25 @ R1+R3			68	182
				ANOVA		
		Source of variation:	------------------------ *p* ------------------------			
		Variety/herbicide (V)	0.87	0.05	<0.01	<0.01
		Starter Mn (S)	0.44	0.81	0.24	0.51
		V x S	0.15	0.09	0.87	0.71
		Foliar Mn (F)			0.06	<0.01
		V x F			0.65	<0.01
		S x F			0.65	0.23
		V x S x F			0.66	0.02

† R1, 12 July; 10-day post R1, 21 July; R3, 27 July; 10-d post R3, 5 August. Samples obtained prior to foliar Mn application at the R1 and R3 stage of growth.

Table 7. Effect of soybean variety/herbicide, starter Mn, and foliar Mn on soybean grain yield at Walworth County, 2008.

		Foliar Mn rate (lb/a) and time of application			
Variety/herbicide	Starter Mn	0	1.25 @ R1	1.25 @ R3	1.25 @ R1 and R3
	lb/a	yield, bu/a			
Non-GR/Conventional	0	30	29	31	27
	5	34	27	31	36
GR/Conventional	0	39	44	44	32
	5	32	41	37	37
GR/Glyphosate	0	43	36	45	36
	5	43	44	39	43

Source of variation:	*p*
Variety/herbicide (V)	0.19
Starter (S)	0.73
V x S	0.37
Foliar (F)	0.78
V x F	0.59
S x F	0.17
V x S x F	0.92

Treatment means:

Variety/herbicide	Yield	Starter Mn	Yield	Foliar Mn	Yield
	bu/a	lb/a	bu/a	lb/a	bu/a
Non-GR/Conventional	31	0	36	0	37
GR/Conventional	38	5	37	1.25 @ R1	37
GR/Glyphosate	41			1.25 @ R3	38
				1.25 @ R1 & R3	35

Table 8. Effect of soybean variety/herbicide, starter Mn, and foliar Mn on soybean grain yield at Dodge County, 2009.

Variety/herbicide	Starter Mn	Foliar Mn rate (lb/a) and time of application: 0	1.25 @ R1	1.25 @ R3	1.25 @ R1 and R3
	lb/a	yield, bu/a			
Non-GR/Conventional	0	50	47	52	48
	5	48	51	47	44
GR/Conventional	0	48	51	49	49
	5	49	49	49	47
GR/Glyphosate	0	52	48	48	46
	5	45	46	49	51

Source of variation:	*p*
Variety/herbicide (V)	0.91
Starter (S)	0.16
V x S	0.89
Foliar (F)	0.58
V x F	0.68
S x F	0.56
V x S x F	0.01

Treatment means:

Variety/herbicide	Yield
	bu/a
Non-GR/Conventional	49
GR/Conventional	49
GR/Glyphosate	48

Starter Mn	Yield
lb/a	bu/a
0	49
5	48

Foliar Mn	Yield
lb/a	bu/a
0	49
1.25 @ R1	49
1.25 @ R3	49
1.25 @ R1 & R3	48

Table 9. Effect of soybean variety/herbicide, starter Mn, and foliar Mn on soybean grain yield at Jefferson County, 2009.

Variety/herbicide	Starter Mn	Foliar Mn rate (lb/a) and time of application: 0	1.25 @ R1	1.25 @ R3	1.25 @ R1 and R3
	lb/a	yield, bu/a			
Non-GR/Conventional	0	45	48	47	48
	5	48	50	49	44
GR/Conventional	0	46	49	45	49
	5	45	50	44	48
GR/Glyphosate	0	51	43	50	43
	5	48	48	47	52

Source of variation:	*p*
Variety/herbicide (V)	0.94
Starter (S)	0.39
V x S	0.60
Foliar (F)	0.62
V x F	<0.01
S x F	0.19
V x S x F	<0.01

Treatment means:

Variety/herbicide	Yield
	bu/a
Non-GR/Conventional	47
GR/Conventional	47
GR/Glyphosate	48

Starter Mn	Yield
lb/a	bu/a
0	47
5	48

Foliar Mn	Yield
lb/a	bu/a
0	47
1.25 @ R1	48
1.25 @ R3	47
1.25 @ R1 & R3	47

Significant treatment interactions:

Foliar Mn	Variety/herbicide: Non-GR/Conv.	GR/Conv.	GR/Glyphosate
lb/a	yield, bu/a		
0	47	46 b†	49
1.25 @ R1	49	50 a	46
1.25 @ R3	48	45 b	48
1.25 @ R1 and R3	46	49 a	47
p	0.25	<0.01	0.42

† Values in columns followed by the same letter are not significantly different at the 0.10 probability level.

Table 10. Effect of soybean variety/herbicide, starter Mn, and foliar Mn on soybean grain yield at Outagamie County, 2010.

		Foliar Mn rate (lb/a) and time of application			
Variety/herbicide	Starter Mn	0	1.25 @ R1	1.25 @ R3	1.25 @ R1 and R3
	lb/a	------------------------ yield, bu/a --------------------------			
Non-GR/Conventional	0	53	55	53	54
	5	53	54	54	55
GR/Conventional	0	56	55	57	55
	5	58	55	58	57
GR/Glyphosate	0	59	55	57	55
	5	57	58	58	55

Source of variation:	*p*
Variety/herbicide (V)	<0.01
Starter (S)	0.29
V x S	0.81
Foliar (F)	0.47
V x F	0.16
S x F	0.64
V x S x F	0.63

Treatment means:

Variety/herbicide	Yield	Starter Mn	Yield	Foliar Mn	Yield
	bu/a	lb/a	bu/a	lb/a	bu/a
Non-GR/Conventional	54 b†	0	55	0	56
GR/Conventional	56 a	5	56	1.25 @ R1	55
GR/Glyphosate	56 a			1.25 @ R3	56
				1.25 @ R1 & R3	55

† Values in columns followed by the same letter are not significantly different at the 0.10 probability level.

QUANTIFYING CORN N DEFICIENCY WITH ACTIVE CANOPY SENSORS

John E. Sawyer and Daniel W. Barker[1]

Precision agriculture technologies are an integral part of many crop production operations. However, implementation for N application has lagged, primarily due to lack of a viable system for variable N rate decisions. Active canopy sensors have been developed as a tool to determine plant N stress deficiency and provide an on-the-go decision for implementing variable rate. There are two general approaches. One is to conduct canopy sensing each year, with a reduced N rate applied preplant, at planting, or early sidedress and then sensing at mid-vegetative growth to determine additional application need. A second is to conduct sensing only if conditions result in N loss from the primary N application, or other factors change expected crop requirements. Both approaches could address variable N fertilization and seasonal conditions.

Canopy reflectance measurement with active sensors is a relatively new method of remote sensing. It is similar to that of natural light reflectance with passive sensing technologies. However, active canopy sensors utilize their own light source and measure light reflectance in real-time at the canopy level. Initial research with the GreenSeeker (NTech Industries, Ukiah, CA) active canopy sensor in Oklahoma documented that active sensors are a viable method to improve N use efficiency in winter wheat (Raun et al., 2002), and when compared to uniform N rate application based on traditional yield goal, N use efficiency was improved 15%. In corn, on-going research has investigated issues such as growth stage for sensing, need for normalization of sensor readings to non-limiting N field areas, and calibration of sensor indices to N fertilization requirements (Teal et al., 2006; Zillmann et al., 2006; Dellinger et al., 2008; Schmidt et al., 2009). Also, use of active sensors to direct variable rate N must include an identification of situations where other factors are limiting growth, such as poor plant stand, excess water, or other nutrient deficiency such as sulfur.

Many canopy indices can be calculated from the visible (VIS) and near-infrared (NIR) reflectance variables collected with active sensors. Some indices emphasize specific plant canopy characteristics such as leaf area index, leaf chlorophyll, whole plant biomass, plant density, canopy temperature, and canopy moisture. These indices were originally developed from passive remote sensing systems, but are now being used to assess plant growth with active sensors positioned near the canopy. An example is normalized difference vegetative index (NDVI), with evaluation and N rate prediction models developed in corn (Sripada et al., 2008). Other indices have been developed that emphasize canopy N status. An example is the chlorophyll index (CHL) developed by Solari et al. (2008), with recent development of an algorithm for corn N (Solari et al., 2010).

An important consideration is the crop stage being sensed. For corn, this is still a subject of research. It appears that the mid-vegetative growth stage may allow for adequate expression of N stress, if it is to occur, and if N deficiency is found corn response to applied N. In addition, each active canopy sensor and associated index may need a specific calibration to the degree of N deficiency stress and relation to optimal N fertilization. The objectives of this research were to assess N deficiency stress levels at the V10 - V12 corn growth stages with active canopy sensors, calibrate active sensors and associated canopy indices, and develop N rate algorithms that can be used to determine variable rate N fertilization.

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Materials and Methods

Nitrogen Trials

This study utilized multiple N rate trials conducted in corn from 2006 - 2008 (62 site-years) at seven Iowa State University Research and Demonstration Farms representing predominant Iowa soils with varying levels of N responsiveness. The trials included corn following soybean and continuous corn, and five to seven N rates in increments from 0 to 240 lb N/acre. Fertilizer N for all site-years was applied in spring prior to planting as ammonium nitrate broadcast on the soil surface, urea broadcast and incorporated, or urea ammonium nitrate solution surface applied and incorporated. Plot sizes were 6 or 8 rows with 30-inch spacing by 50 or 65 ft in length. The tillage system for all trials was chisel plow after grain harvest in fall, and field cultivation prior to corn planting in spring.

Active Canopy Sensor Measurements

The active sensors evaluated were the Crop Circle ACS-210 (CC-210) (Holland Scientific, Lincoln, NE), GreenSeeker "Red" 505 (GS-505), and GreenSeeker "Green" 506 (GS-506) (NTech Industries, Ukiah, CA). The GS-505 was used in this research only in 2007. The GS-506 sensor has not been sold in the marketplace. The CC-210 uses a single light emitting diode that rapidly pulses light at the VIS 590 nm and NIR 880 nm wavelengths. Reflected light from the canopy is captured by two silicon photodiodes on the sensor of varying spectral ranges (400 - 680 nm and 800 - 1100 nm). For that sensor, the VIS and NIR reflectance variable readings were captured and averaged across each plot. The GS-505 emits light at the VIS 656 nm ("red") and NIR 774 nm wavelengths. The GS-506 emits light at the VIS 560 nm ("green") and NIR 774 nm wavelengths. Only canopy indices directly provided by the GS-506 and GS-505 sensors, NDVI and inverse simple ratio index (SRI), were captured from those sensors.

Each individual sensor unit was mounted on a mast and carried by hand through the middle of each N rate plot at a constant speed (4.3 ft/sec) and distance above the canopy (24 - 36 inches) while collecting reflectance data. The active sensors were positioned perpendicular to the row in the nadir position (0^o angle) between the middle two corn rows. Sensing was conducted in June and July when the corn growth stage across N fertilizer rates averaged approximately V12 (ranging from V9 - V14).

Calculations

Multiple indices can be calculated from the measured plant canopy reflectance data provided by the sensors. Indices evaluated in this research, and the calculation equations, are listed in (Table 1). The VIS and NIR reflectance data were not captured from the GreenSeeker sensors, so only a limited number of canopy indices were calculated for those sensors (Table 1). Relative sensor indices for each site-year N rate were calculated using the mean observed or calculated sensor index divided by the mean sensor index from the highest N rate within each trial site-year. Relative indices are indicated with a prefix "r".

Corn grain yield response to applied N fertilizer was calculated for each site-year to determine if N rate or mean N rate contrasted to zero N was significantly different, that is, was the trial site N responsive. If responsive, then yield by N rate was fit to regression models. The fitted regression model for each trial site was used to determine the economic optimum N rate (EONR) using a 0.10 ratio of fertilizer cost ($0.50/lb N) and corn grain price ($5.00/bu grain). The difference in applied N rate from the EONR (dEONR) was calculated as the EONR minus applied N rates within each site-year.

The relationship between canopy indices and dEONR was determined across all site-years for each canopy sensor-index combination by fitting a quadratic-plateau regression model. The adjusted coefficient of determination (adjR^2) was used as a goodness of fit statistic to determine the best regression model. This model is the calibration of the canopy sensor index to N rate requirement (sensor predicted N rate for dEONR less than zero lb N/acre). Without conversion of sensor indices to a relative value, no index provided a good relationship to dEONR (data not shown). Also, only relative canopy indices with high adjR^2 are provided; others with poor model relationships are not given in this report. Regression models were also compared to statistical model confidence limits to determine the variability in sensor predicted N rate with different relative canopy indices.

Quadratic-plateau models of relative canopy index values related to dEONR provide the active canopy sensing index calibration. The quadratic solution of these models was used to provide the prescribed N application rate algorithms. That solution is based on the quadratic equation form ($y = c + bx + ax^2$; where y is the relative sensor index value and x is the N rate), and in a spreadsheet format for these equations is -((-b + (b^2 - 4*a*(c-y))^0.5)/(2*a)). Substituting the coefficients from the calibration model equation and a specific relative canopy sensor index value provides the prescribed N application rate.

Results and Discussion

Crop, Plant Canopy, and Sensing Observations

Sensing multiple N fertilizer rates across years of corn response, crop rotations, hybrids, soils, climatic environments, and fertilization practices resulted in a wide variety of plant canopies, including color and height, and provided for a robust evaluation of canopy sensing. Having diverse cropping conditions for active sensor algorithm development is important and should reflect future potential corn production environments and plant canopies.

Timing of N stress sensing with active canopy sensors in this study and in other recent work has focused around the V10 - V12 growth stages in corn (Solari et al., 2008). This timing may provide the best balance for attempting to accurately estimate corn N stress, provide adequate fertilizer N to growing corn plants when it is most needed, and limit severity of lost yield potential due to N stress. Sensor based in-season N application may be more time consuming compared to pre-plant N application, with concerns about completing applications in a timely manner. During this study, corn growth rate and stage development suggests that if active sensors are used to apply N in-season, the application window that exists in Iowa is approximately 14 days in late June to early July.

Some corn canopy conditions that negatively affected sensing readings and that can exist in production fields were also observed. These included the presence of visible corn tassels, reduced plant population, lodging due to wind damage, and leaf curling due to moisture/heat stress. Active canopy sensing to adjust N rates in-season should be avoided under these conditions.

Active Canopy Sensor Indices Relationship to Nitrogen Rate

As found previously with the SPAD meter, use of relative canopy index values (relative to non-N limited rate) reduced variation and greatly improved the model fit between the canopy indices and dEONR (data not shown). Therefore, relative indices were used for calibration and algorithm development instead of direct index readings. This means that for implementation of active canopy sensing in production fields there needs to be identification of non-N limited corn, that is, areas or strips across field conditions that are known non-N limiting so relative values can be calculated.

All three active sensors discerned corn N deficiency stress. Not all indices, however, were equally well calibrated to N deficiency (Table 2; data not shown for all indices). This also varied somewhat with different sensors. For instance, the rNDVI had a better calibration fit from the CC-210 than the GS-506. In general, the non-linear (rNLI), modified normalized difference vegetative index (rMNDVI), re-normalized difference vegetative index (rRDVI), and rNIR relative canopy indices were not well calibrated. Some of the equations used to calculate canopy indices were originally developed using passive light sources, aerial or satellite platforms, and for measuring a variety of canopy types (crop, grassland, or forest canopies). This may be part of the reason why those canopy indices were not well calibrated to corn N response. The rNDVI, rSRI, modified simple ratio index (rMSRI), and rCHL relative indices were best calibrated, with the quadratic-plateau regression models for the rNDVI, rSRI, and rCHL given in Table 2. The rMSRI relative index calibration model was quite similar to the rSRI and rCHL, and therefore not shown.

The GS-506 and GS-505 sensors had greater variation in the relationship between canopy indices and dEONR compared to the CC-210 sensor (Table 2). It is not know why that occurred. The difference in active sensor performance could be due to the different light source wavelengths (VIS 590 nm vs. VIS 560 nm and NIR 880 nm vs. NIR 774 nm), average field of view, or light detection electronics. The GS-506 sensor is not a commercially available product.

Table 2 and Figure 1 show the relative canopy index calibration models and equation parameters calculated for the active sensors. Each of the relative canopy indices have a similar value at zero dEONR (0.99 - 1.00). The join point values were similar for the rSRI and rCHL (39 to 57 lb N/acre), but lower for the rNDVI index (-13 to 27 lb N/acre). In some of the active canopy sensor indices, there were site-year responses that exhibited greater relative index values than the regression model plateau of 1.00 or 1.01 (Figure 1). This occurred near zero dEONR, and was minimized with the CC-210 rNDVI index. The relative canopy index value rate of change per lb N/acre (model slope) was greatest with the rCHL and rSRI and the least with rNDVI. The larger model slope reflects the greater range of relative index values across dEONR. That is, indices relating to canopy biomass (rNDVI) had a reduced range of relative values across deficit dEONR than indices relating to canopy chlorophyll (rCHL, rSRI, and rMSRI). This may be due to the more subtle differences in canopy biomass across varying level of N compared to differences with canopy chlorophyll.

With several indices having similar calibration goodness of fit, choice of a model to use as an N rate algorithm could be flexible, with focus more on canopy biomass (rNDVI) or canopy chlorophyll (rCHL, rSRI, or rMSRI). Across sensors the rCHL and rSRI indices (Figs. 1 and 2) have the same calibration model and N application rate relationship. Since the index calculation is computationally similar for CHL and SRI, it makes sense that the calibrations are the same for both indices. For rNDVI, the GS-505 and CC-210 have the same relationship to dEONR, but the GS-506 is different. Since the GS-505 was used only in 2007, these relationships were evaluated with all sensors for data just from that year (data not shown). That comparison between canopy indices was the same as with the three-year data.

Prescribed N Rate and Variation

Solving the quadratic portion of the quadratic-plateau calibration model produces an algorithm that can be used to prescribe N application rates. The graph of these algorithm results are shown in Figure 2 for each sensor and the rCHL, rSRI, and rNDVI relative canopy indices. As the relative index values increase, the N rate prescription decreases and rapidly approaches zero as the relative index nears 1.0. This accelerated decrease in N rate per unit of relative index value, along with the variation in canopy index measurements, results in greater potential for N rate error at slight N deficiency. An important outcome of the calibration and N rate algorithm development is the need to have a calibration and N rate prescription algorithm specific for the active sensor and index combination. One calibration/N rate prescription may not work appropriately for different sensors or indices.

If active canopy sensors are to be used for determining needed in-season N application rates, then assessing the level of accuracy for prediction models is needed. Our results indicate that based on the 95% confidence limits for the calibration models, variability in rate was least at -50 to -150 lb N/acre dEONR, with greater uncertainty at 0 to -50 and < -150 lb N/acre dEONR. Sensing slight N deficiencies (algorithm prescribed in-season N application between 0 to 50 lb N/acre) produce greater variability in prescribed N rate (up to 40 lb N/acre) and therefore would reduce the effectiveness of using active sensor based N stress detection for incremental or fine-tuning N application. There may be several reasons for this, including a reduced slope in all index models as dEONR approaches zero lb N/acre (adequate to excess N) and site-year variability (adjR^2 for all regression models ≤ 0.75) in the relationship between deficit N and relative sensor index values. This is similar to issues in sensitivity with N stress sensing using the SPAD meter (Hawkins et al., 2007). Also, when corn is only slightly N deficient, the leaf area index of the canopy is near its greatest level and varies only somewhat from that with adequate N. Within certain limitations, such as associated with detecting slight N deficiencies, sensing with active sensors can address spatial N variability and has potential to improve field scale N management when compared with other N management strategies.

Summary

Active canopy sensors can measure N stress during the mid-vegetative corn growth period. When sensing was performed at the V10 - V12 growth stages, calibration models related relative sensor indices to corn N adequacy/deficit across diverse growing conditions (adjR^2 up to 0.75 for the calibration models). The active sensors and associated canopy indices presented unique combinations of N stress sensing capability. Canopy indices from the GS-506, GS-505, and CC-210 sensors varied in the ability to differentiate corn N stress, that is, the range in relative index values across deficit N, and varied in the calibration fit to N rate response. The GS-506 and GS-505 sensor indices had lower adjR^2 compared to the CC-210 sensor. Also, the rNDVI produced a narrower range in relative values from most to least N deficit than the rSRI and rCHL and smaller absolute variation at a given dEONR. Several relative canopy indices could be used to determine in-season N rate need. For these sensors, the rNDVI, rSRI, rMSRI, and rCHL are options for use in prescribing N applications. Choice could be made on the desire for more information relative to canopy biomass or canopy chlorophyll, and range in relative index values with N deficit corn.

The quadratic solution of the index calibration models developed in this study provide N rate algorithms capable of directing variable in-season N rate application in Iowa and other similar corn production areas. Nitrogen application would be directed when the relative index value is less than the value at zero dEONR. Care is needed to differentiate low index readings that are due to factors affecting plant growth and biomass other than N deficiency (examples are low plant population, plant damage from excess water, or other nutrient deficiencies) that would incorrectly indicate N fertilization need when perhaps none should be applied. In addition is the uncertainty in differentiating N stress and variability in sensor rate prediction between slight N deficiency and adequate/excess N. Therefore, it would be helpful if additional parameters could be incorporated into variable N rate prescriptions to help minimize misapplication.

Acknowledgments

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Table 1. Equations used to calculate canopy indices from reflectance variable readings for the GreenSeeker 505 (GS-505), GreenSeeker 506 (GS-506), and Crop Circle ACS-210 (CC-210) active sensors.

Canopy index†	Equation
	GS-505 and GS-506
NDVI	Index directly from the sensors
SRI	Index directly from the sensors
MSRI	CHL / $(SRI)^{0.5}$ + 1
CHL	SRI – 1
	CC-210
NDVI	(NIR – VIS) / (NIR + VIS)
SRI	NIR / VIS
MSRI	(NIR / VIS) – 1 / $(NIR / VIS)^{0.5}$ + 1
CHL	(NIR / VIS) – 1
NLI	(NIR^2 – VIS) / (NIR^2 + VIS)
MNDVI	(NIR^2 – VIS) / (NIR +VIS^2)
RDVI	(NIR – VIS) / $(NIR + VIS)^{0.5}$
NIR	NIR
VIS	VIS

† NDVI, normalized difference vegetative index; SRI, simple ratio index, MSRI, modified simple ratio index; CHL, chlorophyll index; NLI, non-linear index; MNDVI, modified normalized difference vegetative index; RDVI, re-normalized difference vegetative index; NIR, near-infrared reflectance; VIS, visible reflectance.

Table 2. Quadratic-plateau regression models and parameters for the relative canopy indices derived from the GreenSeeker 505 (GS-505), GreenSeeker 506 (GS-506), and Crop Circle ACS-210 (CC-210) active sensors.

Canopy index†	Regression model‡	n	Join point§	Canopy index @ Plateau	Canopy index @ Zero dEONR	AdjR^2¶
			lb N/acre			
		GS-505				
rNDVI	$y = 1.00 - 0.000100x - 0.0000040x^2$	129	-13	1.00	1.00	0.68
rSRI	$y = 0.99 + 0.000438x - 0.0000063x^2$	129	35	1.00	0.99	0.60
rCHL	$y = 0.99 + 0.000476x - 0.0000073x^2$	129	33	1.00	0.99	0.60
		GS-506				
rNDVI	$y = 1.00 + 0.000200x - 0.0000037x^2$	367	27	1.00	1.00	0.56
rSRI	$y = 0.99 + 0.000553x - 0.0000049x^2$	367	56	1.00	0.99	0.65
rCHL	$y = 0.99 + 0.000690x - 0.0000061x^2$	367	57	1.01	0.99	0.64
		CC-210				
rNDVI	$y = 1.00 + 0.000072x - 0.0000032x^2$	394	11	1.00	1.00	0.75
rSRI	$y = 1.00 + 0.000403x - 0.0000052x^2$	394	39	1.00	1.00	0.75
rCHL	$y = 1.00 + 0.000486x - 0.0000063x^2$	394	39	1.00	1.00	0.74

† rNDVI, relative difference vegetative index; rSRI, relative simple ratio index; rCHL, relative chlorophyll index.

‡ For regression model, *y* is the relative canopy index value; *x* is the N rate differential from the EONR (dEONR), lb N/acre. The models for the GS-505 are from data collected in 2007 only. All models significant at the $P < 0.001$.

§ Nitrogen rate where the quadratic equation joins the canopy index plateau value.

¶ Adjusted R^2.

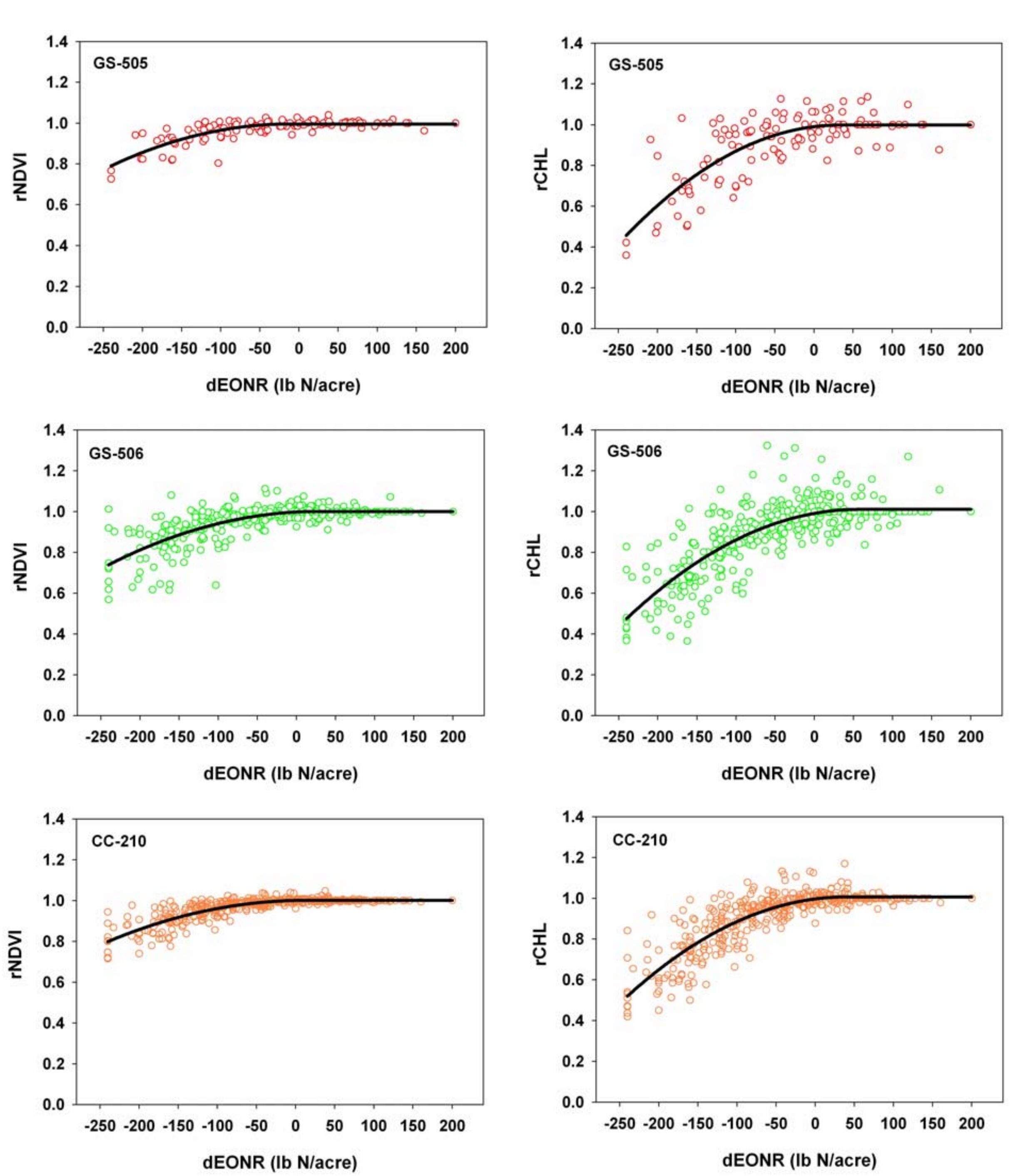

Figure 1. Relative canopy index values and regression models as related to the differential from the economic optimum N rate (dEONR) for the GreenSeeker 505 (GS-505), GreenSeeker 506 (GS-506), and Crop Circle ACS-210 (CC-210) active sensors.

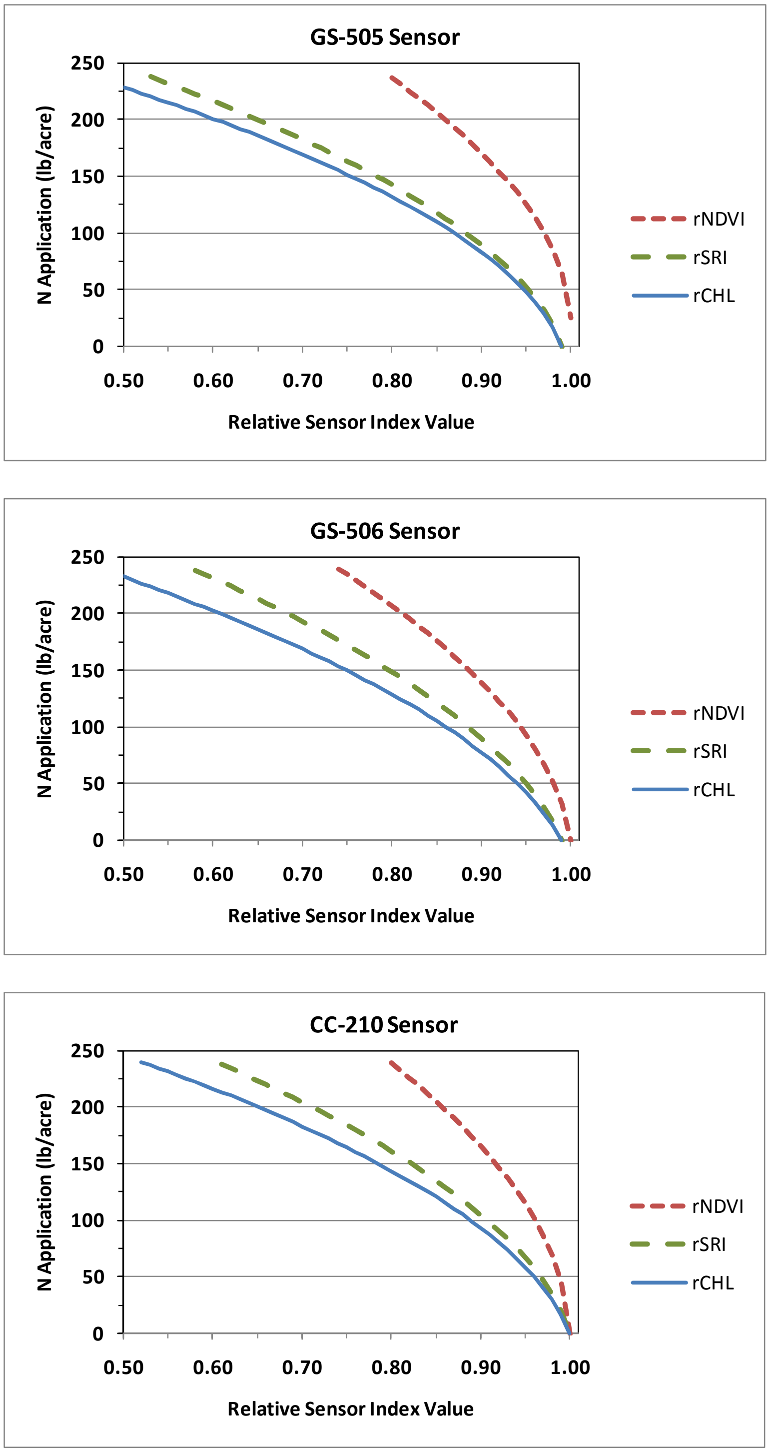

Figure 2. Nitrogen rate application prescriptions derived from the calibration models for the relative canopy indices from the GreenSeeker 505 (GS-505), GreenSeeker 506 (GS-506), and Crop Circle ACS-210 (CC-210) active sensors.

MANAGEMENT EFFECTS ON NUTRIENT AVAILABILITY FROM DAIRY HEIFER MANURE

John Peters[1], Patrick Hoffman[2] and Michael Bertram[3]

Background

Wisconsin dairy producers and heifer growers rear over one million dairy replacement heifers at a cost of 825 million dollars annually. In addition, Wisconsin dairy heifers annually consume 18 million tons of feed and produce 61 million tons of manure. For each individual dairy producer or heifer grower the management objective is to reduce cost and the environmental impact of rearing dairy replacement heifers without compromising future milk production. A new innovation in feeding dairy heifers is to limit-feed dairy heifers a more nutrient dense diet. Because heifers are fed less feed under limit feeding, feed cost and manure excretion are reduced simultaneously.

Research efforts with limit feeding have provided sufficient information for dairy producers and heifer growers to consider adopting limit-feeding management strategies. Limit feeding dairy heifers has been demonstrated to improve feed efficiency, while decreasing maintenance energy requirements and manure excretion. There is also evidence (Hoffman, et al., 2007, Kruse et al., 2010) that limit-feeding dairy heifers has no appreciable carry over effect on dry matter intake, rumen volume, reproduction or milk production. As a result, dairy producers have a solid animal performance research base in which to consider adoption of limit feeding strategies for dairy heifers.

However, limit-feeding alters manure excretion and manure nutrient density, but there is little information on the potential carryover effects of manure from limit-feed heifers on crop production systems. Although manure dry matter excretion is reduced, little is know about the nutrient composition of manure from limit fed heifers and whether it is, or can be, altered by limit-feeding. Data are required to address issues associated with soil fertility and plant nutrition that may be altered by limit-feeding.

Also, reducing or eliminating supplemental P in dairy heifer diets has been studied. Research conducted at the University of Wisconsin (Esser et al., 2009, Bjelland, et al. 2011) showed no animal production advantages to adding supplemental P to heifer diets. Feeding dairy heifers to specific P requirements resulted in the additional benefit of having less P in the manure that needs to be addressed through comprehensive nutrient management planning.

Finally, because recent data from the University of Wisconsin (Hoffman et al., 2007) suggest manure from limit-fed heifers may contain higher levels of nitrogen manure, amendments may be beneficial in dairy heifer management. Beltsville workers (Lefcourt and Meisinger, 2001) directly added 6.25% zeolite to dairy cattle manure and reduced ammonia emission by 50%. Because nitrogen volatilization losses from spreading manure on land are problematic (Jokela and Meisinger, 2008), decreased nitrogen volatilization from heifer manure may yield an additional economic benefit in cropping systems by reducing the need for purchased nitrogen fertilizer.

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Methods and Materials

As part of a North Central regional research project (NC-1042) a series of studies were designed to evaluate the nutrient value of experimental dairy heifer manures in a traditional Wisconsin cropping system. The impact of zeolite addition and limit feeding on manure nutrient retention, in particular N retention, and their effect on N availability in the cropping system was also evaluated. In this study zeolite was applied to the bedding mixture in sufficient quantity so that the manure applied contained approximately 6.25% zeolite by weight. The exception was the one treatment where a double rate was applied (in the barn and at spreading) resulting in the manure containing 12.5% zeolite by weight.

Dairy heifers were managed at the Integrated Dairy Research Facility and field plots were established at the Agricultural Research Station both at Marshfield, WI. The benchmark soils in this predominantly dairy production area of north central Wisconsin are the Loyal and Withee silt loam series. In 2008, the trial was established on field that was predominantly Withee silt loam (fine-loamy, mixed, superactive, frigid Aquic Glossudalfs) and the 2009 site was on a Loyal silt loam (fine-loamy, mixed, superactive, frigid Oxyaquic Glossudalfs). Prior to the establishment of the study, soil samples were taken to measure background fertility levels. Soil samples were also taken at the end of the study to monitor any changes in soil test parameters. Plant tissue samples were taken at silking to help assess the nutrient status of the crop.

The assay crop was field corn as it has the highest N requirement of crops typically grown for dairy feed. The N requirement for corn in north central Wisconsin is approximately 120 lbs/a, which is based on University of Wisconsin recommendations, Laboski, et al. (2006). Corn was grown for two consecutive years to measure both the first and second year availability of the nutrients from the manure treatments. The trial was repeated on two separate field sites with the manure treatments applied in 2008 and 2009 and a second year of corn monitored on each of these locations in 2009 and 2010, respectively.

In all of the site years of the study, corn was planted at 35,000 plants/acre in four replicates of eleven treatments with each plot measuring 15 x 50 feet. The first year treatments included a control with no commercial N or manure, urea applied at a rate to provide 120 lb N/a with and without zeolite, 20 tons/a of fall applied manure from heifers fed a reduced diet (85% of normal) with and without zeolite added to the bedding, this same rate of manure from heifers fed a normal diet with and without zeolite added, 20 tons/a of spring applied heifer manure from a normal feeding regime with and without zeolite and two additional rates of commercial N fertilizer without zeolite. This last treatment was to ensure that adequate N was being supplied to the crop with the normal 120 lb N/a application. The 120 lb/a of N will be provided by commercial fertilizer or one of the manure treatments using the University of Wisconsin guidelines which credit 40% of the total N content of incorporated dairy manure as being available in the first year following application. The nutrient content of the experimental manures will be evaluated by the procedures of Peters (2003).

A second set of plots was established during year two of the study so that first and second year credits can be replicated by year. The second trial site had several modifications to this treatment protocol. Instead of having the limit fed heifer manure treatments, zeolite was added at the time of spreading of fall applied manure and another treatment included both an in the barn addition of zeolite as well as another dose added at the time of spreading of manure from full diet fed heifers. Also, the commercial N rates were reduced by 60 lb N/a for all treatments. This change was also made to the residual crop year (2009) for the first trial site.

In all years of the study there were eleven treatments each replicated four times in a randomized complete block design. In year one, ammonia emission was measured immediately after manure application using a method modified from Svensson (1994). Complete soil analysis were done at the beginning and conclusion of each trial. The field corn plots were harvested for corn silage and for grain yield. Pre treatment and post harvest soil samples were analyzed for organic matter, total N, pH, and available P, K, Ca, Mg, S, Zn, Mn, and B. All analyses were performed by the UWEX Soil and Forage Analysis Laboratory at Marshfield using methods described by Peters (2006).

Results and Discussion

The results of the dietary P phase of this North Central Regional Project 1042 suggest that feeding the NRC (2001) requirement of P to heifers is sufficient for heifer frame growth, health, reproductive efficiency, and lactation yield (Bjelland et al., 2011). This study is unique, as a large number (n=433) of heifers were examined, and detailed measurements were made on a variety of productive and reproductive criteria. Results from this study suggest that the excess P offered by many dairy producers to heifers is not required if endogenous P concentrations in the basal feeds are near NRC (2001) requirements. It also is evident from these results that excess P offered to heifers is not absorbed, and is simply excreted. Given that excess dietary P offered to heifers does not provide any growth or lactation benefits, and the excess P is simply excreted by the heifer, recommendations to limit P supplementation for growing heifers can be justified. However endogenous feed sources must contain adequate concentrations of P to meet NRC (2001) requirements.

Results from the limit-feeding phase of this NC-104 project indicate that limit feeding more nutrient-dense diets to gravid dairy heifers was an equally effective feeding management strategy to control caloric intake, as compared with feeding high-fiber forage diets. Limit feeding resulted in less total consumption of DM and increased feed efficiency, which could reduce the feed cost. In addition, no adverse effects on growth or subsequent lactation performance were observed when gravid heifers were limit fed more nutrient-dense diets. Although decreased manure dry matter excretion was observed, which is of benefit, no practical advantages associated with N and P excretion or utilization were observed. Additional investigations are warranted to investigate strategies to improve N and P utilization in limit-fed heifers.

There were no significant impacts of zeolite treatment on soil test parameters measured. Ear leaf tissue samples collected in the first year of the study indicate that treatments with commercial fertilizer were supplying more N to the crop than those with manure. The average ear leaf tissue N concentration where urea fertilizer had been applied was 2.36% and where manure had been used as the source of N the average ear leaf total N concentration was 1.94%. The dairy heifer manure used in the study was relatively low in estimated first year available N with values ranging from 2.5 lb/ton to 3.4 lb/ton with an average first year available N level for incorporated manure of 2.88 lb/ton. Also, the ammonium-N content of the manure was relatively low, ranging from approximately 20 to 25% of the total N. The manure was from a free stall heifer barn where wood shavings were used as the bedding base. As a result the manure collected for use in this field trial had a relatively high C:N ratio, ranging from 25:1 to 35:1. The high C:N ratio and relatively low ammonium-N content likely resulted in a slower than normal release of N from manure and resultant delay in availability to the crop. This was reflected by the lower N levels in ear leaf tissue when manure was the N source. Ammonia emissions as measured in the field in the first year of the study showed no consistent effect of treatment, so no further ammonia evaluations were done in the second trial.

Since treatments were modified during the course of the trial, a meta-analysis was conducted by SAS on all trial data. This allowed for the comparison of treatments across trial locations and years by utilizing trial as the replicate. Data from the two years of manure application was separated from the residual years to assess potential carryover effects of zeolite application on corn yield. This allowed for the comparison of zeolite treatment by N source (manure vs. fertilizer) in the year the manure was applied (Table 1) and then the effect of zeolite on corn yields in the year following manure application (Table 2).

Silage yields were significantly improved when nitrogen fertilizer was used as the N source as compared to heifer manure (Table 1). However, adding zeolite in the field at the time of urea application did not have any impact on yield. Grain yields were also higher when commercial fertilizer was used instead of manure but the differences were not significant at the Pr>F 0.10 level. The use of zeolite did not have a significant impact on corn yield nor was there a significant zeolite x N source interaction. It is interesting to note that in the first year of the study, corn grain yields where manure was applied were very similar to the zero N control, whereas in the 2009 trial, corn grain yields on the manure treatments were comparable to the commercial N treatments. This may be due to the better growing/mineralization conditions encountered in 2009 as well as that the 2009 site was a Loyal silt loam as compared to the Withee series that was used in 2008. The weather and more poorly drained nature of the Withee soil likely contributed to poorer N mineralization from applied manure.

In the year following application of manure, no effect of zeolite was seen on corn grain or silage yields (Table 2). Residual year yields of both corn grain and silage were considerably lower than in the year of manure application as no supplemental N was applied.

Summary

The use of zeolite mixed in with the bedding of manure collected from a free stall heifer facility or zeolite applied in the field at the time of manure or commercial fertilizer application had no significant impact on corn grain or silage yield in this study. With or without zeolite, yields of corn planted in 2008 were higher where commercial fertilizer was used instead of dairy heifer manure. The heifer manure used in this study was relatively low in total N and NH_4-N content with a relatively high C:N ratio. Combined with less ideal weather and a more poorly drained soil in 2008, this resulted in delayed mineralization and no doubt impacted yields negatively. This same effect was not seen in the study established in 2009 where fertilizer N and manure plot yields were quite similar. Finally, zeolite had no impact on corn yields in the year following application of the zeolite treated manure. Future field studies should explore the use of zeolite in liquid manure from mature dairy animals, which typically contains a higher level of total N and NH_4-N.

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Table 1. Effect of Zeolite treatments on first year corn yield.
Marshfield, WI 2008-2009.

Treatment	Trial site	Year	Corn silage t/a (DM)	Corn grain bu/a
Control - no manure or N fertilizer	1	2008	5.29	95.2
Commercial N, 90 lb/a, without zeolite	1	2008	6.30	119.5
Commercial N, 120 lb/ac, without zeolite	1	2008	5.93	123.6
Commercial N, 120 lb/a, with zeolite in field	1	2008	6.47	121.4
Commercial N, 150 lb/a, without zeolite	1	2008	6.56	132.5
Spring manure, full feed, without zeolite	1	2008	4.39	79.6
Spring manure, full feed, with zeolite in barn	1	2008	4.79	80.5
Fall manure, limited feeding, without zeolite	1	2008	4.75	96.0
Fall manure, limited feeding, with zeolite in barn	1	2008	4.49	128.4
Fall manure, full feed, without zeolite	1	2008	4.16	84.7
Fall manure, full feed, with zeolite in barn	1	2008	4.88	92.5
Control - no manure or N fertilizer	2	2009	5.61	126.4
Commercial N, 30 lb/a, without zeolite	2	2009	6.87	125.9
Commercial N, 60 lb/ac, without zeolite	2	2009	7.51	134.3
Commercial N, 60 lb/a, with zeolite in field	2	2009	6.99	132.0
Commercial N, 90 lb/a, without zeolite	2	2009	7.21	134.3
Spring manure, full feed, without zeolite	2	2009	6.75	124.7
Spring manure, full feed, with zeolite in barn	2	2009	6.59	137.9
Fall manure, full feed, without zeolite	2	2009	6.45	132.8
Fall manure, full feed, with zeolite in barn	2	2009	6.18	131.6
Fall manure, full feed, with zeolite at spreading	2	2009	6.26	133.6
Fall manure, full feed, with zeolite in barn + at spreading	2	2009	7.34	136.2

Meta-analysis of Zeolite treatments on corn grain and silage yield in year of application.
Marshfield, WI.

		Grain yield, bu/a		Silage yield, tons DM/a	
Zeolite	N source	x	SE	x	SE
No	Fertilizer	128.9	18.74	6.72	0.93
No	Manure	113.9	16.71	5.42	0.90
Yes	Fertilizer	126.7	18.74	6.73	0.93
Yes	Manure	112.4	16.71	5.76	0.90
		Pr>F		Pr>F	
Zeolite		0.82	NS	0.48	NS
N source		0.11	NS	0.01	NS
Zeolite x N Source		0.97	NS	0.51	NS

NS = > 0.10

Table 2. Effect of Zeolite treatments on residual corn yield.
Marshfield, WI 2009-2010.

Treatment	Trial site	Year	Corn Silage t/a (DM)	Corn Grain bu/a
Control - no manure or N fertilizer	1	2009	3.45	72.6
Spring manure, full feed, without zeolite	1	2009	3.43	72.3
Spring manure, full feed, with zeolite in barn	1	2009	3.71	63.6
Fall manure, limited feeding, without zeolite	1	2009	3.32	72.3
Fall manure, limited feeding, with zeolite in barn	1	2009	3.57	77.5
Fall manure, full feed, without zeolite	1	2009	2.94	76.4
Fall manure, full feed, with zeolite in barn	1	2009	3.36	77.2
Control - no manure or N fertilizer	2	2010	3.15	64.6
Spring manure, full feed, without zeolite	2	2010	3.42	67.5
Spring manure, full feed, with zeolite in barn	2	2010	3.11	64.5
Fall manure, full feed, without zeolite	2	2010	3.32	68.8
Fall manure, full feed, with zeolite in barn	2	2010	3.32	66.2
Fall manure, full feed, with zeolite at spreading	2	2010	3.49	74.2
Fall manure, full feed, with zeolite in barn + at spreading	2	2010	3.53	73.00

Meta-analysis of Zeolite treatments on corn grain and silage yield in year following
application of manure. Marshfield, WI.

Zeolite	N source	Grain yield, bu/a x	Grain yield, bu/a SE	Silage yield, tons DM/a x	Silage yield, tons DM/a SE
No	Manure	82.2	5.95	3.92	0.32
Yes	Manure	77.0	5.95	3.73	0.32
		Pr>F		Pr>F	
Zeolite		0.55	NS	0.69	NS

NS = > 0.10

FERTILIZER INDUSTRY OUTLOOK

Kathy Mathers [1/]

{This page provided for notes}

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YIELD AND MANAGEMENT OF RR ALFALFA

Dan Undersander [1/]

Establishment of dense vigorous stands of alfalfa is essential for long-term profitability, but establishment can be challenging because seedling alfalfa is vulnerable to competition from annual weeds and wind and water erosion. Roundup Ready Alfalfa was re-introduced last year as a new tool available to farmers growing high quality alfalfa. While not for everyone, it will be useful for many alfalfa growers.

A first and important question is concerning the yield potential of RR varieties. While the RR trait was generally put in better germplasms, early trials (planted in 2006) showed a range of yield potential for RR varieties. It is too early to tell definitely for the next generation of RR varieties since we only have seeding year data from 2011, however it appears again that there will be a range of yields with some RR varieties in the top yielding group and some doing less well. It will be important to check variety trials to select high yielding varieties.

Many Wisconsin farmers have felt the need to seed alfalfa at rates as high as 17 to 18 lb/a. Data from many trials have shown that, regardless of seeding rate, the alfalfa stand thins to 30 to 35 plants/sq ft by the end of the seeding year. Improved stands or yield above 9 to 10 lb seed/a have never been observed. One of the reasons stated for the higher seeding rates is greater competitiveness against weeds. An option for RR alfalfa is to seed at the lower rate and get good, cost effective weed control with Roundup. The lower seeding rate also improves the economics of using RR alfalfa since the technology fee is per bag and the more acres seeded per bag, the lower the fee is per acre planted.

To get good stands of alfalfa we must control weeds during the first 60 days. It is during this time that competition from weeds will cause stand thinning resulting in a stand with greatly reduced yield potential in future years. In some environ-ments alfalfa naturally begins growing rapidly in the spring and stays ahead of the weeds so that not herbicide is needed to get a good, thick, weed-free stand. However, most often weeds do come up with the alfalfa and must be controlled to get good stands. In these situations, Roundup is an effective post-emergent weed control. It has a wide window of application for effective control, relative to other herbicides and also has a short harvest restriction so that alfalfa harvest is not delayed by the herbicide used to control weeds.

Table 1 Harvest restrictions for herbicides registered for use on alfalfa

Buctril	30 days
Butyrac 200	60 days for new seedings 30 days for established stands
Glyphosate **(Weathermax and Ultramax II)**	14 days 36 hours for fields being rotated to another crop **5 trifoliate leaves to 5 days before harvest for Roundup Ready alfalfa**
Poast Plus	7 days for undried forage 14 days for dried hay
Pursuit	30 days
Raptor	20 days

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While Pursuit or Raptor have been reliable herbicides for controlling weeds during stand establishment, they can reduce yield of the cutting to which they are applied. Over 13 site-years of trials in Minnesota and Wisconsin, we have seen and average of 0.2 t/a yield reduction. The yield loss ranged from near 0 to 0.5 t/a in the seeding year and tended to be worse in cooler environments. Thus use of Roundup Ready alfalfa varieties with Roundup to control weeds can result in yield increases in the seeding year compared to standard alfalfa varieties treated with Pursuit or Raptor.

Additionally Roundup is easier to use, since most farms are growing Roundup Ready corn and/or soybeans and already have the herbicide on hand and sprayer calibrated.

We also saw some benefit in 2011 to using roundup ready varieties when field conditions forced late plantings of the alfalfa. Roundup did and excellent job of controlling the different populations of weeds that occurred with the late plantings.

Companion crops reduce stand loss due to wind and water erosion and may suppress growth of some weeds. For spring seedings in the Midwest, companion crops also provide for a guaranteed economic return in the seeding year.

One of the exciting potentials for Roundup Ready alfalfa is shown in the picture where oats was seeded at 1 bu/a, with the alfalfa to provide early weed and erosion control and, in some cases, to help dry out soil. The oats is then killed with killed with Roundup when it is 4 to 6 inches tall. In five site-years of trials between Minnesota and Wisconsin, we have used this treatment with no difference in alfalfa yield during the seeding year whether the oats was seed and killed at six inches or whether the alfalfa was seeded alone. This establishment method has been available using Poast Plus or Select but neither herbicide control broadleaf weeds that sometimes come into the seeding as Roundup will. This method of establishment can meet certain farm plan requirements on erosive land while giving the benefit of direct seedings.

One of the other questions frequently asked is concerning proportion of the seed in each bag that is not Roundup Ready ("nulls"). Plants from these seeds will be killed when the stand is first sprayed with Roundup. The actual amount of nulls is usually less than the stated amount and ranges from 2 to 8% of total seed. Remember that at 12 lb/a seeding rate we are seeding twice the seed that we need and stands will naturally thin to about 30 to 35 plants/a. So whether we lose the 5 to 10% of plants from non Roundup Ready seed has no affect on the final stand. However, it is important to take these "nulls" out early in the stand life so that the stand does not thin naturally, as described, and then get thinned again with Roundup to potentially produce holes in the stand.

We are uncertain of how early in the stand life we need to spray to remove these "nulls" without final stand density at the end of the seeding year. One option may be to seed alfalfa with a cover crop, such as Italian ryegrass or oats, harvest a cutting of the cover crop to increase seeding year yield, spray after harvesting the cover crop and then have a pure alfalfa stand.

We are also examining seeding the alfalfa, spraying with Roundup and then seeding a perennial grass into the stand to establish grass legume mixtures.

On established alfalfa stands weeds seldom cause stand thinning but rather fill holes were alfalfa has died out. Therefore weed control after the first 60 days is seldom economical except for commercial hay growers who receive a premium for pure alfalfa. Other alfalfa growers can feed the weedy forage to animals and would see little return from use of weed on the stand since total forage tonnage is likely to remain constant or may actually decline. Weedy established stands generally indicate thinned stands with low yield potential that should be replaced.

The only exception to the lack of need for weed control on established stands of alfalfa is where winter annual weeds, such as henbit, chickweed, or wild garlic, grow and can cause stand thinning. Roundup is an effect method of controlling these weeds.

Some concern has been expressed about the potential for Roundup resistant weeds in a system with Roundup Ready alfalfa, corn and soybeans. Clearly when any pesticide is used alone and repeatedly, the target organism(s) will develop resistance. We have seen this with fungicides, insecticides, and some herbicides. We have one advantage in alfalfa-corn-soybean rotations over corn-soybean rotations, in that we have the additional weed management tool of frequent forage cutting to keep weeds down. For example mare's tail has reportedly developed Roundup resistance. This could be a problem in corn-soybean rotations but will not be in alfalfa-corn-soybean rotations because frequent mowing will kill the mare's tail. Clearly resistant weeds will eventually become a problem, as in any system where a single herbicide is used continuously, so good stewardship recommends use of some additional herbicide on at least one crop sometime in the rotation to reduce the potential for herbicide resistant weeds.

The other major question has been how to take out alfalfa stands, since many have used Roundup for this. All alfalfa, including Roundup Ready alfalfa, is very susceptible to 2,4-D and Banvel, so we would recommend using one of these herbicides (probably 2,4-D) to take out old stand. We have always recommend using some of one of these herbicides with the Roundup since alfalfa naturally has some Roundup tolerance and non-Roundup Ready alfalfa field treated with Roundup will often have a few skips in control.

In summary, Roundup Ready alfalfa is a good tool that some farmers will find beneficial in their farming systems for one or more of the following reasons:

- Control winter annuals and other special problems
    - Less herbicide damage to new seedings
- Reduced herbicide cost is less
- Ease of herbicide use
    - Using same herbicide as for other crops
    - Broader window of application

A spreadsheet is available on my website (http://www.uwex.edu/ces/forage/) to evaluate cost effectiveness of Roundup Ready alfalfa in your operation.

REMOVAL OF RR ALFALFA IN NO-TILL SYSTEMS

Mark J. Renz[1]

Alfalfa is a key crop in Wisconsin, but if not successfully removed it can be troublesome in subsequent crops. This is especially true in no-till systems. Currently most no-till systems rely on glyphosate to remove the alfalfa prior to planting rotational crops the following spring. Glyphosate however will not be effective at removing Roundup Ready alfalfa, as it is engineered to tolerate this herbicide. In these situations other active ingredients will need to be used to remove the alfalfa crop. Detailed results from a Wisconsin study that evaluated the effectiveness of growth regulator herbicides in removing alfalfa are summarized below. This information as well as other data from across the United States will be presented along with specific recommendations for the upper-midwest.

Wisconsin Study

Research was conducted in Wisconsin in 2006-2007 to evaluate the effectiveness of growth regulator herbicides at removing RR alfalfa stands. Applications were applied at two timings in October that represent typical timings and environmental conditions for alfalfa removal in Wisconsin. The October 5 timing had good environmental conditions conducive for herbicide absorption/translocation and mortality. In contrast the October 19 timing was applied when conditions were sub-optimal with maximum air temperatures below 50 F the day of and the day after application. A range of growth regulator herbicides and rates were evaluated (See Table 2 for details). All treatments were applied to plots that were 10 ft wide by 30 ft long using a hand held CO2 powered backpack sprayer that delivered 15 gallons/a of spray solution. Other site and environmental conditions are summarized in Table 1.

Table 1.Environmental conditions for fall herbicide applications at Arlington, WI.

Timing of treatment	10/5/06	10/19/2006
Height of alfalfa	4-6 inches tall	5 – 7 inches tall
Air/soil temp at time of application	Air = 59 F; Soil =57 F	Air = 39 F; Soil =40 F
Max/min air temp day before application	Max= 62F; Min= 43F	Max = 53F; Min= 35F
Max/min air temp day of application	Max= 57F; Min= 34F	Max = 39F; Min= 31F
Max/min air temp day after application	Max= 62F; Min= 29F	Max = 47F; Min= 25F

In May, the effectiveness of treatments was evaluated. Percent cover of alfalfa was visually estimated, and number of crowns that had green foliage present was counted in each plot. Table 2 summarizes the average (each treatment was replicated four times) values along with significant differences ($p<0.05$). Only Weedmaster applied at 2 pt/a did not have any resprouting plants, however all herbicides were effective at limiting resprouting of alfalfa at the appropriate rate and timing. The early October timing had significantly better results than the later timing. 2,4-D and Banvel performance was reduced at the later timing at the lowest rate. Weedmaster applied in late October did not have any significant reduction in the number of crowns, but control was much more variable between plots. Only Weedmaster applied at 1.5 pt/a in late October had 5 crowns or less resprout the following spring.

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Table 2. Alfalfa cover and # crowns May following fall herbicide applications at Arlington, WI.

Treatment	Rate		Applic. date	% cover*		# crowns / 300 ft^{2*}	
2,4-D Amine + NIS	1.0	pt/a	10/5	5.0	cd	45.8	c
2,4-D Amine + NIS	2.0	pt/a	10/5	1.3	fg	8.5	de
2,4-D Amine + NIS	3.0	pt/a	10/5	0.8	g	2.0	e
Banvel + NIS	1.0	pt/a	10/5	1.0	g	5.0	de
Banvel + NIS	1.5	pt/a	10/5	1.0	g	2.3	de
Banvel + NIS	2.0	pt/a	10/5	0.5	g	0.5	e
Weedmaster + NIS	1.0	pt/a	10/5	1.0	g	5.8	de
Weedmaster + NIS	1.5	pt/a	10/5	0.3	g	0.3	e
Weedmaster + NIS	2.0	pt/a	10/5	0.0	g	0.0	e
2,4-D Amine + NIS	1.0	pt/a	10/19	26.3	b	103.5	b
2,4-D Amine + NIS	2.0	pt/a	10/19	4.3	cd	42.5	cd
2,4-D Amine + NIS	3.0	pt/a	10/19	1.0	fg	8.3	de
Banvel + NIS	1.0	pt/a	10/19	5.0	c	58.8	c
Banvel + NIS	1.5	pt/a	10/19	2.0	de	30.5	cde
Banvel + NIS	2.0	pt/a	10/19	0.8	fg	8.8	e
Weedmaster + NIS	1.0	pt/a	10/19	2.5	fg	23.0	cde
Weedmaster + NIS	1.5	pt/a	10/19	1.0	ef	4.3	de
Weedmaster + NIS	2.0	pt/a	10/19	-		-	
UTC	-	-	-	95.0	a	1000	a

* Treatments within this column that contain different letters were found statistically different with a Fisher's LSD test ($P<0.05$)
NIS = nonionic surfactant (applied at 0.25 % v/v)

Significance

This experiment clearly shows that environmental conditions can alter the level of control with growth regulator herbicides in alfalfa. Applications when conditions promote herbicide absorption and translocation (temperatures at least in the 50s) are the most desirable. Unfortunately time constraints often make for applications during non-ideal conditions. Realize that this IS NOT RECOMMENDED, but if this does occur a reduction in control will likely result. The level of reduction will vary from field to field due to a range of environmental conditions. Spring applications, although not studied, will likely give even poorer results and will be discussed in more detail in the presentation.

Conclusions

This study found that while growth regulator herbicides can remove alfalfa, rates needed to be increased when applied later in the fall. While we all want fields clean at planting, I think it is important to ask ourselves do we need 100% control? How many alfalfa plants surviving are acceptable in your production system? While a few volunteer alfalfa plants are unsightly in a field, yield loss is estimated to be very low indicating 100% control is not needed.

ALFALFA GRASS MIXTURES

Dan Undersander [1/]

Research is developing new understanding of forage, fiber, and the animal's ability to use them. We have also increased understanding of the genetics of alfalfa to allow improved variety selection methods and enhanced performance for the farmer. This paper will consider both topics.

Growing Alfalfa/Grass Mixtures

Generally dairymen have perceived grasses to be too high in fiber for high producing dairy cows. But, with knowledge of digestible fiber, we have learned that the fiber of grass is more digestible than that of alfalfa. This has opened some new opportunities for dairymen and many have begun to incorporate some grass into their rations.

The agronomic reasons for adding grass to alfalfa are:

1) Increased seeding year yields – some grasses, such as Italian ryegrass, will establish faster than the alfalfa and produce more total forage yield in seeding year than alfalfa alone.
2) Wider harvest window on second and later cuttings – many cool season grasses head little or not at all after first cutting, therefore regrowth is primarily leaves which change little in forage quality over 7 to 10 days around harvest time.
3) Faster drying - 30 to 40% grass with alfalfa dries faster than either pure alfalfa or pure grass.
4) Some less winter kill or injury to the alfalfa stand, losses from flooding – some grasses will survive standing water and/or ice in low spots of field better than alfalfa. Beware that some varieties of orchardgrass and tall fescue are not as winterhardy as others and will die before alfalfa.
5) Ability to apply manure to stands with less traffic damage and stand loss – grasses suffer less traffic damage than alfalfa.

Dairy nutritionists are becoming interested in including some grass because:

1) Grass/alfalfa mixtures have higher total fiber than alfalfa alone which may be needed in some high corn silage rations.
2) The fiber of grasses is more digestible than alfalfa.
3) Potential to reduce non fibrous carbohydrate (NFC) of dairy rations –Too much readily fermentable carbohydrate can reduce milk production through acute or sub acute rumen acidosis. One of major contributors to increased lameness in dairy cattle (which has increased in the Midwest in recent years to 20 to 25% of all dairy cattle) has been formulation of high starch, low fiber diets (Cook, 2003). Grass runs about 15% NFC while alfalfa is about 25% NFC and corn silage is about 35% NFC.

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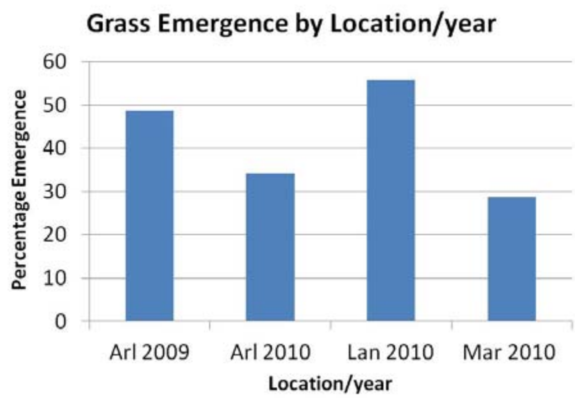
Initial feeding trials we have run have indicated that that we could maintain high levels of milk production when replacing a portion of the corn silage and alfalfa with grass silage, even though dietary NDF increased slightly.

The key to managing alfalfa-grass mixtures for high quality dairy forage is to maintain forage stands that contain about 30 to 40% grass. When the composition of the stand is in this range, nitrogen fixation from legumes can meet the needs of the grass species, and fiber content of the mixture is still acceptable.

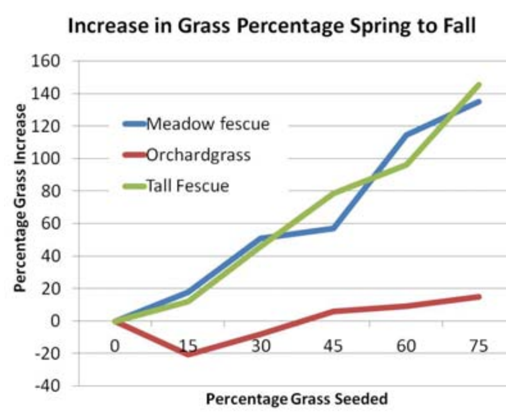
In trials conducted at the University of Wisconsin three grass species (orchardgrass, tall fescue and meadow fescue) were seeded with alfalfa at three. Alfalfa was seeded at the rate of 645 seeds/m^2 with varying grass seeding rates of 15 to 75%. All seed lots had over 90% germination. Seedling emergence was based on plant counts taken 30 to 40 days after seeding As the graph at right the mean grass emergence varied greatly among sites and years.

Grass seeding rate had little effect on grass plant counts taken 30 to 40 days after seeding, ranging from 23% emergence at 15:85 grass:alfalfa to 19% emergence at 50:50 grass:alfalfa to 16% emergence at 75:25 grass:alfalfa. Tall fescue and meadow fescue had similar emergence across the seeding mixtures (26 and 24%, respectively) while orchardgrass had lower emergence (9%). Grass establishment was significantly higher at Lancaster than at the other two sites, suggesting a large environmental effect for establishment.



The reason for this is that the grasses studied begin to germinate at slightly above freezing (about 2 to 4^{o}C) while alfalfa requires slightly warmer conditions (5 to 7^{o}C). The optimum temperature for germination of these grasses is about 15^{O}C and for alfalfa is about 25^{o}C. Alfalfa is much more susceptible to seedling diseases if the early establishment temperatures are lower than optimum but will grow out of the stages rapidly if temperatures are warmer. Grasses also prefer cooler temperatures during the early stages of development while alfalfa predominates when temperatures are higher (above 25^{o}C). Thus the alfalfa to grass seeding rate has much less effect on the final stand than the environment under which the germination occurred.

Emergence of alfalfa was not affected by the grass seeding rate except at the very highest levels of grass seed. Therefore higher grass seeding rates resulted in higher grass percentages in the final mixtures. In general, as grass seeding rate increased, the alfalfa declined as a percent of the total stand. It is also apparent that orchardgrass had less effect on alfalfa stand reduction than the other two species.



It is important to recognize that more plants emerge than contribute to the final stand. In fact the biology is that many plants germinate and begin growing; then the stand thins to what can be maintained by the soil and environment. We have found, for example, with pure alfalfa, not matter how many pounds of seed are used per acre, the stand will thin to 30 to 35 plants per square foot by summer's end.

This study shows that the same principle applies to grasses: at higher seeding rates more plants emerge but then greater thinning occurs as the season progresses. However the fescues did not thin as rapidly as the alfalfa and the percentage of grass plants tended to increase as the season progresses. Orchardgrass has lower germination and declined at about the same rate as the alfalfa so the alfalfa/grass percentage remained about the same as the season progressed.

Thus our recommendation is to seed moderate rates of grass and alfalfa as shown in the table. We would also recommend seeding about 2 lb/a Italian ryegrass (but no more!) to get a cutting of the ryegrass before the alfalfa/grass mixtures are ready to harvest where early season moisture is good. Note that the seeding rate recommendations are generally for 60 to 75 seeds per square foot and expect to get about 30 to 35 plants per square foot by the end of the seeding year.

Recommended seeding rates of grasses with alfalfa to get 30 to 40% grass in stand*

Grass species	Seeding rate (lb/a)	Seeds/ft^2
Orchardgrass	4	18
Tall fescue	6	23
Meadow fescue	6	27

*recommended with 10lb/a alfalfa - 47 seeds/ft^2

Desired alfalfa/grass mixes can be maintained by picking appropriate grass species and varieties. Timothy and smooth bromegrass tend to produce too much forage in the spring but little the rest of the year so we recommend mixing either orchardgrass, tall fescue, or meadow fescue with alfalfa. These species will produce more grass in second and later cuttings.

The choice of grass species has little effect on the total season yield of mixed stand. We have found that, generally, alfalfa/grass mixes yield the same as pure alfalfa stands if the alfalfa is growing well. Thus, while meadow fescue in pure stands tends to yield somewhat less than tall fescue in pure stands, when mixed with alfalfa, the yield of the mixed plot is about the same for the two grasses. Meadow fescue tends to be higher in forage quality than other cool season grass species.

Appropriate selection of grass varieties is crucial to success in alfalfa/grass mixtures. Selecting a good grass variety is more important than the grass species selected! Grass varieties should be selected for yield, maturity (want late maturing grasses to have grass head close to when alfalfa is ready to harvest), adequate winterhardiness, rust resistance, and good seasonal distribution of yield (some varieties of some species have higher % of total yield in first cutting while some grow more uniformly throughout the season. Information for good grass variety selection is available on my website at www.uwex.edu/ces/forage.

FEEDING GRASS TO HIGH PRODUCING DAIRY COWS:
COULD INCLUDING A LITTLE GRASS BE A GOOD THING?

David Combs [1/]

Alfalfa and corn silage are the primary forages grown and fed to dairy cattle in the Midwest, however, there is renewed interest in incorporating perennial and annual grasses into forage cropping systems. High quality grass silages could be a good fit with diets formulated with high quality corn silage and alfalfa. Intensively-managed grass silages are high yielding forages that contain moderate concentrations of fiber (NDF) and low concentrations of non fiber carbohydrate (NFC).

Diets formulated with excellent quality corn silage are often marginal in fiber, and high in NFC content. To balance these diets, it becomes necessary to incorporate feeds that are highly digestible yet contain relatively low amounts of NFC and high amounts of digestible fiber. While alfalfa can provide for some of the deficiencies of corn silage, today's high quality alfalfas often do not contain much more fiber than corn silage and the lower NFC levels in alfalfa are offset by the high amount of ruminally fermented protein contained in these forages. The nutrient profile of high quality grass silage complement the excesses and deficiencies of rations formulated with excellent quality corn silage and alfalfa.

Evaluating Grasses in Dairy Rations

The traditional way to evaluate grasses is to compare them directly to another grass or alfalfa in a feeding trial. Typically, a diet formulated with alfalfa as the only source of forage is compared to a diet formulated with an equivalent amount of grass as the only source of forage. When alfalfa is replaced by an equal amount of grass, the total fiber content of the ration increases. If the dietary levels of NDF are high enough in the alfalfa based diets to limit feed intake by rumen fill, the cows fed the grass-based diets typically consume less DM and produce less milk than those fed an equivalent amount of alfalfa. The overall conclusion of these types of experiments is that grasses are inferior to alfalfa for high producing cows because the higher fiber levels depress feed intake, which in turn limits milk yield. While these types of trials provide valuable information about the energy value of grass forages, they don't necessarily address questions concerning the strategic use of a limited amount of grass to 'fine-tune' levels of NDF or NFC in dairy rations.

Cornell researchers recognized the limitations of these traditional experiments, and suggested that a better way to evaluate grass in dairy rations was to feed equivalent amounts of NDF from grass as from the forage it replaces in the ration (Cherney et al, 2004, Cherney et al., 2002). Results from experiments designed this way typically show that milk yield and intake of grass-based diets are similar to control diets based on alfalfa (Cherney et al., 2004). Some have suggested that while studies designed this way show how grasses could be incorporated into dairy diets, they confirm that grasses are lower in energy and more restrictive in intake, but these 'deficiencies' can be overcome by feeding more grain. Experiments designed this way clearly show that grasses can be used in diets for high producing cows, but are usually designed to look at grass as an alternative to alfalfa as the primary forage in the diet.

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Another approach to evaluating grasses is to consider the grass forage as a feedstuff that contains several nutritional attributes that could complement low-fiber, high-starch diets for dairy cattle. Early maturity grass contains higher proportions of NDF than corn silage or alfalfa, and the fiber is more digestible than alfalfa NDF. In addition, early maturity grasses contain lower levels of NFC relative to alfalfa or corn silage, and less crude protein than alfalfa forage.

Nutritionists sometimes add as much as 2 to 4 lb of straw to corn silage based diets to increase the proportion of dietary fiber. While adding straw increases the total fiber content of the diet, it decreases the digestible energy intake because the fiber in straw is poorly digested and contributes significantly to rumen fill. Grasses would appear to be a better forage to incorporate into high NFC/low fiber diets because unlike straw, the fiber in grasses is more digestible than fiber in corn silage or alfalfa. This suggests that replacing part of the corn silage and alfalfa with high quality grass fiber could shift the proportion of fermented energy from NFC to NDF while minimally reducing the overall digestibility of the diet. This shift in fermentable components would be expected to provide a more steady supply of fermentable substrate to rumen microbes, which could in turn help stabilize the production of rumen acids and minimize the occurrence of ruminal acidosis

Ruminally fermented energy comes from dietary NDF, NFC, CP and fat. If a diet is balanced according to NRC (2001) guidelines (Fig. 1) about 60% of the organic matter fermented in the rumen is from the NFC component of the diet (Fig. 2). The NFC and CP fractions degrade quickly in the rumen to form acids, which tend to decrease rumen pH. The NDF fraction contributes about 21% of the fermented energy supply in the rumen, but since this fraction degrades more slowly, its degradation contributes less to the rumen pH change shortly after feeding than the NFC and CP fractions. If one assumes that optimal milk production and rumen health are achieved when cows are fed to meet the above diet and rumen parameters, we can begin to identify opportunities for incorporating feeds like high quality grass to adjust or fine-tune diets for high producing cows.

A high-quality alfalfa silage, when added to a mix of high moisture corn and a high quality corn silage may not improve the balance of quickly degraded organic matter and degradable fiber because in alfalfa the proportions of fermentable energy from NDF are only 10 to 15% lower than in excellent quality corn silage. This suggests that it would be necessary to replace a large amount of corn silage with alfalfa to significantly shift the profile of ruminally fermented substrates.

It would require much less grass to reduce the proportion of fermented NFC and increase fermentable energy from NDF than with alfalfa. Approximately 45% of the ruminally fermented OM in grass silages is associated with the NDF fraction. This is more than twice the proportion of fermentable energy from NDF than is contained in corn silage. The proportions of fermentable energy in the rapidly degraded NFC and CP fractions are much lower in excellent grass silages than in either alfalfa or corn silage. This approach would suggest that high quality grass silages could be used much like nutritionists use high fiber co-products, such as beet pulp or soy hulls to add fiber and maintain optimal rumen pH.

To test this experimental approach we recently completed a study in which we used a high quality Italian ryegrass silage as a source of digestible fiber in dairy cattle diets. (Table 1). Forty-eight cows were used to test two diets. One diet was formulated with corn silage and alfalfa silage as the only sources of forage was designated as a ‘hot’ diet that was high in NFC and low

Figure 1. Typical distribution of nutrients in diets formulated for high producing dairy cows. (Based on NRC (2001) feeding recommendations).

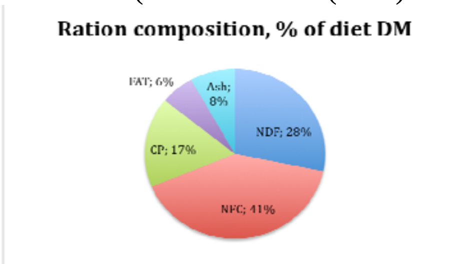
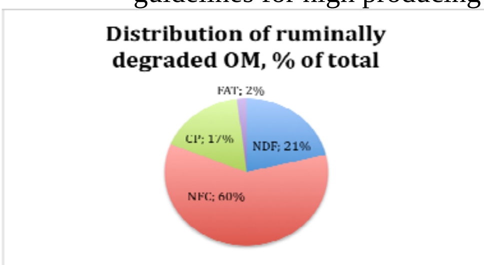


Figure 2. Contributions of fat, protein, non-fiber carbohydrate and fiber to the total organic matter fermented in the rumen for a diet formulated to meet the NRC (2001) guidelines for high producing dairy cows.



in NDF (CS-ALF). Italian ryegrass was used in the second diet to replace about a third of the corn silage and alfalfa (CS-ALF-IR). Replacement of about a third of the corn silage and alfalfa mix with Italian ryegrass raised the total fiber content and lowered the dietary NFC of the diet. Thus we reduced the amount of ruminally digested NFC and increased slightly the amount of ruminally digested NDF by adding Italian ryegrass to the diets. Cows fed the diet including ryegrass silage produced similar levels of milk (96 lb of 4% fat corrected milk) as compared to the diet with no grass. Including grass in dairy rations appears to be a feasible strategy to reduce the NFC level of early lactation diets and increase levels of fiber without reducing milk yield.

Table 1. Partial replacement of corn silage and alfalfa with Italian ryegrass silage did not affect intake and milk production of high-producing dairy cows.

Item	CS-ALF	CS-ALF-IR
Feed, % of TMR		
Corn silage	25	17
Alfalfa silage	25	16
Italian ryegrass silage	0	17
High moisture corn	30	30
Protein/vitamin/mineral	20	20
Diet constituent, % of TMR		
NDF	25	27
NFC	48	46
4% FCM yield, lb/cow/day	96	96
Fat, %	3.6	3.75

Summary

High quality-well managed grasses have potential as a source of highly digestible fiber for high producing dairy cows. The fiber in early maturity grasses is more digestible than alfalfa fiber, and when grasses are used to replace alfalfa fiber, milk production and intake of high producing cows do not appear to be affected. Perhaps the greater opportunity for grasses in dairy rations is as a feedstuff that is high in digestible fiber, and low in NFC. There appears to be a need for these types of feedstuffs when excellent quality corn silage and alfalfa are the core forages in dairy rations.

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SAVING TIME AND FUEL DURING TILLAGE

Matthew Digman [1/]

There are many ways to save fuel in tillage field operations: not tilling, choosing a minimum tillage operation over a heavier one, and ensuring your tractor and implement are set up properly.

As with any farm operation, the value of tillage must be weighed against its cost. The first costs to consider are labor, fuel and machinery. These costs are estimated to range from $9 to $19 per acre, depending on the field operation and equipment used [1]. Additionally, tillage can increase costs of subsequent field operations as loose soil reduces tractive efficiency adding further cost to operations such as planting. Finally, some tillage costs are harder to quantify, including the risk of soil erosion and nutrient loss. Conversely, tillage can have many positive impacts on crop production. These impacts can include remediating soil compaction, managing crop residues and providing favorable spring planting conditions.

Tillage is one of the least fuel-efficient field operations. It's estimated that only 20% of the energy in diesel fuel is available at the tractor's drawbar depending on engine and transmission setup [2]. Furthermore, only 2% of that energy is converted into turning the soil. Combining those two efficiencies tells us that only .4% of the energy in diesel fuel is actually converted into breaking up the ground! Therefore it is important to properly manage your tractor and implement setup to get the most out of tillage operations.

The first step to improving your tractor's efficiency starts before heading out to the field. Proper ballasting and tire pressure are critical to ensure your tractor is efficiently transferring power to your implement. First, start with ballast (weight). Over-ballasting a tractor increases rolling resistance, drive train wear and soil compaction. Rolling resistance is increased as the tractor sinks into the ground and consequently must use more energy to climb out of its tracks. Under-ballasting leads to excessive tire slip as the tractor struggles to grip the soil. The amount of ballast needed depends on the draft requirement of the field operation, but a general rule is 120, 145 and 180 lb per hp for light (greater than 6 mph), moderate (5-6 mph) and heavy (less than 4 mph) draft loads, respectively for two-wheel drive (2WD) or mechanical-front-wheel-drive tractors (MFWD). This rule of thumb is logical because increased field speed generally means the operation you are conducting requires less weight [4]. Additionally, at higher speeds soil mechanical properties can withstand only so much force before giving way, leading to wheel slip.

The second part of ballasting is to have the weight distributed on the tractor properly. Each tractor design (2WD, MFWD, FWD) and implement hitch point (mounted, semi-mounted, towed) requires a different weight split between the front and rear axle. Your tractor's operator's manual will provide the split needed to get the most out of your setup [4].

After the tractor is completely ballasted and hooked up, it's time to check tire pressures. Lower pressures can increase tractive efficiency but can also lower the load rating of the tire. Follow the load and inflation tables provided by your tire manufacturer to ensure you meet their specifications. If you're considering running on the minimum pressure, weigh each axle and divide by the number of tires to be sure the actual weight per tire is what you expect.

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Wheel slip is a good measure of how well your tractor is set up for tillage conditions. Optimal wheel slip ranges from 10 to 15% depending on soil conditions [5]. The optimal slip is on the low end of that range for firm soils and higher for tilled and sandy soils. For a quick check in the field, observe that a properly-ballasted tractor will show deformation in the center of the lug track.

Fuel can be also conserved by matching the power output of the tractor's engine to the power needed by the tillage operation. This is known as the "gear up throttle down" practice [3]. The idea is to select the gear and throttle position that will load the engine sufficiently while maintaining the desired speed for the field operation. This technique is useful where the implement doesn't demand too much power from the tractor, such as disking or situations where the tillage tool is undersized for the tractor. One must take care not to overload the engine when practicing this technique. Most diesel engines can operate efficiently at 20 to 30% of their rated engine RPM, but consult the operator's manual for your specific machine. Black smoke and poor engine response to changes in throttle position are common signs of an overloaded engine.

The final strategy for conserving fuel is to minimize overlapping passes. Strategies for minimizing overlap can range from taking breaks so that you can be more attentive as an operator or employing a guidance (e.g., lightbar, automatic steering) system.

I hope these strategies, (1) only till when necessary, (2) optimize ballast and tire pressure, (3) gear-up throttle down, and (4) stop covering the same ground, can save you time and fuel.

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EVALUATION OF FOLIAR FUNGICIDES ON ALFALFA, 2011

Paul Esker, Bill Halfman, and Bryan Jensen[1/]

Introduction

Current trends in agronomic field crop production (corn and soybean) have been towards the use of foliar fungicides to increase yield in the absence of disease to promote "plant health." Trials conducted across Wisconsin and the region has indicated very inconsistent results. Recently, Headline® (BASF, Research Park Triangle, NC) was approved for use in alfalfa. We have received numerous questions from growers and university researchers regarding the benefits of foliar fungicide use in alfalfa grown for hay. Many of these questions have been focused on the use of a fungicide in a tank mix combination with an insecticide with the hope of providing a positive synergistic yield response. Thus, the objective of this study was to conduct field research trials in Wisconsin to examine the benefit of using a foliar fungicide, foliar insecticide, or both in alfalfa.

Methods

Two experiments were conducted during the 2011-growing season. One was conducted at the Arlington Agricultural Research Station (Arlington, WI) and the second was conducted on a grower field in Tomah, WI. The Arlington trial was in its second year and would be classified as a high yielding environment. The Tomah trial was in its fourth year of production.

At each location, a randomized complete block experimental design was used. The number of treatments at each site differed due to logistical and space challenges of examining too many treatments at Tomah. At Tomah, the treatments were: Headline® (6 fl oz/a), Headline ® (6 fl oz/a) + Respect ® (4 fl oz/a), Respect® (4 fl oz/a), and an untreated check (UTC). All plots measured 20 x 30 ft and were replicated four times. In addition to those treatments, at Arlington, the following additional treatments were also examined: Quadris® (6 fl oz/a), Warrior II ® (1.28 fl oz/a) + Quadris® (6 fl oz/a) and Warrior II ® (1.28 fl oz/a), as well as several experimental compounds (*data not shown*). Plots dimensions were 20 x 50 ft and were replicated four times.

At Arlington, the alfalfa variety was Dairyland Hybriforce-2400 (Dairyland Seed, West Bend, WI). This variety carries resistance for bacterial wilt, Fusarium wilt, Phytophthora root rot, Verticillium wilt, anthracnose (race 1) and aphanomyces (race 1). The variety at Tomah was not known because of loss of planting records.

Trials were conducted during the second and third cuttings at both locations and were conducted in unique sections of the fields to avoid possible interactions between experiments. All treatments were applied using a CO^2 powered back pack sprayer which delivered 20.4 GPA at Arlington and 20.6 GPA at Tomah. Application timing was between 6 to 9 inches at all locations.

[1/] Extension Pathologist, Dept. of Plant Pathology, UW-Madison; Monroe Co. UW-Extension; UW IPM Program, respectively.

Yields were taken using small plot harvesters. Subsamples were pulled from the harvested forage and sent to the Marshfield Soil and Forage Analysis Laboratory (Marshfield, WI) for NIR analysis. The following data were collected from each site: yield (T/a), forage quality, insect sweep counts and disease severity ratings (severity as a % and severity based on a 1 to 6 scale). Harvest timing was meant to reflect the forage cutting schedule of alfalfa grown for dairy forage. At Tomah, harvest was conducted prior to bloom while at Arlington, it was at 10 to 20% as it was necessary to enable the research farm to harvest the bulk sections of the field first.

Arlington Results

Visual differences were noted in the insecticide treated plots prior to the second cut harvest. There was evidence of a deeper green color with stands slightly taller than the UTC and those treated only with a fungicide. Overall, however, there was no evidence of differences among treatments in terms of yield in dry matter tons per acre ($P > 0.10$). There was evidence of lower disease severity in plots that received a foliar fungicide application ($P < 0.10$) and there was less defoliation in the second cut ($P < 0.10$). Insect pressure was relatively low and no single insect (potato leafhopper, plant bugs and pea aphids) exceeded individual economic thresholds.

No visual differences among treatments were noted for the third cut. There was evidence of a difference in yield in the third cut ($P < 0.10$); however, there was no pattern observed regarding specific treatment effects and the UTC fell in the middle of the yields. Similar to second cut, disease severity was lower with the application of a foliar fungicide, however, disease severity in the third cut was approximately half of what it was in the second cut.

Tomah Results

Overall, stand density and crop vigor were lower at Tomah compared to Arlington. Disease severity was lower in plots that received a foliar fungicide ($P < 0.10$). However, insect abundance was low in the second cut, and overall, there was no evidence of a statistical difference in either second crop yield or quality. Results were similar for third crop although there was some evidence of differences among treatments for several quality factors ($P < 0.10$).

Conclusion

Overall, results were inconclusive across the two trials in 2011. While there was evidence of reductions in disease severity and defoliation in some alfalfa crops, overall, there was no evidence of differences in terms of yield. Based on this year’s trial, additional trial data are needed before recommendations can be made regarding foliar fungicide use in alfalfa.

BIOLOGY AND MANAGEMENT OF WESTERN BEAN CUTWORM IN THE GREAT LAKES REGION

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REFUGE RULES, RESISTANCE, AND ROOTWORMS

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RESISTANCE IS NOT FUTILE: SBA HOST PLANT RESISTANCE

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UNINTENDED CONSEQUENCES: THE EFFECTS OF FIELD CROP SEED TREATMENTS UPON HONEYBEES

Christian Krupke [1/]

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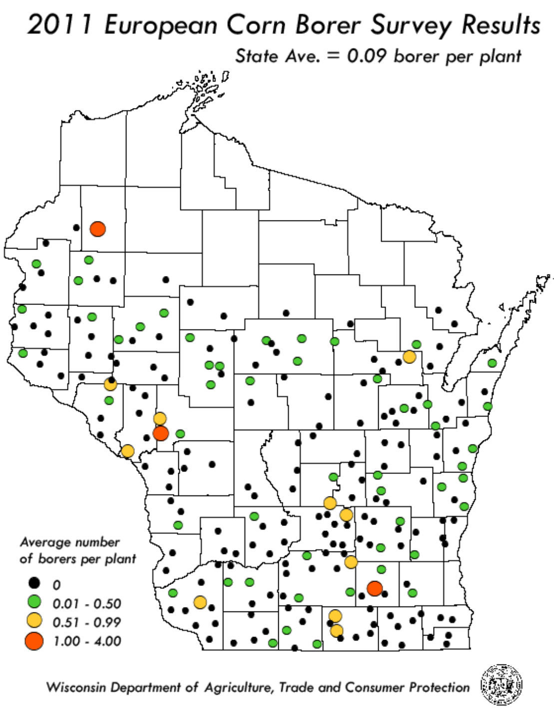
WISCONSIN INSECT SURVEY RESULTS 2011 AND OUTLOOK FOR 2012

Krista L. Hamilton[1/]

European Corn Borer

Larval populations remained historically low in 2011. The seventieth annual fall abundance survey in September revealed a state average of 0.09 borer per plant, the fourth lowest since record-keeping began in 1942. Minor population reductions from 2010 were charted in the southwest, central and northeast agricultural districts and increases occurred in the south-central, southeast, east-central, north-central and northwest areas. Larval densities in the south-central



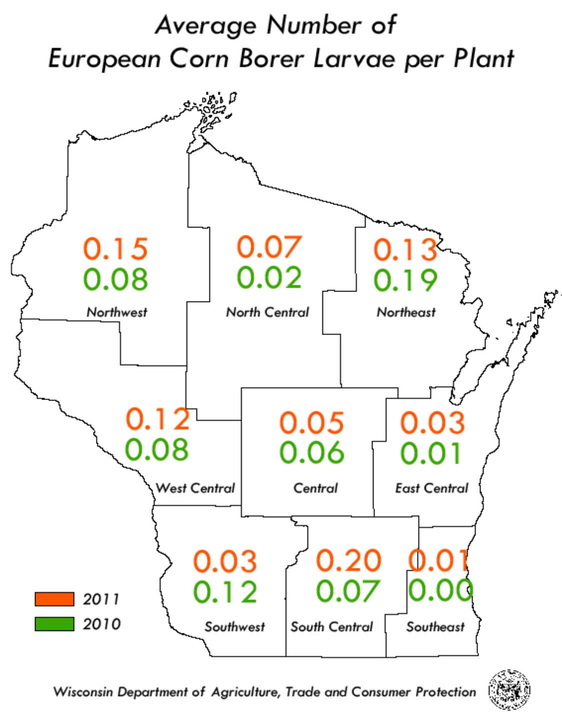


Table 1. European corn borer fall abundance survey results 2002-2011 (Average no. borers per plant).

District	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	10-Yr Ave
NW	0.44	0.20	0.13	0.01	0.27	0.24	0.12	0.06	0.08	0.15	0.17
NC	0.26	0.14	0.20	0.36	0.16	0.35	0.18	0.10	0.02	0.07	0.18
NE	0.75	0.23	0.22	0.33	0.23	0.07	0.12	0.12	0.19	0.13	0.24
WC	0.71	0.16	0.05	0.24	0.42	0.52	0.04	0.10	0.08	0.12	0.24
C	1.21	0.44	0.06	0.44	0.51	0.42	0.11	0.06	0.06	0.05	0.34
EC	0.44	0.20	0.22	0.25	0.11	0.21	0.20	0.09	0.01	0.03	0.18
SW	0.65	0.34	0.10	0.49	0.20	0.28	0.05	0.06	0.12	0.03	0.23
SC	0.86	0.51	0.05	0.67	0.38	0.33	0.07	0.02	0.07	0.20	0.32
SE	0.61	0.21	0.02	0.35	0.16	0.12	0.04	0.00	0.00	0.01	0.15
State Ave.	**0.66**	**0.30**	**0.10**	**0.40**	**0.29**	**0.31**	**0.09**	**0.06**	**0.07**	**0.09**	**0.24**

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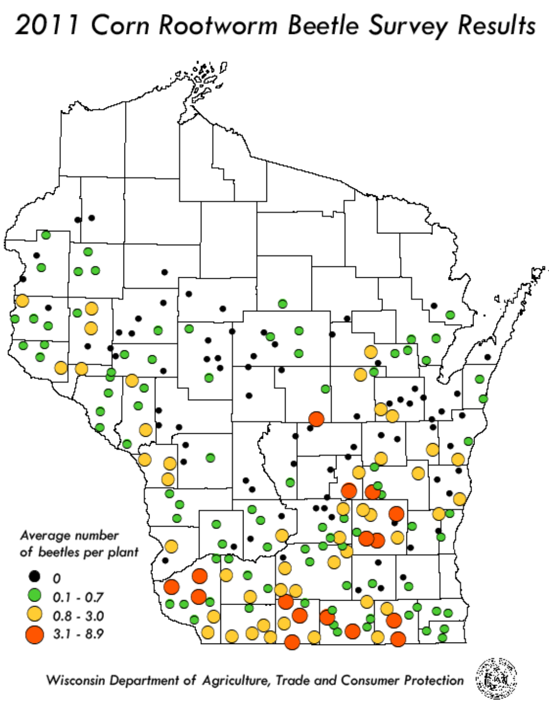
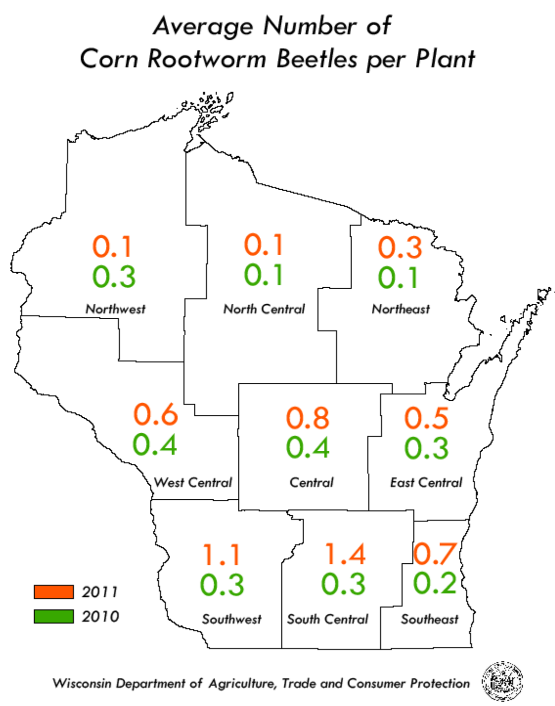
district increased to 0.20 per plant, or 20 larvae per 100 plants. On the basis of the fall survey results, a continued low population trend is expected for 2012.

Corn Rootworm

Results from the August beetle survey showed a substantial population increase in the southern and central districts. The 2011 state average beetle count of 0.7 per plant represents a more than two-fold increase over the historic low average of 0.3 per plant documented in 2010. The largest increase occurred in the south-central district where the average escalated sharply from 0.3 to 1.4 beetles per plant. Population increases were also noted in the southwest, southeast, west-central, central, east-central and northeast districts. By contrast, beetle counts in the northwest and northeast areas were extremely low at 0.1 per plant.

The survey findings indicate a high potential for root damage to continuous corn in the southern two-thirds of the state in 2012. Corn producers in these areas will need to consider crop rotation or another form of rootworm management for next season.





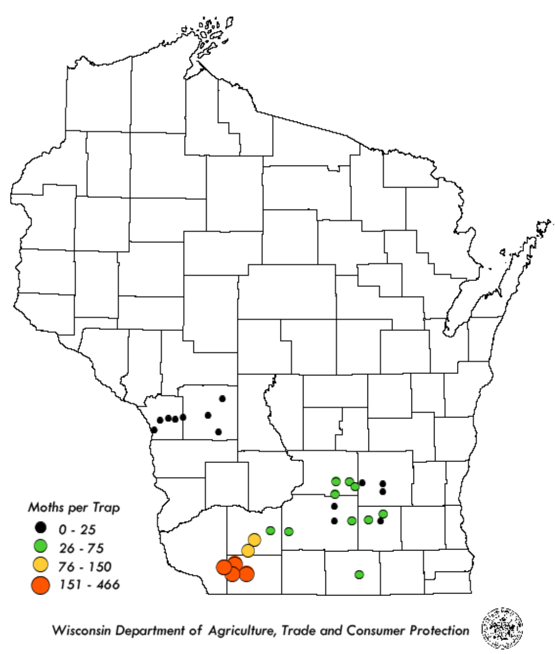
Corn Earworm

A lengthy flight began by July 27 and continued though September 21. The eight-week migration yielded a cumulative total of 4,571 moths at 15 sites, with a well-defined peak from August 4-10. Compared to 2010, the flight was smaller and moth activity was more concentrated in the south-central and central counties. Late sweet corn and other susceptible crops such as tomatoes and snap beans remained under a moderate to severe threat until mid-September.

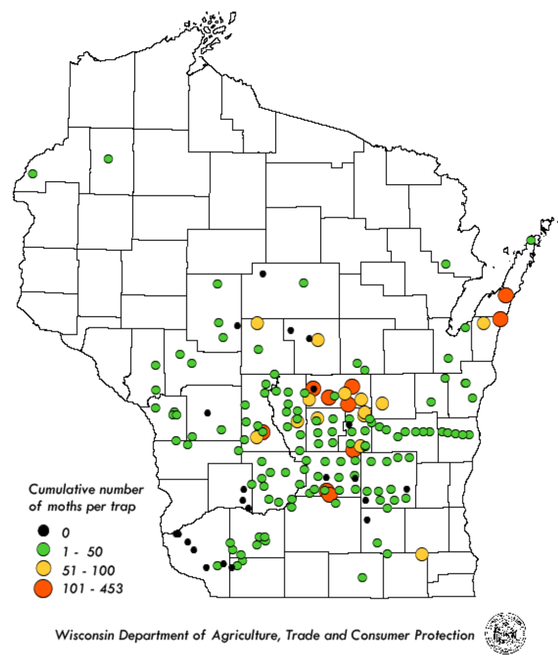
Black Cutworm

Delayed planting, late weed control and the largest moth migration in 10 years resulted in localized black cutworm problems this season. Larval progeny of the earliest migrants reached the destructive cutting stages by May 30 and infestations were noted in Dane, Dodge, Grant, Jefferson, Jackson, La Crosse and Vernon counties in early June. Damage estimates ranged from 3% cut plants to as high as 40% in exceptional fields. Insecticidal seed treatments labeled for black cutworm control proved ineffective in some instances and rescue applications were required. The threat from this early-season pest subsided by late June.

2011 Cumulative Black Cutworm Trap Counts



2011 Western Bean Cutworm Trap Counts



Western Bean Cutworm

Moth counts decreased significantly from the previous year, according to the statewide trapping program. The 2011 cumulative capture of 4,895 moths was a 55% reduction from 10,807 moths collected in 2010. Larval infestations resulting from the flight were also less prevalent and severe this year, although a few scattered fields had a fair number of larvae in the ears.

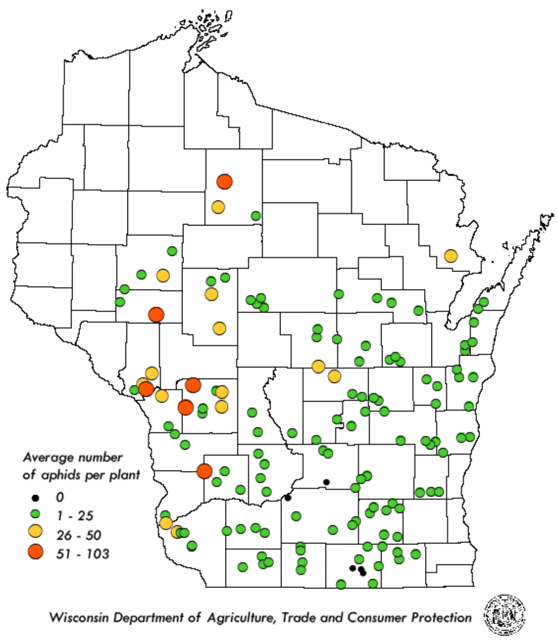
Japanese Beetle

Adults became prevalent in flowering soybeans by late July and foliar damage surpassed economic levels during the first two weeks of August. Controls were applied to fields in Chippewa, Dane, Eau Claire, Kenosha, Rock and Walworth counties, with unsatisfactory results in a few cases. According to survey observations and reports, Japanese beetles were far more abundant this season than in the last several years. The largest populations were noted on lighter soils in the southeast, south-central and northwest areas.

Soybean Aphid

Densities remained below economic levels this season. The annual survey conducted in July and August showed the state aphid count to be 12 per plant. This average compares to 16 aphids per plant last year and is only marginally higher than the record low density of 11 per plant documented in 2004. Soybean fields were sampled in two intervals, first in late July and again in August, for a total of 284 observations in 142 fields. Aphid densities were below 103 per plant in all surveyed fields, with the exception of a single Portage County site which had an average count of 451 per plant on July 29. Natural control agents, insecticidal seed treatment, high temperatures, and several heavy precipitation events all limited soybean aphid population growth in 2011.

Soybean Aphid Survey Results August 2011



Average Number of Soybean Aphids per Plant

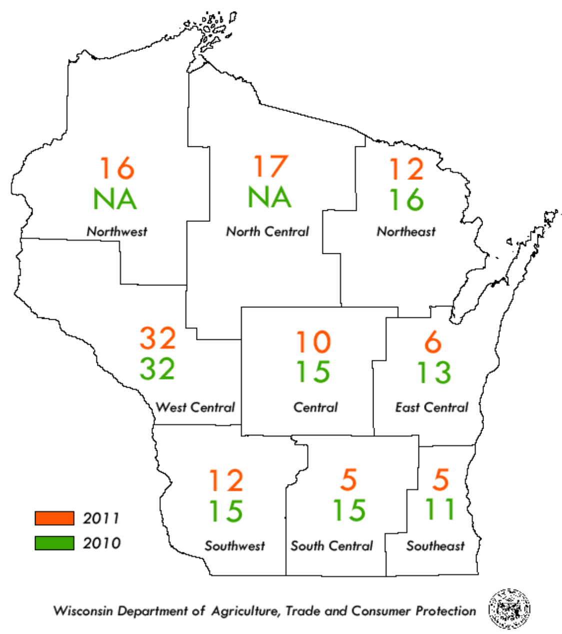


Table 2. Soybean aphid survey results 2003-2011 (Average no. aphids per plant).

District	2003	2004	2005	2006	2007	2008	2009	2010	2011
NW	566	1	306	56	13	90	49	—	16
NC	93	7	113	22	109	—	89	—	17
NE	170	25	42	58	13	34	22	16	12
WC	632	9	198	101	356	121	112	32	32
C	680	43	175	44	170	142	94	15	10
EC	968	5	124	159	10	66	16	13	6
SW	149	2	44	55	302	14	6	15	12
SC	993	11	75	30	188	98	72	15	5
SE	1268	6	91	23	54	23	3	11	5
State Ave.	**758**	**11**	**118**	**69**	**164**	**70**	**53**	**17**	**12**

DISTRIBUTION OF SCN HG TYPES IN WISCONSIN

Ann MacGuidwin[1/]

Introduction

Heterodera glycines, the soybean cyst nematode (SCN), is the most important disease of soybean in the United States (Wrather and Koenning, 2006). Fifty-four counties in Wisconsin are infested with SCN and many fields suffer yield losses due to this pest. The most efficient and economical tactic to manage SCN is host resistance. Sources of SCN resistance for soybean group 0 – group 2 varieties derive from three sources, PI 548402 ("Peking"), PI 88788, and PI 437654. The PI 88788 source of resistance is the most common background in commercial varieties and it is effective for maintaining yield in fields with disease potential due to SCN.

Heterodera glycines nematodes are variable for their susceptibility to the host defense mechanisms conferred by resistance genes. Some individuals are able to develop successfully in SCN-resistant plants, while others infecting the same plant die. Producers who know what proportion of the nematodes in their fields can overcome the PI 88788 source of resistance have an advantage because they can switch to soybean varieties with "Peking" based resistance.

A standardized assay for profiling SCN populations for their response to SCN-resistance genes has been adopted by nematologists (Niblack et al., 2002). The assay, referred to as the Hg Type test, is conducted under controlled conditions using procedures and interpretation based on years of research. The format for presenting the results of an Hg Type test have also been standardized to a naming convention that is easier to use than the former SCN "race scheme" that required testing the population on 12 different indicator lines to make "race" assignment. For the Hg Type Test naming convention, any population with more than 10% of its members able to develop on PI 88788 is referred to as an Hg Type 2. Any population with more than 10% of its members able to develop on "Peking" is an Hg Type 1. An Hg Type 1.2 population shows 10% or more development on both "Peking" and PI 88788 soybean genotypes.

The Wisconsin Soybean Marketing Board has sponsored a free SCN-testing program for more than 10 years. Soil samples are currently submitted to the UW-Madison Plant Disease Clinic for a SCN detection assay. The results from the assay consist of an egg count for a 100 cc subsample of the soil submitted for analysis. The MacGuidwin laboratory conducts an Hg Type Test on the samples positive for SCN. In order to conduct the test, nematodes from the sample are cultured on a SCN-susceptible variety for two to four months or until sufficient numbers of nematodes have been produced. Due to the time required for the nematode culturing step, the Hg Type test is conducted one calendar year after the soil samples were submitted.

The Hg Type Test

Cysts of SCN are harvested from susceptible soybeans and crushed to release the eggs used for the test. Approximately 2,500 are added to 24 pots filled with heat-pasteurized soil. Eight

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soybean indicator lines are planted into each of three cups, seven of the lines are SCN-resistant ("Peking", PI 88788, PI 90763, PI 437654, PI 209332, PI 89772, and PI 548316) and one is SCN-susceptible ("Lee 74"). The plants are grown conditions conducive to SCN development. After 30 days the soybean plants are removed from the pots and the SCN females that have developed on the roots are counted. If the average number of females recovered from the SCN-susceptible control exceeds 100 the Hg Type test is considered valid. The counts of females are used to calculate the average number of females developed for each of the seven SCN-resistant lines and this average is divided by that of the susceptible line and then converted to a percentage by multiplying by 100. The number that results from this calculation is called the Female Index. If the Female Index for a soybean indicator line is 10% or greater, the SCN population is considered to be virulent on that line and named accordingly. The seven soybean indicator lines are always assigned the same number so that all SCN populations virulent on the same indicator line have the same Hg Type name.

Results for Samples Assayed 2006 – 2010:

SCN populations representing 109 farms were assayed for Hg Type over the five year period 2006 to 2010. The total number of populations assayed for each year and number virulent on "Peking" (Hg 1), PI 88788 (Hg 2), both (Hg 1.2) and neither (Hg 0) are presented in Table 1. The most common Hg Type was Hg 2, which was contrary to the popular belief that Hg 0, formerly referred to as "Race 3", is predominant in Wisconsin.

Table 1. Virulence phenotypes of SCN populations assayed for Hg Type for samples collected in 2006 to 2010. Each SCN population represents a single farm enterprise.

Year	Hg 0	Hg 1	Hg 2	Hg 1.2	Total
2006	4	0	11	5	20
2007	3	2	11	1	17
2008	1	3	13	5	22
2009	6	0	20	8	34
2010	4	1	7	4	16

The Female Index (FI) indicates the virulence of the SCN population for different SCN-resistance genes; the higher the female index the less likely it is that varieties derived from that source of resistance will suppress nematode development and maintain yield. The FI is not a perfect predictor of soybean variety performance in the field, but FI values above 50 warrant concern. The midpoint (median) FI value from 2005-2010 was less than 10 for "Peking" and ranged from 14 in 2007 to 22 in 2008 for PI 88788, suggesting that host resistance is an effective and valuable tool for most Wisconsin producers (Table 2). Some producers do have cause for concern, however, because the SCN populations in their fields appear to be adapted to the PI 88788 source of resistance. Information submitted with the samples showed that these SCN populations had not been exposed to SCN-resistance genes in their current location. Research on cyst nematodes shows that can be disseminated in animal droppings and moved by farm equipment, so nothing is known about their source of origin.

Table 2. Median Female Index values for SCN populations tested for Hg Type in 2005-2010 and the percentage of samples with Female Index values greater than 50.

Year	# Virulence Assays	Median FI on "PI 88788"	Median FI on "Peking"	% of Samples with FI > 50 on "Peking"	% of Samples with FI > 50 on "PI 88788"
2006	20	17	2	5	5
2007	17	14	3	0	18
2008	22	22	5	0	5
2009	34	17	2	3	12
2010	16	18	1	0	19

The data suggest a pattern to Hg Type in Wisconsin (Table 3). The western part of the state had fewer Hg Type 0 populations and 91% of the populations from the west were adapted to PI 88788 to some extent as compared to 76% for eastern region.. Thirty-eight percent of the SCN populations in the eastern part of the state were adapted to "Peking" as compared to 13% in the west. It is impossible to conclude why these differences occur, but one possibility is that the primary means of dispersal for SCN varies by region.

The Hg Type testing confirmed that Wisconsin producers should use SCN-resistant varieties thoughtfully to preserve the yield advantage available today. There are no data to suggest that varieties with PI 88788 backgrounds are currently failing, but the widespread distribution of SCN already adapted to PI 88788 means producers should remain informed about the population densities of SCN in their fields. Periodic soil sampling for SCN can reveal the buildup of resistance-breaking populations and is a best-management practice for every infested field.

Table 3. Median Female Index values and the percentage of SCN populations with a Female Index greater than 10 for populations tested during 2005-2010 in Wisconsin. †

Region	Median Female Index		% of samples with virulent "SCN populations			
	Peking	PI 88788	Hg 0	Hg 1	Hg 2	Hg 1.2
East	4	15	16	6	44	32
Central	2	14	23	7	57	19
West	1	23	6	3	81	10

† Counties representing eastern Wisconsin were Brown, Fond du Lac, Outagamie, Ozaukee, Racine, Sheboygan, Walworth, Washington, Waukesha, and Winnebago. Counties representing central Wisconsin were Adams, Columbia, Dane, Dodge, Green, Green Lake, Jefferson, and Rock. Counties representing western Wisconsin were Buffalo, Chippewa, Dunn, Eau Claire, Grant, Iowa, LaCrosse, Lafayette, Pepin, Pierce, Polk, Richland, St. Croix, Trempeleau, and Wood.

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MANAGING PHYTOPHTHORA CROWN AND FRUIT ROT IN PICKLES, PEPPERS, AND SQUASH

Amanda J. Gevens[1]

Introduction

Phytophthora crown and fruit rot of vegetable crops, caused by the oomycete *Phytophthora capsici* has the potential to cause significant yield losses in cucurbit, solanaceous, and legume crops worldwide. In Wisconsin, Phytophthora crown and fruit rot has been a sporadic disease in vegetable production for the past 20 years. In the previous 10 years, weather patterns were generally dry and the disease was limited to small parcels of susceptible crops throughout Wisconsin.

Results and Discussion

This potentially aggressive disease, caused by the soilborne water mold *Phytophthora capsici*, can infect a broad range of crops including summer squash, zucchini, winter squash, pumpkins, melons, cucumbers, peppers, tomatoes, and eggplant. Over the past few years, reports of this pathogen have also been made on snap and lima beans in commercial fields in the Midwest and Mid-Atlantic regions of the U.S. Symptoms of Phytophthora include water-soaking of lower stem or crown of a plant resulting in complete wilting of plants, and water-soaking on fruit often associated with white talcum-like pathogen sporulation on surfaces (see pictures below). Breakdown of plant tissues by this pathogen can be rapid and can occur on fruit post-harvest. To avoid Phytophthora, the following measures should be taken: do not plant susceptible crops on fields with recent history of this disease, provide good drainage (raised beds are beneficial), avoid planting in low-lying areas of fields, practice good irrigation management to avoid standing water and extended periods of leaf wetness, apply effective protectant fungicides when conditions favor infection in known infested fields. Coming off of such a wet week, it is critical that growers of susceptible crops scout their vegetable fields for Phytophthora. Roguing of infected plants from the production field when disease is identified early can aid in limiting spread of disease. Do not allow infected fruit to sporulate and persist in production fields. Culls can continue to provide inoculum for remaining plants. Because Phytophthora is soilborne, soil from infested fields remaining on equipment should be removed prior to moving to a new or ‘clean’ field. Every effort should be made to avoid introducing this pathogen into uninfested fields.

Fungicides can be effective in managing Phytophthora when environmental conditions favor disease. The keys to making fungicides work best for you are: 1) select most effective fungicides with no known resistance in your field/area, 2) make a thorough application particularly if fruit are to be protected and are beneath a dense foliar canopy, and 3) make frequent applications when conditions favor disease and crop growth is rapid.

In 2009 through 2011, years of higher than average precipitation during the growing season of May through October, Phytophthora was problematic in winter squash, peppers, and pickling cucumbers. To optimize control recommendations, collections of *P. capsici* isolates from six fields in two production areas were made in 2010 and 2011 to survey for resistance to mefenoxam. Of the six fields, two had been in small grain/corn-vegetable rotations for

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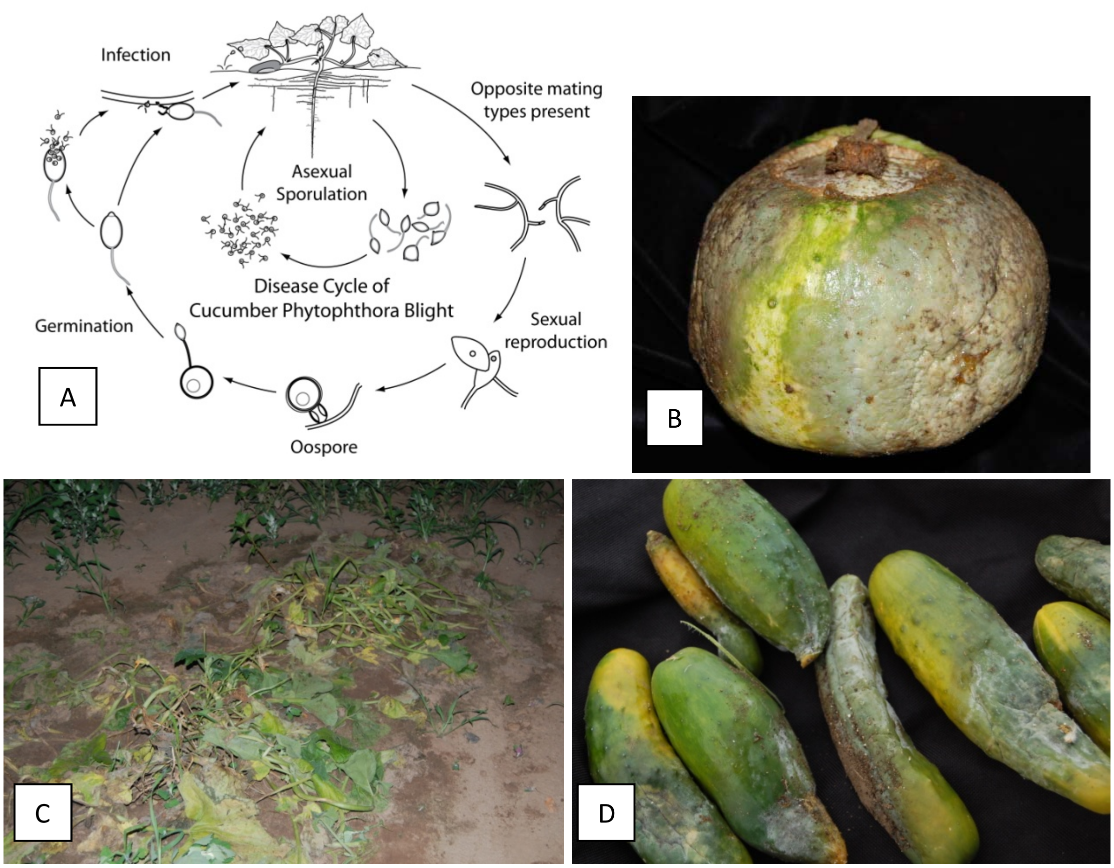
approximately 40 years with no use of mefenoxam- or metalaxyl-containing fungicides. Isolates of *P. capsici* collected from the two fields (10 total) in 2010 were sensitive to mefenoxam with roughly 20-29% growth on 100 ppm mefenoxam-amended media compared to the control. In the remaining four fields sampled in 2011 from a production region ~20 miles to the north, mefenoxam-containing fungicides were routinely relied upon for Phytophthora control in primarily snap bean-cucumber rotations. Isolates from the four fields were intermediately sensitive to mefenoxam with ~45-82% growth on fungicide-amended media.

When mefenoxam-containing fungicides are no longer effective, fungicides with activity against Phytophthora crown and fruit rot include: Ranman (cyazofamid), Forum (dimethomorph), Tanos (fanoxadone + cymoxanil), Presidio (fluopicolide), Aliette (fosetyl-al), Revus (mandipropamid), and Gavel (zoxamide + mancozeb).

Further details on fungicides described above can be found in the 2011 Commercial Vegetable Production in Wisconsin Guide A3422. An online pdf can be found at the link below or a hard copy can be ordered through the UWEX Learning Store.

http://learningstore.uwex.edu/assets/pdfs/A3422.PDF



Phytophthora crown and fruit rot pictures include A: disease cycle on cucumber, B: symptoms on winter squash fruit, C: wilting symptom on winter squash plants, and D: fruit rot and sporulation on cucumber fruit.

WHAT HAPPENED WITH CUCURBIT DOWNY MILDEW AND POTATO AND TOMATO LATE BLIGHT IN 2011?

Stephen A. Jordan[1] and Amanda J. Gevens[2]
{With contributions from Anna Seidl[3] & Amilcar Sanchez Perez[3]}

Introduction

On vegetable and potato crops, the water molds, or fungus-like, oomycetous plant pathogens, which threaten the greatest crop losses include *Pseudoperonospora cubensis* (causal agent of downy mildew on cucumbers), and *Phytophthora infestans* (causal agent of late blight on potatoes and tomatoes). Downy mildew and late blight can both be aerially dispersed over long distances and genotypes identified in the region are not known to be soilborne at this time (1, 3). Initial inoculum and infection occurs as the result of movement of spores in the air from diseased fields to healthy, infected seed or transplants, or by overwintering plant tissues harboring the pathogen from the previous year (e.g. volunteers, cull piles, compost piles). In Wisconsin in 2011, both diseases made minor appearance on vegetable crops.

Results and Discussion

Cucurbit downy mildew caused by the fungus-like pathogen *Pseudoperonospora cubensis* has become more prevalent in the Midwestern & Great Lakes states and throughout the U.S. over the past 5 years. Growers of cucurbits (cucumber, squash, melon, pumpkin) in the Midwestern U.S. states, may recall rare occurrences of late season downy mildew on squash or watermelon crops over the last four decades. Why, since the mid-2000's, has downy mildew become problematic on cucumbers mid-production season? Why has this disease revisited some Midwestern states with greater regularity and aggressiveness?

Since 2005, the Midwestern U.S. has seen cucumber as the first cucurbit crop infected with downy mildew with symptoms detected as early as mid-June. In 2011, pumpkin, butternut squash, cantaloupe, watermelon, and yellow summer squash were also infected in several states, but symptoms were not detected until late-July. It is not known if our region has had two different strains of cucurbit downy mildew, an early-arriving strain aggressive on cucumber and a late-arriving strain aggressive on pumpkin, squash, and melon or if we have one strain that gets established on cucumber and spreads to other less susceptible cucurbits after inoculum has increased locally. We do know that once downy mildew is in a region, it can be a continual challenge until harvest or frost.

Cucurbit crops in the Midwest have typically not needed routine application of fungicides for downy mildew control. For ~40 years, varietal resistance in commercial cucumber and some melon varieties, conferred by the recessive *dm1* downy mildew resistance gene, was effective in controlling disease. Pumpkin, squash, and watermelon crops were without this resistance and would sporadically become infected with downy mildew late in the production season. It had

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been standard recommendation that pumpkins in northern states were to be planted and harvested early to avoid risk of downy mildew because the pathogen could make its way north on late season air currents. The strain(s) of the downy mildew pathogen that have recently made their way to our region are not adequately controlled by *dm1* resistance that held up for decades.

Whether there has been a change in the pathogen population by way of a genetic mutation or introduction of an invasive and aggressive cucumber strain, or if changes in environmental conditions have promoted increased virulence is unknown. North Carolina State University researchers determined that recent eastern U.S. populations of cucurbit downy mildew were much more diverse in host range and pathogenicity than was previously known, with *Cucumis* species (cucumber, melon) having greater susceptibility to most pathogen isolates than *Cucurbita* species (squash, pumpkin).

Downy mildew, like other members of the water molds, is favored by warm temperatures (65-85°F) and wet field conditions. In 2010, areas of Wisconsin received over 30 inches of rainfall from May to October, the highest quantity of precipitation recorded over the production season since 1895. Conducive weather coupled with presence of the pathogen resulted in downy mildew in multiple cucumber producing areas of the state.

While downy mildew does not cause fruit infection on cucurbits, the pathogen can defoliate plants leaving fruit at risk for sunscald and secondary infection. Foliar symptoms include pale green-yellow angular (squared off within veins) lesions on leaf surfaces with corresponding and distinctive fuzzy brown growth on leaf undersides. The fuzzy growth is the pathogen producing thousands of new sporangia (spores) which can become airborne and further spread the pathogen within field and beyond at a rate of approximately 6 miles/day. Early infections can be tricky to identify, as they may mimic a nitrogen deficiency, angular leaf spot, or even virus symptoms. The pathogen is an obligate parasite, requiring living plants to remain viable. The pathogen cannot overwinter in the soil on its own, as production of persistent soilborne spores (oospores) have not been found here in Wisconsin.

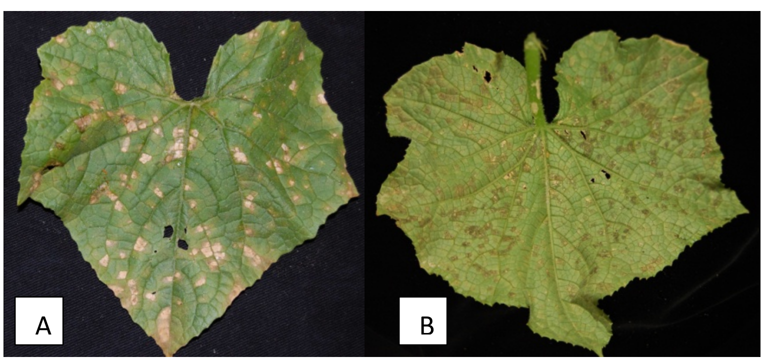
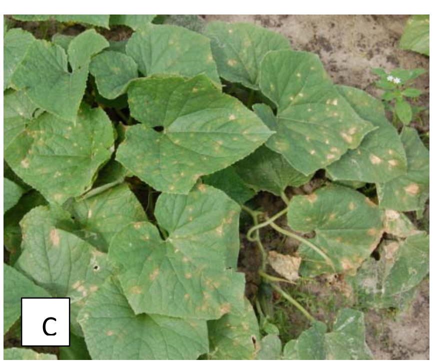
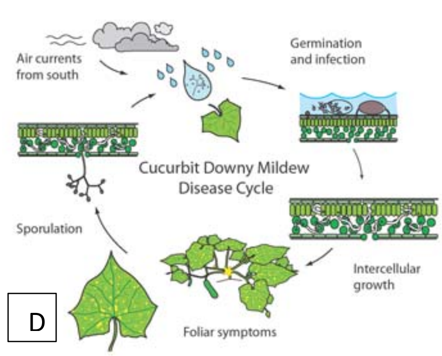


Figure 1. Symptoms of downy mildew on cucumber. A) Mature, angular, necrotic downy mildew lesions on cucumber leaf surface. B) Fuzzy, brown, pathogen sporulation on leaf underside. C) Cucumber downy mildew in the field. D) Cucurbit downy mildew diseaes cycle. Created by Rosemary Clark, formerely of UW-Vegetable Pathology.





Management

Currently, with mid-season risk of spore movement and lack of commercially available and durable varietal resistance in cucurbits, fungicide applications are essential for protection of yield and quality. The selection of fungicides, timing of application, and thoroughness of application are critical for effective disease control. Fungicides should be applied prior to or at first sign of infection to best control cucurbit downy mildew. Based on field research in multiple states including Michigan and North Carolina, effective fungicides for downy mildew control include zoxamide+mancozeb, fluopicolide, propamocarb hydrochloride, cyazofamid, and famoxadone+cymoxanil. The effective control program for cucumber established at Michigan State University by Dr. Mary Hausbeck, which I recommend to producers in Wisconsin, specifies a 7-day spray interval of the previously listed materials tank-mixed with either mancozeb or chlorothalonil when initiated **before** downy mildew is found in the field. Fungicides should be alternated so as to manage the potential development of fungicide resistance. Sprays are tightened up to a 5-day interval when initiated **after** disease is found in the field. For cucurbits other than cucumber, the program above is modified to expand the spray intervals from 7 to 10-day **before** disease, and 7-day **after** disease is found in the field. Downy mildew can be well controlled in cucurbit crops with use of effective fungicides, however, this adds a significant increase to the cost of production and success is contingent upon careful attention to regional extension vegetable disease reports and careful field scouting to appropriately time fungicide application.

To aid in tracking cucurbit downy mildew in your county and beyond, the website: http://cdm.ipmpipe.org/ offers forecasting of the disease based on confirmed reports across the U.S. The ipmPIPE (or **i**ntegrated **p**est **m**anagement **P**est **I**nformation **P**latform for **E**xtension and Education) cucurbit downy mildew website provides a publicly accessible site for sharing of cucurbit downy mildew detections, as well as symptom descriptions and management recommendations by region. The site is maintained by researchers at North Carolina State University with collaboration from researchers across the U.S., including Wisconsin. With the multitude of tasks that growers have to manage in the field, office, and marketplace, I recommend use of the CDM ipmPIPE Alert System (link on left side bar of website) which sends you an email or text message when downy mildew is reported within a selected geographic radius around your farm. Also, consider e-mail list serve membership to the University of Wisconsin Extension Vegetable Crop Update newsletter each week through the growing season for downy mildew status reports. Newsletters may be sent out by your grower association or can be directly accessed each week at our UW-Vegetable Pathology website: http://www.plantpath.wisc.edu/wivegdis/.

Research is ongoing in the U.S. and worldwide to better understand the pathogenicity, host resistance, and spread of cucurbit downy mildew. Advances in resistance breeding will greatly aid in improved disease control and sustainability of cucurbit production in Midwestern states and worldwide.

Late blight, is the most limiting disease to potato production worldwide and has been recognized as a significant agricultural concern since the Irish potato famine in the late 1840s. Two mating types are needed to produce sexual, persistent soil-borne oospores. The population is largely clonal outside its center of origin in the Toluca Valley of Mexico, relying on production of asexual sporangia for persistence. Nationally, US-1 (A1) was the predominant clonal lineage until the late 1980s-early 1990s, when US-8 appeared. US-8 was the opposite mating type (A2) and was insensitive to mefenoxam, a fungicide with exceptional activity against oomycetes, but with a specific mode of action that effectively selects for insensitivity.

After 2002, Wisconsin growers enjoyed a 6-year respite from this disease, until it appeared in 2009, with follow up performances in 2010 and 2011. In these years, isolates were collected from potato and tomato from across the state. Allozyme genotype was resolved using cellulose acetate electrophoresis. This revealed 3 banding patterns which profiled US-22, US-23, and US-24. All isolates of US-22 and US-23 were sensitive to mefenoxam, while isolates of US-24 showed partial insensitivity. US-22 isolates were of the A2 mating type, and US-23 and US-24 isolates were of the A1 mating type. Isolates of opposite mating types were geographically separated in the state in 2010.

The late blight in WI in 2009 was part of a nationwide epidemic likely initiated by tomato transplants, thus one clonal lineage, US-22, predominated. In 2010, the sources of late blight are unknown, but US-22 may have overwintered on plant material protected under the early heavy snowfall. US-24 was found only on potato in central WI, and US-23 was found only on tomato, primarily in areas of WI with concentrated suburban tomato gardens. This year, WI had an early (7 July) and isolated detection of late blight on tomato in Waukesha Co. caused by US-23. Late blight did not again reappear until confirmed on 26 and 27 August in Waushara and Adams Cos. (US-23 and US-24).

In the laboratory, we demonstrated that by pairing US-22 (A2) with US-23 or US-24 (both A1), oospores can be formed at 12, 16, and 20°C on detached leaves of 3 varieties of tomato and a single variety of potato ('Katahdin'). The greatest concentration of oospores was seen at 16°C, an optimum temperature for promotion of late blight epidemics in production fields. To date, opposite mating types have not been identified in the same field or county within the same production year in Wisconsin. Further studies are designed to better understand the overwintering and germination potential of oospore. Constant monitoring and managing of late blight through use of varietal resistance and well-timed and –selected fungicides is essential in order to efficiently and effectively control late blight and maintain geographical separation of mating types.

Management

With the late season presence of the late blight pathogen in WI, it is critical that growers remain on alert and prepared for late blight control from field to storage.

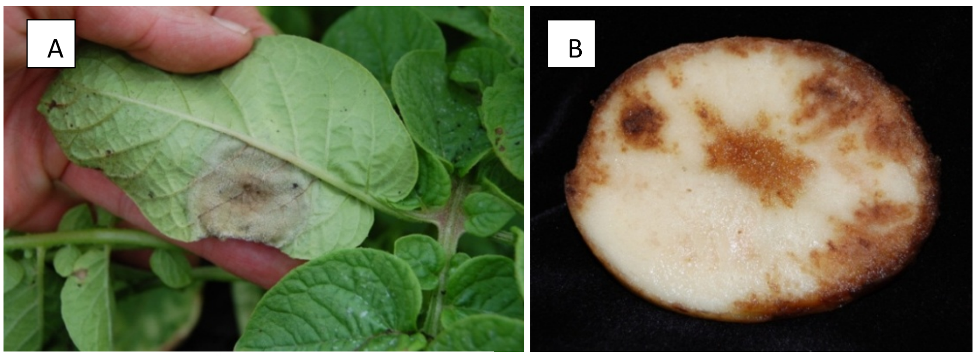
Late-season potato late blight disease management practices should include the following:

1) Continue to scout fields regularly. Scouting should be concentrated in low-lying areas, field edges along creeks or ponds, near the center of center-pivot irrigation structures, and in areas that are shaded and protected from wind. Any areas where it is difficult to apply fungicides should be carefully scouted.
2) Avoid excess irrigation and nitrogen. If foliage is infected with late blight, spores can be washed down through the soil and infect tubers. Green vines can continue to be infected and produce spores even at harvest. Additionally, green and vigorous vines are hard to kill and skin may not be well-set at digging resulting in higher risk of post-harvest infection by late blight and other diseases.
3) Allow 2-3 weeks between complete vine kill and harvest. Fungicide applications should be continued until vines are dead. When foliage dies, spores of the late blight pathogen that remain on the foliage also die. This practice will prevent infection of tubers during harvest and development of late blight in storage.
4) Do not produce cull piles of late blight infected tubers. Such piles are a significant source of spores and centers of large piles may not experience freezing/killing winter temperatures which serve to kill tuber tissue and the pathogen. Culls should be spread on fields not intended for potato production the following year in time that they will freeze

completely and be destroyed during the winter. Potato culls can also be destroyed in some other way such as chopping, burial, burning or feeding to livestock.

5) Keep tubers dry in storage. Air temperature and humidity should be managed so as to avoid producing condensation on tubers. Condensation can promote spore production of the late blight pathogen in storage. Application of fungicidal materials on tubers entering storage. Avoid or limit long term storage of tubers from fields in which late blight was detected.

Wisconsin fungicide recommendations for late blight can be found in the University of Wisconsin Extension Publication entitled “Commercial Vegetable Production in Wisconsin,” publication number A3422 (http://learningstore.uwex.edu/assets/pdfs/A3422.PDF) and additional information is provided in weekly newsletters during the growing season (provided at the vegetable pathology website: http://www.plantpath.wisc.edu/wivegdis/).



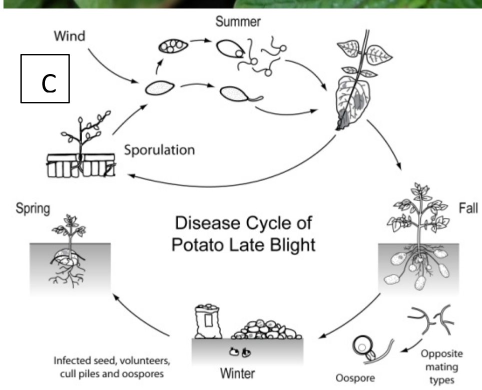


Figure 2. Potato late blight symptoms and disease cycle. A) Lesion on potato leaf displaying pathogen sporulation on underside. B) Internal late blight symptoms on potato tuber. C) Potato late blight disease cycle. Depiction was created by Rosemary Clark, formerly with UW-Vegetable Pathology.

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EFFECT OF SIMULATED SYNTHETIC AUXIN HERBICIDE DRIFT ON SNAP BEANS AND POTATOES

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Concern exists among specialty crop producers and processors related to the potential introduction of agronomic crops tolerant of synthetic auxin type herbicides. While anecdotal observations of synthetic auxin herbicide drift on specialty crops have been reported, quantitative data on injury and crop yield is often lacking. The objective of this study was to determine the effect of simulated synthetic auxin drift on potatoes and snap (green) beans. In potatoes, simulated dicamba drift was evaluated at three rates (1.4, 4.2 and 7.0 g ae/ha) and two timings. In snap beans, 2,4-D and dicamba were evaluated individually at the same rates described above but at one application timing. When dicamba was applied to 25 cm tall potatoes, visual injury 10, 24 and 30 days after treatment (DAT) increased with application rate, but by 38 DAT injury was greater than in the non-treated control only at the highest application rate. Potato tuber size distribution was variable and total yield did not differ among treatments and the non-treated control. In snap beans, injury from dicamba 7 DAT ranged from 19% at the low application rate to 45% at the high application rate. By 18 DAT, injury from 2,4-D was similar to the non-treated control. However, early-season injury delayed snap bean flowering and reduced crop yield compared to the non-treated control for all treatments except where the lowest rate of 2,4-D was applied. Snap bean injury from dicamba was greater than that from 2,4-D at all visual rating timings and crop yield was reduced compared to where 2,4-D was applied and the non-treated control.

It is important to note that the results presented are from a single season; this study will be repeated in 2012 and differences between years may be observed given varying environmental conditions. While harvested crop quality was observed, this research did not attempt to quantify any potential herbicide residue in the raw product. Commercial acceptance of a potentially affected crop would likely rely not only on visual observations but also on pesticide residue testing relative to domestic and international tolerances, if established.

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ADVANCING CARROT IPM – NEW TOOLS FOR NEMATODE AND LEAFHOPPER CONTROL

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Abstract. Insect and nematode management programs on processing and fresh market carrot crops in Wisconsin rely heavily on the use of frequent foliar applications of insecticides. Many of the pesticides used are broad spectrum chemicals that present considerable, well documented risks to the safety of farm workers and the environment including at-plant treatments of oxamyl and successive foliar applications of synthetic pyrethroids and protectant fungicides. This research attempts to refine and replace current practices, which rely on frequent foliar sprays of broad spectrum insecticides with an

economically viable system that relies on reduced-risk and carbamate-alternative insecticides applied as seed treatments or as in-furrow applications to minimize farm worker exposure to pesticides and mitigate adverse effects on human health, the environment, and non-target organisms. An outcome of this integrated research and extension program in Wisconsin is a management approach which can be tailored to meet the needs of a diversity of stakeholders representative of processing producers and an emerging potential market for a fresh, cut-n-peel segment. Compared to current IPM practices, these reduced-risk systems will increase the sustainability and thus the profitability of carrot production, enhance natural enemy populations and biological control, and reduce adverse effects on farm workers and applicators.

Background and Rationale. Because there is a moderate to low tolerance for insect and disease damage to carrot crops, growers often rely on frequent pre-plant and successive foliar applications of insecticides to manage the complement of nematode and insect pests plus foliar pathogens. The majority of insecticides now used on these crops are older, broad-spectrum insecticides that pose risks to farm worker safety and the environment (USDA-NASS Agricultural Chemical Use Database USDA-NASS 2007), and are subject to FQPA-related regulatory actions. The following problems are a brief summary of the targets of this project.

Figure 1. Adult aster leafhopper, *Macrosteles quadrilineatus*, Forbe

Aster Leafhopper & Aster Yellows Phytoplasma (AYp). The AYp pathogen is vectored primarily by the aster leafhopper (*Macrosteles quadrilineatus* Forbes, formerly *M. fascifrons* Stål) in a persistent and propagative manner (Fig. 1). The leafhopper acquires AYp by feeding on infected plants and may carry and transmit AYp over great distances. A defining feature of the aster leafhopper's biology is the early season migration of the insect from the Gulf-states to Upper Midwest. This early season migratory behavior has been reported to influence the potential for aster yellows epidemics in the upper Midwest regions of the United States (Chiykowski and Chapman 1965). And presumably, the first AYp to enter carrot in Wisconsin is vectored by these adult female leafhoppers reportedly migrating from grain crops in the southern U.S. Long-distance migrants begin to arrive in Wisconsin in late April to mid-May as carrot and small grain cover crops are germinating. Aster yellows disease is caused by the AYp, which is a small prokaryote that is taxonomically placed in the provisional genus, *Candidatus*. As noted previously, this organism is obligately associated with its plant and insect host(s) and has not been successfully cultured in the laboratory to date (which has slowed research progress due to the inability to obtain a "pure" culture). The symptoms caused by AYp are as varying as the number of plant species infected by AYp, but the most common disease phenotypes include vein clearing, chlorosis, stunting, and twisting of the stems and leaves, proliferation of stems and the development of adventitious roots (Fig. 2). These symptoms lead to direct yield and quality losses and processing problems which results from malformed roots challenges associated with cleaning raw product. Currently, the decision to intercede and implement a pest control practice (e.g. insecticide spray) is based upon calculation of the Aster Yellows Index (AYI). Control practices strictly utilize insecticide sprays (primarily Group 3 synthetic pyrethroids, IRAC, Mode-of Action Classification http://www.irac-online.org/) that target not only the aster leafhopper, but will impact all other beneficial insects present in the crop. The synthetic pyrethroids are a class of chemicals that have been introduced over the past three decades for a variety of insecticidal uses including both agricultural and domestic applications. These materials currently comprise the backbone of low-cost registrations which are relied upon for use against the aster leafhopper in support of the AYI. The synthetic pyrethroids were conditionally registered beginning in 1984 for use on selected crops and currently, EPA is assessing risks to non-target organisms. Several of these synthetic pyrethroids remain conditionally registered for use on vegetables grown in muck soils, however, each of these chemicals is highly lipophilic and in aquatic environments tend to strongly adsorb to sediments. Under section 4 of the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), US EPA continues to re-evaluate existing pesticides to ensure that they meet current scientific and regulatory standards. These compounds are broadly characterized as having a wide spectrum of activity often with acute oral neurotoxicity to mammals, notable chronic effects as endocrine disruptors, and are classified as both mutagenic and carcinogenic. With the advent of novel, reduced risk, and less broad spectrum seed treatment registrations for many homopterous, sucking insect pests (e.g. thiamethoxam), the continued RED eligibility of this important class of insecticides could be in jeopardy.

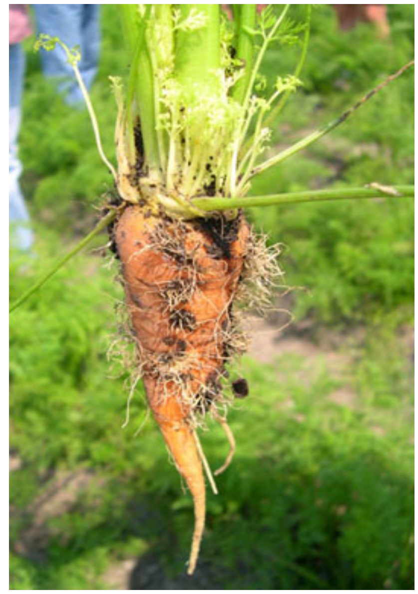

Figure 2. Symptoms of aster yellows phytoplasma in carrot illustrating 'witches-brooming' in foliage and epicormic branching in the roots.

Root-Knot Nematode. Root-knot nematodes (*Meloidogyne* spp.) are major pathogens of vegetables throughout the United States and the world, and particularly in carrot production in the upper Midwest where they impact both the quantity and quality of marketable yields. In addition, root-knot nematodes interact with other plant pathogens, resulting in increased damage caused by other diseases including the foliar pathogens. Only the northern root-knot nematode (NRKN; *Meloidogyne hapla)* has been documented in carrot grown on organic or mineral soil in Wisconsin, as it is able to survive the extreme low temperatures during winter. The NRKN has a wide host range consisting of more than 500 crop and non-

Figure 3. Root knot nematode on carrot (*Meloidogyne* spp.) NCSU, Dept. of Plant Pathology)

crop weed species, including weeds common to both muck and mineral soils. The increasing occurrence and damage of this nematode to carrots grown on muck and mineral soils in Wisconsin has been so severe in certain circumstances to cause marketable yield losses of carrots reduced by as much as 45% in commercial fields and even complete rejection of whole loads. Above-ground symptoms on carrots heavily infected with M. *hapla* include general stunting, delayed maturity, and a patchy and uneven stand. Roots of severely infected carrots exhibit forking, galls, hairiness, and even stubby roots as typical symptoms (Fig. 3). Adversely affected root systems of carrots heavily infected by *M. hapla* are also not efficient in the uptake of water and nutrients that are necessary for normal plant growth leading to susceptibility to other foliar pathogens including Alternaria leaf blight (ALB) caused by *Alternaria dauci* and Cercospora leaf spot (CLS) caused by *Cercospora carotae*, as well as infestation by phytophagous insects including the aster leafhopper.

The NRKN are obligate endoparasites that complete most of their life cycle within their host roots and survive in soil as eggs and also second stage larvae. The infective second stage juveniles' hatch from the eggs and move through the soil in search of roots of suitable host plants. Juveniles usually penetrate host roots just behind the root tip region and establish their special permanent feeding sites (giant cells) in the vascular tissues during early root development, often in the first 2-3 weeks of stand establishment. Control of the nematode can be accomplished through the rotation of cover crops grown between the main crops including rye, barley, oats, and wheat as these have been shown to be non- or poor hosts to this nematode. Rotating carrot with a non-host crop such as sweet corn and other grain crops, if economically possible, can be effective in reducing damage levels of NRKN, however current crop rotations on many commercial farms are of limited value as most crops grown, including potatoes, snap beans, onion, and carrot are susceptible. Effective and economical control is most often achieved with the use of pre-plant nonfumigant-type nematicides including oxamyl (Vydate® L); the primary pesticide tool registered for use in Wisconsin. Oxamyl is a carbamate used to control insects, mites, and nematodes first registered in 1974 by DuPont, Inc. Initial registered application methods included ground, foliar spray, soil spray, soil drench, root dip, preplant incorporated, or transplant water. In recent years, the registrant has undertaken a number of voluntary actions to reduce exposures human and environmental exposures to include the deletion of specific uses (ornamentals, greenhouse, and soil mixing uses), lowered application rates, and established seasonal maximums, restricted entry intervals, and extended pre-harvest intervals. <u>The potential for new, reduced risk, and less broad spectrum seed treatment registrations targeting the NRKN (e.g. abamectin), increasingly provides pest management alternatives for long term control of nematode pests and resulting infection.</u>

Project Purpose. Protection of young seedlings against plant parasitic nematodes and vectors of plant disease is a major concern in carrot production. In Wisconsin, protection against the northern root-knot nematode (NRKN) is of great significance often because of their wide-spread distribution in carrot production fields and their low threshold for causing economic damage. Injury to the growing carrot root tip by the nematode's parasitic activity causes forking and stubbing, in particular during the first few weeks after seed germination. While soil fumigants typically provide excellent efficacy against soil-borne pathogens, the use of soil pesticides in Wisconsin, and other locales, is likely to decline because of regulatory pressure to limit potential air quality and non-target exposure problems. These issues will further foster efforts to develop nematode resistant carrot cultivars as well as new seed treatments that deliver small amounts of nematicides to the target root zone. The low application rates associated with seed treatments are likely to result in reduced risk for the user and environment as well as increased production efficacy.

Currently several agrochemical companies are developing combinations of their plant protection products to provide seed treatments with a wide spectrum of activity against pests and diseases. Recent greenhouse trials with a development product of Syngenta Crop Protection has indicated that carrot seed treatments containing the nematicide, 'abamectin' will provide very useful protection against the early attack of NRKN. The treatments increased carrot stand in heavily root-knot nematode-infested sandy loam and typically reduced root galling by two rating classes. Abamectin, a natural fermentation product of the bacterium *Streptomyces avermectinius,* has been known since the mid-1970s for its insecticidal and antihelmintic activity, but it has never been registered as a soil-applied nematicide. However, branded as Avicta®, it has been registered in the U.S. since 2006 as a cotton seed treatment with activity against plant parasitic nematodes. More recently it received U.S. EPA registration in several vegetables as well as corn. While nematicidal seed treatments do not provide comparable efficacy to fumigants, they might be useful in combination with other nematode management tactics and as a replacement for the carbamate oxamyl (Vydate).

Potential Impact. The goal of the National IPM Program outlined in the National Road Map for IPM (www.ipmcenters.org/Docs/IPMRoadMap.pdf) is to improve the economic benefits of adopting IPM and to reduce potential risks to human health and the environment. Current IPM practices for carrots and many other vegetable crops rely extensively on frequent foliar sprays of older, broad spectrum insecticides including oxamyl (Vydate®)and synthetic pyrethroids (Asana®, Permethrin®, etc.). Although successful from the perspective of managing insect pests in a cost-effective manner, this approach presents considerable, well documented risks to the safety of farm workers and the environment. We propose to refine and implement a pest management program based on reduced risk insecticides and an application technology that: 1) minimizes farm worker exposure to high-risk pesticides and newer RR insecticides, 2) reduces environmental risks by utilizing insecticides with a more friendly environmental profile on an as needed basis to reduce or eliminate drift and run-off into water resources; and 3) creates incentives for adoption by the grower community by documenting enhanced profitability. The project encompasses the leading vegetable producing region in the state where issues concerning water quantity and now water quality are emerging as real and important issues. The multidisciplinary cooperation of research and extension specialists in applied vegetable pest management and program evaluation will enable these reduced risk IPM programs to be evaluated and refined to meet the needs of carrot producers in Wisconsin and potentially throughout much of the carrot producing regions of the upper Midwest and California. Specifically, this project addresses 3 of the 8 research needs

identified in the Road Map for IPM: (1) development of advanced management tactics for specific settings, (2) improved efficiency of suppression and demonstration of cost effectiveness, and (3) development and implementation of new delivery methods to expand options for IPM implementation. This project will train graduate students in pest management and evaluation that will contribute to future advances in IPM. The extension component includes diverse strategies to maximize grower adoption of reduced-risk programs and enhance public awareness of advances in mitigating adverse effects of pest management on human health and the environment. Given the uncertainty of the Group 1 (carbamate) and Group 3 (synthetic pyrethroid) insecticides and future re-registration eligibility decisions from EPA, the outcomes of this research are critical for documenting alternative strategies to control key insect pests in carrot crops.
crop destruction associated with experimental treatments.

IRRIGATION FOR VEGETABLE CROPS IN CENTRAL WISCONSIN

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AGROTERRORISM: WHAT WE NEED TO BE LOOKING FOR

Joseph Spang [1/]

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FIFTY YEARS OF CONTINUOUS CORN: EFFECTS ON SOIL FERTILITY

Matt Ruark, Larry Bundy, Todd Andraski, Art Peterson [1/]

Introduction

Long-term experiments provide an opportunity to evaluate the sustainability of agricultural practices (Jenkinson, 1991). Evidence of sustainability in continuous corn production systems would include stable or increasing productivity over time as indicated by crop yields and maintenance or enhancement of key soil fertility factors such as soil organic matter content. The objectives of this paper are to present results from a 50-yr experiment showing the effects of long-term continuous corn and N-fertilizer use on corn yields, response to applied N and lime treatments, and effects of the long-term treatments on soil organic matter content and soil pH.

Materials and Methods

This long-term continuous corn experiment is located at the Arlington Research Station (43°18'N; 89°21'W), approximately 42 km north of Madison, WI. The soil at the site is a Plano silt loam (fine-silty, mixed mesic, Typic Argiudolls) developed under prairie vegetation in loess deposits over glacial till (Vanotti and Bundy, 1996). The site has 0 to 1% slope and low soil erosion potential. Initial treatments consisted of three N rates (applied as ammonium nitrate) arranged in a randomized complete block design with four replications (Andrew et al., 1963). Subsequent N and lime treatments were incorporated into the experimental design using a split-plot treatment combination (Motavalli et al., 1992). Nitrogen was applied as anhydrous ammonia from 1963-1984 and from 1993-2007. Nitrogen rates changed over time (Table 1), and during 1984 to 1992, each long-term N treatment received N rates of 0, 84, 168, and 252 kg N ha^{-1} as urea to study the residual effects of the original N treatments on N availability to corn (Motavalli et al., 1992). During this period, data for the medium LTN rate were taken from the 168 kg N ha^{-1} treatment and data for the high LTN rate were taken from the 252 kg N ha^{-1} treatment. In 1985, one-half of each long-term N plot was limed to raise the pH to 6.5-7.0. An additional lime application was made in 1988 to achieve the desired pH range. Dolomitic limestone with a neutralizing index value of 80-89 was used for the lime applications.

Corn was grown in the experimental area each year since 1958 using adapted hybrids and recommended pest management methods. At corn planting, starter fertilizer was applied each year as a band 5 cm below and 5 cm to one side of the seed. The average (1958- 2007) annual rate of nutrients applied in starter fertilizer was 10, 19, and 37 kg ha^{-1} of N, P, and K, respectively.

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Broadcast applications of K fertilizer [as 0-0-60 ($N-P_2O_5-K_2O$)] were made to the entire experiment at a rate of 112 kg K ha^{-1} in both 1987 and 1991. Since 1984, corn was grown in 76-cm rows with seeding rates of 79,000 to 86,000 seeds ha^{-1}. The hybrids used were selected from those that performed well in the Wisconsin Corn Hybrid Trials conducted at the Arlington Research Station (see Lauer, 2010). Hybrids and soil insecticides used since 1986 are listed in Table 2. Hybrids with transgenic traits have been used since 1999. Corn was harvested for grain each year and all residues were incorporated into the soil by moldboard plowing in the spring (1958-1983) or fall (1984-2007). Although chisel plowing currently is the typical tillage practice for corn production in the region, moldboard plowing was the prevailing tillage method when the experiment was initiated in 1958, and this tillage was continued through 2007 to maintain cultural practice continuity throughout the long-term study. Grain yields are reported at a moisture content of 155 g kg^{-1}.

Initial (1958) soil test levels in the experimental area were: pH 6.5 to 7.0; available P 15 to 25 mg kg^{-1}; exchangeable K 80 to 95 mg kg^{-1}; and organic matter 30 to 35 g kg^{-1} (Andrew et al., 1963). Soil samples (0 to 15 cm) were collected periodically during the course of the experiment and were analyzed for available P, exchangeable K, pH, and organic matter (Kelling et al., 1991; Laboski et al., 2006). Soil samples (six to eight cores/plot) were obtained from four replications of each of the three LTN treatments. After lime treatments were applied in 1985, soil samples were taken from both lime treatments. Before 1991, soil organic matter was determined using the colorimetric chromic acid oxidation procedure described by Combs and Nathan (1998). Organic matter in soil samples collected in 1991 and subsequent years was measured using the loss of weight on ignition method (Combs and Nathan, 1998; Schulte et al., 1991). From 1984 to 2005, soil tests averaged 58 mg kg^{-1} for P and 140 mg kg^{-1} for K. These soil test results for P and K confirmed that levels of these nutrients equaled or exceeded the optimum levels recommended for corn production at the study site (Laboski et al., 2006).

Results and Discussion

At the medium and high LTN rates, yields increased during the 1958 to 1983 period (Fig. 1). Some of this increase could be due to the increase in the LTN rates during this time period. From 1984 through 2007, medium and high LTN rates significantly increased corn yields every year compared to the control LTN rate (Fig. 1). When the data was combined over years, yields were significantly increased ($p<0.01$) by LTN additions, but were not significantly different between the medium and high LTN rate treatments. Yields at both medium and high LTN rates increased dramatically (100%) over time with little difference between the two rates (Fig.1). For the 50-yr period (1958-2007), yields in the medium and high LTN treatments increased linearly by about 150 kg ha^{-1} yr^{-1} while yields in the control LTN treatment have remained relatively constant over time. After 1985, data shown in Fig.1 are from the with lime treatment. A similar pattern of increasing yields over time occurred when data from the without lime treatment were analyzed separately. The annual yield increase over the 50-yr period for the un-limed treatment was 142 kg ha^{-1} yr^{-1} for the medium LTN rate and 124 kg ha^{-1} yr^{-1} for the high LTN treatment.

A major source of this yield gain is likely the genetic improvement of corn hybrids. Several studies comparing the simultaneous yield performance of corn cultivars from various eras from 1930 to present (Hallauer et al., 1988) show that newer hybrids have consistently greater yields likely due to improve-ments in genetic potential and adaptation to improved cultural practices (Castleberry et al., 1984; Duvick, 1984; Lauer et al., 2001). In some of these studies, much of the yield gain is attributed to genetic improvements in the modern hybrids. Lauer et al. (2001) showed that since 1930, corn forage and stover yields increased by 1.4 and 0.7% yr^{-1}, respectively while ear yields increased by 2.4% yr^{-1}. In our experiment, hybrid genetic improvement undoubtedly contributed to the observed yield gain at the medium and high LTN rates by enhancing apparent NUE and by increasing resistance to stresses such as greater plant density and unfavorable climatic conditions (Fig. 1). The relatively stable yields over time in the control LTN (0 kg N ha^{-1}) treatment suggest that hybrid genetic improvement alone does not account for the long-term yield gain. Improved management techniques such as appropriate fertilizer additions, increased plant densities (consistent with increasing hybrid tolerance), effective pest control techniques, optimum planting dates, and selection of improved hybrids over the course of the experiment were also probable contributors to yield gain.

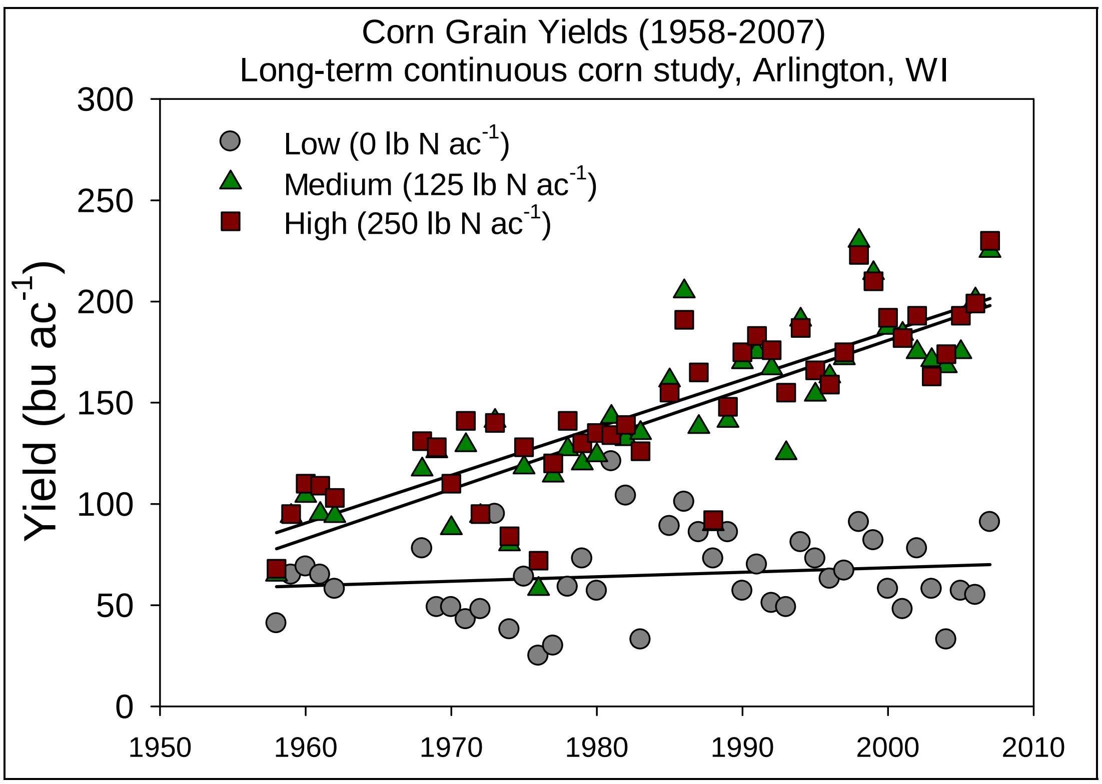

Figure 1. Corn yields from 1958 to 2007 with 0, 125, and 250 lb a^{-1} of N.

Soil organic matter concentration measured by routine soil test methods varied substantially among years during the 1963 to 2005 period (Fig. 2) likely due to variability in repeated soil sampling and laboratory analysis. Overall, the data indicate that soil organic matter concentrations in the 0- to 15-cm depth were maintained during the 50 yr of continuous corn production and LTN applications. Soil organic matter measurements were limited to the 0-15 cm soil depth. However, research by Jenkinson et al. (2008) and Syswerda et al. (2011) suggests that surface soil sampling may be adequate for assessing management practice effects on soil C. In our study, soil organic matter levels were not significantly affected by LTN treatments in 1984 or 1991, but soil organic matter was significantly higher at the medium and high LTN rates compared to the control LTN treatment in 1995 through 2005. Lime treatments did not affect soil organic matter levels, and there were no N by lime treatment interactions.

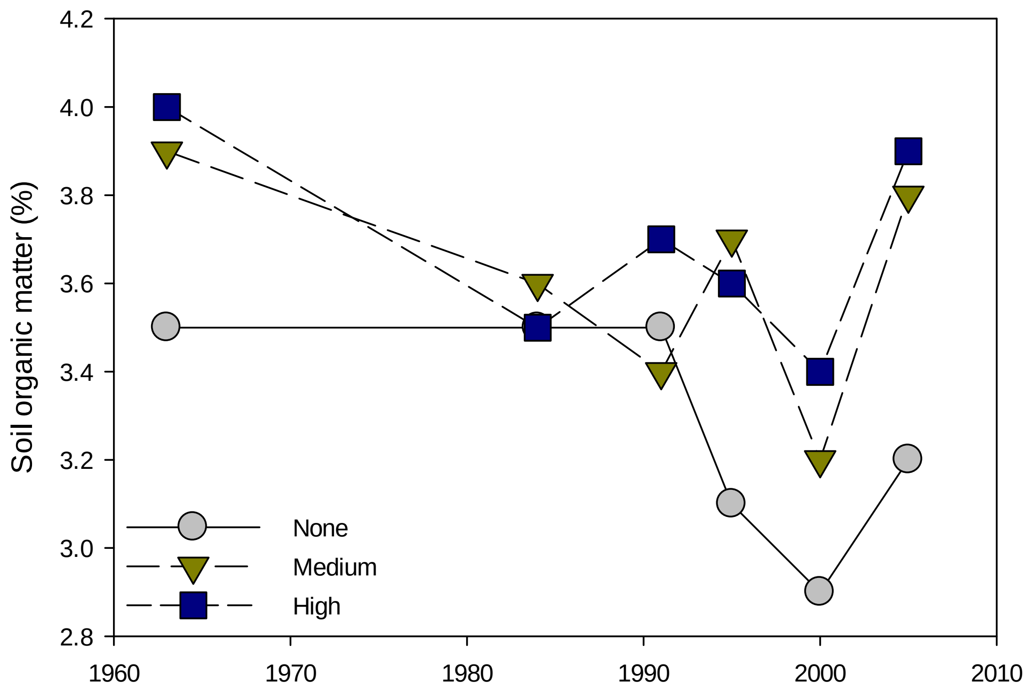

Figure 2. Soil organic matter concentrations measured between 1962 and 2005.

As expected, soil pH declined with long-term N additions due to acidity formed during nitrification of ammonium-N, and the drop in pH values was greatest in the high LTN treatment (Fig. 3). Once lime treatments were applied in 1985, soil pH in the limed plots increased while pH values in the un-limed plots remained relatively constant. Lime additions significantly increased average corn yields by 0.54 Mg ha^{-1}. There was no significant interaction between N and lime treatments on yield. In individual years, lime addition significantly ($p < 0.10$) increased corn yields in 14 of 23 years since 1985. In these years, the N by lime interaction was significant ($p < 0.10$) in only four of the 14 years suggesting that lime and N treatments usually influence yield independently. Overall, these results emphasize the importance of lime applications as part of sustainable agricultural practices, especially in high-yielding grain production systems receiving substantial N inputs.

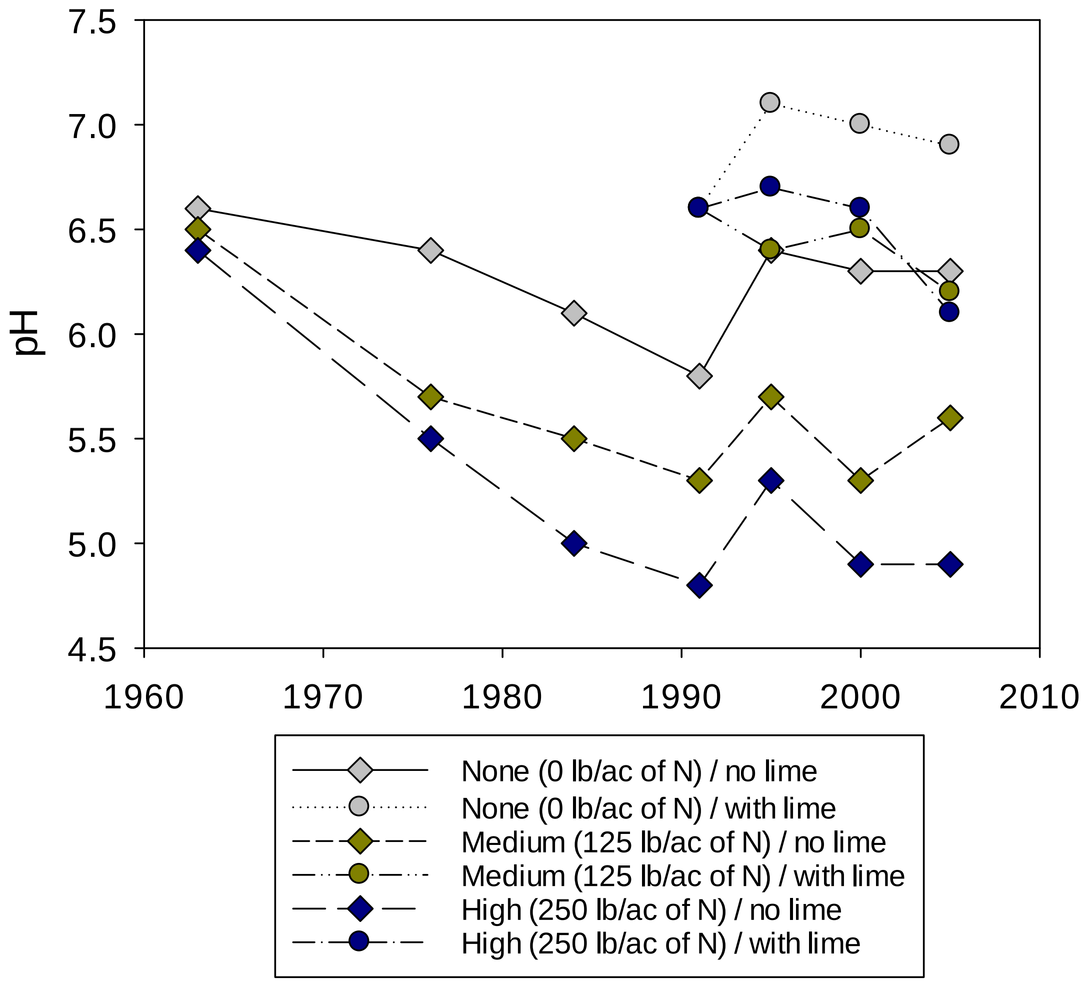

Figure 3. pH levels measured between 1962 and 2005

Conclusions

Continuous corn yields with N fertilizer additions increased dramatically (100 %) during the 50-yr experiment with much of the yield gain likely due to genetic improvements of the corn hybrids used and improved management practices. Highest yields were obtained in the most recent years of the experiment, and did not require greater fertilizer N applications indicating an apparent improvement in corn N use efficiency. Soil organic matter levels were maintained or increased in the medium and high LTN treatments, providing evidence that long-term N fertilizer additions do not inherently reduce soil organic matter. Without lime addition, soil pH declined in the N fertilizer treatments and liming increased corn yields in most years. Lime and N treatments usually influenced yield independently and both inputs are required to maintain the sustainability of this cropping system. Results from this long-term study demonstrate the value of improved corn hybrids, appropriate N application rates, and use of liming materials for the long-term agronomic sustainability of continuous corn cropping systems in the northern Corn Belt. No evidence of a decline in productivity from long-term corn monoculture or N fertilizer use was detected when lime applications were used to maintain soil pH levels.

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NUTRIENT MANAGEMENT REGULATORY PANEL

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{This page provided for notes}

[1/] Wis. Dept. of Agriculture, Trade & Consumer Protection, Natural Resources Conservation Service, and Wis. Dept. of Natural Resources, respectively.

MAKING NMP WORK: A CONSULTANT'S PERSPECTIVE

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{This page provided for notes}

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GOSS'S WILT: WHAT'S ALL THE HULLABALOO?

Carl A. Bradley[1]

Introduction

Goss's wilt, caused by the bacterium *Clavibacter michiganensis* subsp. *nebraskensis*, has made a resurgence through Midwestern corn fields recently. In affected fields, yields have been decreased, and many are scratching their heads on why this disease is making a reappearance in the Midwest.

Historical and Current Status

Originally named "leaf freckles and wilt", Goss's bacterial wilt of corn was first described in Nebraska in the 1970s (Wysong et al., 1973). The disease is caused by the bacterium *Clavibacter michiganensis* subsp. *nebraskensis*. During the 1970s and 1980s, Goss's wilt had been found identified in several Midwestern states, including Illinois and Wisconsin (Wysong et al., 1981).

Although Goss's wilt had been identified in states east of the Mississippi River in the 1980s, outbreaks of the disease in states like Illinois and Wisconsin have been sporadic to non-existent. Beginning in the late 2000s, Goss's wilt was beginning to re-appear in some Midwestern states such as Illinois and Indiana (Ruhl et al., 2009). In 2011, the University of Illinois Plant Clinic confirmed Goss's wilt in thirty-one Illinois counties (Fig. 1). Outbreaks of Goss's wilt also were severe in Iowa in 2011 (A. Robertson, personal communication). The recent resurgence of Goss's wilt in the Midwest is related to at least one factor of the "disease triangle". The disease triangle consists of the pathogen, the host, and the environment. More data are needed to better understand specifically which of the factors of the disease triangle are related to the recent outbreaks.

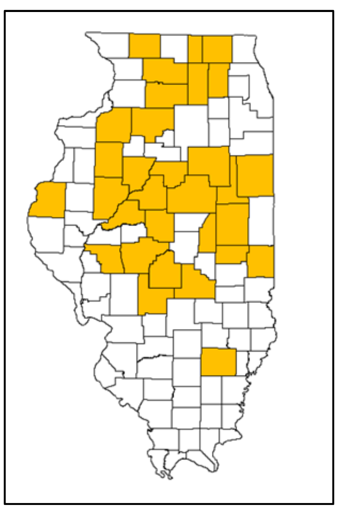

Fig. 1. Counties in Illinois with confirmed cases of Goss's wilt in 2011 (Source: University of Illinois Plant Clinic).

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Symptoms

Leaf symptoms of Goss's wilt appear as large tan to gray lesions with dark spots, often referred to as "freckles", within the lesions. Edges of lesions may appear "water-soaked", and bacterial exudates may be visible on the surface of affected leaf areas, giving the lesions a shiny appearance (Fig. 2). In severe cases, bacteria may become systemic, enter the xylem, and cause wilting. Because wounds on the plant tissue must be present for the Goss's wilt bacterium to cause infection, fields that have been subjected to hail, high winds, and heavy rainfall are more likely to be affected.

Fig 2. Symptoms of Goss's wilt on a corn leaf.

Management

No in-season control options are available to protect against Goss's wilt or to reduce the spread of disease within a field. The primary management methods are planting corn hybrids with higher levels of resistance to Goss's wilt, rotating to non-host crops, and tilling to bury and speed up the decomposition of affected residue.

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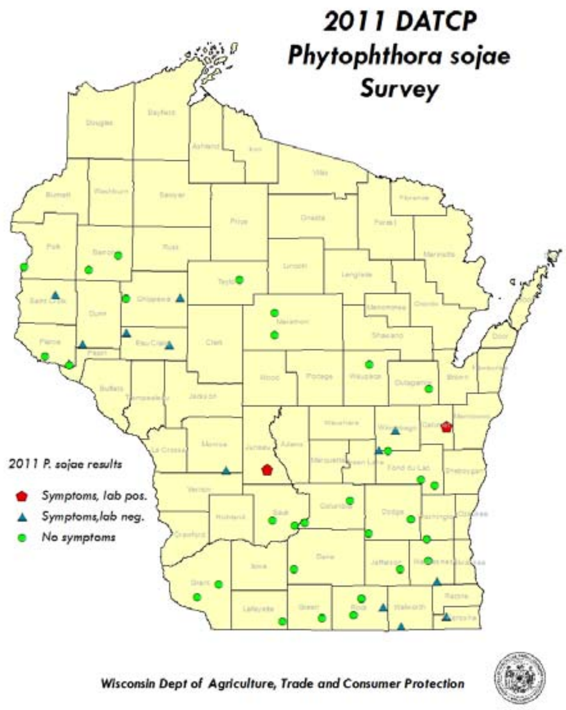
2011 DATCP WISCONSIN CROP DISEASE SURVEY

Adrian Barta[1], Anette Phibbs and Sue Lueloff[2]

The Pest Survey Program of the Wisconsin Department of Agriculture, Trade and Consumer Protection conducts monitoring and detection surveys for targeted exotic and key endemic agricultural and wildland plant pests. For more information on programs and results, please visit http://pestsurvey.wi.gov/

Phytophthora root rot of seedling soybeans

2011 was the fourth consecutive year in which the DATCP Pest Survey team conducted a statewide survey for Phytophthora root rot of soybeans (caused by *Phytophthora sojae*). From June 16 to July 9th, 50 randomly selected soybean fields in early vegetative stages were visited throughout Wisconsin. While fields were selected randomly, surveyors chose seedlings from areas within each field that showed stunting or wilt symptoms. Symptomatic seedlings were carefully dug up and transported to DATCP's Plant Industry Laboratory for testing. Symptomatic plants were observed in only 15 of the 50 fields visited.



Seedling roots were tested for the presence of the root rot pathogen *Phytophthora sojae* by molecular testing (PCR, polymerase chain reaction) of DNA extracted from root tissue. Testing showed 2 of 15 samples tested positive for *P. sojae*.

Phytophtora sansomeana, a species recently detected on soybeans and corn in the Midwest, was not found during this survey.

Preliminary work (still in progress as of press date) indicates that a majority of samples collected from symptomatic material are positive for *Pythium* sp. Further results will be posted at **pestsurvey.wi.gov** as they become available.

P. sojae infected fields has historically been found in all soybean growing regions of the state. More information on soybean plant health and root rot caused by *P. sojae* can be found at this University of Wisconsin website: http://www.plantpath.wisc.edu/soyhealth/prr.htm.

Foliar Diseases of Winter Wheat

Between May 6 and June 28, 42 wheat fields in 10 central and north-central Wisconsin counties were surveyed for disease presence. Wheat fields ranged in maturity from Feekes Stage 5 (leaf sheath strongly erected) to Feekes 10.5.3 (flowering complete to base of spike). Powdery mildew

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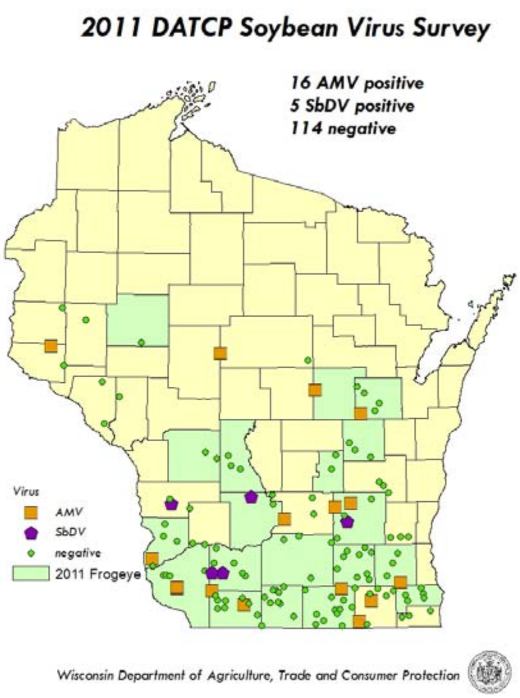
(*Blumeria graminis)* was the most commonly observed disease, detected in 22 fields. Symptoms of tan spot (caused by *Pyrenophora tritici-repentis)* was found in 6 fields; Fusarium head blight was detected in one field and loose smut (*Ustilago tritici*) was observed in one field. Trace levels of leaf rust (*Puccinia triticina*) were found in five fields. No stem rust (*P. graminis*) or stripe rust (*P. striiformis)* were detected in this survey period.

One significant find in the survey was the first laboratory-confirmed case of Cephalosporium stripe (causal agent *Cephalosporium gramineum*) on wheat in Wisconsin. A sample collected on May 24 from a field in Rock County showed distinctive symptoms of Cephalosporium stripe. Isolates from samples from the positive field were conclusively identified by the Plant Industry Laboratory through DNA sequencing. Morphological features were confirmed by the UW Plant Disease Diagnostic Clinic and by the USDA National Mycologist. Symptoms were found in only one field of 42 surveyed. Examinations of the field history and management practices provided no illumination on the origin or causes of this disease emergence. According to Dr. Craig Grau of the UW-Madison (emeritus), infections have been occasionally suspected over the years but never confirmed. Follow-up surveys in the area are planned for 2012.

Stripe rust was identified from two barberry cultivars being offered for sale in Wisconsin nurseries. Barberry cultivars must be tested and determined to be resistant to stem rust (*Puccinia graminis*) to be legal for trade in the Midwest. The two cultivars which showed signs of infection, 'Emerald Carousel' and 'Golden Carousel', had been tested by the USDA Cereal Disease Laboratory and were on the approved list. Upon investigation by the Plant Industry Laboratory and consultation with the CDL, it was determined through DNA sequencing that the aecia observed were of *P. striiformis*, the causal agent of stripe rust, not the regulated *P. graminis*, the causal agent of stem rust. While stripe rust is not a regulated organism, the presence of *P. striiformis*-susceptible barberry in the state may pose some of the same concerns as with *P. graminis*.

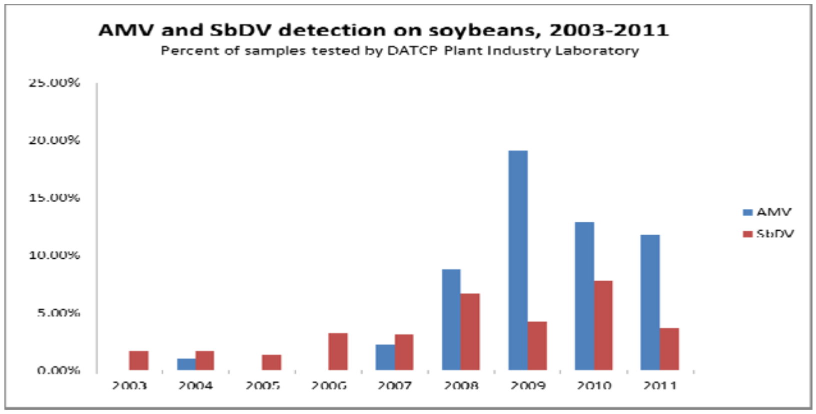


Soybean virus survey

Leaf samples were collected from 135 soybean fields between July 27th and September 30th (targeted at R3 or later) for laboratory virus testing. Target viruses were alfalfa mosaic virus (AMV) and soybean dwarf virus (SbDV), a potential emerging disease of soybean. Laboratory analysis was conducted using reverse-transcription polymerase chain reaction (RT-PCR).

Of the 135 samples collected, 16 were determined to be positive for AMV, and five samples were positive for SbDV. The latter virus was first detected in Wisconsin in 2003, and is of concern because it is aphid-vectored. Both research and real-world experience suggest that the soybean aphid (*Aphis glycines*) is an inefficient vector of the virus, but large aphid populations could result in significant SbDV impact on soybean yield.

For the second consecutive year, field observations of symptoms of frogeye leaf spot, caused by *Cercospora sojina*, were well above historical norms. Symptoms of frogeye leaf spot were observed in 40 of 135 fields, in 19 Wisconsin counties.

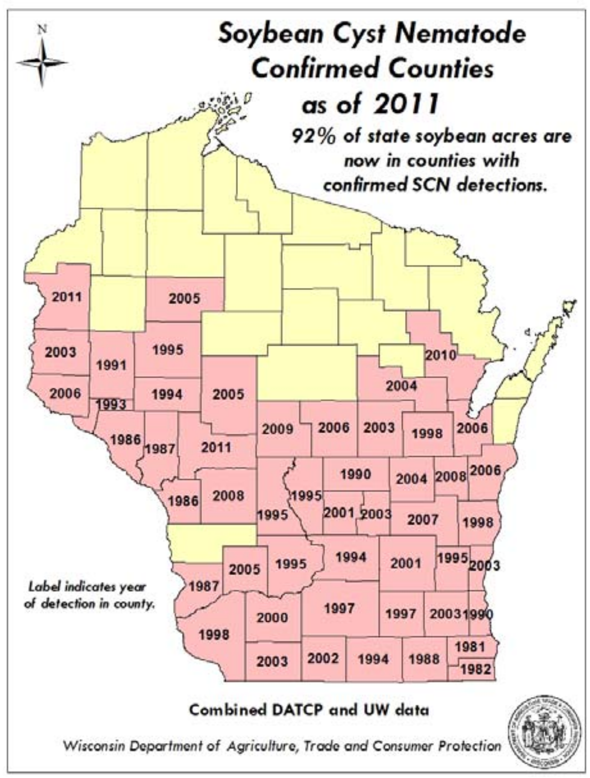


Seed Corn Survey

A total of 58 corn samples from 271 acres of seed plots in seven counties (Adams Columbia, Dane, Eau Claire, La Crosse, Rock and Sauk) were tested to meet export requirements. Stewart's wilt (caused by *Pantoea stewartii*) was not detected in any sample. Twenty out of 58 samples (34%) tested positive for Goss's wilt (*Clavibacter michiganensis* pv. *nebraskensis*). This is the second consecutive year that high levels of Goss's wilt have been detected in corn in Wisconsin and throughout the Midwest. In 2011 Goss's wilt was found in Columbia, Dane, Eau Claire, La Crosse and Rock Counties.

Soybean cyst nematode survey

Soil sampling in 2011 led to the detection of soybean cyst nematode (*Heterodera glycines*) in Jackson and Polk counties, bringing the number of Wisconsin counties where the nematode is known to occur to 55, comprising 92% of the soybean acreage in the state. Soybean growers in any part of the state are strongly urged to test fields for the presence of soybean cyst nematode.



FUNGICIDE RESISTANCE: IT'S REAL!

Carl A. Bradley[1]

Introduction

Beginning in the mid-2000s the use of foliar fungicides in field crops such as corn and soybean has increased dramatically. In 2007, approximately 20% of the corn grown in the Midwest was sprayed with a foliar fungicide (Munkvold et al., 2008), and this percentage has remained steady with perhaps some slight increase. In some cases, fungicides are applied solely for hopes of a yield benefit with no regard to disease risk (Bradley and Ames, 2010). With high commodity prices, this non-IPM use of foliar fungicides may increase, which increases the risk of fungicide resistance.

Fungicide Resistance

Fungicide resistance is a function of two factors – the selection pressure applied by the fungicide and the genetic variability within the pathogen population. The magnitude of the selection pressure applied by the fungicide depends on the frequency of application as well as some inherent properties of fungicide active ingredients. The quinone outside inhibitor (QoI) fungicides (also referred to as strobilurins) are the most popular group of fungicides applied to corn and soybean fields in the Midwest. Because the QoI fungicides have a single inhibitory mode of action on fungi, a high risk of selecting individuals in the targeted fungal population with reduced sensitivity (resistance) to QoI fungicide exist. Every time a fungicide is applied, a selection pressure is applied to the targeted fungal population (even if applications are made only once per year). In pathogens that have a high level of genetic variability, even a once-per-season selection pressure may be enough for fungicide resistance to develop.

Case Example – Frogeye Leaf Spot

Frogeye leaf spot of soybean, caused by the fungus *Cercospora sojina*, is a disease that had been controlled quite well with QoI fungicides. However in 2010, *C. sojina* isolates were identified in Tennessee that were resistant to QoI fungicides (Zhang et al., 2012). Additional *C. sojina* isolates from soybean fields in Illinois, Kentucky, and Missouri also have since been identified (Table 1). These isolates are highly resistant to QoI fungicides, and even if use-rates are tripled, QoI fungicide products cannot control these isolates.

Recent research at the University of Illinois was initiated to identify fungicides other than QoIs that could control these QoI fungicide-resistant strains of *C. sojina*. Results of this research indicated that fungicides in the triazole group as well as thiophanate methyl (a benzimidazole fungicide) were effective in controlling the QoI fungicide-resistant strains.

In light of the discovery of QoI fungicide-resistant strains of *C. sojina* as well as the results of research focused on controlling these strains, the following recommendations have been developed:

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- Only apply a foliar fungicide when necessary, based on disease observations and risk.
- Utilize integrated management strategies when controlling diseases such as frogeye leaf spot that combine strategies such as resistant varieties, tillage, and crop rotation along with fungicides.
- If a fungicide will be used, consider applying a fungicide that contains effective active ingredients with different modes of action or tank-mixing effective fungicides with different modes of action.

Table 1. Locations of confirmed strobilurin fungicide-resistant strains of *Cercospora sojina*.

State	County	Year(s) resistance identified
Illinois	Gallatin	2010, 2011
	Pope	2010, 2011
Kentucky	Caldwell	2010 (no samples from 2011)
	Calloway	2011
	Carlisle	2011
	Hickman	2011
	Livingston	2011
	Marshall	2011
Missouri	Pemiscot	2011
Tennessee	Dyer	2011
	Gibson	2010, 2011
	Lauderdale	2010, 2011
	Lawrence	2011

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2011 UNIVERSITY OF WISCONSIN and UW-EXTENSION CORN FOLIAR FUNGICIDE RESEARCH: RESULTS FOR V5 AND 41 APPICATION TIMINGS

Paul Esker[1/], Mike Ballweg[2/], Jerry Clark[2/], Bill Halfman[2/], Richard Halopka[2/], Matt Hanson[2/], Steve Huntzicker[2/], Richard Proost[3/], and Bryan Jensen[3/]

Introduction

Since 2007, members of the University of Wisconsin and UW-Extension have conducted on-farm corn foliar fungicide research in the state. Results from these trials have indicated that there has not been an economic advantage from using these products; however, continued high corn commodity prices have led producers to continue to ask questions about the use of foliar fungicides for corn. In particular, ques-tions have expanded to include applications of foliar fungicides at the V5 stage of development. Because insufficient data is lacking in Wisconsin to compare applications made at V5 with those made at R1, on-farm research trials were conducted in 2011 around the state using both large strip and small plot methods.

Plot design

Large scale trials were conducted in Chippewa, Clark, Dodge (two trials), and Washington counties. The experimental design was a randomized complete block and treatments were replicated three to four times and sized to fit within a grower's field. Fungicides were applied using either the grower's or custom applicator's equipment. The fungicide tested was Stratego YLD (Bayer Crop Science, Research Park Triangle, NC). The fungicide rate was either 2.5 fl oz/a (V5) or 5.0 fl oz/a (R1).

Small plot research trials were conducted in La Crosse and Monroe County (two trials). The experi-mental layout was a randomized complete block design with three replications. Plots measured 10 ft wide by 50 ft long. Fungicides tested included: Headline (BASF, Research Park Triangle, NC), Headline AMP (BASF), Quadris (Syngenta, Greensboro, NC), Quilt Xcel (Syngenta), and Stratego YLD (Bayer CropScience). The application rates and timings were: Headline (V5; 6 fl oz/a), Headline AMP (R1; 10 fl oz/a), Quadris (V5; 6 fl oz/a), Quilt Xcel (R1, 10.5 fl oz/a), Stratego YLD (V5, 2.5 fl oz/a), and Stratego YLD (R1, 5 fl oz/a).

Results

Yield was not significantly affected in 4 of the 8 plots. In the plots were yield was significantly affected, Streatego YLD sprayed at the V5 stage of corn development had a negative effect on yield in two locations (Dodge #1 and LaCrosse), but had a positive influence on yield at Monroe #1. Three treatments having significantly higher grain moisture at harvest than the Untreated Check (UTC) and include Headline AMP and Quilt both sprayed at R1 at the La Crosse location and Headline AMP sprayed

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[1/] Professor, Dept. of Plant Pathology, UW-Madison. [2/] UW-Extension Sheboygan, Clark, Monroe, Dodge, and LaCrosse counties, respectively. [3/] UW NPM Program.

at R1 at the Monroe #1 location. Test weight was not significantly affected at five locations. However, test weight was negatively influenced by Stratego YLD at the R1 timing in the Washington County plot. Also, V5 applications of Headline, Quadris and Stratego YLD negatively affected test weight at Monroe #2. Conversely Quilt significantly increased test weight at the Monroe #1 plot.

Stalk health ratings were not available for all plot, however, at the Monroe #1 plot, Quadris sprayed at v5 as well as Headine AMP and Stratego YLD (both sprayed at R1) significantly decreased stalk health ratings. Foliar disease pressure was low at all locations and there were no statistically difference at either V5 or R1 stages of development. At the pre-harvest assessment in Clark County both timings of Strategy YLD significantly decreased foliar diseases. Also, all R1 applications at La Crosse decreased disease severity. However, Stratego YLD sprayed at V5 significantly increased disease severity. Fungicides did not affect disease severity at the other locations.

Table 1. Results from large strip, on-farm trials in Wisconsin in 2011.

County	Treatment	Growth stage	Rate (fl oz/a)	Yield (bu/a)	Grain moisture (%)	Test weight (lb/bu)	Stalk rating (0-5)	Tassel death (n=30)	Disease severity V5 (%)	Disease severity R1 (%)	Disease severity R5 (%)
Chippewa	UTC	-	-	163 a[a]	16.3 ab	56.0 a	NA	1.3 a	5.0 a	8.3 a	8.3 a
	Stratego YLD	V5	2.5	161 a	16.3 b	56.7 a	NA	2.7 a	5.0 a	5.0 a	8.3 a
	Stratego YLD	R1	5.0	160 a	16.6 a	56.0 a	NA	3.0	5.0 a	6.7 a	8.3 a
Clark	UTC	-	-	176 a	21.3 a	51.7 a	0.33 a	NA	0 a	1.0 a	8.33 a
	Stratego YLD	V5	2.5	177 a	20.8 a	52.7 a	0 a	NA	0 a	0.67 a	4.33 b
	Stratego YLD	R1	5.0	171 a	21.3 a	52.4 a	0.33 a	NA	0 a	1.0 a	5.0 b
Dodge #1	UTC	-	-	236 a	18.8 a	NA[b]	0.5 a	0 a	0 a	1.0 a	2.8 ab
	Stratego YLD	V5	2.5	226 b	18.7 a	NA	0.5 a	0 a	0 a	1.0 a	3.2 a
	Stratego YLD	R1	5.0	240 a	18.5 a	NA	0.5 a	0 a	0 a	1.0 a	2.2 b
Dodge #2	UTC	-	-	219 a	21.4 a	55.0 a	0.5 a	0 a	0 a	1.0 a	3.0 a
	Stratego YLD	V5	2.5	215 a	21.1 a	55.0 a	0.5 a	0 a	0 a	1.0 a	3.0 a
	Stratego YLD	R1	5.0	218 a	21.1 a	55.0 a	0.5 a	0 a	0 a	1.0 a	3.0 a
Washington	UTC	-	-	164 a	19.7 a	55.6 a	0.0 a	0.20 a	1.0 a	1.0 a	2.0 a
	Stratego YLD	V5	2.5	166 a	19.6 a	55.7 a	0.0 a	0.05 a	1.0 a	1.0 a	1.0 a
	Stratego YLD	R1	5.0	153 b	19.8 a	54.9 b	0.25 a	0 a	1.0 a	1.0 a	2.0 a

[a] Means within a column for a given location that are followed by the same letter are not significantly different (P = 0.10, Duncan's New Multiple Range Test).
[b] NA = not available.

Table 2. Results from small plot, on-farm trials in Wisconsin in 2011.

County	Treatment	Growth stage	Rate (fl oz/a)	Yield (bu/a)	Grain moisture (%)	Test weight (lb/bu)	Stalk rating (0-5)	Disease severity V5 (%)	Disease severity R1 (%)	Disease severity R5 (%)
La Crosse	UTC	-	-	168 ab[a]	21.1 ab	54.0 a	0.4 a	0 a	0.5 a	10 b
	Headline	V5	6.0	155 c	20.7 b	54.3 a	0.4 a	0 a	0.5 a	10 b
	Headline AMP	R1	10.0	174 a	22.6 a	54.3 a	0.4 a	0 a	0.5 a	5 c
	Quadris	V5	6.0	162 bc	20.2 b	54.3 a	0.4 a	0 a	0.5 a	12 b
	Quilt Xcel	R1	10.5	163 abc	22.3 a	54.0 a	0.4 a	0 a	0.5 a	7 c
	Stratego YLD	V5	2.5	167 ab	19.9 b	54.3 a	0.4 a	0 a	0.5 a	15 a
	Stratego YLD	R1	5.0	171 ab	19.8 b	54.3 a	0.4 a	0 a	0.5 a	5 c
Monroe #1	UTC	-	-	136 b	21.4 b	53.7 b	1.6 a	0 a	0.5 a	1.0 a
	Headline	V5	6.0	152 ab	21.1 b	54.3 ab	1.2 ab	0 a	0.5 a	1.3 a
	Headline AMP	R1	10.0	150 ab	22.9 a	53.7 b	0.9 b	0 a	0.5 a	1.0 a
	Quadris	V5	6.0	145 ab	21.6 b	54.3 ab	0.8 b	0 a	0.5 a	1.3 a
	Quilt Xcel	R1	10.5	141 ab	21.9 b	55.0 a	1.3 ab	0 a	0.5 a	1.0 a
	Stratego YLD	V5	2.5	165 a	21.8 b	54.0 ab	1.2 ab	0 a	0.5 a	1.3 a
	Stratego YLD	R1	5.0	150 ab	21.4 b	54.0 ab	0.8 b	0 a	0.5 a	1.0 a
Monroe #2	UTC	-	-	140 a	21.8 b	54.3 a	0.7 a	0 a	0 a	1.0 a
	Headline	V5	6.0	132 a	22.6 ab	52.7 c	0.9 a	0 a	0 a	1.0 a
	Headline AMP	R1	10.0	130 a	21.9 b	54.0 ab	0.9 a	0 a	0 a	1.0 a
	Quadris	V5	6.0	124 a	23.3 ab	53.0 b	1.1 a	0 a	0 a	1.0 a
	Quilt Xcel	R1	10.5	135 a	23.5 ab	54.0 ab	0.9 a	0 a	0 a	1.0 a
	Stratego YLD	V5	2.5	124 a	24.4 a	53.0 bc	0.9 a	0 a	0 a	1.3 a
	Stratego YLD	R1	5.0	133 a	22.3 ab	54.3 a	0.7 a	0 a	0 a	1.0 a

[a] Means within a column for a given location that are followed by the same letter are not significantly different ($P = 0.10$, Duncan's New Multiple Range Test).

BREEDING FOR RESISTANCE TO WHITE MOLD IN SOYBEAN

Craig R. Grau[1/]

White mold of soybean continues to be an important disease of soybean. The boom or bust nature of white mold is problematic for developing a management plan for this disease. Defensive trait packages have improved dramatically for soybean varieties the past 10 to 20 years. However, this is not the case for white mold. Complete and stable resistance white mold has yet to be incorporated into a commercial soybean variety. There are several factors that contribute to this situation. First, not all seed companies consider white mold as a primary defensive trait. Although numerous sources of resistance are available, most sources are ancestral varieties and are primitive for yield and other agronomic traits. A major bottleneck appears to be the difficulty of moving white mold resistance into high yield potential varieties. Lastly, many varieties are rated as tolerant to white mold, but few provide a consistent performance from field to field in years with high white mold potential.

The Wisconsin Soybean Marketing Board and the North Central Soybean Research Program currently funds a project designed to provide methods and soybean germplasm to contribute to the effort to make available soybean varieties with complete and stable resistance to white mold.

An ancestral variety was identified in field and greenhouse trials to express a high degree of resistance to white mold. The ancestral variety was crossed with improved public lines and currently 902 progeny lines are in the program.

Progeny lines were selected for agronomic traits in field nurseries, but all selection for white mold resistance has occurred in a greenhouse environment. White mold field nurseries are inconsistent and not conducible for selecting white mold resistant plants for advancement. White mold field nurseries are needed for final evaluations but not for selection of individual plants to advance as breeding lines.

Individual plants have been selected and advanced at each of 8 generations. Most commercial soybean breeders stop selecting individual plants at 3 generations. Thus, our lines are highly inbred whereas commercial varieties are heterogeneous for physiological traits. A line must express white mold resistance at each generation to be advanced. Susceptible lines have been advanced and will be used in genetic studies.

Most programs inoculate plants prior to flowering in greenhouse white mold trials. We have determined the R1 (flowering) growth stage to be best for inoculating with the white mold fungus. In addition, most methods call for ratings 14 days after inoculation.

[1/] Professor Emeritus, Department of Plant Pathology, University of Wisconsin-Madison, Madison, WI 53706.

We record final ratings at the R6 growth stage. Plants within a line may express high resistance 14 days after inoculation but express susceptibility as the plants reach later growth stages.

The expected outcome of the project is the release of soybean lines with complete resistance to white mold and genetic markers to assist breeders with selection for this defensive trait.

BREEDING CORN FOR SILAGE: RESOURCES AND TECHNOLOGIES DEVELOPED IN THE UW PROGRAM

Natalia de Leon [1/]

About 6.4% of the ~87 million acres of corn harvested in the U.S were dedicated to silage production in 2010. Of those, approximately 750,000 acres were located in Wisconsin, the largest silage producing state in the U.S. (USDA, 2010). Maize silage is produced by ensiling the whole plant harvested a few weeks prior to physiological maturity. The starch from the grains and the complex carbohydrates in the cell walls are the primary sources of energy for the complex community of anaerobic microbes that reside in the gastrointestinal tract of ruminant animals (Van Soest, 1994; Coors and Lauer, 2001). Substantial improvements in forage digestibility have been achieved through traditional breeding in maize (Frey et al, 2004; Gustafson et al, 2010) as well as through the incorporation of large mutations such as the brown *midrib3* (Sattler et al., 2010).

For many years, the focus of many corn silage breeding programs has been improving the digestibility of the whole maize plant without a detailed understanding of what plant components on the cell wall of these materials or the relative contribution from the easily digestible grain provided that improvement. This approach has tended to increase the relative proportion of grain in the final forage mix and this has had a detrimental effect on dry matter yield and quality (Coors and Lauer, 2001). While increasing whole plant digestibility is still the primary goal of breeders, a better understanding of the relative contribution of grain relative to stover as well as specific changes in fiber and lignin content and composition has been crucial for the development of more efficient decision making process in breeding programs.

The UW corn silage breeding program has unique germplasm specifically designed to produce high-quality inbreds for use as parents for silage hybrids. An important component in the success of this program relates to fruitful interactions with animal nutritionists and corn extension specialist as well as the development of specific protocols to guide the identification of improved germplasm resources. We will present results that illustrate the technologies used and the resources generated by this program.

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BREEDERS VS. AGRONOMISTS: WHAT WE LEARNED FROM THE SOYBEAN DECADES STUDY

Scott Rowntree, Shawn Conley and Paul Esker[1]

Soybean [*Glycine max* (L.) Merr.] yields in the United States have improved at a rate of 0.35 bu yr^{-1} (23.4 kg yr^{-1}) since national soybean yield data was first recorded in 1924 (USDA-NASS, 2010). The consistent annual yield gain observed in soybean has been attributed to continued varietal improvement via plant breeding and the adoption of improved agronomic practices by U.S soybean producers (Specht and Williams, 1984). Previous research has found that past genetic improvements have resulted in an annual increase in soybean yield of 0.15-0.44 bu ac^{-1} yr^{-1} (10-30 kg ha^{-1} yr^{-1}), or approximately 0.5-1.0% yr^{-1} (Specht et al., 1999). The relative contribution of genetic improvement made by soybean breeders towards overall yield gain is estimated to be 0.184 bu ac^{-1} yr^{-1} (12.5 kg ha^{-1} yr^{-1}), or 50%, among hybridized cultivars released post-1940 (Specht and Williams, 1984).

Although half of yield gain in soybean can be attributed to genetic improvement made by soybean breeders, the remaining half of yield improvement is hypothesized to be the result of improvements in agronomic practices by soybean growers and the interactions of these agronomic practices with improved genetics. Researchers have speculated that changes in a number of agronomic practices by soybean growers have contributed to overall soybean yield improvement, including: earlier planting dates, narrower row spacing, planting at optimum seeding rates, improved weed control and herbicide use, and reduced harvest losses (Specht et al., 1999).

Arguably, the most critical and cost-free cultural management decision that a grower can make to maximize soybean grain yield is to plant soybean at the appropriate planting date (Cartter and Hartwig, 1963; Robinson et al., 2009). Currently, optimum planting dates in the northern U.S. range from early to mid-May (Heatherly and Elmore, 2004), although recent literature suggests that even earlier planting in late April can help to maximize soybean yields in the Midwest (De Bruin and Pedersen, 2008; Robinson et al., 2009). Based on these more recent publications, the trend has been towards planting soybean earlier in the Midwestern U.S. than historical planting trends (USDA-NASS, 2011). We hypothesize that this has thus contributed to the observed increase in soybean yields over time.

The objectives of this study were to determine the effects of earlier soybean planting on (i) seed yield, (ii) seed quality & mass, and (iii) soybean phenology over time. Research was conducted in 2010 and 2011 at Arlington, WI, Urbana, IL, and West Lafayette, IN. Fifty-nine MGII varieties (released 1928-2008) and 57 MGIII varieties (released 1923-2007) were planted at target dates of 1 May (early) and 1 June (late), representing a distribution of historical release years. A mixed-effect regression analysis was used to model change over time in yield, seed quality, and seed mass parameters for each maturity group.

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Results

Yield

Soybean yields for MGII varieties were not affected by planting date (p=0.78), indicating no yield penalty for delaying planting from the beginning of May until the first week in June (Figure 1). The failure to observe negative response to delayed planting in MGII soybeans contradicts past research across the upper Midwest advocating late April-early May planting for yield maximization (De Bruin and Pedersen, 2008; Pedersen and Lauer, 2003; Robinson et al., 2009), although results from this study were similar to the work of Oplinger and Philbrook (1992) who noted no difference in soybean yield at 1 May and 31 May planting dates at the Arlington Research Station.

The magnitude of yield response to early planting is very location and year specific (De Bruin and Pedersen, 2008), which may be the reason for similar yields at both May and June planting dates for the MGII varieties. There was evidence of a linear increase in soybean yields over the year of variety release (p<0.0001). The lack of evidence of a planting date by release year interaction indicated that an equal slopes model was valid for examining yield gains over time for the MGII varieties. When regressed over all release years, the annual rate of yield gain was estimated to be 0.27 bu yr^{-1} at both planting dates. The annual rate of yield improvement observed in this study represents an average gain of 0.55% yr^{-1} and is consistent with previous estimates of annual yield gain in MGII soybeans.

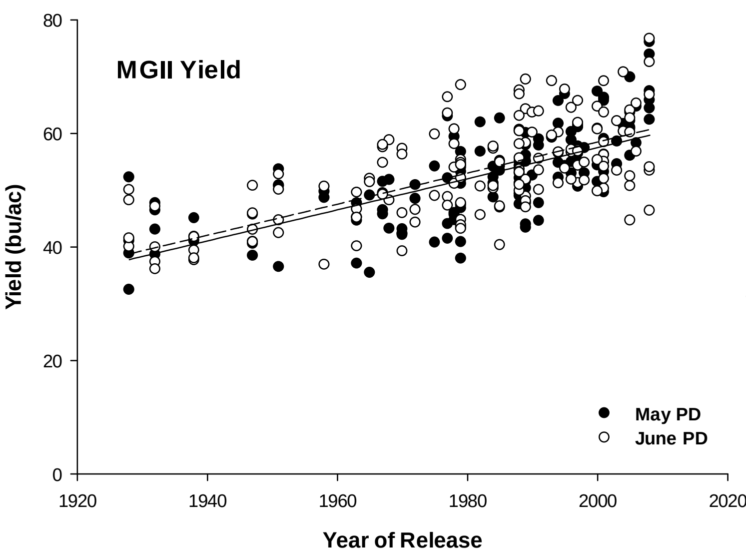

Figure 1. MGII soybean yield at early and late planting (2010-2011).

May Yield = 0.274x – 490.5; S.E. of the Slope: 0.024
June Yield = 0.274x – 489.5; S.E. of the Slope: 0.024

Crop Phenology

The duration of vegetative growth (V1 to R1) was affected by planting date (p = <0.001), with soybeans planted in early May spending a longer period of time in vegetative growth compared to those planted in early June planting. Similar results were presented by Bastidas et al. (2008), who also noted a decrease in the number of days soybeans took to reach beginning flower (R1) as planting date was delayed. Duration of vegetative growth stages of MG II soybean has decreased (p=0.0642) over variety year of release, with more recently released varieties spending less time in vegetative growth prior to flowering (Figure 2).

Although the duration of vegetative growth has decreased over variety year of release, the rate of time spent in vegetative growth was not the same (p=<0.001) for both planting dates. No change in the duration of vegetative growth was observed over variety year of release when soybean planted in early June. There was however a significant decline (0.05 days yr^{-1}) in the time spent in vegetative growth when soybeans were planted in early May. These results suggest that more recently released soybean varieties, when planted at the recommended time in early May, reach flowering and the reproductive stages of growth sooner than earlier released cultivars. The decrease in the time spent in vegetative growth is accompanied by an increase in the amount of time spent in reproductive growth among more modern varieties (discussed below).

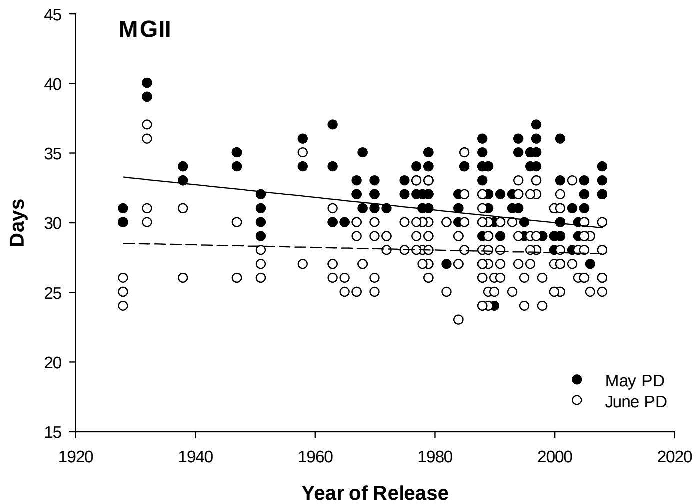

Figure 2. Duration of vegetative growth of MGII soybean at early and late planting (2010-2011).

May Yield = -0.0455x + 121.99; S.E. of the Slope: 0.025
June Yield = -0.0093x + 46.45; S.E. of the Slope: 0.015

The number of days spent in the reproductive phases of growth (R1-R7) has increased (p<0.0001) linearly with variety year of release in MGII soybeans (Figure 3). Additionally, the time spent in reproductive growth is longer for soybean planted in May compared to the June planting (p = 0.01). The rate of increase in reproductive duration over year of release was twice as high in the May (0.09 days yr^{-1}) planting versus the June (0.046 days yr^{-1}) planting, suggesting that more recently released varieties respond positively to earlier planting by spending a greater amount of time in reproductive growth and seed-filling period.

Because yield is often the main selection criteria for soybean breeders, we hypothesize that the decrease in vegetative duration and the increase in reproductive duration of soybean growth was an unintended consequence in breeding efforts. It is likely that while selecting for yield, breeders unknowingly selected for the varieties that reached the reproductive stages of growth sooner and were able to translate the longer period of time spent in the seed-filling period into yield at earlier planting. Preliminary investigation of our data suggests that there might be evidence that the number of days to maturity within the MGII grouping may also be increasing over release year. More modern varieties may be reaching maturity later than their earlier released varieties, and the impacts of lengthening maturity on soybean yield over time are under investigation.

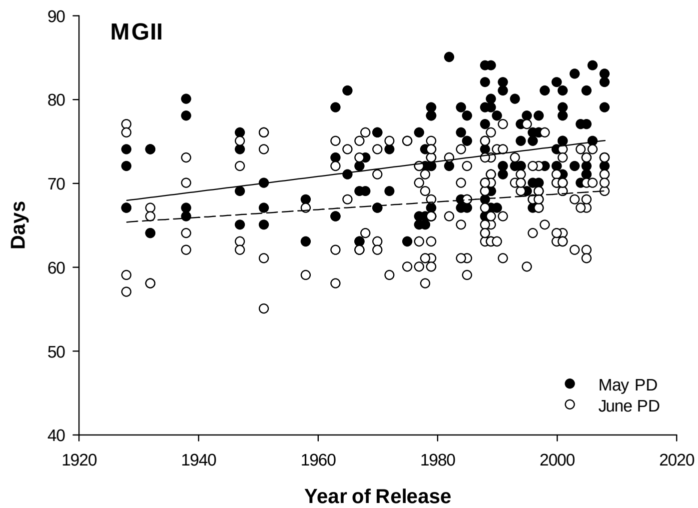

Figure 3. Duration of reproductive growth of MGII soybean at early and late planting (2010-2011).

May Yield = 0.0893x – 104.21; S.E. of the Slope: 0.031
June Yield = 0.04634x – 23.96; S.E. of the Slope: 0.016

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DAIRY MANURE TREATMENT EFFECTS ON SOIL TEST PHOSPHORUS

Carrie A.M. Laboski and Paulo Pagliari[1]

Introduction

Because of increasing environmental concerns related to manure disposal, some farms are adopting manure handling systems that diminish the potential environmental problems associated with the large amount of manure produced in relatively small areas. For example, in Wisconsin as of 2007, there were 20 farms with fully operational anaerobic manure digesters with an average of 1,474 cows in each farm (USDA, 2010). Manure liquid-solid separation is another alternative option to manure handling. The separated liquid can be reused in barns as flush water, a crop nutrient source, or irrigation water; whereas, the separated solids can be recycled as bedding, used as nutrient source for crop production, or sold off farm as a horticultural amendment (personal communication with farmers). Manure composting has been used as an alternate manure handling process. Composting decreases the total amount of manure through water loss and also eliminates most of the pathogens in manures (Rynk et al., 1992). In-barn composted bedded packs are an alternative option to complete composting and consist of bedding layers (e.g., saw dust) that are constantly added to the barn floor without removal of the older layer. The bedded pack is aerated daily to stimulate microbial decomposition.

There has been little or no research that investigated and compared the effects of manure in-barn composted bedded pack, anaerobic digestion, or liquid-solid separation on the forms of inorganic and organic manure P. It is possible that manipulation systems that are known to use microorganism to mediate the process, such as composting or anaerobic digestion, can affect the distribution of the organic and inorganic P fractions in manure. For example, Sharpley and Moyer (2000) used sequential fractionation to quantify the change in the P fractions when dairy and poultry manure are composted. Composting increased the inorganic P fraction in dairy manure by reducing both the organic and residual fractions.

Anaerobic digestion of animal manure is mediated by bacteria, which degrade organic compounds and release inorganic compounds during the digestion. This process could alter the mechanisms controlling P solubility from treated manures. However, in a laboratory bench-scale study, anaerobic digestion of dairy manure was reported to have no effect on manure P solubility (Güngör and Karthikeyan, 2005). In a different study, when raw and anaerobically digested swine manure samples were applied to a silty clay loam soil, similar increases in STP were observed with both manures (Loria and Sawyer, 2005). The authors concluded that the anaerobic digestion of swine manure did not affect the mechanisms controlling P solubility and, therefore, no significant differences were observed in the increase in STP after raw and treated manure application (Loria and Sawyer, 2005). These two studies show that anaerobic digestion of animal manure, may not alter the manure P interactions with soil with regard to increases in STP after manure addition.

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In liquid-solid separation systems most of the changes would be expected to be a result of the mechanical manipulation of the manure. For example, if all manure inorganic P is in a dissolve (Møller et al., 2000), which indicates that the dissolved and precipitated forms of P in manure are in dynamic equilibrium. form, liquid-solid separation could concentrate most of the inorganic P in the liquid fraction. Or if most of the P in manure is in the precipitated form, then liquid-solid separation could concentration the P in the solid fraction. However, liquid-solid separation of cattle and swine manure has been reported to result in liquid and solid fractions that have similar P concentrations

There are no peer-reviewed publications that report the effects of dairy manure treatment on the manure P fractins and subsequently on soil test phosphorus (STP). Therefore, this research was conducted to evaluate the effect of manure treatment (in-barn composted bedded pack, liquid-solid separation without digestion, and anaerobic digestion with liquid-solid separation) on the increase in STP after manure application.

Methods and Materials

Manure and Soil Collection

Eighteen dairy (*Bos taurus*) manure samples (a mix of feces + bedding + urine) were collected from five commercial farms in Wisconsin with three different treatment systems: in-barn composted bedded pack, liquid-solid separation, and mesophilic anaerobic digestion with liquid-solid separation. Each of the treatment system is illustrated in Figures 1 and 2. Three samples were collected from an in-barn compost bedded pack (system 1) including a sample from the top (0 to 1 ft), the middle (1to– 2 ft), and the bottom layers (2 to 3 ft). In the in-barn composted bedded pack system, new layer of bedding is added daily, after which, an aeration practice mixes the new bedding and existing bedding + manure + urine to a depth of 8 to 10 inches. As the depth of the bedded pack increases because of deposition of feces, urine, and addition of new bedding layer, the lower layers are not aerated. Seven samples were collected from two liquid-solid separation systems, system 2 and system 3. For system 2, the separation system was composed of four stages, starting with a Mclanahan coarse sand separator, then passing through Mclanahan hydrocyclones fine sand separator, following the samples go through a fan separator and in the last stage samples pass through dissolved air floatation, which separates the manure liquid and solid fractions. The manure samples collected from system 2 included raw samples before entering the system, and liquid and solid samples after they passed through the dissolved air flotation. For system 3, the separation system is similar to that of system 2, but includes an additional centrifugation system, which separates the separated liquid into two fractions, tea water and concentrate. Samples collected from system 3 included the raw manure prior to separation, separated solid, concentrate, and tea water. Eight samples were collected from two anaerobic mesophilic digestion systems, system 4 and system 5. In these systems, raw manure is fed into the digester, after manure is digested it passes through a screw press system that separates the digested manure into liquid and solid fractions. The samples taken from these systems included one raw (prior to entering the digester), one post digestion but prior to liquid-solid separation, one liquid after separation (digested separated liquid), and one solid after separation (digested separated solid). After collection, samples were stored at -20°C until use. Dry matter content, electrical conductivity (EC), pH, total N, total potassium (K), and total dry ash P (P_t) were measured according to Peters et al. (2003) (Table 1). Total carbon (C), was measured by dry combustion using a Leco CNS-2000 analyzer (Leco, 2000). Water extractable P was measured after equilibrating manure with water in a 1:100 (manure dry matter to water) ratio for four hours He et al. (2006).

Five soil series that represent a range in soil properties under agricultural production in Wisconsin were collected from fields that had not received manure applications for at least 5 years (Table 3). Soil samples were collected from each site to a depth of 0 to 6 inches. After collection, the soils were moist sieved to pass through a 5-mm sieve, air-dried on a greenhouse bench, and stored in a sealed container until needed. A subsample of each soil was ground to pass through a 2-mm sieve and used for chemical analysis. Soil pH was measured in water (1:1 ratio w/w); organic matter (OM) content was measured by loss on ignition; electrical conductivity (EC) was measured using the water saturated paste method (Brown, 1998). In addition, particle size analysis was performed using the hydrometer method of Bouyoucos (1962). Extractable P was measured using the Bray P-1 test (Brown, 1998), and determined by the molybdate blue method of Murphy and Riley (1962). Calcium, Mg, potassium (K), and sodium (Na) were extracted using ammonium acetate (NH_4OAc, pH buffered at 7.0, Brown, 1998) and determined by atomic absorption. Cation exchange capacity (CEC) was estimated according to Brown (1998).

Manure and Soil Incubation Study

All 18 manures, triple superphosphate fertilizer (TSP), and a control (no fertilizer or manure) were applied to each soil in a full factorial, completely randomized design with four replications. Manure or fertilizer was manually mixed with 50 g of the sieved and air-dried soil at a rate of 40 mg P kg $soil^{-1}$ (183 lb P_2O_5/a). The dry matter content of the tea water manure was very low and it was not possible to supply 40 mg P kg $soil^{-1}$ without adding water in excess of field capacity. Therefore, the application of this manure was based on an amount of irrigation water (10 inches) that might typically be applied in a growing season in Wisconsin and resulted in a 16 mg P kg^{-1} (73 lb P_2O_5/a) application rate. Each individual sample was incubated at 25°C for 70 days in a specimen cup covered with a perforated cover to allow for air exchange. Soil moisture content was maintained between 40 to 60% of gravimetric water content by weighing the cups on a weekly basis and adding deionized water as required. After 70 days, samples were oven-dried at 35°C for 48 hours, ground to pass through a 2-mm sieve, and extracted with Bray P-1. The increase in soil test phosphorus (STP) was determined by subtracting the mean Bray P-1 in the control treatment of each soil from the Bray P-1 determined in each replication of the different treatments applied to that same soil. The soil P buffer capacity PBC was calculated by dividing the P application rate by the increase in soil test P.

Statistical Analysis

All statistical analysis was performed in JMP 9.01. The effect of manure treatment for a given soil and treatment system and the effect of soil for a given manure treatment were evaluated with a mixed model with Tukey means separation at the P-value <0.05. All manure PBCs were compared to the fertilizer treatment for the appropriate soil using a Dunnett's test.

Results

The PBC determined when fertilizer was incubated with soil ranged between 9 and 13 lb P_2O_5/a/ppm. The PBCs that are currently used in determining fertilizer rate guidelines (A2809) are 18 lb P_2O_5/a/ppm for silt loam soils (groups A – D) and 12 lb P_2O_5/a/ppm for coarse-textured soils (group E) (Laboski, et al., 2006). The present PBC are generally lower than values in A2809, which is typical of incubation studies compared to field studies. The Waymor soil had a significantly higher PBC compared to the other soils while the Mahtomedi (group E) tended to have the lowest PBC.

For the composted bedded pack system, the middle layer tended to have a lower PBC compared to the top and bottom layers, though not always significant. In system 2 liquid-solid separation, a PBC could not be calculated for the separated solids because soil test P decreased or increased very minimally. In the Dodgeville and Mahtomedi soils, the separated liquid had a significantly lower PBC compared to raw manure, but was not different for the other soil series. In system 3 liquid-solid separation, tea water generally had the lowest PBC, but was only significant in the Waymor and Dodgeville soils. On the other hand, separated solids had the greatest PBC though not always significantly different than other manures in this treatment system.

For the anaerobic digestion and separation system 4, there were no differences in PBC for raw slurry, digested slurry, digested separated liquid, or digested separated solid for any soil except Hortonville where the digested separated solid had a significantly lower PBC compared to digested separated liquid. Similarly for system 5 anaerobic digestion and separation, there were no differences in PBC for raw slurry, digested slurry, digested separated liquid, or digested separated solid for any soil except Dodgeville and Antigo. Digested separated solids had a significantly lower PBC compared to raw slurry in the Dodgeville while on the Antigo soil, digested separated liquid had significantly lower PBC compared to raw slurry.

The PBC for each manure treatment on each soil were compared to the PBC for fertilizer on that soil to determine if P source affects PBC. For the top layer of the compost bedded pack manure, PBC was always significantly greater than fertilizer. In 47% of the comparisons, PBC for manure was significantly greater than fertilizer on the Dodgeville soil. Manure PCB was greater than fertilizer on the Hortonville soil in 35% of the comparisons. On the whole, manure PBC is not different than fertilizer PBC, though there is some variation.

Additional data analysis is needed to determine if soil and/or manure properties can be used to predict when manure will increase soil test P less than fertilizer (greater PBC).

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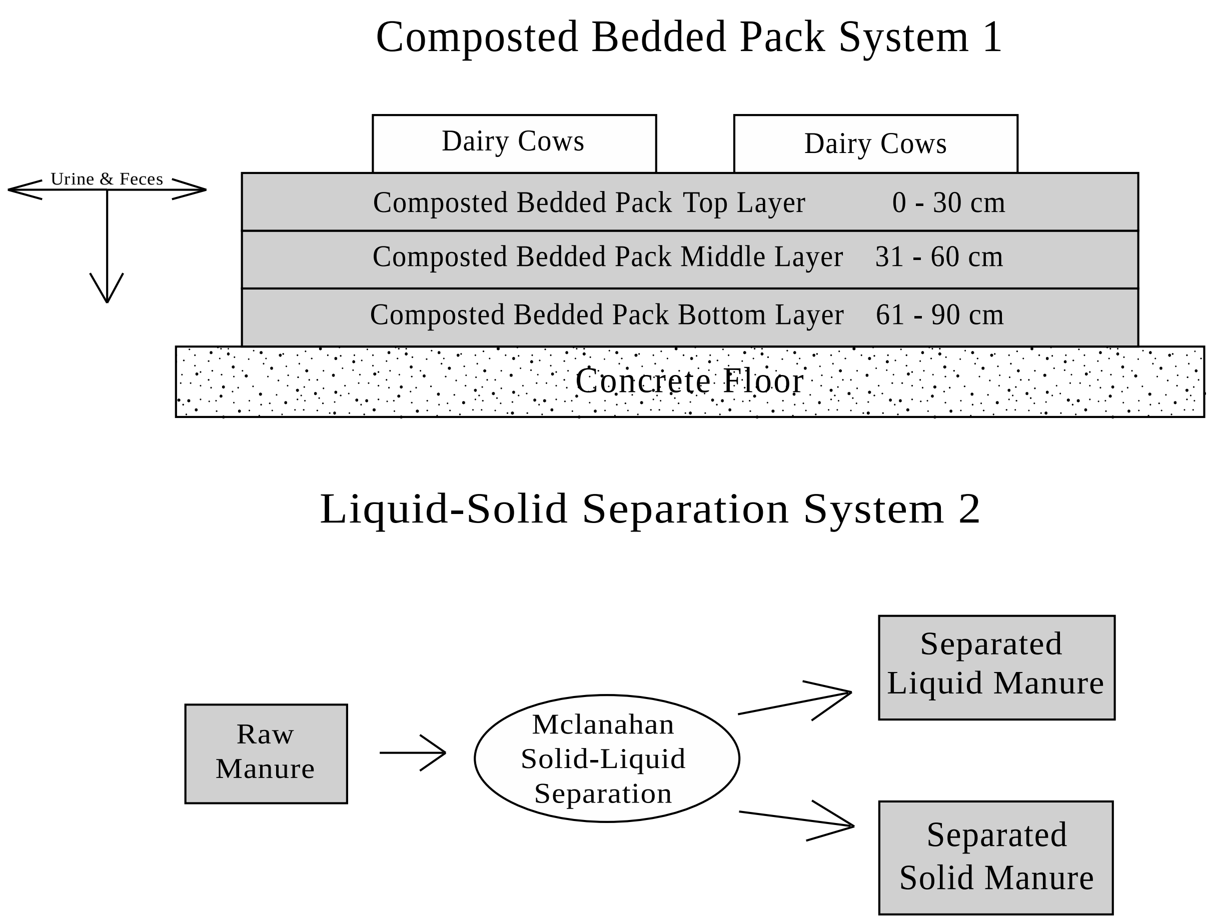


Figure 1. Schematics for the manure treatment systems 1 and 2 studied in this research. Gray box indicate stage where manure samples were collected.

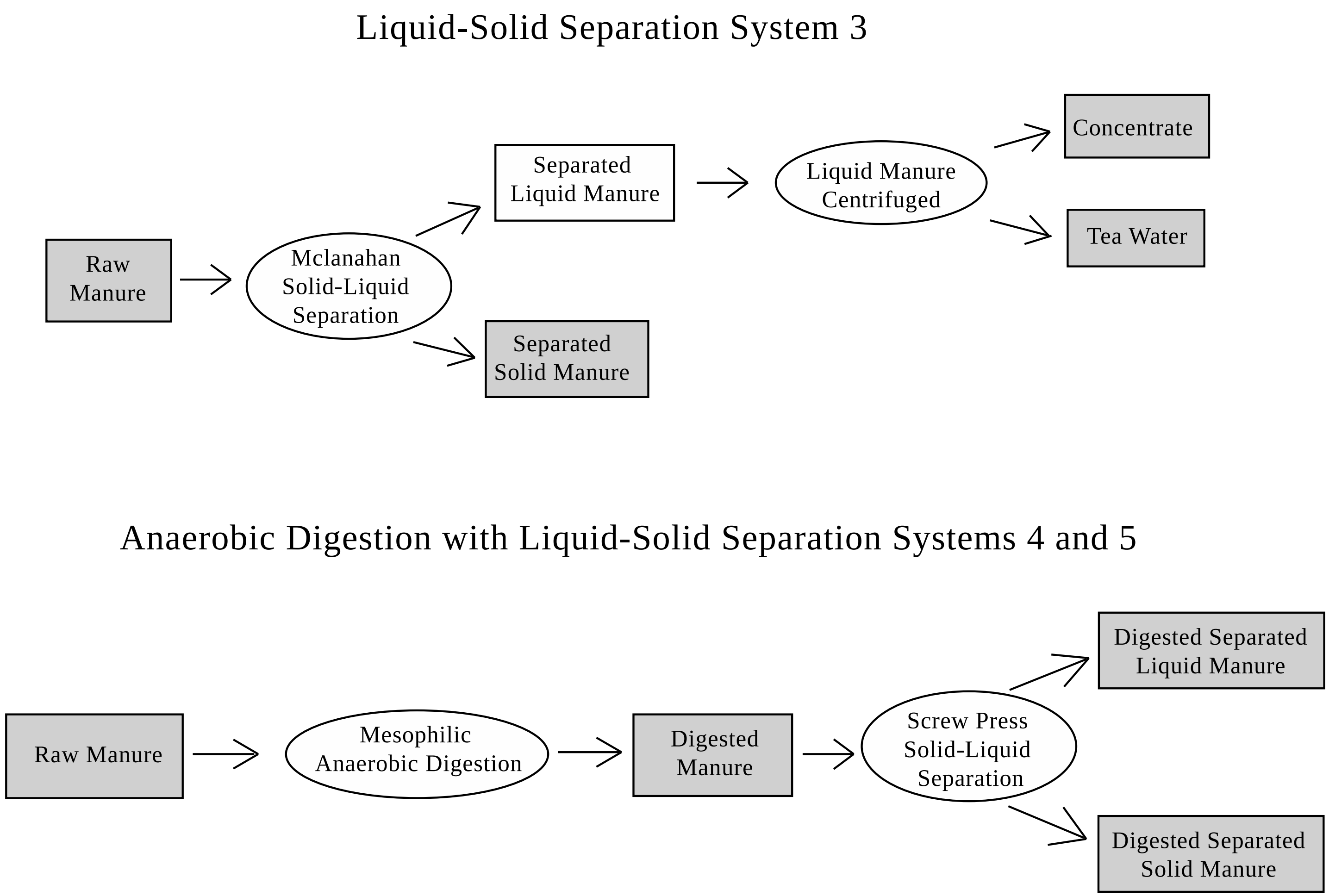


Figure 2. Schematics for the manure treatment systems 3, 4, and 5 studied in this research. Gray box indicate stage where manure samples were collected.

Table 1. Selected physical and chemical properties of manure.

System	Manure†	DM	pH	EC	C:N	Total N	NH_4-N	Total K_2O	Total P_2O_5	WSP_2O_5‡	WSP_2O_5/ Total P_2O_5
		%		dS/m		———	———	lb/T §	———	———	%
Composted Bedded Pack											
1	Top layer	33.7	9.3	2.9	38	8.1	1.3	14.6	2.8	1.32	48
	Middle layer	33.4	9.4	2.7	33	9.4	3.3	13.6	5.7	1.87	33
	Bottom layer	31.4	9.7	2.5	29	10.0	2.5	13.6	5.3	1.62	30
Liquid-Solid Separation											
2	Raw-2	10.6	6.8	9.8	12	7.0	3.8	5.1	2.6	0.64	25
	SL-2	3.6	6.8	14.1	5	4.3	1.7	3.0	1.6	0.95	60
	SS-2	28.6	6.7	2.1	15	17.2	0.6	4.8	2.0	0.03	1
3	Raw-3	7.0	8.3	7.9	14	3.8	1.8	4.2	1.6	0.31	20
	Concentrate-3	6.1	6.9	11.9	6	8.9	3.1	4.1	3.6	0.64	18
	Tea water-3	1.0	8.0	10.4	3	2.0	1.7	5.4	0.1	0.05	71
	SS-3	23.2	8.3	1.3	13	14.4	0.9	3.9	3.1	1.68	55
Anaerobic Digestion / Separation											
4	Raw-4	4.0	8.1	6.8	7	4.8	2.8	3.0	2.2	0.19	9
	Digested-4	5.4	7.5	9.9	6	6.9	4.2	4.4	2.7	0.21	8
	DSL-4	3.9	7.5	17.3	5	6.4	3.3	4.5	2.7	0.15	6
	DSS-4	24.8	8.3	1.5	18	12.4	3.5	6.5	8.1	1.54	19
5	Raw-5	6.0	8.7	10.9	7	7.1	4.3	5.6	3.0	0.19	7
	Digested-5	5.1	9.8	8.8	6	6.4	4.3	5.1	2.4	0.16	7
	DSL-5	3.1	7.8	19.4	3	6.5	4.5	5.5	1.9	0.08	4
	DSS-5	32.8	8.2	1.8	18	15.7	3.9	7.9	14.3	2.20	15

† DSL, digested separated liquid; DSS, digested separated solids; SL, separated liquid; SS, separated solid

‡ WSP_2O_5, water soluble phosphate

§ Units are pounds per ton of “as is” manure. For liquid manures, multiple by 4.165 to convert to pounds per 1,000 gallons.

Table 2. Selected soil physical and chemical properties.

	Soil series				
Soil properties	Antigo	Dodgeville	Hortonville	Mahtomedi	Waymor
A2809 Soil Group	D	B	C	E	A
pH	5.6	5.7	6.9	6.7	6.6
OM, %	3.4	3.4	2.9	1.5	2.9
Sand, %	55.9	18.2	17.9	87.9	48.9
Silt, %	41.0	66.0	70.0	9.0	40.0
Clay, %	3.1	15.8	12.1	3.1	11.1
Bray P-1, %	24	18	43	16	30
CEC, $cmol_c\ kg^{-1}$	4	12	11	6	13

Table 3. Phosphorus buffer capacity of manure and fertilizer when applied to five Wisconsin soils in a laboratory incubation.

System	Treatment	Waymor	Dodgeville	Hortonville	Antigo	Mahtomedi
		lb/a P_2O_5 applied per ppm soil test P				
Fertilizer	TSP	13 A	10 B	9 B	9 B	8 B
Composted Bedded Pack						
1	Top layer	29*‡ a AB†	73* a A	28* a AB	19* a B	18* a B
	Middle layer	15 b AB	16 a A	16* b A	11 b AB	8 b B
	Bottom layer	25* a A	23 a A	10 b B	15* ab B	14 ab B
Liquid-Solid Separation						
2	Raw-2	20* a A	22 a A	18 a AB	17 a B	12 a B
	SL-2	18 a A	16 b A	14 a AB	10 a B	10 b B
	SS-2	na§	na	na	na	na
3	Raw-3	17 ab B	38* a A	9 a B	13 a B	12 b B
	Concentrate-3	15 ab B	20* bc A	12 a B	14 a B	8 b C
	Tea water-3‡	11 b A	12 c A	10 a A	6 a B	9 b A
	SS-5	25* a AB	31* ab A	11 a B	16 a AB	25* a AB
Anaerobic Digestion / Separation						
4	Raw-4	16 a AB	18* a AB	21* ab A	13* a AB	9 a B
	Digested-4	14 a B	13 a BC	18 ab A	10 a BC	9 a C
	DSL-4	13 a B	17* a AB	27* a A	11 a B	10 a B
	DSS-4	15 a A	16 a A	12 b A	11 a A	14 a A
5	Raw-5	16 a B	28* a A	13 a BC	13* a BC	11 a C
	Digested-5	17 a B	26* ab A	17* a B	11 ab C	12 a C
	DSL-5	15 a B	26 ab A	15 a B	10 b B	12 a B
	DSS-5	15 a AB	20 b A	17* a AB	11 ab B	13 a AB

† Within a soil series and manure treatment system, means with the same lower case letters are not significantly different (P-value<0.05). Within a manure treatment (row), means with the same uppercase letters are not significantly different.
‡ Within a soil series, means followed by an * are significantly different from the fertilizer treatment.
§ na, not applicable. Soil test P either decreased or increased very minimally when manure was applied; P buffer capacity could not be calculated.

IMPACTS OF ANAEROBIC DIGESTION AND SOLID/LIQUID SEPARATION ON NUTRIENT AVAILABILITY IN MANURE

R.A. Larson[1]

Managing manure as a fertilizer source is an important factor to maintain a profitable and sustainable food production system. The greater management incorporated into understanding the nutrient cycling throughout the entire system can greatly increase crop yields, reduce chemical fertilizer needs, reduce manure handling and processing costs, and limit the environmental impacts. Many manure management processes can impact the availability of nutrients and should be factored into manure management plans to realize the potential benefits. Anaerobic digestion and solid/liquid separation (including bedding recovery units) are increasing in on-farm use around the United States as a component of manure management systems. Anaerobic digestion is a proven waste to energy technology which produces biogas and digestate from anaerobic microbial degradation of organic sources. Nearly all on-farm systems in the United States have a mechanical solid/liquid separation system following digestion which fractions the digestate into a solid and a liquid product. Solid/liquid separators known as bedding recovery units use aerobic processes to degrade organic material also resulting in a similar solid and a liquid portion following processing. Processing of manure using digestion and/or a solid/liquid separation process can impact the nutrient and pathogen content of each stream. Digestion results in mineralization of nutrients and pathogen reductions based on system design of temperature and retention time. Separation (including bedding recovery units) can result in fractioning of nutrients as well as moisture, resulting in increased control of nutrient streams for increased management of manure. The liquid fraction following separation has increased content of soluble nutrients and is commonly land applied as a fertilizer source. The solid fraction is commonly used on-farm as a bedding source, but as it contains concentrated organic nutrients can also be sold as a value added product. However, the lack of data for real world performance has limited the use of these end products and has reduced revenues and resulted in operational problems for many dairies in Wisconsin.

In order to assess real world performance of digesters and solid/liquid separation systems, an assessment of 9 on-farm systems is being conducted over the course of one year. The study design includes sampling every other week pre and post digestion (if a digester is on-farm) and the solid and liquid portion after separation. This allows for assessment of the digestion process and the separation system. Samples are evaluated for nutrients, solids, pathogens (particularly those associated with herd health) and pathogen indicators. The results can be used to assess if digesters and separators are performing as designed. Additionally, these data can provide performance data on the various digester designs and separator equipment. The fractioning of nutrients is critical for assessing nutrient management practices and investigating the impact of recycling manure through the system on nutrient content in both streams. Results of the nutrient portion of this study will be presented for the first 5 months of sampling. These results are critical to developing more profitable nutrient management strategies with reduced environmental impact.

[1] Rebecca Larson, Assistant Professor, Department of Biological Systems Engineering, UW-Madison, 460 Henry Mall, Madison, WI 53706

FARM BILL UPDATE: EARLY THOUGHTS OF WHAT MAY COME

Paul D. Mitchell [1/]

The debate surrounding the 2012 Farm Bill has been building as the current 2008 Farm Bill is set to expire. The primary message out of Washington has been that budget cuts will come, including to the USDA and the Farm Bill. This presentation will present some of the main proposals that have been floated so far and offer insights on what to expect in terms of where the expected cuts will come. Of course, all bets are off as to what the politicians will finally decide.

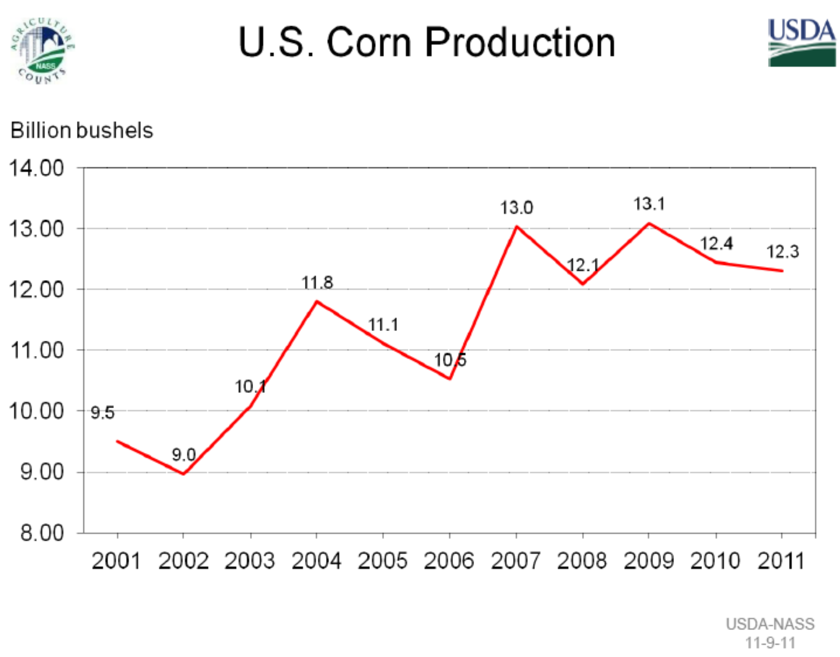
The presentation will be an early look at what will be covered more comprehensively at the University of Wisconsin's 2012 Agricultural Economic Outlook Forum on January 25, 2012. The Forum will coincide with the release of the 2012 Status of Wisconsin Agriculture Report. Those interested, can register online at http://www.cals.wisc.edu/agoutlook. For more information, email agoutlook@cals.wisc.edu or phone 608-262-9812.

[1/] Associate Professor, Dept. of Agricultural and Applied Economics, Univ. of Wisconsin-Madison.

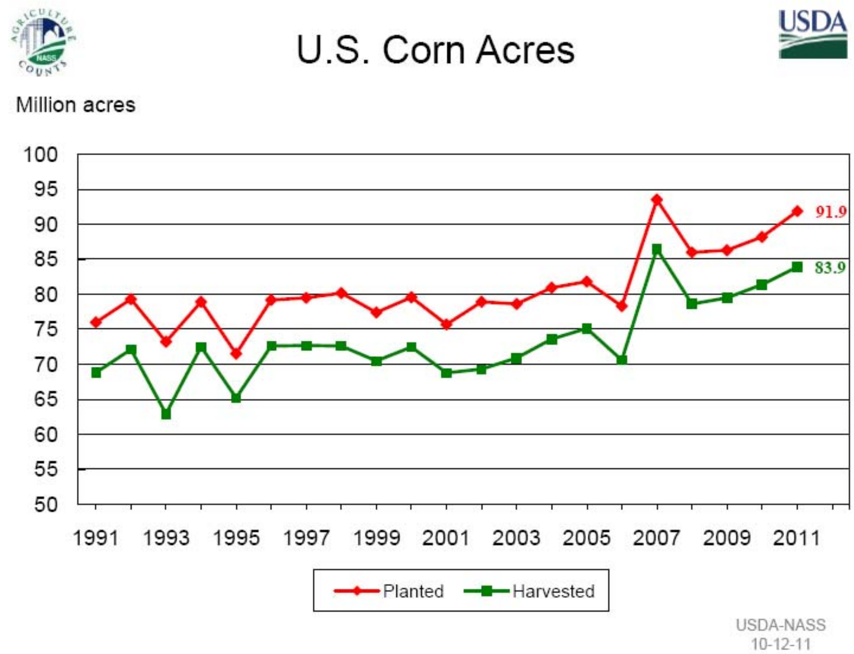
BACK-TO-BACK HIGH YIELDS AND PRICES: MARKETING IN 2012

David C. Moll [1/]

Last year a strong bull market run continued in grain prices, new all-time highs in corn futures prices were set. Does 2012 have the same momentum behind it? Let's take a look at some of the factors that allowed the bull market to stay in place. Ultimately when the bull market started during July 2010, demand driven markets propelled prices higher. Demand from both domestic and foreign markets was picking up following for wheat, corn and soybeans. World wheat supplies stumbled with the drought that the Black Sea region faced. As the fall of 2010 unfolded US corn production failed to meet expectations and producers harvested a 12.4 billion bushel crop. The strong demand ate away the crop to a tight 840 million bushels, resulting in a very tight 6.6% ending stocks to total use. For 2011 crop prospects, there was the possibility to pick up more corn acres during the spring but wet growing conditions in the eastern Corn Belt and some delays in planting throughout the Midwest meant plantings were about 92 million acres. That is the 2nd largest US acreage. If more acres were planted though it could have softened the market as extra acreage would make ample supply less risky. That could be a huge factor in 2012, if returns per acre remain where they are, at much higher returns from corn than the competing crop (typically soybeans) then there could be another big shift in acreage this spring. Time will tell if the US surpasses the record 93 million planted corn acres of 2007. If demand is held constant and 94 or 95 million acres of corn were planted how much less risk is there in 2012 production meeting demand needs?



[1/] Grain Marketing Outreach Specialist, UW Extension.



Marketing grain in 2012 will likely come with a very uncertain future. Strong demand with large supplies will likely keep prices elevated. The pricing environment will remain volatile though as small changes to fundamentals cause large prices changes in a tight ending stocks environment. As input prices continue to rise, protecting one's downside risk while leaving room for upside revenue potential will be a difficult piece to balance. If demand weakened and supplies were ample it would result in a very different price direction. It was not too long ago when (a mere 19 months) when corn prices were barely above $3.00 a bushel and the bottom did not look like there was any support. This was after the bull market rally reaching above $7.00 a bushel. The probability of a $3.00 in 2012 is not likely but if there were a dramatic change in fundamentals it could happen. Ending stocks have been this tight in two other time periods over the last 40 years, in the mid-1970s and in 1996. In the mid-1970s ending stocks were tight for two consecutive marketing years but in the third year the demand shattered. Ending stocks in 1996 were just as tight but an increase in acreage the following year rebuilt ending stocks. What will happen this time around?

The drought in Texas continues to make many leery about the potential for devastating 2012 production in the south and if the drought conditions persisted and spread into the Midwest then surely all bets are off on how high prices would go. There would likely be new all-time highs in commodity futures prices. How likely is this to occur though and how much would demand weaken from livestock production along the way?

With tight ending stocks it is relatively easy to point to news stories that show the sky being the limit on corn and soybean prices again in 2012 and if weather puts supply in question then it will likely bring prices higher as supplies are already tight, but how much downside risk are you willing to accept with increasing input prices.

Historically during marketing years when yields fall below trend-line then the highest prices are seen during August through January of the year to ration demand and then after leading into the spring prices move much lower as enough rationing occurred. Will that happen in 2012? This is still yet to be seen.

In Wisconsin producers had high yields for the second year in a row and with the high prices had high revenue per acre. Wisconsin corn yield was 160 bushels per acre for corn and 47 for soybeans. Nationally, corn production was 12.3 billion bushels and soybean production was 3.03 billion bushels. 2011 corn production is the 4th largest in history and soybeans remained in the average over the last 7 years. Even with the large productions nationally and in Wisconsin, basis levels were strong during harvest at nearly 50 cents better per bushel than in 2010.

When marketing the rest of the 2011 crop and making contracts for the 2012 crop consider your financial position and how much downside price risk you can take. Even though the outlook remains for bullish prices, history says that bulls die and when fundamentals change it is typically heavily in the other direction as supplies pass demand. Will that happen in 2012 or in the teen years?

One thing is expected, though, margins will likely be tight in 2012 and be even tighter in the teen years. Even if prices remained high, input prices will be rising at a faster rate to catch up or if prices lagged input prices would likely be reduced at a slower rate. The back-to-back high yields and prices seen of the last two years have been really good times.

MOBILE WEB TOOLS FOR AGRONOMY

Roger Schmidt [1/]

Abstract

Mobile internet use is changing how global and local agriculture operate and expand their businesses. This presentation will demonstrate how the University of Wisconsin Nutrient and Pest Management (NPM) program and the UW Integrated Pest Management (IPM) program are working with a 'mobile first' attitude to help Wisconsin's agricultural community benefit in this changing environment.

Background

Gone are the days when a grower needed to turn on a radio or television at a specific time of the day to listen to an agricultural commodities report. Now, this task can be done at any time in any location using a smartphone or a text message. Coming are the days when growers and consultants will not need to shuffle stacks of paper, hand written field records, or piles of reference booklets from desktop to the pickup truck and back and forth again. These tasks will be done faster and easier with a smartphone or a tablet device either in standalone mode or connected to a cloud server directly from the field. There will not be a need to "hold that thought" when a question or information need arises during any part of the day or night.

Using new technologies that the mobile internet provides appears poised to make farm management less time consuming and more profitable. Farmers are using the mobile internet to connect with the university, consultants and other farmers, without being tied to their desktops. Read, chat, buy, sell, order parts, check remote machinery operation, access GPS, use location based weather data, setup new international markets; all these tasks and more can be accomplished from a mobile situation. To adapt to this new mobile internet trend which is becoming widely prevalent, the NPM and IPM programs have set out moving forward with mobile internet technologies of their own. The programs are making sure, however, to maintain their traditional communication methods ranging from face-to-face meetings to printed handout materials. Some of the specific technology tools the programs are looking at include YouTube, Twitter, and WordPress websites, iPhone, iPad and Droids apps, eBook format publications, and Blackboard webinar virtual meeting rooms. (Product names are not an endorsement or rating.)

Results and Discussion

A 'mobile first' attitude means that each time work is done on a communication project, a program considers the possible mobile internet issues first, and then looks at traditional methods. This allows a program to build in mobile connection from the start, and saves time and money doing future adaptations.

Videos: F or the past three years IPM and NPM have been recording videos in the field and posting them on YouTube using UWEX's video channel. These are short 3- to 5-minute videos that can be played back at any time in full high definition on laptops and mobile devices. You can

[1/] Nutrient and Pest Management Program, University of Wisconsin-Madison.

see our playlists at http://youtube.com/uwipm . In total, the videos have received thousands of viewings.

Websites: Beginning this year, the Wisconsin Crop Manager (WCM) newsletter will be using a WordPress website optimized for both traditional desktop and mobile device access. In addition, all news articles will be linked in a Twitter list for additional mobile access.

Wisconsin Crop Manager website -- http://ipcm.wisc.edu/wcm

Wisconsin Crop Manager on Twitter -- http://twitter.com/WisCropMan

Apps: NPM has developed two iPhone and iPad apps that are available in the iTunes store for free download.

http://itunes.apple.com/app/n-price-calculator/id455090088?mt=8

The N Price calculator app (Fig. 1) allows you to compare the price of various forms of nitrogen fertilizer products in terms of their price per pound of nitrogen. Nitrogen fertilizers such as anhydrous ammonia, urea, and urea ammonium nitrate (UAN) vary in their nitrogen content and are sold on a price per ton basis. This app converts the price of each fertilizer product from price per ton to price per pound of nitrogen — allowing for "apples to apples" comparisons. By comparing the price per pound of nitrogen from multiple fertilizer sources on the N Price Calculator's Price List, the cheapest source of nitrogen can be identified.

http://itunes.apple.com/us/app/corn-n-rate-calculator/id455298473?mt=8

The MRTN guidelines in the Corn N Rate app (Fig. 2) are designed to assist producers in selecting an N rate that improves profitability when N and corn rates fluctuate. Maximum return to N (MRTN) is the N rate that will be most profitable for a particular N:Corn ratio. The MRTN rate is the LARGE number expressed in lbs N/acre (total to apply) including N in starter. Below that number is the range of N rates that result in profitability within $1/acre of the MRTN rate.

A third app soon to be released by the UW IPM program is the 'IPM Toolkit" for iPhone and iPad. This app will feature a mobile connection to all the IPM YouTube videos, a listing of current WCM newsletter articles, as well as a select list of IPM related picture and publication references.

The hope is to also make these three applications available for Android version smartphones as soon as possible.

eBooks: Different from PDF publications, ePub formatted documents allow for dynamic changes in font size and page layout making reading on a smartphone or tablet easier. This year, NPM has begun to publish documents in both formants. A good demonstration is to look at the NPM publication, *"Frost Seeding Red Clover in Winter Wheat"*.

Webinars: Lastly, IPM recently held a series of online webinar training sessions that are helping participants prepare for an upcoming Wisconsin CCA exam. This webinar series broadcast UWEX state specialist and their PowerPoint presentations via live internet connection. Participants were able to ask questions online, and view the recorded presentations at any later date of their choosing. Instead of paper handouts, reference materials were provided as web links to online document files. One noteworthy comment from a participant was that they were happier with online-only content because of its portability for access anywhere and everywhere the internet reached. Another advantage on the webinar format was that it allowed one of the specialists to provide a live presentation directly from a location in Canada, thus avoiding a scheduled conflict.

Conclusions

A ‘mobile first’ attitude has saved the NPM and IPM programs time and money in providing important communication avenues allowing Wisconsin’s agricultural community and the university to work together regardless of location.

- Using YouTube allows easy remote viewing and inclusion of videos in mobile apps. Videos that are not on YouTube, have no native mobile connection; they need to be converted.
- Using mobile formatted websites and eBooks similarly provide a native mobile connection for display on smartphones and tablets. Content for the websites and for the publications only has to be entered once at the beginning, and then flows to either traditional or mobile formats. Also, the new mobile website has a built in link to Twitter.com allowing our news stories to achieve a wider reach with little extra work.
- Using native iPhone and iPad apps provides the users will an interface that is optimized beautifully for mobile use. Distribution worldwide is handled by the iTunes market place.

The NPM and IPM programs will continue to work on and improve a “mobile first” attitude to advance its connection with Wisconsin’s agricultural community’s needs. The goal will be to facilitate communication at any time and in any location, using both traditional and new mobile internet methods.

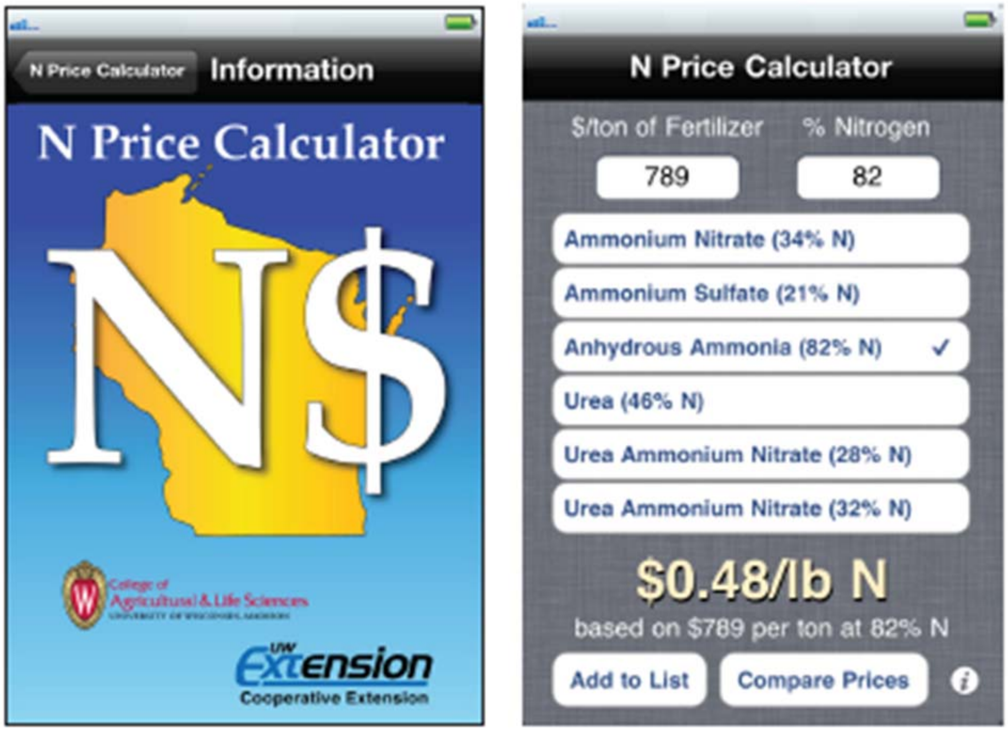


Figure 1. N fertilizer price app home screen and data entry/response screen.

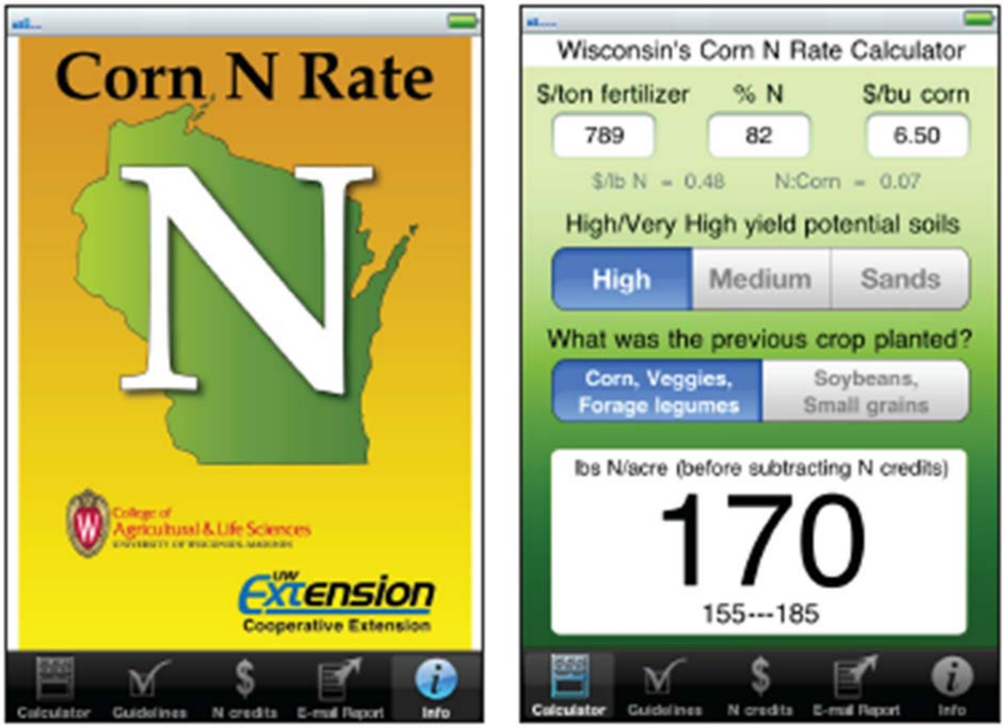


Figure 2. Corn N rate app home screen and data entry/response screen.

COVER CROP DECISION TOOL AND ON-FARM NETWORK

{An update on UW Extension cover crops research and education programming}

Kevin B. Shelley[1]

Background

Cover crops can be planted to provide soil cover during otherwise idle intervals, or fallow periods, in a given crop rotation – that is, between harvest and planting of commodity or feed crops. In Wisconsin, a cover crop might be planted after harvest of a short season crop such as a small grain or vegetable crop. Cover crops are grown to benefit the soil by preventing erosion, adding organic carbon, recycling or adding plant nutrients, and by enhancing microbiological communities associated with biological diversity. Some plant species used as cover crops provide pest management functions within a crop rotation. The term "cover crop" is really a catch-all phrase for numerous uses associated with soil improvement and conservation, nutrient management (green manure), pest management (weed and disease suppressors) and reduced reliance on purchased fertilizers and pesticides. Plant species best suited to use as cover crops tend to be fast, aggressive growers for which affordable seed is readily available. Other desirable traits depend on the desired function, such as erosion control, nitrogen fixation, nutrient scavenging, soil carbon addition (soil builder), weed suppression or disease suppression.

Examples of cover crops for use in Wisconsin

Legumes	**Non-legumes**
Hairy or chickling vetch	Oats, barley, Winter (cereal) rye
Red clovers	Annual ryegrass
Crimson clover	Buckwheat
Field pea, Austrian winter pea	Forage (oilseed) radish

Cover crops in grain and processing vegetable production are usually grown for short durations (less than a full season) and without intention of harvest. However, in organic and fresh market vegetable production, covers may have one or 2-year residence in a field for nutrient and pest management purposes. There are limited examples of living covers, or "living mulches," which are inter-planted to grow within the growing commodity crop itself. Also, what is known as a short season cover crop in a grain or processing vegetable rotation, may also be an important source of harvested or grazed forage (planned or contingent) if the farm includes livestock enterprises.

Interest in cover crops is growing among farmers for a variety of reasons. For example, planting winter cereal rye following corn silage harvest is often recommended by county conservation specialists to help farmers meet soil loss reduction and/or nutrient management goals in conservation planning. The rye will provide over-wintering ground cover that will be terminated in early spring as a cover crop. Or, it can be left to grow until boot stage and harvested as an early season forage crop prior to planting the season's main crop. Rye is also commonly planted after short season vegetable crops in Wisconsin's central sands region to curtail wind erosion. Seeding medium red clover into established winter wheat in early spring is done by some farmers to establish a nitrogen fixing, weed smothering cover following the wheat crop's harvest. These two are practices for which UW research and management guidelines exist.

[1/] Outreach Program Manager, Univ. of Wisconsin Nutrient and Pest Management Program, 445 Henry Mall, Madison, WI 53706. 608-262-7846.

Other species and practices may have less of a research base behind them and have been pioneered more by farmers and seed companies themselves. For example, in recent years numerous articles have appeared in crop production magazines featuring the Tillage Radish®. Tillage Radish® is a selection of the large, white daikon radish, and is among the types referred to as forage radish, and oilseed radish. The Tillage Radish® is marketed with the claim that it can help to relieve soil compaction as its large tap root grows down into the soil profile, providing a sort of "bio-tillage" as well as other soil quality benefits. It has particular interest among no-till cash grain producers. One Wisconsin-based seed company reports selling Tillage Radish seed to plant over 8,000 acres in summer of 2011, mostly planted after wheat.

Also, forage-type radish, turnips and rape are gaining interest as cover crops among cattle grazers. These forage brassicas can be planted after short season crops, such as wheat, to fill a niche for late summer, fall and sometimes early winter grazing. Some advocates suggest planting these brassicas in a "salad" or "cocktail" mix that includes an annual legume, such as berseem clover, and a grass, such as annual ryegrass or a small grain like oats. This can help to establish a cover with a lower seeding cost and is thought to maximize soil ecological benefits by providing species diversity.

<u>UW Extension Cover Crops Workgroup</u>

In 2010, UW Extension (UWEX) educators formed a workgroup,* partnering with colleagues from other agencies, to provide Wisconsin farmers, crop production advisors and conservation specialists with research-based information about opportunities for using cover crops and their potential benefits. In 2011, the group's main activities included: professional development training for soil and water conservation agency staff on cover crop uses in Wisconsin; initiation of on-farm data collection (on-farm network); and, collaborative development of an on-line decision tool for selecting cover crop species for a given farm's situation.

<u>On-farm Network</u>

In 2011, several UWEX workgroup members teamed up with Wisconsin farmers to establish on-farm cover crop research and demonstration trials. The purpose is to jointly learn more about how to manage various cover crop species and evaluate their potential utility and economic value. Specific objectives include:

Learn more about how to establish, grow, harvest and/or terminate cover crops of interest - particularly with species of more recent interest;

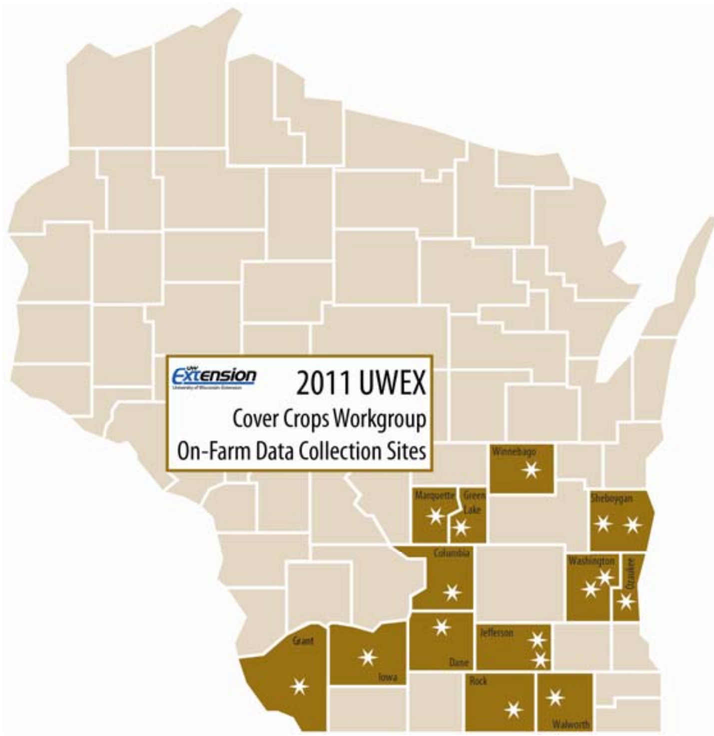
Evaluate the extent to which various cover crops provide benefits (agronomic/economic) relative to their cost of establishment, harvest and termination;

Begin to quantify environmental and conservation functions associated with the cover crop;

Identify needs for more rigorous research (laboratory, greenhouse, and research station);

Refine county-specific recommendations generated by the Midwest Cover Crops Council Cover Crops Decision Tool.

Most of the 2011 on-farm fields were planted to tillage or forage radish, radish mixed with other grass and legume species, or other forage brassica mixtures. Most of the cover crops were planted in early August following wheat harvest. Some were planted in late August or early September following oats or fresh market vegetable crops. One site focuses on medium red clover following winter wheat and another on winter rye after corn silage. In fall of 2011, data was collected on biomass production and nitrogen assimilation by the cover crops at 15 sites where the covers will winter kill or are fall-terminated. Some of the forage and tillage radish



2011 On-farm data collectors:
Nick Schneider
Heidi Johnson
Richard Proost
Mike Ballweg
Jim Stute
Gene Schriefer
Keith Van der Velde
Rhonda Gildersleeve
Tim Wood
Kevin Shelley
Matt Ruark

With cooperating farmers

trials are measuring the effect of N fertilizer and/or manure applications on biomass production and N recovery. Similar data will be collected from the rye trial (Columbia County) in spring 2012. The fall data collection protocol and laboratory analyses are provided by Dr. Matt Ruark at UW-Madison Soil Science Extension.

Plans for 2012 data collection vary across sites. Some will measure pre-plant soil nitrate levels in early spring and compare different N application rates applied to corn following the cover crop. At the Winnebago County site soil water infiltration rates will be measured and compared between the cover vs. no-cover treatment from 2011. Others will compare the 2012 crop's yield between the 2011 cover vs. no cover treatments and may include N fertilizer rate treatments. The Sheboygan, Ozaukee and Washington County project will conduct an in-depth economic analysis. Others, such as those sites producing fresh market vegetables, will make only qualitative observations as to the effect of the 2011 cover crop on the 2012 commodity crops.

<u>On-line decision tool for selecting cover crops in Wisconsin</u>

The Midwest Cover Crop Council (MCCC) Cover Crop Decision Tool is a web-based system designed to assist farmers in identifying cover crop options for their farm. Current versions support identifying cover crop options applicable to row crop rotations. Cover crop options provided by the tool are based on the following criteria:

1. County frost/freeze data
2. Cash crop planting and harvest dates
3. Field drainage, tile and flooding information
4. Desired cover crop attributes (reason for cover crop use):

Nitrogen source,	Nitrogen scavenger,
Soil builder,	Erosion fighter,
Weed fighter,	Good grazing,
Quick growth,	Lasting residue,
Forage value,	Seed/grain value,
Ability to be inter-seeded with the cash crop	

The program provides technical information and guidance on planting and managing the cover crops of interest. These fact sheets are based on regional and state specific research papers and educational publications. The foundation of information within the tool comes from the Sustainable Agriculture Research and Education (SARE) publication Managing Cover Crops Profitably, 3rd edition (http://www.sare.org/publications/covercrops/covercrops.pdf). The current version of the tool has been completed for Indiana, Michigan, Minnesota, Ohio, and Wisconsin. County specific information and ratings provided by the tool are based in input from a local team of experts who use a combination of research literature, on-farm experience and practical knowledge. For the Wisconsin version, this team was comprised of a sub-group of the UWEX cover crops workgroup.

The Cover Crop Decision Tool is a project of the MCCC. The MCCC is a diverse group from academia, production agriculture, non-governmental organizations, commodity interests, private sector, and representatives from federal and state agencies. The MCCC collaborates to promote the use of cover crops to address soil, water, air, and agricultural quality concerns in the Great Lakes and Mississippi river basins. MCCC member states/provinces include Indiana, Michigan, Ohio, Manitoba, Ontario, Illinois, Wisconsin, Minnesota, Iowa, and North Dakota. Learn more about the MCCC at http://www.mccc.msu.edu. The cover crops selector tool can be accessed at: http://www.mccc.msu.edu/selectorINTRO.html.

***UWEX cover crops workgroup members**

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