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Distinguished Service Awards

Distinguished Organization Award
Landmark Agronomy – Evansville
{For Exemplary Industry Professionalism}

Education Award
Carrie Laboski, UW Dept. of Soil Science
{For Leadership & Commitment
to Educational Excellence}

Outstanding Service to Industry
Joan Viney, Wis. Crop Production Association
{For Dedication & Support to WCPA and Its Members}

Board Member Service Award
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{For Full-Term Board of Director Service}

President's Service Award
Mike Mleziva
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2010 – 2011
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THE MOST IMPORTANT TOOL IN THE NITROGEN MANAGEMENT TOOLBOX

Carrie A.M. Laboski[1]

Nitrogen management continues to be one of the biggest challenges facing crop managers. High fertilizer prices, confusion about fertilizer technologies, and weather uncertainties are just a few of the issues encountered when trying to balance economic and environmental sustainability. The purpose of this paper is to outline how understanding the N cycle is the most important tool that you can use to make profitable N management decisions.

Details of the N cycle are discussed in depth in most soil fertility textbooks. An abbreviated but still very useful discussion is provided in UWEX Publ. no. A3588 "Management of Wisconsin soils" (Schulte et al., 2005). The N cycle is depicted in Figure 1. Several real world scenarios will be used to demonstrate how an intimate knowledge of the N cycle is beneficial to making sound N management decisions.

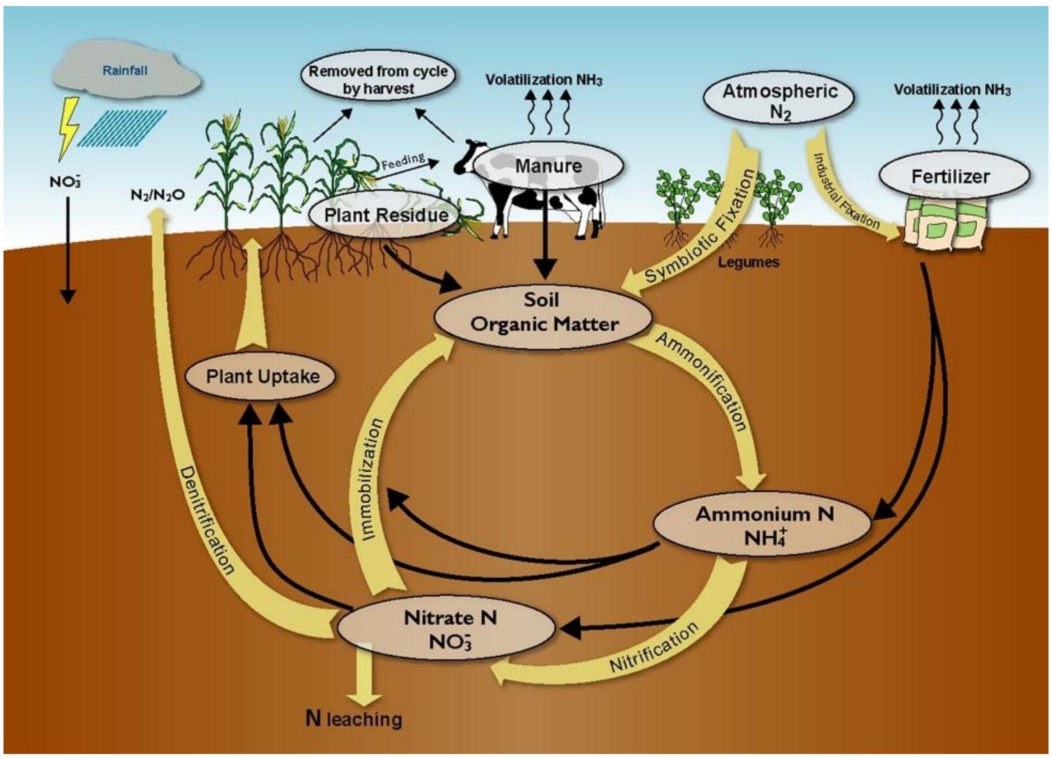

Figure 1. The nitrogen cycle (Schulte et al., 2005).

Situation 1: Sandy soils

Nitrate leaching is the biggest concern on sandy soils. Therefore all efforts should be made to reduce the potential for nitrate leaching. Ammonium containing fertilizers are preferred over nitrate sources. Ammonium is held on the soil's cation exchange capacity and is not leachable. Ammonium is converted to nitrate by soil bacteria in the nitrification process in a relatively short period of time. Preplant applied polymer-coated urea fertilizers, such as ESN, have been shown to

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increase yield over other N sources applied preplant when heavy rainfall occurs after planting. However, split applications of ammonium sulfate have been shown to be superior to preplant polymer-coated urea during years with high rainfall (Bundy and Andraski, 2007). The polymer coating slowly releases urea, which reduces its' leachability. Urea-containing fertilizer should be incorporated within two days of application by tillage or by one-quarter inch of rainfall/irrigation. If urea remains on the soil surface, N volatilization losses will occur. Nitrogen should be applied just before peak demand. Sidedress or split (preplant + sidedress) applications are preferable to spring preplant applications and fall applications should be avoided. Splitting of N applications into three or more application timings has not proven to be superior to sidedress or a single split application. Nitrification inhibitors, such as nitrapyrin (NServe), temporarily stop the conversion of ammonium to nitrate. Thus, they have the ability to reduce the potential for nitrate leaching by holding N in the ammonium form. Nitrification inhibitors applied with preplant N applications can increase yield compared to preplant applications without inhibitor; however past research has shown no yield benefit to sidedress applications with inhibitor.

Be sure to adjust total N application rates to reflect forage legume or manure N credits to reduce potential for N leaching. On sandy soils, water is more limiting than N in most years. Thus, unirrigated sandy soils should have a lower rate of N applied compared to irrigated sands. Any N that is unused is an unnecessary expense and has the potential to leach into ground water. If irrigating, be sure that irrigation amounts do not exceed the soil's water holding capacity. See Wolkowski et al. (1995) for more details.

Situation 2: Excessive rainfall on silt loams

Excessive rainfall during the growing season has been a troublesome issue over the last several years. On silt loam soils the biggest question is, "how much N have I lost?" In this situation denitrification is the portion of the N cycle that needs to be understood. High rainfall amounts resulting in standing water can cause nitrate to be converted into the gases dinitrogen or nitrous oxide and subsequently released to the atmosphere. Denitrification occurs because soil bacteria are breaking down organic matter under low oxygen conditions and the bacteria use nitrate in a biochemical process. Thus, it is important to understand that several environmental factors determine if denitrification occurs and to what extent. Nitrate must be present. If nitrate is not present or is in low concentrations, denitrification losses will be minimal. Denitrification occurs in wet soils with low oxygen concentrations. Therefore, the longer the time period when soils are saturated, then a larger percentage of nitrate can be denitrified. Denitrifing bacteria work faster in warm soils, particularly when soil temperature is greater than 75°F. Soils with low soluble organic carbon will have less potential for denitrification than soils with high soluble organic carbon. Thus, nitrate that resides deeper in the soil profile (e.g., below 12 inches) where there is less organic matter will have a greatly reduced or minimal probability of being denitrified. Denitrification is negligible in soils with a pH < 5.0. Thus, pH likely doesn't limit denitrification on most of our cropland in Wisconsin.

If denitrification losses are suspected a PSNT sample could be used to assess the N status of the fields. If the concentration of N in this one-foot soil sample is greater than 21 ppm, then there should be adequate N for the crop. There are a couple caveats when using the PSNT in this manner. First, it will work best if N was broadcast rather than band applied. Soil samples collected from fields where N was banded, may not accurately represent the N status of the field. Second, even in medium- and fine-textured soil, nitrate may have moved into the second foot of soil. In this case, the PSNT won't measure all of the N that is in the root zone and available for the crop. Additional details and considerations for heavy rainfall situations can be found in Laboski (2008).

Sidedress N applications reduce the potential for denitrification losses from excessive early season rainfall. However not all producers use sidedress N application. It situations where all of the N is applied preplant to fields that *often* have saturated soil conditions, a nitrification inhibitor, may be a economical choice to help maintain N in the ammonium form that is not subject to denitrification losses. For more information on the economics of using a nitrification inhibitor see Laboski (2006).

Situation 3: Topdressing in no-till corn or grass pasture

In no-till corn production and grass pastures topdressing N is a common practice. Ideally an ammonium form of N, such as ammonium sulfate or ammonium nitrate, would be used because ammonium is not subject to volatilization losses. Because of high price and low availability, ammonium sulfate and ammonium nitrate may not be viable fertilizer materials. Thus, urea-containing fertilizers may be used even though up to 20% of the N may volatilize if the urea is not incorporated with rainfall within two days. Controlling volatilization losses are a key aspect of successfully managing the N cycle in this situation. Volatilization losses are greater in following soil and climatic conditions: no rainfall, high temperatures, high soil pH, intermediate humidity (50-90%), low clay and organic matter content, and crop residues on the soil surface. In these situations, a producer may consider using a urease inhibitor, such as NBPT (ie Agrotain), to halt conversion of urea for 7 to 10 days until adequate rainfall can wash the urea into the soil. Polymer-coated urea is another option to limit N volatilization losses.

Situation 4: Fall N applications

Fall N applications can be troublesome because there are numerous opportunities for N to be lost before the crop can take it up. Fall fertilizer N application should be avoided on sandy soils or other soils that have a high probability of leaching N to ground water with the exception of fall seeded crops. For fall application on silt loam soils, nitrate-containing fertilizers should be avoided because the nitrate can be immediately lost though leaching and denitrification. Ideally fall manure and fertilizer applications will be made once the soil temperature is less than 50° because the nitrification and mineralization processes are dramatically reduced at low soil temperatures. Nitrification inhibitors may be beneficial at reducing the potential for nitrate losses, when N is applied in the fall, particularly the early fall.

Situation 5: Manured fields and forage legumes in the rotation

In 2009 numerous agronomists observed that manured fields ran out of N before the end of the growing season, with some noting lighter green corn in early- to mid-July. An additional observation was that fields with spring applied manure looked worse than fall applied manure. Agronomists questioned why this happened and what could be done about it. Having low manure N availability in a year with a cool spring is not unexpected because the availability of the organic N is dependent upon soil bacteria to mineralize it. When early growing season soil temperatures are cool, mineralization occurs more slowly. If the entire growing season remains cool, as it did in 2009, then it is likely that the actual N availability may be less than expected. Past research in Wisconsin has shown that if July–August temperatures are at or above the average after a cool spring, the total amount of organic N mineralized with be close to expectations.

The pre-sidedress nitrate test (PSNT) can be used to verify manure credits if it is suspected that there is low N availability. Note that when May–June temperatures are more than 1° below normal, then the PSNT sometimes underestimates the N credit, suggesting that a higher sidedress application rate is needed, when perhaps it is not. If manure credits were determined with book values estimates of total N content, then it may be useful to have manure tested in the future, because the manure from that farm may not be very close to the "average" manure that is used in the book values.

First-year corn after alfalfa needs substantially less N fertilizer than corn following corn. At times agronomists observe that first-year corn appears to need more N than predicted with MRTN and the book value alfalfa credit. If low N availability following alfalfa is suspected, then a PSNT can be used to determine whether or not a sidedress application of fertilizer N is required. The PSNT can also be used to verify second-year forage legume credits.

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RESIDUE MANAGEMENT: 2020 AND BEYOND

Richard Wolkowski [1/]

Residue management should be a focus of every producer's crop management plan. Crop residue is known to be important for erosion reduction, supplying of organic matter for maintaining soil tilth, and as a sink for plant nutrients that are released to subsequent crops. The amount of crop residue at the surface has traditionally been linked to soil conservation programs, and it is generally accepted to be the farmer's best tool for controlling erosion. As the yield potential of crops has increased, the amount of residue has increased. This has been viewed as problematic by some, especially for corn, where the additional residue is considered to be a hindrance to tillage. The greater residue has caused some producers to "size" the residue by chopping or installing chopping heads on their combines. In many instances the crop residue is baled and removed, especially in years like 2010 when crops matured early. Furthermore, traits such as "Bt" have anecdotally been linked to slower residue decomposition and have resulted in more aggressive residue management by producers.

Producers should be encouraged to establish "tillage goals" that fit their soil types, equipment capability, and management skills. Several years ago Professor Ron Schuler from the UW Biological Systems Engineer Department outlined these goals based upon the need for conservation practices, the soil and residue condition, and the crop rotation. Tillage practices based on these goals will vary from one area to another and one producer to another. His list included:

- Quantity and type of residue and soil condition prior to tillage
- Desired final residue cover, distribution, surface roughness, and seedbed condition
- Presence of compaction or rutting
- Power and time requirement
- Planter capability
- Other management issues (e.g., fertilizer or manure incorporation, conservation programs)

Tillage Management Trends

While the forecast for residue management ten or twenty years into the future may be similar to predicting next week's weather, a sense of what might be expected can be learned by examining recent trends. The WDATCP has been able to collect limited, but useful, data through the annual transect surveys conducted in several counties. This survey uses a standard protocol to estimate soil erosion equation factors and tillage type at defined locations typically spaced at 0.5 mile increments on a prescribed driven route. The data are useful for assessing conservation programs and for future education in soil management. The state-wide data are summarized in Table 1. The presented comparison sums fall and spring moldboard and chisel tillage into one tillage category. Corn data are for corn grain systems. Soybean data are pooled for drilled, and

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narrow and wide row planting systems. The "other" category includes tillage with disks, field cultivators, and strip-tillage. These data show several trends. First, no-till production systems are increasing for both crops, presumably because of enhanced weed control management options through the glyphosate resistant trait and improvement in planter technology that simplify no-till management. It is assumed that most no-till systems use some type of residue managing coulters. The amount of moldboard tillage has steadily decreased, most likely because of the increased time required for plowing and the price of fuel. Chisel tillage has become the full-width alternative for many producers in both corn and soybean. The increase in farm size has also likely contributed to the increased percentage of no-till and chisel systems because of the time savings associated with these practices. Finally, participation in government programs and nutrient management planning, both of which lead to a focus on farming within "T" have become increasingly important. Note that the nature of the growing season can affect tillage management. The 2009 growing season resulted in a very late harvest and therefore less time for tillage before freeze-up. This likely increased the amount of fields that were either no-tilled or chisel plowed, with a substantial reduction in moldboard plowing. The 2011 transect data may show a drop in these categories because of the early harvest and extra time that was available for tillage.

Table 1. Wisconsin tillage transect data for 1996 – 2010, (Source: WDATCP).

Tillage	1996	2000	2005	2008	2009	2010
	------------------------------------ % of fields ---------------------------------------					
Corn						
No-till	6	11	22	20	22	29
Chisel	37	39	33	52	53	58
Moldboard	52	49	43	12	12	5
Other	5	1	2	16	13	8
Soybean						
No-till	2	29	46	40	45	49
Chisel	59	39	34	38	37	38
Moldboard	28	22	19	5	7	5
Other	11	10	2	17	11	8

Expert Forecasts

Several Midwestern university faculty were asked how they felt tillage and crop residue management would change in the next 10 to 20 years. One researcher felt there would be both pessimistic and optimistic outlooks for the future of residue management that would affect farmer adoption of the various practices. Pessimism was based on the recent cool, wet springs that caused challenges with planting and increased soil compaction. Some producers are growing more corn on corn, which leads to residue accumulation and slower growth if the residue is not incorporated. Finally, he believed some are concerned with nutrient stratification in long-term no-till and weed shifts that are often encountered as tillage practice changes. Optimism for more no-till for some producers comes from an increasing awareness for the need for improved soil conservation. Recent heavy rains have resulted in significant erosion, which progressive growers won't tolerate. Other factors that enhance management in high residue environments are tillage and planting equipment that is better designed to handle more residue and hybrids that are better adapted to the early cool and wet conditions. This researcher predicts growth in strip-tillage that helps moderate some of the concerns with early growth suppression and surface compaction. Vertical tillage systems, if proven to be superior to other full-width systems like chisel, may also expand. He urges producers to make their tillage management decisions on research, not anecdotal observations and equipment company marketing.

Another researcher felt that the demand for corn grain or biomass for fuel in the Midwest would drive an effort to produce maximum yields. His concern is that this may trump conservation practice policies leading to greater tillage intensity on the landscape. More corn on corn would be expected to lead to more full-width tillage, of which most would be chisel plowing or similar practices. This year he has observed more stalk removal via baling than he's ever seen in the past ten growing seasons. Such practices that remove 50% or more of the surface residue increase the potential for erosion. There was a concern that removal of residue would lead to reduced soil organic matter and poorer soil quality in the long term.

A third regional expert believes that equipment limitations and a shortage of quality labor may limit the ability to produce crops in high residue systems. It is known that speed, soil and residue conditions, the utilization of technology such as RTK guidance, and operational costs will affect the capacity to successfully grow crops in no-till or similar high residue systems. Farmers have begun to use implements that claim to provide "vertical tillage," most likely because of their ease of operation and the fact that they can cover a lot of ground running these tools at 10 mph. The fact that these tools provide full-width tillage, size residue, and show a bit of bare soil are some of the reasons for the current high interest in their adoption. This person suggested that if society is serious about combating soil erosion and runoff then government programs that promote residue management through incentives will be necessary. The availability of significant funds for such programs in these budget times is an issue and will likely not improve in the future. Finally, many of the grain production soils in the Midwest are somewhat poorly drained necessitating tiling. Tiling these soils removes a large element of production risk, but may increase the delivery of nutrients to surface waters via the discharge in drainage water.

Climate Change Effects

Concerns regarding the effect of climate change on agriculture have been expressed as warmer weather impacts cropping management and weather patterns have resulted in more intense rains in the past decade. The effects of climate change can be argued, but the observation of the frequency of intense storms has been documented. The Soil Conservation Workgroup of Wisconsin Initiative on Climate Change Impacts (WICCI) prepared a report that outlined the current situation and considered the potential soil erosion impacts in the future. Figure 1 shows the trend for the increasing intensity of rain storms over the past six decades. There was some variation between locations around the state. An increase of up to 60% more storms of at least one inch was observed in the past 30 years at some locations, whereas others showed a decrease in recent years. In general these data show a trend for more intense rain storms in the past ten to twenty years (one only has to think of the storms of June 2008 or September 2010 to support that observation), which will lead to more soil erosion. As the trend continues, and perhaps worsens, the potential for increased soil loss is a real possibility.

Another Wisconsin agricultural trend that is apparent is the change in cropping system that has occurred as smaller dairies are closed. Larger dairies are utilizing more corn silage, which leaves little residue. Wisconsin Agricultural Statistics show that in the past 40 years production acres of corn for grain have doubled, whereas hay acres have been reduced by 50%. There are nearly 10 times as many acres in soybean production in the same time period. It is recognized that intensive tillage in a corn/soybean rotation can increase soil loss, compared to longer rotations that contain several years in hay production. Much of this shift is occurring in the Driftless Area of southwest Wisconsin, where loess soils predominate on steeply sloping land. Intensive tillage on these soils would have serious consequences.

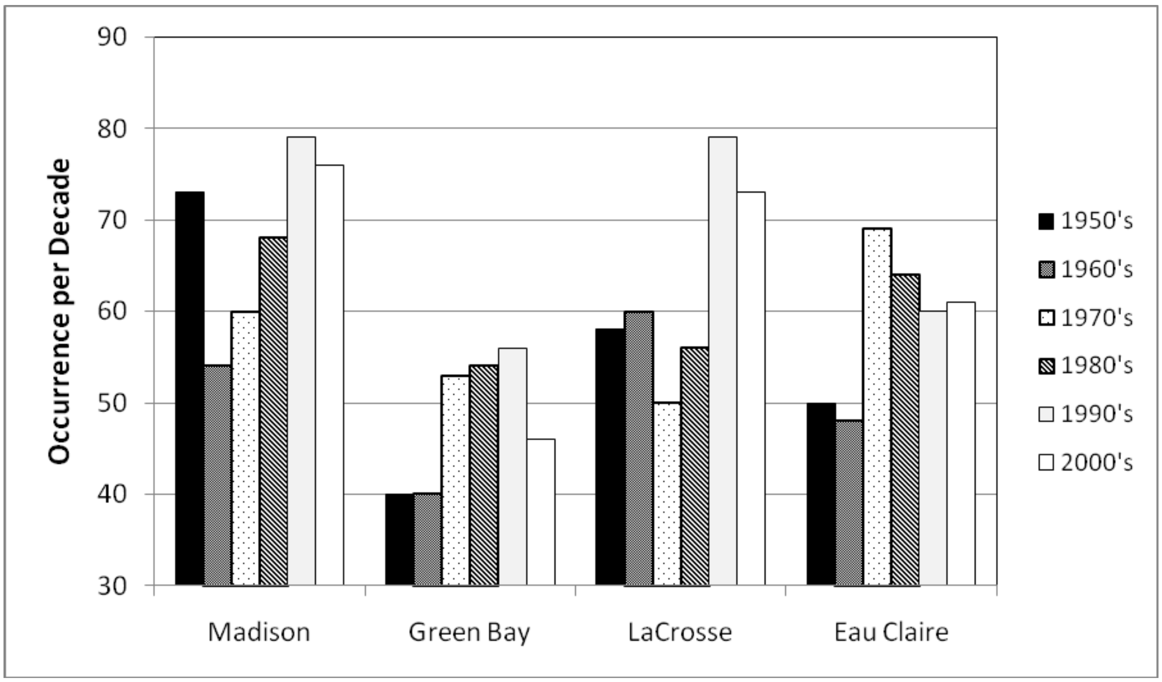

Figure 1. Occurrence of daily precipitation events greater than one inch at three Wisconsin locations. Source: WICCI Soil Conservation Working Group report, Univ. of Wisconsin Madison, 2010 (adapted from Kucharik et al., 2009).

The WICCI report suggests that there is indeed a risk for greater soil erosion in the future. The USDA-NRCS National Resource Inventory estimates that the average soil loss for Wisconsin in 2007 was 4.44 tons/acre (± 0.25 ton/acre), which is an increase of 0.72 ton/acre determined just ten years earlier in 1997. The recent DATCP transect survey shows that about 75 % of Wisconsin fields meet “T”, which is down slightly from about 80% 10 years ago. Future modifications of factors in the soil loss equation by NRCS will modify the “T” value for some Wisconsin soils. While it is predicted that this may affect about a third of our soils, significant changes in tillage management, along with associated conservation practices and crop rotation will be needed to meet program goals in some locations.

Post-harvest Residue Management

A common practice for producers concerned with large amounts of residue from high yield corn production is to size residue, either by utilizing a chopping head on the combine or chopping stalks post-harvest. Stalk chopping has become ubiquitous on the landscape, especially in early seasons like 2010. Stalks are chopped, of course, to reduce their size and improve their flow through tillage equipment. Furthermore, removal of the chopped stalks as bales or flail-chopped materials has raised concerns about soil quality, which is made worse when manures are not returned to these fields. The consequences of stalk chopping, in addition to added equipment and fuel cost and operator time, is the fact that subsequent tillage will bury more residue compared to fields where stalks are not chopped. A recent study conducted at the Arlington Agricultural Research Station (Wolkowski, unpublished data) compared treatments with and without post-harvest flail chopping in continuous corn in either a chisel or no-till system. Surface residue measurements were made immediately after fall chisel tillage in 2010. The tillage x chopping interaction was statistically significant (Pr>F = 0.04). Under chisel tillage chopping reduced surface residue from 61 to 42%, whereas the change in no-till was minimal just 96 to 94%. Subsequent secondary tillage next spring in the chisel system may reduce the surface residue below 30% in the chopped environment, while it is expected to be well above that mark where the residue was not chopped. Chopping in no-till can leave a mat of residue that may keep the surface of the soil wetter, whereas some un-chopped residue will remain upright and may allow for better air circulation and drying prior to planting. This study evaluated chopping conducted in the fall of 2009, which was not found to affect the early season soil temperature, emergence rate, final stand, early season plant height, or corn grain yield measured in 2010.

Summary

Most everyone will agree that soil conservation is a very important issue and that farmers hold the key to keeping erosion in check. Conservation tillage and other factors that impact surface crop residue during the growing season are a producer’s best option for controlling erosion, especially when appropriately coupled with suitable crop rotations and supporting conservation practices on the landscape. A combination of factors is expected to affect tillage and crop residue management in the future, which will become increasing challenging if rainstorm intensity and the potential for soil erosion increases as expected. Cropping system practices will change to meet current demands, whether that be biofuel production, livestock feed, or food and industrial uses. Economic consideration will drive many decisions and it is incumbent upon those in higher education and the service community to provide demonstrated alternatives that farmers can use with success. Farmers are an adaptive group who are likely to support reasonable options for practices or systems that improve productivity and profitability, while limiting environmental risk.

PESTICIDE CONTAINER AND REPACKAGING UPDATE

Mark McCloskey [1/]

Flowcharts describing this pesticide container, labeling, and repackaging presentation will be available as a PDF to view and download from the Wis. Crop Management Conf. materials web site at <http://www.soils.wisc.edu/extension/wcmc/>.

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SNAP-PLUS UPDATE AND ROUNDTABLE DISCUSSION

Sue Porter [1/] and Laura Ward Good [2/]

Snap-Plus version 1.132 was released in September, 2010. It includes improved report packages, more problem flagging to guide planning, and 39 new crops. The 2011 release will be updated software (version 2). Over the next several years, GIS mapping capabilities will be added to version 2.

Snap-Plus is available for download from www.snapplus.net.

For information on the newest release, look for the link in the "Important News" (red) box on the Snap-Plus home page.

Look in the Snap-Plus Help file for a complete list of new features in the current version.

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IRRIGATION AND THE GROUNDWATER BUDGET: NO FREE LUNCH

William L. Bland[1]

Introduction

Irrigation is fundamentally the act of distributing water onto soil that is not quite wet enough to keep crop plants growing at their best. But as the old saying goes, there is no free lunch. We pay for irrigation in some obvious ways–equipment, energy–but also in some harder-to-count ways. Irrigation water has to come from somewhere–what are the impacts of this extraction? How much irrigation is too much?

Irrigation water comes from rivers, lakes, and groundwater. In Wisconsin groundwater is the main source of irrigation water, and it is groundwater pumping that is raising the most concerns. How do we understand the costs that irrigation imposes on the groundwater? First, a brief review of the basics of groundwater. Groundwater resides in near-surface layers of Earth, in the pores and cracks within and between materials such as sandstone, sand and gravel, and limestone. A significant body of such geological material with pores filled with water is called an *aquifer*. Water in soil, lakes, and rivers may become groundwater by percolating downward into an aquifer, in a process termed *recharge*. Groundwater can escape its dark confines by bubbling up to the surface as a spring, or seeping upward through the bottoms of lakes, streams and rivers, a process called *discharge*. When we try to track the rates of recharge, discharge, and changes to the amount of water stored in a aquifer we say that we are working out its *budget*. Some aquifers were filled many thousands of years ago and no longer undergo much recharge or discharge, while in other aquifers water is just passing through (slowly) from areas of recharge to areas of discharge. In the most common type of aquifer we call the upper boundary of the fully-full-of-water (saturated) pores the *water table*.

When we drill a new well and pump from it for irrigation (or manufacturing or drinking) we are adding a new discharge point to the aquifer. What is the impact of a new discharge? How much can we safely extract through it? This is one of the key questions surrounding the sustainability of irrigation.

An intuitive answer–that turns out to be wrong–is that the rate at which we extract water by pumping from an aquifer should not exceed the rate of recharge to the aquifer. One way to recognize that this is too simple an answer is to imagine the aquifer system before any wells are drilled into it. Water enters the aquifer as recharge, lingers a time as it moves slowly toward a discharge (there can be several), and finally is discharged to the surface (Fig. 1A). The amount of water stored in the aquifer, often reflected in the elevation of the water table, is the result of a balance between the inputs and outputs–recharges and discharges–of water. Add another discharge and this balance is upset. Imagine that an acquaintance proposes adding a new automatic deduction to your bank account–will this be alright as long as it is for less than your automatically deposited paycheck?

For your bank account and an aquifer a new discharge will begin to lower the balance/ water table. If you do not make some adjustments this will eventually empty your bank account. In the case of groundwater aquifers what happens is the water table becomes deeper and changes shape in ways that decrease the water flows to other discharges. There's no free lunch, something's gotta' give, you can't get something for nothing...

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The impacts of reducing other discharges by pumping from a well depend on the situation. When the elevation of a water table drops, flow out a spring may slow, or even stop. We do not know how many springs have disappeared in the Madison area as a result of pumping by the city water utility. A more subtle impact occurs when discharge into a stream bottom is reduced by pumping in the vicinity (Fig. 1B). The average flow in the stream may just be slightly reduced, by a small enough amount that it is difficult to measure amidst the daily, monthly, and annual natural variation. The effects may not be of significance during months and years of high stream flow (because of rain and snow), but can be deadly at times when stream flow is naturally small. The situation in the Little Plover river near Stevens Point is a good example of this.

There is a saying in ecology (ascribed to various thinkers): “You can’t do just one thing.” It reminds us in a subtle way that there are always multiple implications for any one of our actions. Fortunately for humans Earth is bountiful, and we can do lots of things without causing damage–although, like every other species on Earth, we cannot help but bring about a bit of change. Irrigation (and every other extraction of water from rivers and groundwater) reduces some other discharge. If we are fortunate, the impacts will be so small that we hardly notice and, if the impact can be measured, no one else cares. When impacts are large, though, our choices about how we manage groundwater become everyone’s business, rightfully so.

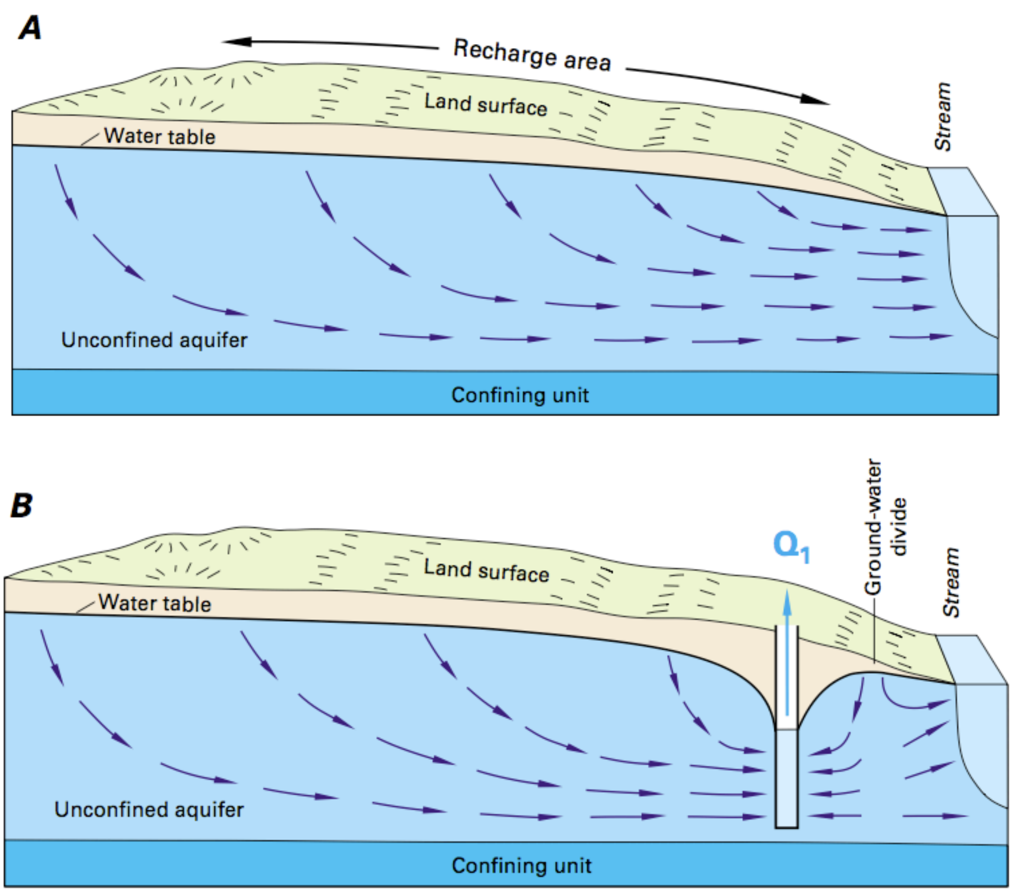

Figure 1. A. Schematic of groundwater recharge, flow, and discharge to a stream, in the absence of human intervention. **B:** When groundwater is extracted from a well this new discharge changes the water table and reduces discharge to the stream. *Source:* USGS circular 1186.

AGRICULTURAL DRAINAGE: FUNCTION AND VALUE

John Panuska [1/]

ABSTRACT

Agricultural drainage is used throughout the North America and in Wisconsin to improve crop production by removing excess surface (flooding) and subsurface (root zone) water from fields. This discussion focuses on the operating principals and design considerations of subsurface (tile) drain systems. In addition, a basic framework is introduced to evaluate the cost and benefit for drain tile installation. Crop production on certain soil types and landscapes is significantly enhanced by subsurface drainage. This includes areas with low permeability soils, isolated low pockets and lands with low slope gradients. Only water draining freely from the soil profile by gravity is removed by drain tiles. Tile drains are intended to function at atmospheric pressure as gravity flow systems. Flow occurs as a result of differences in the water surface elevation (e.g., the water table and tile elevations), thus making a positive (free flowing or pumped) outlet critical to their operation. The initial flow collector in the tile drain system is the perforated lateral. The depth to which tile laterals will lower the water table and water removal rate are a function of drain depth, spacing, soil permeability. Drain depth typically ranges from 3 to 6 ft and spacing from 30 to 100 ft. Laterals drain to mains and submains where the flow rate is governed by inside pipe roughness, pipe size and slope. Mains and submains must be sized to convey the flow from all upstream laterals. Tile drain systems eventually discharge into a surface water conveyance system or ditch. These ditches can be part of a legal (Wis. Stat. Chap. 88) public drainage system or county drainage system administered by a county drainage board. The drainage board oversees the maintenance on the county ditch system and assesses benefited land owners to cover the costs.

The decision to install a tile drain system is driven by a number of factors including economics (cost-benefit). There is no formal standard method in Wisconsin for conducting a cost-benefit analysis for subsurface drains. However, an approach developed ~ 30 years ago by Dr. Leonard Massey, UW-Madison BSE and John Prunuske has seen widespread use for benefit assessment by county drainage boards and can be used for estimation purposes. Annual benefits are determined on the basis of potential corn yields, assuming best available farming practice, the susceptibility of the land to flooding and the groundwater depth. Corn is used as the basis because it is the common commodity for which data are readily available. In addition, virtually every farmer has grown corn and is aware of the economics and conditions necessary to insure a successful harvest. Up-to-date corn yield data by soil type and production cost can be obtained from the NRCS “Soil Survey Interpretations” and USDA “Cost of Production” data, respectively.

Benefits are determined by adjusting an optimal base value per acre benefit along with several other adjustment factors as summarized by the equation:

Benefit per Acre = (Base Benefit) x (Yield Factor) x (Groundwater Factor) x (Flood Factor)

The base benefit is the net annual per acre return for corn. It is determined using the gross return (best yield x current corn market price) for the best yielding soil within the project area, less the

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estimated production costs. With good drainage, this yield can be anticipated on an annual basis. Without the drainage, this yield would be obtained perhaps one year of five, if at all. The additional net yield and average return per acre per year are determined on a five year basis. The rate of return on investment is then used to determine the level of initial investment that the calculated annual gain would support over five years. The yield factor in the above equation is the ratio of the specific soil's yield to that of the best yielding soil in the project area. Other adjustment factors include the groundwater depth and frequency of flooding. These factors are arbitrary and are based on best professional judgment of those who developed the method.

When making a decision on drain installation understanding the operating principals allows for greater appreciation of the functional benefits and limitations of the system. Cost-benefit analysis evaluates the longer term financial viability of the system. Both are critical to making an informed decision on agricultural drain installation.

IMPLICATIONS OF DRAINAGE ON FARM BILL PROGRAM PARTICIPATION

Robert D. Weihrouch [1/]

Introduction

Nearly half of the original wetlands in the U.S. have been lost. Many were drained and converted to agriculture production. The beneficial functions and values that wetlands provide to society are now universally recognized. The Food Security Act of 1985 ('85 Farm Bill), as amended, required persons who wanted to participate in USDA programs and receive benefits to be in compliance with the Highly Erodible Lands (HEL) and Wetland Conservation provisions of the Law. "Swampbuster" provided an incentive for landowners to not drain/convert wetlands for commodity crop production.

Discussion

The Natural Resources Conservation Service (NRCS) was given the technical responsibility for identifying and delineating wetlands on agricultural lands. USDA program participants are allowed to maintain drainage systems as they occurred on December 23, 1985 (date the Farm Bill was signed). Planting a commodity crop on wetlands converted after that date would cause the person to be ineligible to receive USDA program benefits during that year. The 1990 Farm Bill changed the ineligibility trigger from planting a commodity crop on a converted wetland to the act of manipulating a wetland to make production more possible. The Farm Bill has many different labels with definitions and allowable maintenance of existing drainage systems. There's Prior Convert Cropland (PC), Farmed Wetland (FW), Farmed Wetland Pasture and Hayland (FWP), and others.

Swampbuster wetland manipulations only impact persons who are USDA program participants. There are no civil or criminal penalties as there can be with the Clean Water Act (Section 404), WDNR's Chapter 30, NR299 and NR103, or County Shoreland Zoning Ordinances. This presentation will concentrate on the Farm Bill's Swampbuster requirements and only briefly mention the jurisdiction and regulatory authority of other agencies.

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GRAIN MARKETING – HOW TIGHT ARE ENDING STOCKS?

David C. Moll [1/]

The 2010 growing season can be summarized by an early planting, higher temperatures, consistent rains, early harvest and record yields. As of December 10, 2010 USDA forecasted the Wisconsin corn crop at 162 bushels per acre, a new state record and 50 bushel per acre soybeans. Nationally, the corn crop is pegged at 154.3 and soybeans at 43.9. Grain prices traded downward from planting season until the mid-summer when demand for U.S. grains became stronger. There were production shortfalls in the world in China and Russia, which resulted in Russia placing an embargo on wheat exports. The growth in demand outpaced the large production levels resulting in a tighter year-over-year ending stocks situation. Corn ending stocks-to-use ratio is at historic lows. Moving into 2011, the tight ending stocks will continue to keep the grain markets at relatively higher price levels, but will also allow for high daily price volatility, as well as large price swings.

Corn

Nationally, the corn yield expected to be 154.3 bushels, just below the 30 year trend line. The yields combined with the 88.2 million acres planted in 2010 created the third largest United States corn crop on record. Nationally the northern tier states, North Dakota, Minnesota, Wisconsin, Michigan, and New York are having record yield years. The northern tier states benefited from higher growing degree days while further south, yields were dampened by higher night temperatures during pollination. In Wisconsin, records were set in yields and production at 162 bushels per acre and 477 million bushels.

Demand is expected to increase over the 2009 crop marketing year. Feed and residual use is stable to slightly smaller compared to the year, with some reductions in livestock production. Beef production is expected to be 2% lower, pork production is expected to be 7% lower and poultry production up by 3%.

Ethanol demand continues to grow but at a much slower rate than the past 3 years as production is approaching the 15 billion gallon level set in the Renewable Fuels Standard. However, October 2010 experienced the largest ethanol production in US history. The ethanol blender's credit and ethanol import tariff is set to expire on December 31st and as of the time of this writing, Washington was considering extending it. The state ethanol blending mandates will still exist and will provide a partial floor for ethanol production in the United States, but the blending mandates could also be filled by importing ethanol, likely from Brazilian sugarcane.

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The growth in demand exceeding the large supply, it is expected to pull the ending stocks to 832 million bushels and thus having a 6.2% stocks to use ratio. This stocks to use ratio is at historic low levels, the lowest stocks to use ratio was 5.0% from the 1995 /96 marketing year. The Wisconsin 2010/11 marketing year average price is expected to be $5.05, edging out the previous high years from 2007 and 2008 of $4.20 and $4.06, respectively. With the tight ending stocks, relatively higher prices are expected for the 2010 crop. Marketing in 2011 is going to take discipline, as there will likely be information which supports one's views but as production risk subsides, prices could fall very quickly. Any bearish changes in supply or demand could result in significant price deterioration. However if there is bullish changes from a reduction in supply or an increase in demand, it would put the tight ending stocks position even tighter. When holding out for higher prices in 2011, it might be wise to consider some type of downside price protection.

Soybean

National soybean yield is expected to be 43.9 bushels per acre. This is only a small reduction compared to last year's record yield of 44.0 bushels per acre. The state yield is 50 bushels per acre edging out the previous state record yield of 48 bushels per acre from 1998. Here in the state there are 25% more soybeans anticipated than last year with a record production of 80 million bushels.

Even though there is a record large production, demand is also larger than last year with a record large export demand expected. Over the last several years exports have continually set records and the 2010/11 marketing year is expected to set another. 2009 was a record export year and even more soybeans are expected to be marketed in the 2010 crop marketing year. In the 2009 crop marketing year, China imported 60% of our soybean exports. With such a large portion of our exports headed to one country there is huge risk potential with their usage levels. For 2011 though, China is expected to import similar or even more than last year as they have outstanding sales on 80% of what they did last year and experienced a reduction in 2010 production. With the 2010 crop this is expected to increase, as of the writing, China has accepted delivery or has forward contracts on approximately 80% of what was exported to them last year. With these high early sales, it is likely that more soybeans will be export to China this next year. The US dollar is currently weak relative to other currencies. However a weak US Dollar allows for more exports as our soybeans are viewed as being cheaper. When looking at the other two main soybean exporting countries, the market is still trying to size up South American production. Last year Brazil and Argentina had a record crop, this year production is currently forecasted at similar levels with increases in acreage but a modest reduction back to trend yield. The big question is just how large of a crop South America will have. Currently, there is a La Nina affecting the southern hemisphere, which is pulling moisture from their crop.

Soybean crush is also expected to maintain production levels as last year, as demand for vegetable oils and soybean meal grow. The soybean oil domestic demand is expected to increase by 7% in the 2010/2011 marketing year. The price of soybean oil is expected to be 47 cents per pound, while 2008 and 2009 were 32 cents and 36 cents, respectively. Soybean oil exports are expected to be higher than the 2008 crop but lower than last year's demand. Biodiesel is expected to increase in 2011 nearly doubled over 2009 production but still less than the 2007 record production year. Soybean meal usage is expected to be similar to 2008 levels and slightly less than 2009 as higher prices limit feed use domestically. Soybean meal exports are projected less than last year's record by about 17% but still the second highest soybean meal exports on record.

With the strong export demand and relatively stable demand from soybean crush the ending stocks for the 2010 crop is expected to be 165 million bushels. The U.S. season average farm price is expected to be $11.45, while the Wisconsin average soybean price is expected to be $11.25.

Summary

The U.S. corn and soybean crops are large but robust demand will result in a year-over-year reduction in ending stocks for 2010/11. Producers who prefer to speculate on higher prices for their 2010 and 2011 production might still want to consider some price protection for their crops. With the tight ending stocks that are currently suggested by the strong demand in both the corn and soybean markets, prices are expected to be relatively higher in 2011 than in previous years. Currently, we are in the upper range of prices compared to the previous four years. If demand rationing occurs or concerns about 2011 production begin to disappear prices can respond negatively. With these higher prices though also comes a lot of risk, as demand begins to waiver so too could the prices. The challenge for producers will be to maintain a clear set of market objectives in the face of continual market hype. Those looking for reasons to delay marketing their crop will likely find plenty of rationale for additional price increases, but, like prior demand driven markets, once the speculative interest wanes and concerns about 2011 production subside, prices can retreat in dramatic fashion.

GMO SMACKDOWN: TRAITED VERSUS CONVENTIONAL

Joe Lauer[1]

Buying corn hybrids is more confusing than ever. In the past corn was sold as dent corn and farmers had to worry about performance issues whether it was a single-cross, three-way cross, or double-cross. Then specific markets emerged and waxy, high-oil, brown midrib, leafy and nutrient dense hybrids were marketed. Today we still have many of these hybrids with genes targeted for specific uses. Most of the confusion today about hybrid selection is due to the combinations of available transgenes that protect yield better than ever before.

A farmer told me that his seed company had significantly dropped the price of a SmartStax hybrid to a price point that was similar to an average hybrid. The farmer felt that he got a "good deal." But, was it a good deal? How should we approach hybrid selection decisions involving transgenes? Certainly seed price is a factor. But even an expensive hybrid with many transgenic traits sold cheaply could be even more expensive for that grower if it doesn't yield well.

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

In this paper, I would like to review these principles of hybrid selection and expand on one of them – "Every hybrid must stand on its own." I will use the Mon810 (YieldGard) event as an example, but in the presentation I will include Mon810, TC1507 (Herculex1) and Bt11 (AgrisureCB).

What criteria should you select hybrids for?

In Wisconsin the two major uses of corn are grain and silage. There has been enough breeding progress, especially in corn silage, that the hybrid selection criteria for grain versus silage uses are different. The most important consideration regardless of use is yield. For grain, moisture at harvest can often mean the difference between profit and loss in the northern Corn Belt. For corn silage hybrids, large differences exist for quality parameters such as starch content and NDFD.

Table 1. Criteria for selecting corn grain and silage hybrids.

Criteria for Grain Hybrids	Criteria for Silage Hybrids
Grain yield	Forage yield
Grain moisture	Forage quality (i.e. Starch content, NDFD, and NDF)
Plant lodging	Insect resistance
Insect resistance	Disease resistance
Disease resistance	Plant lodging
Grain quality (i.e. Test weight, kernel breakage susceptibility)	Forage moisture
Other factors	Other factors

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Use multi-location averages to compare hybrids

Use multi-location information to evaluate grain yield, grain moisture, and standability. Today, most universities compile hybrid yield data over multiple locations. They statistically make these comparisons by testing the same set of hybrids at each location. Begin with trials that are nearest to you. Compare hybrids with similar maturities (harvest grain moisture) usually within about a 2% range in grain moisture. To ensure genetic diversity on your farm, divide the trials into two or three groups based upon grain moisture.

Consider single location results (even if the trial was conducted on your farm) with extreme caution. Use single location information (your own on-farm trial) to evaluate test weight, dry-down rate, grain quality and ease of combine-shelling or picking. The way you approach the hybrid selection decision, e.g. single-location versus multiple-locations, makes all of the difference in subsequent profitability. For more information regarding selection strategies and predicted yield increases see http://corn.agronomy.wisc.edu/AA/A012.aspx. There are many possible sources of comparative yield performance data including strip-trials (seed company and independent) and replicated-trials (F.I.R.S.T. and university). Each source of data has it's own strengths and weaknesses.

Evaluate consistency of performance

Look for hybrids that yield consistently across a diverse set of conditions. Be wary of any hybrids that finish in the bottom half of any trial. Seed companies benefit greatly from all those on-farm trials that farmers participate in (numerous weather patterns and pest situations per year). So if you concentrate on your on farm results (or the local area results), you miss out on the benefits of all the testing that goes on nationally. Corn breeders define hybrids as "stable" when they have a minimum of interaction with environments. Most hybrids are stable, but a few get reputations as "racehorse" or "workhorse" hybrids. These are difficult to characterize because it takes numerous environments to determine.

Pay attention to seed price

A major change in extension recommendations has occurred recently due to corn seed costs that have dramatically increased. It is not unheard of for seed of high-performing premium hybrids with transgenic traits to cost over $250 per bag, whereas 10 years ago, premium seed would cost about $80-$100. It is important to compare the "difference" between any two hybrids. A price that is different by more than $50-$100 per bag must be carefully considered because it is difficult to make up the bag price difference with increased yield. For a further discussion of this principle, please see http://corn.agronomy.wisc.edu/AA/pdfs/A073.pdf. Also a seed cost calculator is available at http://corn.agronomy.wisc.edu/Season/DSS.aspx.

Buy the traits you need

Remember that transgenic "traits do not increase yield, they protect yield." There are pros (safety, efficacy, and insurance discounts) and cons (expense and resistance potential) to using transgenic traits. Wisconsin is fortunate in that our landscape often includes alfalfa and pasture as part of our crop rotations. We can use these crops to help control pest outbreaks and slow development of resistance to transgenic events. Unfortunately up to this time, it was often difficult to buy the specific traits that you need. However, this is changing and in the near future there will be more opportunity to purchase specific traits.

Every hybrid must stand on its own

Every hybrid must "stand on its own" for performance. You don't know what weather conditions (rainfall, temperature) will be like next year. Just because it is transgenic and you pay extra for traits does not mean it will be high performing. Performances of hybrids with transgenic events vary by year and the combination of events stacked into the hybrid. We see transgenic hybrids ranked at the top and bottom of a hybrid trial. Therefore, the most reliable way to predict hybrid performance next year on your farm is to consider past performance of individual hybrids over a wide range of locations and climatic conditions. We see large difference among hybrids within a family (see Table 5 of http://corn.agronomy.wisc.edu/AA/A060.aspx).

Materials and Methods

For all corn hybrid evaluation trials a descriptor of the trial is the trial average. Trials are often broken into high- and low-yielding environments. All hybrids grown in a trial can be compared to the trial average. For Figures 1-3 and Table 2, I calculated a grain yield difference (bushels/Acre) between the trial average and hybrids with various transgenic technologies. Growers are usually not interested in all hybrids; rather it is the group that ranks near the top of a trial that is of most interest. Therefore, I also calculated the grain yield difference of the Top 20% of the hybrids by recalculating the average of the Top 20% hybrids and subtracting the average of various hybrid transgenic technologies. If the transgenic technology did not finish in the Top 20%, then the top hybrid for that technology was selected as the representative in the Top 20% calculations. The data source was the University of Wisconsin hybrid evaluation trials from 1990 to 2010.

Results and Discussion

Conventional hybrids have been tested in trials every year (Figure 1). The number of conventional hybrid Genotype x Environment (GxE) means in the UW trials has decreased from a maximum of 1963 GxEs during 1995 to 17 GxEs in 2009. In 1992, the first tissue cultured hybrids were tested. In 1996, the first transgenic hybrids were tested.

Beginning about 1999, conventional hybrids yielded less than the trial average. Grain yield of conventional hybrids has steadily decreased compared to the trial average to a low of 11 bu/A below the trial average in 2008. Since then yield of conventional hybrids has improved and in 2010 conventional hybrids were no longer different from the trial average.

For hybrids in the Top 20%, the conventional group yielded above the trial average of the Top 20% from 1998 to 2000. Since 2006, the conventional hybrids in the Top 20% have yielded significantly below the trial average.

Transgenic events have been sold commercially in Wisconsin since 1996. The events are offered for sale by seed companies either singly or in numerous combinations (stacks). As an example, one of the first commercial transgenic events sold to farmers was the Mon810 (YieldGard) event beginning in 1997 (Figure 2). Right from the beginning, hybrids with the Mon810 event yielded above the trial average for all hybrids until 2007. Among the Top 20% group, Mon810 hybrids yielded above the trial average beginning in 2001. The Mon810 event achieved it greatest yield difference from the trial mean in 2002, the last peak year of fall European corn borer larvae numbers (WI DATCP survey). Since 2007, hybrids with the Mon810 event in the Top 20% group have yielded below the trial average.

The Mon810 event has been stacked with other transgenic events (Figure 3) including Roundup Ready 2 (Nk603), YieldGard Plus (Mon863) and the triple stacks - YieldGard Plus RR2 (Mon810+ Mon863+ Nk603) and YieldGard VT Triple (Mon810+ Mon88017+ Nk603). The pattern of the performance of stacked hybrids varies by year and the combination of transgenic events. The YieldGard RR2 stack has done exceptionally well when measured against all hybrids in a trial. In the the Top 20% group, it took nearly 6 years (1999 to 2004) before this stack beat the trial average (2005 to 2007).

Figure 1. Relative performance of conventional corn hybrids compared to the trial average of all hybrids and the Top 20% of the hybrids. Grain yield difference (bu/A) = hybrid average – trial average. Error bars represent the standard error of the mean.

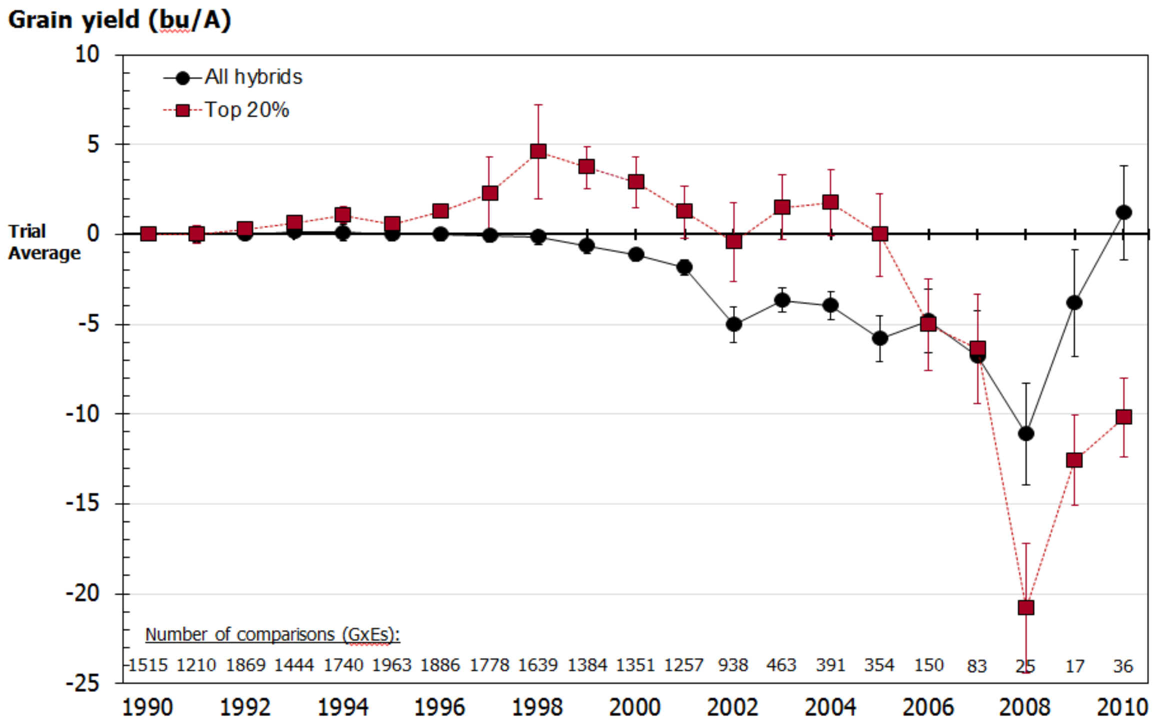
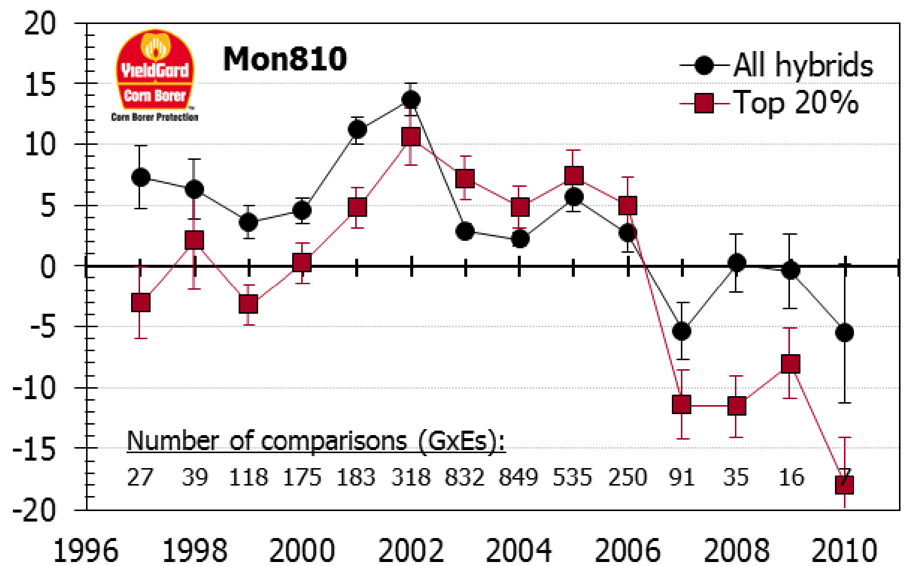


Figure 2. Relative performance of corn hybrids with the Mon810 transgene compared to the trial average of all hybrids and the Top 20% of the hybrids. Grain yield difference (bu/A) = hybrid average – trial average. Error bars represent the standard error of the mean.



The Mon810+Mon863 stack was grown in the UW trials from 2005 to 2008. In 2007 and 2008 this stack yielded at the trial average for all hybrids and only in 2008 for the Top 20% group. The triple stack Mon810+Mon863+Nk603 yielded similar to the trial average in every year of testing between 2005 and 2010 for all hybrids and the Top 20% group. Finally the YieldGard VT Triple technology (Mon810+Mon88017+Nk603) has performed exceptionally well, especially within the Top 20% group.

The performance of the Mon810 transgenic event is typical of most transgenic events. It takes time for the event to be properly incorporated into genetic backgrounds of elite, high performing and adapted hybrids. In 2010, growers were particularly interested in the new SmartStax hybrids containing 8 traits and 34 transgenes. Their performance was average for all hybrids and the Top 20% group (Table 2), and they were average in all Wisconsin production zones.

So is the SmartStax hybrid a “good deal? Not likely, given the price in 2010 and the below average performance against other transgenic combinations. But it also depends on whether the traits were needed for the field the grower intended to plant the hybrid. If a grower doesn’t need all of the traits, he probably could have grown another cheaper hybrid and produced more grain yield. Given the track record of other transgenic introductions into the market, the expectation is that SmartStax hybrids will eventually be a high yielding combination of transgenic events – but not just yet.

Figure 3. Relative performance of corn hybrids with the Mon810 event stacked with other events compared to the trial average of all hybrids and the Top 20% of the hybrids. Grain yield difference (bu/A) = hybrid average – trial average. Error bars represent the standard error of the mean.

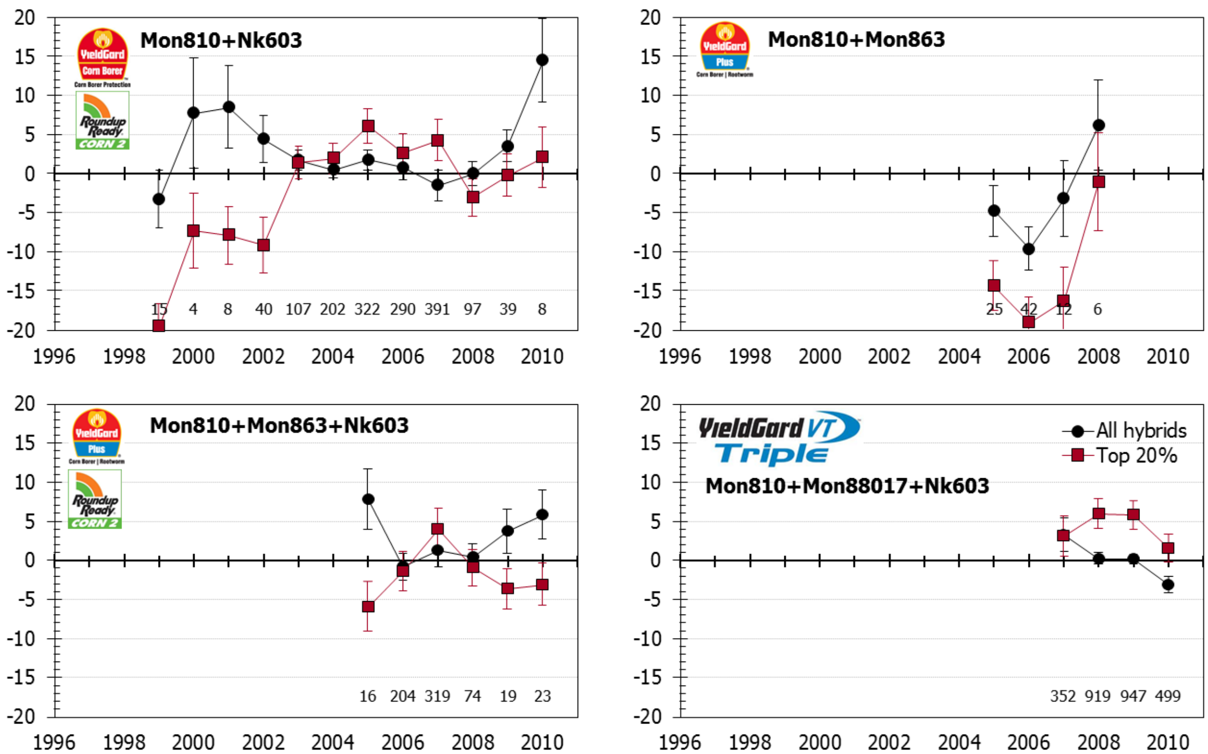


Table 2. Performance of corn transgenic technologies in Wisconsin during 2010. Values are summarized for the Top 20% of hybrids and for all hybrids across Wisconsin and within each production zone.

		Top 20%		All Hybrids					
Technology	Traits: Events	GxE[†]	Diff.[‡]	GxE	Diff.	South	South central	North central	North
		N	bu/A	N	--------------- bu/A ---------------				
	Conventional: None	26	-10.2	36	1.2	-0.8	2.1	-8.3	12.3
	CB: Mon810	7	-18.0	7	-5.4	-14.6	--	1.5	--
	LL: T25	11	-0.9	18	5.4	--	0.1	8.1	--
	RR: GA21	17	-8.6	23	0.8	-0.2	-4.0	7.1	--
	RR: Nk603	42	4.4	118	4.5	-0.3	6.1	9.6	-2.5
Agrisure CB/LL	CB,LL: Bt11+T25	13	-6.3	30	2.7	--	--	2.4	3.1
	CB,RR: Mon810+Nk603	8	1.8	8	14.5	--	--	11.4	17.7
Agrisure CB/LL/RW	CB,CR,LL: Bt11+MIR604+T25	9	-18.4	9	-6.1	-8.9	-0.7	--	--
	CB,CR,RR: Mon810+Mon863+Nk603	17	-3.0	23	5.9	14.3	3.4	6.3	--
YieldGard VT Triple	CB,CR,RR: Mon810+Mon88017+Nk603	107	1.6	499	-3.1	-0.5	-1.1	-4.2	-8.3
VT TRIPLE PRO CORN	CB,CR,RR: Mon89034+Mon88017+Nk603	18	-4.1	53	2.4	4.3	-0.2	3.9	--
Agrisure GT/CB/LL	CB,LL,RR: Bt11+T25+GA21	39	0.1	104	5.0	--	-1.2	3.2	10.0
	CB,LL,RR: TC1507+T25+Nk603	60	5.2	209	1.7	6.9	1.6	-1.0	-2.4
Agrisure 3000GT	CB,CR,LL,RR: Bt11+MIR604+T25+GA21	58	-0.1	248	-1.7	-3.4	1.8	-6.5	3.4
	CB,CR,LL,RR: TC1507+DAS591227+T25+GA21	13	-17.1	20	-6.8	-10.5	-9.8	-1.7	--
	CB,CR,LL,RR: TC1507+ DAS591227+ T25+ Nk603	31	4.5	115	2.4	0.9	1.3	4.3	12.1
	CB,CR,LL,RR: TC1507+ Mon89034+ DAS591227+ Mon88017+ T25+ Nk603	33	-2.4	105	-2.2	-1.0	-2.2	-3.8	-2.6
	LSD (0.10)		6.3		6.8	13.0	9.3	9.2	12.0

[†] GxE: Number of replicated hybrid means used to calculate Diff.
[‡] Diff.: Grain yield difference = hybrid average – trial average

Key References

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SMACKDOWN: TRAITED VS. CONVENTIONAL SOYBEAN VARIETY PERFORMANCE

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

Soybean seed price will continue to be a major driver of seed sales in 2011. Preliminary quotes on base seed price (minus discounts, seed treatment, and promotions) have ranged from the mid $30's (conventional) to the high-$50's (RR2Y®) on a per-bag, untreated basis. Growers are also challenged with a multitude of seed treatment offerings that not only confound variety selection, but also significantly increase seed price. Such a huge discrepancy in price and seed treatment options has growers struggling over their 2011 variety selection decisions.

Since 2003, we have seen a divergence in soybean yield potential between conventional and Roundup Ready (RR®) soybean varieties in our WI trials. To further characterize these yield differences and test the yield potential of LL® soybean, we included several high yielding RR®, RR2Y®, and LL® soybean varieties as checks in our conventional and traited herbicide trials in 2010. Additionally, using our existing glyphosate resistant soybean variety trials, we can directly compare the yield of RR® and RR2Y® varieties. This information provides growers with yield and economic comparison among the different soybean traits offered.

Roundup Ready Soybean Tests

Averaged across all varieties that carried either the RR® or RR2Y® trait in our glyphosate resistant soybean variety trials, RR2Y® significantly out-yielded RR® by 1.2 to 2.8 bu/acre in our Southern, Central, and North-Central testing regions (Fig. 1). Within each region however there were both high yielding (starred) RR® and RR2Y® variety offering for growers, suggesting that through careful variety selection, high yielding varieties are available that may be less costly.

Conventional and Traited Herbicide Soybean Tests

In our Southern tests (two locations), we found high yielding varieties in all the LL®, RR®, RR2Y®, and conventional herbicide soybean categories (Please see Table 6 of the 2010 WI Soybean Variety Test Results: http://soybean.uwex.edu/soytrials/printable/index.cfm). Comparing yields between traits, and across two locations, RR2Y® out-yielded the other traits in the southern region (Fig. 2a). In contrast, at our N. Central conventional and traited herbicide soybean test, we found high yielding varieties in the RR®, RR2Y®, and conventional herbicide soybean categories (Please see Table 7 of the 2010 WI Soybean Variety Test Results). However, averaged across varieties RR2Y® traited varieties out-yielded both RR® traited and conventional soybean varieties and were equal to LL® in the North Central test (Fig. 2b). These results, further suggest that growers have many high yielding options available to them among and across traits in all regions of WI.

Based on the yield potential and variable costs including seed price, seed treatment, and herbicide management program, it is critical for growers to conduct a thorough economic analysis prior to purchasing seed of any conventional or traited variety. To aid in this decision making process, we recommend using Dr. Joe Lauer's Crop Seed Price Calculator found at (http://corn.agronomy.wisc.edu/Season/DSS.aspx). This tool allows growers to directly compare varieties based on yield potential, seed price, seed treatment or herbicide management program.

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Figure 1. Soybean yield comparison between RR® and RR2Y® soybean traits in the 2010 WI Southern, Central, and North-Central Roundup Ready soybean tests.

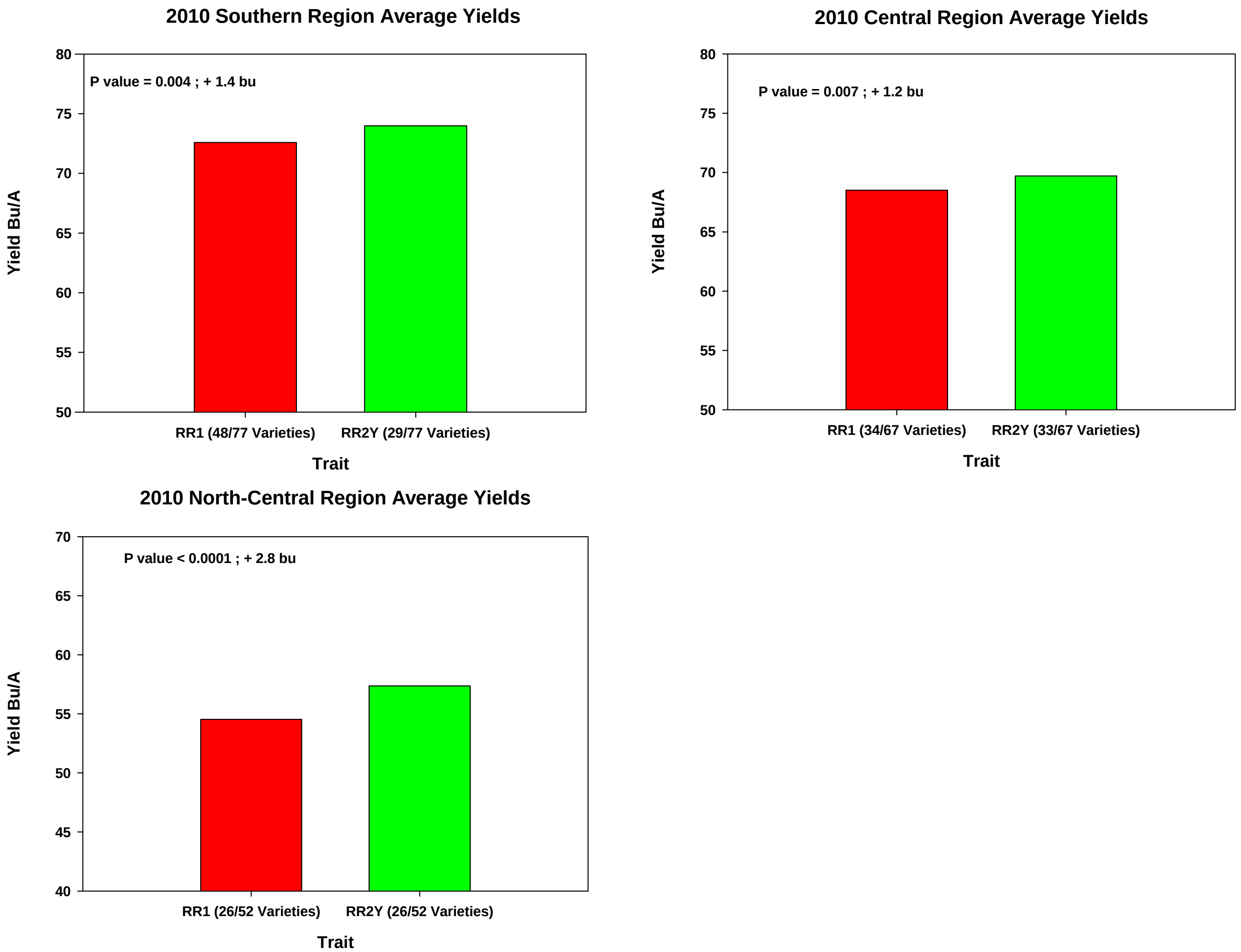
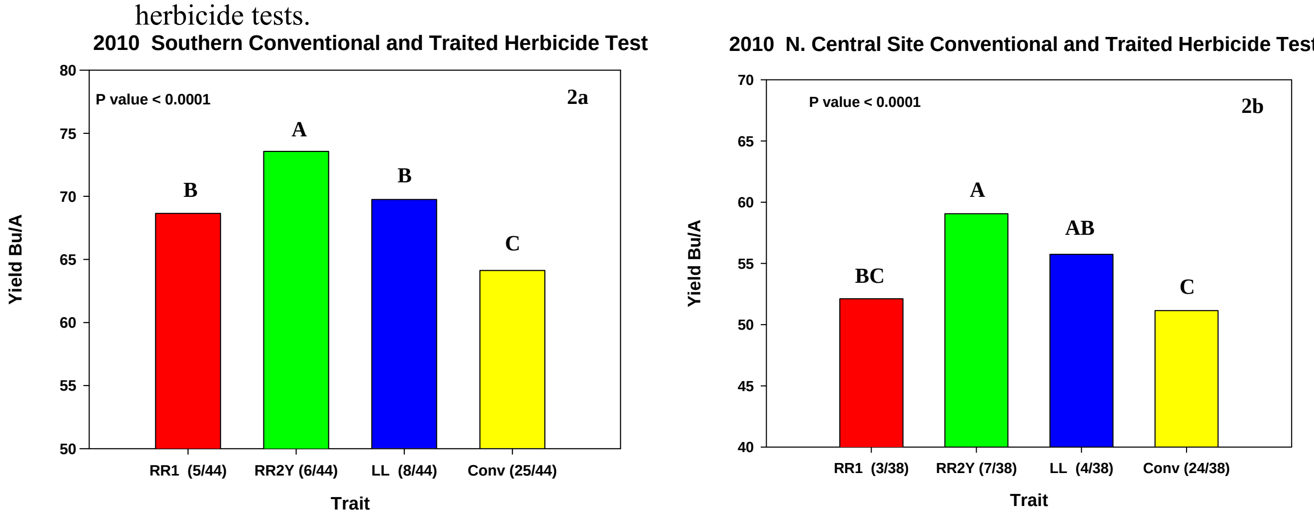


Figure 2. Soybean yield comparison between RR®, RR2Y®, , LL®, and conventional, , soybean traits in WI 2010 Southern (2a) and North Central (2b) Conventional and Traited herbicide tests.



WHEN DO LATE-SEASON MANAGEMENT DECISIONS NO LONGER INFLUENCE CORN YIELD?

Joe Lauer[1]

Numerous in-season management decisions need to be made growing corn. Some inputs are relatively easy decisions to make and must be legally followed, i.e. pesticide applications. Other decisions are more difficult with no clear guidelines due to the unpredictability of environmental influences. For example, irrigating for the last time during a growing season is influenced by the growth stage, the amount of plant green leaf area, the yield potential of the crop, the amount of rainfall predicted, the amount of stored water in the soil profile and the air temperature and humidity which will drive the evapotransporation process to cool the plant if needed. Some things can be measured like green leaf area, yield potential, and stored water, but other things are vague yet need to be considered in the decision.

Not only is the environment fickle, but the plant must be able to respond to the management input decision. A grower must ask the question, “Can I affect yield with this decision?” Or will they end up throwing “good money after bad” and increase their cost of production. Can inputs add to yield or are we just preventing further yield decreases from occurring. Examples of decisions that need to be made include:

1) Cultivation
2) Planting date and plant density
3) Last irrigation
4) Last split-application of nitrogen and micronutrients
5) Pest management and economic thresholds
    a. Insect control (most common)
    b. Foliar fungicides
    c. Rescue weed control treatments
6) Management after an abiotic stress like frost, hail, drought and/or flooding
7) Potential lodging problems due to stalk quality

These decisions affect yield by preventing further losses, but can some decisions increase yield? A good understanding of what corn yield consists of is important to understanding the decision process. Grain yield in corn is comprised of the yield components: ears per unit area, kernel number per ear consisting of kernel rows and kernels per row, and kernel weight (Figure 1).

Each of these yield components is determined at different stages in the lifecycle of the plant. Yield components develop by initial cell division near the growing point and formation of numerous primordial tissues that eventually become ears or kernels. Often the number of these early structures is greater than what the plant is later capable of supporting. The plant "adjusts" yield components according to environmental and management influences that take place during the growing season.

The plant has the "potential" to produce more ears and kernels than what is "actually" harvested. For example, the corn plant typically produces 6 to 10 ear shoots, but only one ear (at most two) actually develops. In some years, hybrids may produce 20 rows of kernels on an ear, but most of the time only 12 to 16 rows of kernels develop on the hybrids used in Wisconsin. If you were to examine the ear shoot at the V18 stage (just prior to tasseling) using a microscope, you could count 50 to 60 kernel ovules in a kernel row. Multiplying the number of kernel ovules by the number of kernel rows indicates that 600 to 1200 kernels could potentially grow on an ear. Usually only 300 to 600 kernels develop on the ears of Wisconsin hybrids. Likewise, test weight (an indirect measure of kernel weight) is affected by environmental stresses. In the Wisconsin Corn Hybrid Performance

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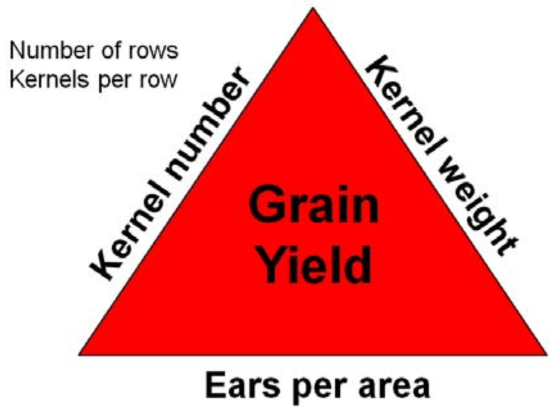
Trials, test weight has ranged between 45 and 62 pounds per bushel. Usually we consider 56 pounds per bushel an average for corn.

Figure 1. Yield components of corn.



The tasseling, silking, and pollination stages of corn development are extremely critical because the yield components of ear and kernel number can no longer be increased by the plant and the potential size of the kernel is being determined. Table 1 describes when yield components are at their greatest potential and when under normal conditions are actually determined and are not further affected under typical conditions. For example, the potential number of ears per unit area is largely determined by number of seeds planted, how many germinate, and eventually emerge. Attrition of plants through disease, unfurling underground, insects, mammal and bird damage, chemical damage, mechanical damage, and lodging all will decrease the actual number of ears that can be produced. The plant often can compensate for early losses by producing a second or third ear, but the capacity to compensate ear number is largely lost by R1 and from then on no new ears can be formed.

Table 1. Corn growth and development stages when yield components are at maximum potential and actually determined (105 day hybrid).

Iowa State University Growth Stage	GDU required to reach growth stage	Yield components Potential	Actual
VE (Emergence)	125	Ears/area	-----
V6 (six leaf collars)	470	Kernel rows/ear	"Factory"
V12	815	-----	Kernel rows/ear
V18	1160	Kernels/row	-----
R1 (Silking)	1250	Kernel weight	Kernel number Ears/area
R6 (Black layer)	2350	-----	Kernel weight

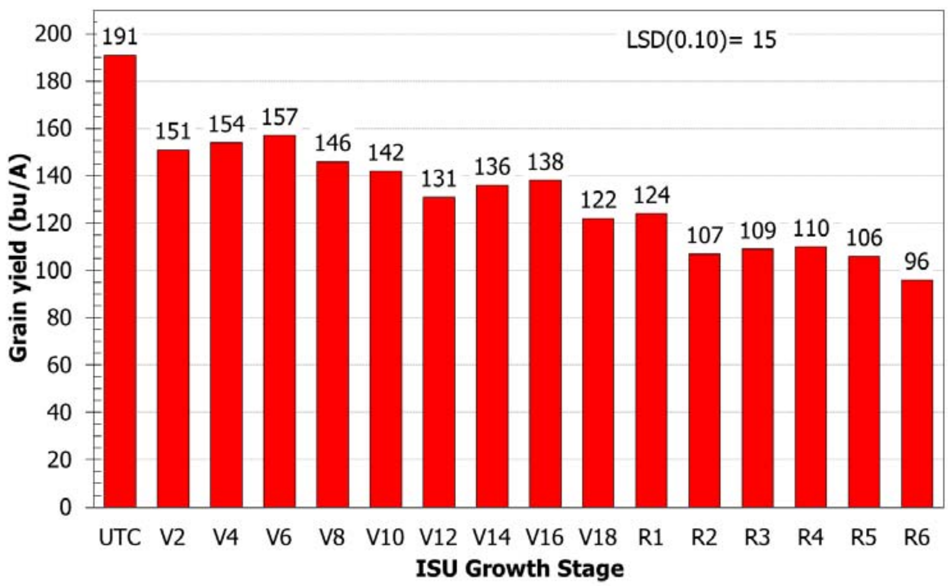
Likewise, kernel number is at its greatest potential slightly before R1, the actual number of kernels formed is determined by pollination of the kernel ovule. The yield component of kernel number is actually set by pollination and fertilization of the kernel ovule. If the ovule is not pollinated, the kernel cannot continue development and eventually dies. No new kernels form after the pollination phase is past.

The only yield component remaining with some flexibility is kernel weight. For the first 7 to 10 days after pollination of an individual kernel, cell division occurs in the endosperm. The potential number of cells that can accumulate starch is determined. At black layer formation (R6) no more material can be transported into the kernel and yield is determined.

One approach to studying the impact of whether management decisions can still impact yield is to do thinning studies at various growth stages. Plants are removed (thinned) thereby increasing the resources available to remaining un-thinned plants. When every other plant is removed, remaining plants have twice the resources that remain for the season that could eventually contribute to yield.

In 2009, plots were thinned with every other plant removed at different growth stages (Figure 2). Yield of the un-thinned plots was 191 bu/A. The lowest yield was corn thinned at R6 (physiological maturity) that was exactly half (96 bu/A) of the yield in the un-thinned plots. Three step changes seemed to occur during the corn life cycle. Grain yield was greater for plants thinned between V2 and V10, which was greater than plants thinned between V12 and R1, and which was greater than plants thinned between R2 and R6.

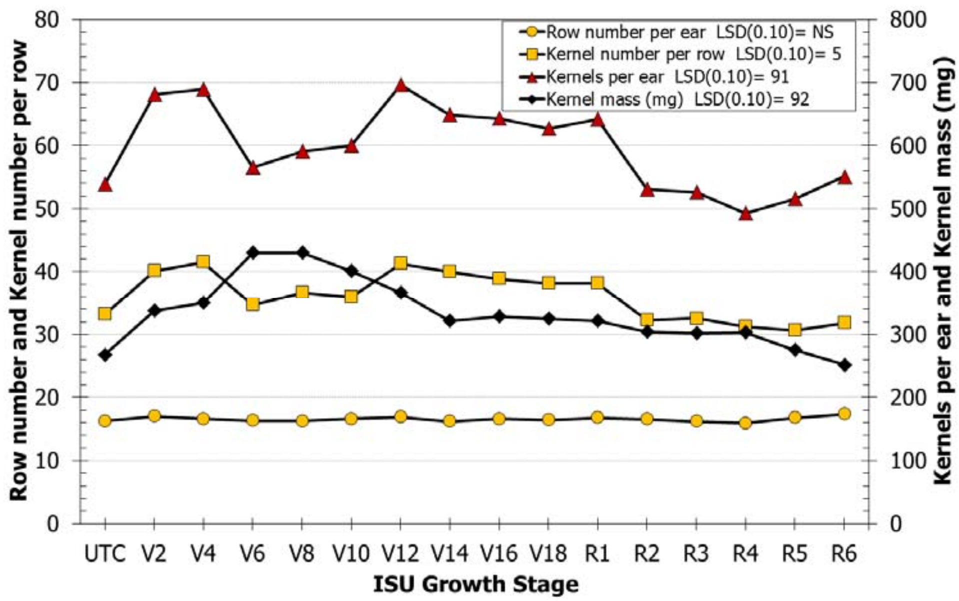
Figure 2. Grain yield of corn when every other plant is removed at various growth stages. Data were collected at Arlington during 2009 in plots with an initial plant density of 30,900 plants/A.



The effect of thinning on yield components is shown in Figure 3. Ears per plant and row number per ear were not affected by thinning at any time during the life cycle of this hybrid. Kernel number (kernels per row and kernels per ear) were at a maximum between V2 – V4 and V12 – R1. Kernel mass was at a maximum between V4 – V12. Most yield component adjustments occurred prior to R1. During grain-filling (R2 – R6) yield components were set and increasing resources to the plant by thinning every other plant did not affect grain yield.

Thus, most management decisions that could increase yield need to occur before the R2 (blister) stage. After this stage yield components are largely set and only yield attrition will occur through smaller kernel size. Numerous sources describe the results of management decisions and environmental influences that can affect kernel size. Afuwaka and Crookston (1984) described the impact of defoliation (simulating early frost) on grain yield between R4 and R6. Corn response to hail events have been simulated (Baldridge, 1976; Hicks and Peterson, 1976; Johnson, 1978; Shapiro et al., 1986; Vorst, 1990; Lauer et al., 2004). Guidelines for irrigation management have been described by many (Claassen and Shaw, 1970; Jama and Ottman, 1993; Howell et al., 1998; Irmak et al., 2000).

Figure 3. Grain yield components of corn when every other plant is removed at various growth stages. Data were collected at Arlington during 2009 in plots with an initial plant density of 30,900 plants/A.



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CHARACTERIZING WEED RESISTANCE TO GLYPHOSATE: THE GIANT RAGWEED AND COMMON LAMBSQUARTERS STORY IN WISCONSIN

Dave Stoltenberg [1]

Abstract

In Wisconsin, nearly 70% of farmers perceive that weeds have become more difficult to control with glyphosate over time, including both common lambsquarters and giant ragweed. Many have reported variable or inconsistent response of common lambsquarters to glyphosate. One of our goals has been to investigate the variable response of common lambsquarters to glyphosate, including potential resistance to glyphosate. We have characterized the response of more than 40 common lambsquarters populations to glyphosate from across southern Wisconsin. We have not found any of these populations to be resistant to glyphosate. However, we have observed variable responses among these populations to glyphosate. Our results suggest that variability of common lambsquarters to glyphosate is most apparent following treatment with low rates of glyphosate (e.g., 0.375 lb ae/acre). Such variability is much less or not apparent following treatment with higher rates of glyphosate (e.g., 1.5 lb ae/acre), at which shoot biomass is greatly reduced and injury is severe relative to non-treated check plants. We've also found that the relationship between a field history of exposure to glyphosate and less sensitivity to glyphosate was inconsistent. That is, in some instances less sensitivity (to low rates of glyphosate) was associated with a field history of previous glyphosate use, but in other instances, such a relationship was not apparent. We think it's likely that our results reflect natural or inherent variability among common lambsquarters populations to glyphosate.

Subsequent field research conducted to determine the role of several factors that may contribute to the inconsistent control of common lambsquarters to glyphosate found little relationship between poor control and several environmental conditions (relative humidity, temperature at the time of treatment, minimum and maximum temperature before and after treatment). Although we didn't identify environmental conditions that explained reduced glyphosate efficacy in all cases, we found that rainfall occurring up to 4 hours after glyphosate application and greater plant height (e.g., 8-inch compared to 4-inch tall plants) can be important factors contributing to the inconsistent control of common lambsquarters.

Giant ragweed is considered to be the most competitive weed species in Midwest cropping systems. In Wisconsin, farmers consider giant ragweed as their most troublesome weed in corn and second most troublesome weed in soybean (second to common lambsquarters). Although resistance of several giant ragweed populations to glyphosate has been confirmed in other states, resistance has not to date been confirmed in Wisconsin. However, we are currently investigating a giant ragweed population from southwest Wisconsin (Grant County) for potential resistance to glyphosate, as well as a second population from southeast Wisconsin (Rock County). Preliminary greenhouse experiments on the Grant County giant ragweed population found differential injury among plants to glyphosate applied at 0.75 lb ae/acre. However, at 3.0 lb ae/acre, plants were severely injured or killed. Subsequent lab experiments on the Grant County population showed little or no difference in target site enzyme (EPSP synthase) response to glyphosate between suspected resistant and susceptible plants. Additional experiments are being conducted to more fully characterize the response of the Grant County population to glyphosate. Suspected resistance of the Rock County giant ragweed population was reported in 2010. Experiments are being planned or are underway to quantify the whole-plant and enzyme response of this Rock County giant ragweed population to glyphosate.

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MANAGING EMERGING OLD WEED PROBLEMS IN WISCONSIN

Timothy L. Trower, Mark Renz, Bryan Jensen and Larry Binning [1/]

Common dandelion (*Taraxacum officinale*) and field horsetail (*Equisetum arvense*) continue to be troublesome weeds in Wisconsin and are common in no-till fields. Two factors contributing to a resurgence of these weed species are reduced tillage and changes in herbicide programs in corn and soybeans. We have conducted on-farm trials on dandelion and off-farm trials on field horsetail for the past several years, the results of which will be presented here.

Dandelion

Dandelion is uniquely designed to succeed in no-till systems. It is a deep-rooted perennial that is one of the first weeds to green-up in the spring and one of the last to go dormant in the fall. Seed production at the Arlington Research Station typically starts in late April to early May. Systemic herbicides are required to control mature dandelions while contact herbicides may be sufficient to control seedlings. Tillage can be effective in reducing the number of mature dandelion plants but will not eliminate them entirely. As with most difficult weeds, a systems approach which includes tillage, crop rotation and herbicide selection will provide the best results.

Trials conducted at the Arlington Research Station in 2009 and 2010 investigated the efficacy of various herbicides and application timings to control mature dandelion in a no-till corn system. Fall treatments were applied on 14 Nov. 2008 and 23 Nov. 2009 and the spring treatments were applied on 4 May 2009 and 20 April 2010. Both fall applications were made after a killing frost.

Table 1. Dandelion control-fall compared to spring applications (2009 and 2010).

		Application	Percent fandelion control				Yield[de]
Treatment	Rate	timing	Early[a]	Mid[b]	Late[c]	Harvest[de]	(bu/a)
2,4-D + Roundup PowerMax +	16 fl oz + 0.75 lb ae +	Fall	82	69	40	3	53
AMS	17 lb/100 gal	Spring	0	38	72	40	58
Canopy EX+ COC +	1.1 oz + 1% v/v +	Fall	95	91	88	93	60
2,4-D + Roundup PowerMax	16 fl oz + 0.75 lb ae	Spring	0	46	71	53	52
Synchrony + COC + AMS	0.375 oz + 1% v/v + 2.5 lb	Fall	90	75	47	28	57
2,4-D + Roundup PowerMax	16 fl oz + 0.75 lb ae	Spring	0	50	80	66	59
Enlite + COC + AMS	2.8 oz/a + 1% v/v + 2.5 lb	Fall	90	79	46	5	57
Roundup PowerMax	0.75 lb ae	Spring	0	74	86	71	58

[a] 151-173 days after treatment (DAT) fall application, 2-3 DAT spring application

[b] 163-187 DAT fall application, 15-16 DAT spring application

[c] 182-199 DAT fall application, 28-34 DAT spring application

[d] 2010 data only

[e] includes in-season glyphosate application

[1/] Senior Outreach Specialist and Assistant Professor, Dept. of Agronomy; Outreach Specialist-IPM and Professor Emeritus, Dept. of Horticulture, respectively, UW-Madison.

Differences in dandelion control were observed among the fall-applied treatments. Canopy EX and Synchrony tank mixed with 2,4-D and glyphosate and Enlite tank mixed with glyphosate all provided better dandelion control at spring green-up than 2,4-D tank mixed with glyphosate. Dandelion control decreased with all treatments except Canopy EX at subsequent evaluations. Canopy EX provided 88% dandelion control at the final evaluation 182-199 DAT compared to 47 to 40% dandelion control for the remaining treatments. Differences in control were also observed between the fall and spring application timings. All fall-applied treatments provided greater dandelion control at the mid-evaluation than the spring application. This trend was reversed at the late evaluation as spring applied 2,4-D/glyphosate, Synchrony tank mixes and Enlite tank mixes all provided better dandelion control than fall applied. Conversely, fall applied Canopy EX tank mixes gave better dandelion control that spring applied. A final evaluation was taken prior to soybean harvest to determine season-long control. It is important to remember that an in-season application of glyphosate at 0.75 lb ae/a was applied to all treatments. Fall-applied Canopy EX was the best overall treatment, averaging 93% dandelion control compared to 53% control for spring-applied. Spring-applied 2,4-D/glyphosate, Synchrony and Enlite provided better dandelion control at harvest than fall applications. No differences in soybean yields were observed among treatments. The results show the importance in matching the proper herbicide treatments to the cropping system. Fall-applied treatments will provide reduced early-season dandelion competition in instances where a crop is to be planted early where spring applications may be desired when planting maybe delayed.

The second objective was to evaluate various fall-applied herbicide treatments of dandelion control the following spring.

Autumn, Canopy EX, Synchrony, Enlite, Express and Sharpen tank mixes all provided 90% or greater dandelion control at spring green-up. Dandelion control decreased with most of the treatments at the mid and late evaluation. Canopy EX was the best overall treatment, providing 88% dandelion control at the late evaluation. Autumn and Express tank mixes were the only other treatments that gave greater than 50% control, averaging 74 and 67% control, respecttively. Sharpen/glyphosate and Sharpen/Express tank mixes were only evaluated in 2009 and provided contrasting results. Sharpen/glyphosate gave good initial burn-down, 90% compared to 66% control with Sharpen/Express. Dandelion control decreased by 24% with the Sharpen/glyphosate tank mix at the late evaluation and only 8% with the Sharpen/Express tank mix. No differences in yields were observed among treatments.

Field Horsetail

From a biology standpoint, field horsetail is a very unique plant. It is a perennial that reproduces mostly by rhizomes, but it also produces spores in the early spring. The role of the spores is not well understood. The first indication that field horsetail is in a field is the emergence of tan-colored stalks in the early spring. The stalks are topped by a cone-shaped body which contains the spores. The stalk dies soon after spore release and is replaced by the vegetative phase, a green plant that resembles a small Christmas tree. Filed horsetail is a very competitive plant that can cause significant yield reductions. Populations generally start at the edges of fields and slowly spread. Like many perennials, field horsetail is favored by reduced tillage.

Results have been extremely variably among locations and between years (results not shown). In 2010, no differences in field horsetail control were observed among the soil-applied herbicide programs. Steadfast plus Hornet applied postemergence provided the least amount of ground cover when evaluated 23 July, averaging 5% compared to 29% for the standard treatment of Dual + atrazine + SelectMax applied preemergence. The field horsetail population decreased dramatically during the late fall for unknown reasons. No differences in yield were observed among the treatments.

Summary

Both dandelion and field horsetail require a system approach to provide best results. Understanding the weed biology and factors that favor weed development are important in determining the best integrated approach. Work continues at the Arlington Research Station to determine the optimum application timing and best herbicide treatments to control common dandelion.

Table 2: Comparison of fall-applied herbicide treatments (2009 and 2010).

Treatment	Rate	Application timing	Percent dandelion control Early[a]	Mid[b]	Late[c]	Harvest[de]	Yield[de] (bu/a)
Autumn + COC PowerMax + AMS	0.3 oz + 1% + 0.75 lb ae + 2.5 lb	Fall	91	87	74	48	56
Distinct + NIS + Roundup Original + AMS	2 oz + 0.25% v/v + 0.75 lb ae + 17 lb/100 gal	Fall	74	64	47	20	52
Distinct + 2,4-D + NIS + Roundup Original + AMS	2 oz + 16 fl oz + 0.25% v/v + 0.75 lb ae + 17 lb/100 gal	Fall	85	76	57	48	57
2,4-D + Roundup PowerMax + AMS	16 fl oz + 0.75 lb ae + 2.5 lb	Fall	82	69	40	3	53
Valor + AMS + 2,4-D + Roundup PowerMax	2 oz + 2.5 lb + 16 fl oz + 0.75 lb ae	Fall	82	69	41	20	54
Canopy EX+ COC + 2,4-D + Roundup PowerMax	1.1 oz + 1% v/v + 16 fl oz + 0.75 lb ae	Fall	95	91	88	93	60
Synchrony + COC + AMS 2,4-D + Roundup PowerMax	0.375 oz + 1% v/v + 2.5 lb 16 fl oz + 0.75 lb ae	Fall	90	75	47	28	57
Enlite + COC + AMS Roundup PowerMax	2.8 oz/a + 1% v/v + 2.5 lb 0.75 lb ae	Fall	91	80	46	5	57
Express + NIS + AMS + 2,4-D + Roundup PowerMax	0.25 oz + 0.25% v/v + 2.5 lb + 16 fl oz + 0.75 lb ae	Fall	93	82	67	51	62
Sharpen + COC + Roundup PowerMax + AMS[f]	1 fl oz + 1% v/v + 0.75 lb ae + 2.5 lb	Fall	90	79	48		
Sharpen + Express + COC + AMS[f]	1 fl oz + 0.25 oz + 1% v/v + 2.5 lb	Fall	66	68	58		

[a] 151-173 days after treatment (DAT) fall application
[b] 163-187 DAT fall application
[c] 182-199 DAT fall application
[d] 2010 data only
[e] includes in-season glyphosate application
f 2009 data only

Table 3. Field horsetail control in field corn.

Treatment	Rate	Application timing	Percent ground cover 7/1	7/23	10/18	Yield (bu/a)
Dual II Magnum + atrazine +	1.67 pt + 1 qt +	Pre	23	29	19	171
SelectMax + COC	4 fl oz + 1%					
Dual II Magnum + atrazine +	1.67 pt + 1 qt +	Pre	24	18	5	192
RU + 2,4-D + AMS	22 fl oz + 1 pt + 3.4 lb					
Dual II Magnum + Python+	1.67 pt + 1 oz +	Pre	38	23	6	174
atrazine+ RU + NIS + AMS	1 qt + 11 fl oz + 0.25% + 3.4 lb					
Dual II Magmun + Sharpen +	1.67 pt + 1 fl oz +	Pre	24	31	9	183
atrazine + COC + AMS	1 qt + 1% + 3.4 lb					
Dual II Magnum + Python +	1.67 pt + 1 oz +	Pre	29	29	6	162
Sharpen + COC + AMS	3 fl oz + 1% + 3.4 lb					
Dual II Magnum + RU + AMS fb	1.67 pt + 11 fl oz + 3.4 lb	Pre	1	14	4	188
Steadfast + Status + COC + AMS	0.75 oz + 5 oz + 1% + 2 lb	Post				
Dual II Magnum + RU + AMS fb	1.67 pt + 11 fl oz + 3.4 lb	Pre	33	48	11	157
Yukon + NIS	4 oz + 0.25%	Post				
Dual II Magnum + RU + AMS fb	1.67 pt + 11 fl oz + 3.4 lb	Pre	24	50	16	177
Status + RU + NIS + AMS	5 oz + 22 fl oz + 0.25% + 2 lb	Post				
Dual II Magnum + RU + AMS fb	1.67 pt + 11 fl oz + 3.4 lb	Pre	18	5	0	189
Steadfast + Hornet + COC + AMS	0.75 oz + 4 oz + 1% + 2 lb	Post				
Dual II Magnum + RU + AMS fb	1.67 pt + 11 fl oz + 3.4 lb	Pre	30	34	8	179
Laudis + atrazine + MSO + AMS	3 fl oz + 1 pt + 1% + 1.7 lb	Post				
Python + RU + NIS fb	1 oz + 11 fl oz + 0.25%	Pre	21	19	8	193
RU + AMS	22 fl oz + 3.4 lb	Post				
Sharpen + COC + AMS fb	3 fl oz + 1% + 3.4 lb	Pre	45	53	5	186
RU + AMS	22 fl oz + 3.4 lb	Post				

SOIL pH AND CROP RESPONSE TO LIME SOURCE AND TILLAGE

Richard Wolkowski and Carrie Laboski [1/]

Overview

Maintaining the proper soil pH through liming agricultural soils is a hallmark of modern crop production. Benefits of liming include the optimization of nutrient availability and utilization, the reduction of available levels of Al and Mn, the enhancement of N_2 fixation in legumes, and improvement in the microbial-aided process of organic matter breakdown. The most common liming material by far in Wisconsin is crushed dolomitic limestone or aglime. Deposits of dolomitic limestone are common in the western, southern, and eastern portion of the state. Few, if any, deposits of limestone are found in the central and northern areas. Other lime sources include various by-product materials and calcitic lime, which is not indigenous to the state and therefore must be transported at significant expense. Lime should be applied according to recommendations that are based on a current soil test. The recommended rate is determined by soil pH desired for the most demanding crop in the rotation, the pH buffering potential of the soil, the soil pH, and the neutralizing index of the lime. The neutralizing index reflects both the purity of the lime relative to calcium carbonate and how finely it has been ground. Obviously purer and more finely ground materials, having more surface area, will react faster pound for pound compared to impure or coarser materials.

It is generally recommended that lime be thoroughly incorporated by tillage to optimize neutralization throughout the plowlayer. Even with good mixing it generally takes up to three years to reach the target pH, although the majority of the pH change is often noted in the first year. Cropping systems such as long-term no-till and managed pastures present a dilemma relative to soil pH management. Without tillage soil pH change in the plowlayer is dependent on the movement of the carbonate anion (CO_3^{-2}) through the soil. Remember it is the anion that reacts with the H^+ in the soil to form carbonic acid (H_2CO_3), which dissociates to CO_2 and H_2O. This movement is slow and has been estimated to occur at a rate of 0.5 to 1 inch/year.

Research on liming has been conducted in the UW Soil Science Department for decades, in large part due to the support of the industry through a tonnage fee on lime sales. A classic study conducted by UW Soil Science Professors J.R. Love and R.B. Corey, along with the UW Marshfield Soil Testing Lab Director C.C. Olsen examined the effect of particle size and rate on soil pH change. They applied dolomitic lime of various mesh sizes to an acidic Withee silt loam soil at rates ranging between none and 64 tons/acre. Figure 1 shows the soil pH change over three years for an application of six tons/a. These data demonstrate the importance of the fineness of grind on neutralizing soil pH. More data on this study are available in UWEX Pub. A3671 *Choosing Between Liming Materials*. A similar study was also conducted at the Arlington Agricultural research station in the late 1950s, which was re-sampled to depth by Professors E.E. Schulte and K.A. Kelling 24 years later (Figure 2). The results of their evaluation showed

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that the pH change migrated below the depth of tillage and that the change was rate dependent. This study confirms the speculation that the liming effect migrates about 1 inch/year.

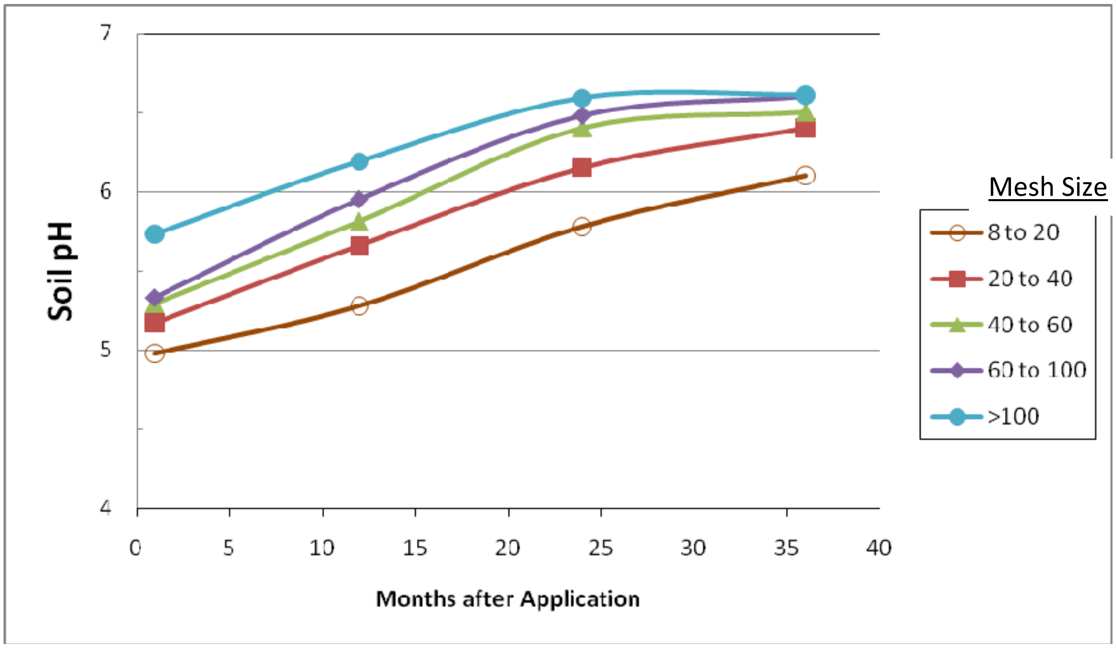


Figure 1. Effect of lime of various mesh sizes applied at six ton/acre on the change in soil pH of a Withee silt loam (after Love et al., 1960).

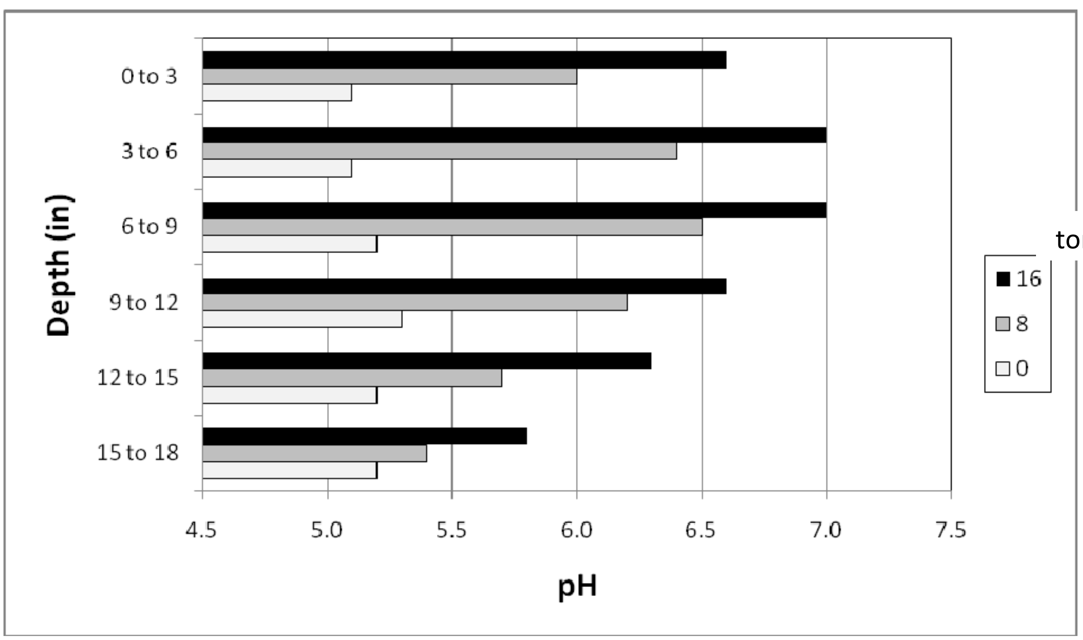


Figure 2. Effect of 20–40 mesh lime rate on the change in soil pH with depth on a Plano silt loam after 24 years (after Peters et al., 1996. UWEX Pub. A3671).

The current recommendation for soil sampling long-term no-till fields is to include a 0- to 2-inch sample, along with the plowlayer sample. The 0- to 2-inch sample is only analyzed for soil test components that provide a lime recommendation. Presumably producers would consider the application of lime that would be appropriate for neutralizing acidity in the shallow surface zone. Communication with our lab staff suggests that very few fields are sampled in this way. Recent incremental sampling studies by Wolkowski (unpublished data) demonstrated that acidification is typically confined to the surface two inches in long-term no-till. Table 1 shows the pH levels in a field where various tillage practices had been in place for 20 years at the Arlington Agricultural Research Station. Lime was never applied in this time period and N fertilizer was broadcast to corn each season at the recommended rate. Clearly the mixing of the soil by tillage increased acidification at a greater depth, which followed the pattern of intensity from moldboard to chisel to no-till. Therefore a strategy to apply lime to address the surface acidification of such a soil may be appropriate for many long-time no-till fields.

Table 1. Soil pH as affected by 20 years of continuous tillage management, Arlington, Wis.

Depth (inch)	Moldboard	Chisel	No-till
0 - 2	5.7	5.6	5.6
2 - 4	5.9	5.6	6.5
4 - 6	6.0	5.8	6.6
6 - 8	6.0	6.3	6.6

Wolkowski, unpublished data.

Arlington Lime Source, Rate, and Tillage Study

A study was established at the Arlington Agricultural Research Station in the spring of 2009 to evaluate the response of a field that had been in no-till for at least 20 years to the application of two sources of lime applied at four rates of application in a chisel and no-till system. The experiment was set up in a split-split plot treatment arrangement with tillage as the main plot, lime source (NI 70–79 dolomitic aglime or pelletized calcitic lime) as the subplot, and rate (0, 1, 2.5, and 5 ton/acre) as the sub-subplot. Treatments were pre-weighed for the 10 x 40 foot plot area and were applied by hand. Appropriate plots were then chisel plowed twice and then field cultivated to establish a seedbed. Pioneer Brand 92Y20 soybean was planted in 30-inch rows, which were harvested for grain the following fall. The site was seeded to alfalfa in the spring of 2010 (Dairyland HybriForce 2400) and was harvested twice during the seeding year.

Soil samples were collected each year by sampling single whole cores to a depth of 8 inches, as well as 2-inch incremental cores to a depth of 8 inches from all plots in the spring and fall. The spring 2009 samples were collected prior to lime treatment and tillage. Spring samples were analyzed for pH, organic matter, P and K, whereas the fall samples were analyzed for pH only.

Soil pH

The pre-treatment soil pH values for the two inch increments and the 0- to 8-inch depth are shown in Table 2. These samples were collected prior to tillage from every plot so pH change could be more precisely monitored. This field had an average plowlayer pH of 6.0 and showed modest stratification, having a difference of about 0.5 pH unit in the plowlayer from the surface down into the soil. The soil pH changed from 5.7 to 6.3 from the surface down to eight in. Overall the variability of the samples was low and is consistent with the variability associated with the measurement of soil pH. Table 3 shows the main effect of tillage, lime rate, and lime source on the soil pH for the 0- to 2-inch and 0- to 8-inch depth for each of the 2009 and 2010 samplings. Tillage and lime rate both significantly affected soil pH in the surface two inches and the entire plowlayer; however, lime source had no effect on pH in either increment. Chisel tillage resulted in soil pH values that were higher than those in no-till in both the surface two inches and plowlayer because of better mixing in the soil. As expected, soil pH increased with increasing lime rate.

The relationship between tillage and lime source for soil pH for the study period when applied at 2.5 t/a is shown in Figure 3. This comparison was made to determine if the two lime sources performed differently in the two tillage systems. The Pr>F values for tillage x lime source interaction in the 0- to 2-inch depth for the 5-month sampling was 0.10, and 0.07 for the same depth at 17 months indicates a strong relationship between these factors. These data show that the aglime produced similar pH values in the 0- to 2-inch increment in chisel after 17 months, whereas the pell-lime produced a pH that was 0.4 units higher in the no-till treatment. This response may be caused by the fineness of the lime in the pellet and perhaps the somewhat higher solubility of the calcitic lime used to make this material. This relationship was not significant at the other depth increments. It should be recognized that past research has shown that lime may take up to three years to react to reach its target pH and therefore the final soil pH values may not differ.

Table 2. Pre-treatment soil pH values for the lime study site (avg. of 64 measurements).

Depth (inch)	Average	Standard deviation	Range
0 – 2	5.71	0.22	5.3 – 6.4
2 – 4	5.80	0.20	5.2 – 6.2
4 – 6	6.14	0.18	5.5 – 6.5
6 – 8	6.30	0.17	5.9 – 6.4
0 – 8	5.98	0.17	5.6 – 6.4

Crop Yield

There was no significant effect of lime source or rate on soybean yield in 2009 (Table 4). Chisel tillage significantly increased yield compared to no-till. The 0- to 2-inch and 0- to 8-inch soil pH values were less than the target pH of 6.3 for soybean. Thus, a response to liming would be expected, though none occurred. It is possible that the 0- to 8-inch pH of 6.0 or 6.1 was not low enough to result in poor N fixation and subsequent yield loss.

The effect of tillage, and lime source and rate on the yield of both cuttings of alfalfa in the 2010 seeding year is shown in Table 5. Yield was substantially higher in the chisel, compared to no-till. The no-till treatment was infested with a high population of dandelion, which were very competitive with the new seeding. It was decided to maintain the stand to avoid further disturbing the soil by reseeding and the fact that a growth response in the no-till was

Table 4. Soybean yield response to liming and tillage, Arlington, Wis., 2009.

	Chisel		No-till	
Lime rate (t/acre)	70 -79	Pell-lime	70 -79	Pell-lime
	------------------------------------ bu/acre	-------------------------------------		
0	37	42	38	30
1	40	41	38	30
2.5	40	41	38	31
5	36	41	35	32
Pr>F				
Tillage	0.02	Lime rate	0.82	
Lime source	0.60	T * LR	0.91	
T * LS	0.25	LS * LR	0.30	
		T * LS * LR	0.73	

visibly affected by lime rate. Lime source did not affect the yield of either cutting. Lime rate increased the yield of both cuttings. There were several interactions between treatments that were significant. One was that between tillage and lime rate, where relative yield response to increasing lime rate was generally greater in no-till than it was under chisel tillage. The interaction between lime source and rate was significant for the second cutting.

Table 5. Alfalfa yield response to liming and tillage, Arlington, Wis., 2010.

	First Cutting				Second Cutting			
	Chisel		No-till		Chisel		No-till	
Lime rate (t/acre)	70 -79	Pell-lime	70 -79	Pell-lime	70 -79	Pell-lime	70 -79	Pell-lime
	------------------------------------ ton dry matter/acre	---------------------------------						
0	1.30	1.36	0.79	0.52	1.23	1.33	1.06	0.85
1	1.35	1.41	0.90	0.56	1.42	1.27	1.20	0.97
2.5	1.37	1.33	0.91	0.67	1.41	1.38	1.15	1.09
5	1.46	1.37	0.92	0.67	1.35	1.47	1.13	0.99
Pr>F								
Tillage	<0.01				<0.01			
Lime source	0.26				0.34			
T * LS	0.27				0.28			
Lime rate	<0.01				<0.01			
T * LR	<0.01				<0.01			
LS * LR	0.37				<0.01			
T * LS * LR	<0.01				<0.01			

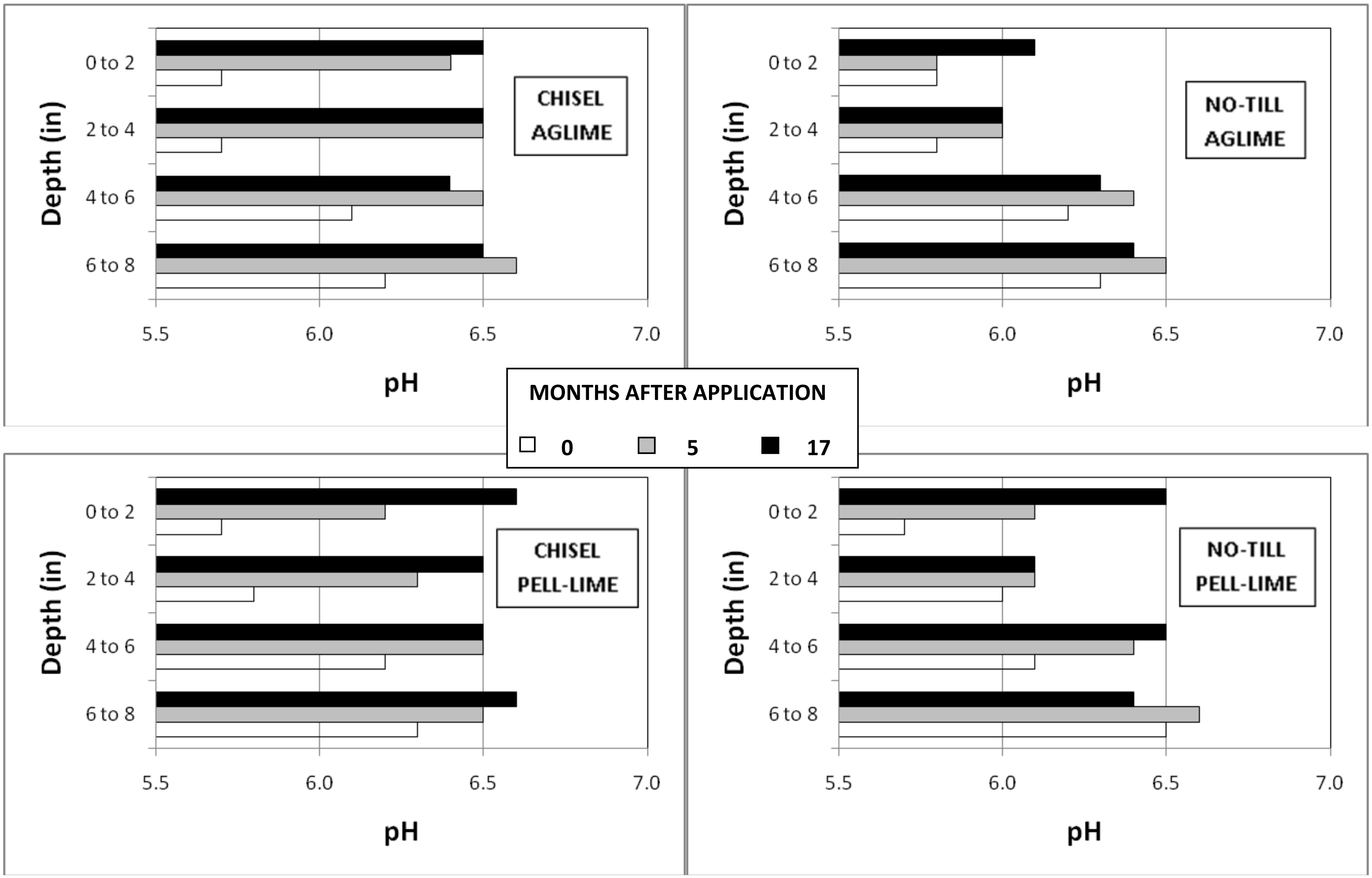
Summary

Soil pH management through liming is a basic practice for optimizing crop yield. Producers are faced with several liming practice concerns based on tillage and lime source. Soil pH stratifies over time in no-till or other low disturbance systems, becoming more acidic at the surface. Without tillage lime can not be uniformly mixed after application. A study was established in 2009 to examine the relationship between tillage, lime source, and lime rate on soil pH change and yield. Preliminary results from this research shows that pelletized lime was more effective than an aglime for adjusting the pH in a short time in no-till. This response did not appear to translate into an increased yield of either soybean or alfalfa. Also growers should compare the price of lime when making management decisions. It may be possible to purchase two to three times as much aglime compared to pelletized lime when comparing the value of each material on a pound for pound basis.

Table 3. Main effect of tillage, and lime source and rate on the soil pH in the 0- to 2-inch and 0- to 8-inch depths, Arlington, Wis., 2010.

Treatment		Pre-treatment (Spring 09)		Fall 2009		Spring 2010		Fall 2010	
	Depth (inch)	0–2	–8	0–2	0–8	0–2	0–8	0–2	0–8
Tillage	Chisel	5.7	6.0	6.2	6.3	6.3	6.2	6.3	6.3
	No-till	5.7	6.0	5.9	6.2	5.9	6.1	6.1	6.2
Source	Aglime	5.7	6.0	6.0	6.2	6.0	6.1	6.1	6.3
	Pell-lime	5.7	6.0	6.1	6.3	6.1	6.2	6.3	6.3
Rate (t/a)	0	5.7	6.0	5.8	6.1	5.7	6.0	5.8	6.0
	1	5.8	6.0	6.0	6.2	6.0	6.1	6.0	6.2
	2.5	5.7	6.0	6.1	6.3	6.2	6.2	6.4	6.4
	5	5.6	6.0	6.3	6.3	6.3	6.3	6.5	6.5
Pr>F									
Tillage		0.47	0.35	<0.01	0.03	<0.01	0.03	0.01	0.02
Lime source		0.83	0.99	0.43	0.54	0.37	0.18	0.05	0.73
T * LS		0.06	0.27	0.10	0.13	0.01	0.15	0.07	0.08
Lime rate		0.12	0.70	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
T * LR		0.26	0.84	<0.01	0.04	0.82	0.32	0.04	0.08
LS * LR		0.84	0.85	0.98	0.42	0.15	0.02	<0.01	0.13
T * LS * LR		0.07	0.63	0.03	0.31	0.33	0.79	0.50	0.79

Figure 3. Soil pH change by depth as affected by tillage and lime source at 0, 5, and 17 months after application, Arlington, Wis. (2.5 t/a).



SHALLOW VERTICAL TILLAGE: IMPACT ON SOIL DISTURBANCE AND CROP RESIDUE

Kevan Klingberg and Curtis Weisenbeck [1]

Introduction

Wisconsin farmers have begun using a new generation of vertical tillage implements designed to conduct shallow tillage and better distribute crop residue. These machines cause minimal soil inversion. Their main working component is a set of straight and/or wavy coulters, which directs soil disturbance downward in slots, a couple of inches wide by a couple of inches deep. Some crop producers are interested in shallow vertical tillage because current corn hybrids have stalks that slowly decompose due to genetic enhancements for insect resistance. The high levels of previous year corn residue in 1-pass no-till planting systems can reduce yields due to cool wet soils, slow seed germination and the physical challenges of planting into previous year(s) crop residue. Crop consultants and farmers have recognized the value of conducting a small amount of tillage in order to size the existing residue, condition the seedbed, and/or incorporate livestock manure, lime or other nutrients. Some farmers are considering replacing their 1-pass no-till planting system with a 1-pass shallow vertical tillage + plant system.

As the use of shallow vertical tillage implements increases, their impact on soil and water conservation, as well as nutrient management needs to be evaluated. Crop producers intuitively believe these tillage tools have a less invasive and different impact on soil disturbance and residue management, compared to disking, field cultivating or chisel plowing.

Study

A representative to the UW-Discovery Farms Steering Committee, appointed by the Wisconsin Soybean Board, requested that the Discovery Farms Program evaluate the soil and water conservation impacts of these vertical tillage implements. Discovery Farms worked with a private crop consultant on 5 farms in Western Wisconsin to evaluate shallow vertical tillage on 14 crop fields (spring 2010). Staff worked with NRCS to design the study to measure soil and residue parameters used within RUSLE2. The crop consultant identified the farms, and worked with Discovery Farms staff to collect field data and summarize findings. Field data collected included soil disturbance and surface residue remaining within five days after a single-pass shallow vertical tillage operation conducted in the spring.

Methods

Participating farmers used their own vertical tillage implement, operated at usual speed and depth. All implements had 2 gangs of forward-facing non-concave blades, either straight or waved. Blades were spaced at 10 inches, with the back gang off-set from the front by 5 inches.

These machines created slices of disturbed soil in the same direction of travel, every 5 inches. The three machines represented in this study (not an endorsement or exclusive list, represents

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participant's machines) included: 1) Great Plains Turbo Till with rolling spike and reel (TT); 2) Summers Supercoulter Plus with rolling spike and reel (SCP1); and 3) Summers Supercoulter Plus with rolling chopper (SCP2).

The line-transect method was used to estimate % crop surface residue cover. Soil disturbance was evaluated using parameters of the NRCS Soil Tillage Intensity Rating (STIR). Trenches were dug perpendicular to tillage travel line to measure individual coulter tillage depth and width, as well as associated non- disturbance areas.

Results and Discussion

Soil disturbance and remaining surface residue after 1-pass shallow vertical tillage varied by field and farm based on soil type, machine characteristics and operating depth. Deeper operation, more aggressive machinery, and sandier soil resulted in more soil disturbance and less surface residue. Table 1 shows field site, soil type, implement used, previous crop, residue remaining and soil disturbance depth and width for 14 crop fields where single-pass shallow vertical tillage had been conducted within the previous five days.

Table 1. Crop residue remaining and soil disturbance after 1-pass shallow vertical tillage

Farm	Soil	Implement *	2009 Crop	Residue (%)	Tillage Depth (inches)	Tillage Width (inches)
Go1	silt loam	TT	cgr	90	1.5	1.5
Go2	loamy sand	TT	sb	75	2	2
Go3	sandy loam	TT	cgr	90	1.5	2
Go4	silt loam	TT	cgr	94	1.5	1.5
Go5	silt loam	TT	cgr	90	1.5	1.5
Gr1	silt loam	TT	cgr	90	2.5	3
Cr1	loamy sand	TT	cgr	70	2.5	2
Cr2	loamy sand	TT	cgr	75	2.5	2
Ha1	loam	SCP 1	cgr	69	2.5	3 / 1
Ha2	f s loam	SCP 1	cgr	88	2.5	3 / 1
Ha3	silt loam	SCP 1	cgr	86	2.5	3 / 1
Ol1	silt loam	SCP 2	cgr	78	3	3 / 1
Ol2	f s loam	SCP 2	cgr	76	3	3 / 1
Ol3	silt loam	SCP 2	cgr	78	3	3 / 1

* TT = Great Plains Turbo Till with rolling spike and reel; SCP 1 = Summers Supercoulter Plus with rolling spike and reel; SCP 2 = Summers Supercoulter Plus with rolling chopper.

In general, it is safe to say that on silt loam soil, conservative 1-pass shallow vertical tillage created slices through the field such that every five inches of field width has a two inch wide by two inch deep tilled area and three inches of "undisturbed" soil. Conservative 1-pass shallow vertical tillage can result in 40% of field coulter tilled to a two inch depth, while 60% remains untouched by coulters and disturbed only by the rear attachments. Sandy soils tended to show similar depth and a more homogeneous horizontal soil disturbance.

The NRCS - RUSLE2 soil loss model offers implements within its field operations database for shallow vertical tillage machines. They are referred to as seedbed conditioners, and are presented as a combination of: 1) coulter caddy; 2) coil tine or rotary or spike harrow; and/or 3) rolling basket.

Conservation planners choose the seedbed conditioner combination most appropriate to the vertical tillage implement being used by the producer they are working with. All of these implement components, plus others, are listed individually within the RUSLE2 field operations database and can be chosen to create an ala carte tillage operation - based on machinery characteristics, crop residue and soil disturbance.

Depths and surface area disruption values observed through this project were comparable to those defined in RUSLE2 for various seedbed conditioner combinations. Shallow vertical tillage can disturb 100 % of the soil surface area due to a combination of coulters plus rear attachments. The degree of soil and residue disturbance created by shallow vertical tillage is influenced by depth, speed and machine characteristics.

Sometimes vertical tillage machinery is equated with tandem disking when discussing soil disturbance. The concave configuration of most disk blades, along with angled gangs, moves soil laterally, cuts and buries residue and dislodges most prior year root systems. Tandem disks create complete lateral soil movement compared with what this project showed to be very limited lateral soil movement for 1-pass shallow vertical tillage. Subsequent visits to study fields revealed that as soon as producers begin running a 2-pass shallow vertical tillage + planting system, soil disturbance increases and similarities with tandem disking become more apparent.

One-pass shallow vertical tillage maintained significant amounts of prior year corn plant roots, intact, anchored and still in place, post tillage. Regardless of soil type, 22,000 – 25,000 in-place corn roots per acre were observed. This was based on traditional population count methods for defined row widths. These anchored corn roots represented as much as 80% of common corn planting rates.

Post emergence observations showed that one-pass shallow vertical tillage did not bury much residue, yet residue was sized smaller to move through high residue planters, leaving 75 - 80 % of previous corn residue in place, as well as 80 % of last year's corn roots intact and still in the ground.

Conclusion

Tillage has numerous functions, including residue management, soil mixing and weed control. Most crop producers in Wisconsin have dramatically reduced tillage to save soil, time and fuel. Some have implemented 1-pass no-till planting systems with various attachments for residue management in front of seed placement. Still others want to maintain the soil and water conservation benefits of high residue planting systems, yet desire prior season residue to be cut smaller and/or they desire a small degree of soil mixing.

Crop consultants and agricultural producers intuitively know that conservative operation of vertical tillage implements has less of an impact on soil disturbance and residue management than disking or field cultivating. Producers who are serious about using these tillage tools as a 1-pass + plant system should invite their soil and water conservation planning professional, along with their crop consultant to do field observations with them to properly evaluate prior season residue remaining, along with depth and width of soil disturbance. In cropping scenarios where the desired rotation depends on very limited or no tillage in order to maintain conservation compliance, conservative 1-pass shallow vertical tillage might be an option, on a site specific basis. Conservative and shallow are key phrases when considering the use of these implements on cropland landscapes that have high soil loss potential. As soon as producers begin making 2 or more passes with vertical tillage implements prior to planting, similarities with tandem disking become more apparent as soil disturbance increases.

Future Research Needs

Two observations from within this project need additional study: 1) evaluate the soil quality and conservation value of maintaining intact prior year root systems after 1-pass shallow vertical tillage; and 2) field-validate the similarity of soil loss prediction between shallow vertical tillage and tandem disking + field cultivating systems.

Additional studies should be initiated to evaluate the impact / effectiveness of shallow vertical tillage for 1) Minimizing soil loss; 2) Water infiltration; 3) Fertilizer, lime and manure incorporation; 4) Season of operation; 5) Early season soil drying and warming; 6) Use on tile drained preferential flow – critical sites.

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A REVIEW OF FERTILIZATION STRATEGIES FOR WINTER WHEAT

Matthew D. Ruark [1/]

Introduction

With winter wheat acreage in Wisconsin expected to rise, now is a good time to review what nutrient management considerations should be made. Winter wheat is a crop managed during two growing seasons, so careful attention to soil testing and fertilizer inputs should be made.

Nitrogen Rate and Timing

Our current UW recommendations for nitrogen (N) fertilization for winter wheat are 90 lb ac^{-1} for soils with < 2% OM, 70 lb ac^{-1} for soils with 2 to 9.9% organic matter, 40 lb ac^{-1} for soils with 10 to 20% organic matter and 0 lb ac^{-1} for soils with organic matter greater than 20%. These recommendations are across a yield range of 20 to 100 bu ac^{-1}. A nitrogen credit of 40 lb ac^{-1} should be taken if wheat follows soybean. Over-application of N fertilizer is not recommended for insurance, as yield declines in wheat have been reported with over-applications of N and increased potential for lodging.

Based on recent data (Conley and Gaska, unpublished) for four site years, there was no benefit from applying 20 lb ac^{-1} of N in the fall (with the remainder of the N applied in the early spring). Thus, applying N in the early spring will provide the most benefit. Further split applications of N during the spring do not appear to provide any yield benefit and have often shown yield decreases.

Soil and Tissue Tests

The pre-plant soil nitrate test (PPNT) is recommended for winter wheat (along with corn and sweet corn). Soil tests should be taken in the late summer and taken in two depth increments: 0 to 1 ft and 1 to 2 ft. A minimum of 15 soil cores should be taken from random locations over a 20 acre area. The depth increments should be submitted separately and labeled accordingly. It is important to label the samples properly so the soil test laboratory knows which soil samples are related. One soil test recommendation will be made for each set of depth increments. When the PPNT result is less than 50 lb ac^{-1}, then no N credit should be taken. When the PPNT is greater than 50 lb ac^{-1}, then the N credit is equal to the difference between the PPNT and 50 (e.g., if the PPNT is 70, then the N credit is 20 lb N ac^{-1}).

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Plant tissue tests can be used at tillering or prior to heading to evaluate the nutrient status of the plant. In both cases, collect the newest fully developed leaf and collect at least 50 plants to ensure enough plant material for analysis. However, tissue samples have not been shown to be an effective method to manage nitrogen (Bundy and Andraski, 2001)

Phosphorus and Potassium

Wheat grain removal is 0.5 lb P_2O_5 per bushel and 0.35 lb K_2O per bushel. Wheat straw removes 6 lb P_2O_5 per ton of dry matter and 28 lb K_2O per ton of DM. If wheat is grown for grain or grain and straw, it is in demand level 3, which is also used for alfalfa, corn silage, irrigated field crops and low-demand vegetable crops. Thus, the optimum soil test level for P will be greater compared to that of soybean but only slightly greater than corn. Thus, from a P and K management standpoint, it is very simple to incorporate winter wheat into an alfalfa, corn or corn silage rotation while being able to manage wheat in the optimum range.

Sulfur and Micronutrients

Wheat grain is a low demand crop for sulfur (S), boron (B), molybdenum (Mo) and zinc (Zn). Wheat grain is a medium demand crop for copper (Cu) and a high demand crop for manganese (Mn). If wheat is grown for grain and straw, the demand categories are the same for wheat grain, except that it is a medium demand crop for sulfur. Sulfur application should be applied following the Sulfur Availability Index (SAI). There is no soil test for copper that will predict copper need, copper should be evaluated using plant tissue tests and copper should only be applied if verified by plant analysis. If copper is to be applied on loams, silts and clays, UW guidelines suggest 8 lb of Cu per ac if broadcast and 2 lb ac^{-1} if band applied. Lower rates (4 lb ac^{-1} broadcast, 1 lb ac^{-1} band applied) are recommended on sandy soils and higher rates (12 lb ac^{-1} broadcast, 3 lb ac^{-1} band applied) are recommended on organic soils. If using copper chelates, reduce the application rates by one-sixth.

DO CORN HYBRID TRAITS AFFECT NITROGEN USE EFFICIENCY?

Carrie A.M. Laboski[1], Todd Andraski[1], and Joe Lauer[2]

Background

The number of acres planted to corn rootworm (*Diabrotica* spp.) (CRW) resistant corn (*Zea mays* L.) hybrids have increased in recent years. The CRW resistant corn hybrids may have a greater yield potential because of reduced stress from CRW larval feeding resulting in larger root systems. Many agronomists believe higher N rates are needed to achieve the greater yield potential associated with these hybrids. However, larger root systems of CRW resistant hybrids could result in greater N use efficiency and perhaps a reduced N fertilizer need compared to non-CRW resistant hybrids.

Corn yields have increased over time because of improved genetics and management (Duvick, 1984). O'Neill et al. (2004) found that newer corn hybrids exhibited greater grain yield response to applied fertilizer N and greater N fertilizer use efficiency compared to older (1970s) hybrids. Yields under N deficient conditions varied among individual hybrids and these yield differences were not related to hybrid era (older or newer). Their study included only two N rates (0 and 224 lb/a); thus, more detailed analysis regarding variability of the economic optimum N rate between hybrid eras could not be determined. Vanotti and Bundy (1994) reported that optimum N rates for corn were similar at high and low yield levels from a 24-yr corn N rate study conducted from 1967 to 1990 at Lancaster, Wisconsin. They concluded that conditions which promote high corn yields, such as adequate moisture and temperature, improve the efficiency of available N use by the crop and greater amounts of applied N are not needed. Whether the greater yield potential associated newer hybrids have a similar effect on N use efficiency and optimum N rates is unknown.

There is no record in the published literature of research focusing on the N use efficiency and N needs of CRW resistant vs. non-resistant corn hybrids. Research on the integration of corn hybrid traits, including CRW resistance, with various N management systems is in the preliminary stages at the University of Minnesota (Gyles Randall, personal communication). There has been some research conducted on the influence of N fertilizer on CRW larval feeding. Riedell et al. (1996) found that banded-split N applications resulted in a larger root system and greater tolerance to CRW larval feeding damage compared with broadcast-preplant N applications. However, Roth et al. (1995) found that N fertilizer timing (at planting, sidedress, or split) did not affect corn root damage ratings. In other research, leafy and non-leafy corn hybrids, which differ in their leaf canopy and root morphology, were found to respond similarly to N fertilizer (Costa et al., 2002; Subedi et al., 2006). The objective of this study is to determine if corn hybrids with the transgenic corn rootworm resistant gene vary in their N use efficiency and N need compared to non-resistant hybrids.

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Materials and Methods

A field research study was conducted in 2008, 2009, and 2010 at the University of Wisconsin Agricultural Research Station at Arlington on a Plano silt loam soil (fine-silty, mixed, superactive, mesic Typic Argiudoll). The study was conducted in a new field each year to avoid previous year treatment effects and where corn was planted for several years to increase the probability of moderate to severe corn rootworm pressure. Treatments consisted of eight corn hybrids and six nitrogen rates in a factorial of corn hybrid and N rate in a randomized complete block design with four replications. A description of corn hybrids is shown in Table 1. The corn hybrids included two pairs of hybrid isolines with and without the corn rootworm resistance gene (hybrids 1 and 2; hybrids 3 and 4), two of the overall best non-rootworm resistant hybrids available in Wisconsin (hybrids 5 and 6), and two of the overall best rootworm resistant hybrids available in Wisconsin (hybrids 7 and 8). The goal of using a suite of hybrids is to reflect isoline differences as well as real-world choices that growers make when selecting a hybrid. Unfortunately not all hybrids selected were available in each year of the study. Appropriate hybrid substitutions were made when necessary (Table 1). Nitrogen fertilizer (as NH_4NO_3 in 2008 and UAN-28% in 2009 and 2010) rates ranged from 0 to 200 lb N/acre in 40 lb N/acre increments and was applied early post-emergence broadcast (2008) or band-injected at about a 6-in. depth between rows (2009 and 2010).

Soil test P and K levels were interpreted as either high or excessively high according to Wisconsin nutrient guidelines (Laboski et al., 2006). Soil pH and organic matter values averaged 7.0 and 3.6%, respectively. The sites were chisel plowed in fall or spring and the seedbed was prepared for planting using a soil finisher in spring. Preplant soil nitrate test (PPNT) samples collected in spring indicated minimal carryover NO_3-N content in the soil profile (0 to 3 ft) from the previous year. Corn was planted in early May with 30-inch row spacing at 34,000 to 36,000 seeds/acre with 3-gal./a 10-34-0 pop-up starter fertilizer in the furrow (2008) or no starter fertilizer (2009 and 2010) and 4.4 lb/acre of soil insecticide (Force 3G) in a T-band. Conventional herbicides were used to control weeds. Initial plot size was four-rows wide (10 ft.) and 25-ft long in 2008 and 40-ft long in 2009 and 2010. Plot lengths were trimmed to 20-ft in 2008 and 30-ft in 2009 and 2010 and corn plants within each plot were counted and thinned to a uniform stand density (30,350 plants/acre in 2008 and 2009; 34,294 plants/acre in 2010) at the V4 to V5 corn growth stage. Corn rootworm ratings were determined by digging 20 roots of the standard nontransgenic hybrid (#6) planted without soil insecticide. Corn rootworm ratings were conducted in late July. The average rating was 1.12 in 2008, 0.19 in 2009, and 1.50 in 2010 using the 0 to 3 node-injury scale (Oleson et al., 2005). Corn grain yield was determined by harvesting all ears from the middle two rows from each plot using a plot combine in late October or early November. Corn grain yields are reported 15.5% moisture.

Data were analyzed using PROC MIXED for the appropriate experimental design (SAS Institute, 2002). Significant mean treatment differences were evaluated using Fisher's protected LSD test at the 0.10 probability level. Maximum yield N rate economic optimum N rate (EONR), and grain yield at the yield maximizing N rate or EONR was determined using regression analysis (PROC REG or PROC NLIN). The EONR for corn grain reflects several N fertilizer to corn grain price ratios including 0.05, 0.10, 0.15, and 0.20 reflecting, for example $5.00/bu corn grain and $0.25, $0.50, $0.75, and $1.00/lb N fertilizer, respectively.

Results and Discussion

The 2008 and 2009 growing seasons with cooler than normal with July 2009 being noteworthy in that the average air temperature was 5.9 degrees below the 30-year average. The 2010 growing season temperatures were slightly greater than 30-year averages. The 2008 and 2010 growing seasons had above-average precipitation amounts with June and July rainfall at 10.6 (2008) and 9.0 (2010) inches above the long-term average. On the other hand, 2009 was slightly drier than normal in July.

The yield response to applied N for each hybrid in each is shown in Figure 1. The overall yield levels in 2009 were lower than 2008 or 2010 and are likely a result of the cooler growing season in 2008. Regression models for the yield response to applied N were fit for each hybrid each year. These models were used to calculate the N rate which maximized yield, along with the N rate and yield at the economic optimum N rate (EONR) for several N:corn price ratios (0.05, 0.10, 0.15, and 0.20) (Table 2). When the yield maximizing N rate (YMNR) was determined by combining all hybrids within a year, the YMNR was somewhat lower in 2009 compare to 2010 or 2008. This may be a result of heavy rainfalls in June and July 2008 and 2010, which may have resulted in some N loss. When comparing near isolines with and without the CRW trait, the YMNR and EONRs are sometimes greater in the CRW traited hybrid and sometimes lower for both Pioneer and DeKalb isolines and there were no trends that were consistent within or between years (Table 2). These data suggest that there may not be a relationship between CRW traited hybrids needing more or less N fertilizer than untraited hybrids.

There are numerous ways to define N use efficiency (NUE); however only a few are explored in this paper. One way to assess NUE is to measure the efficiency of converting N supplied by the soil only (zero fertilizer N) into yield. In 2008 and 2009 there was no significant difference between hybrids with regard to their yield at zero N (GY_{noN}) (Table 3). In 2010, hybrids 1 and 2 (Pioneer isoline pair) had significantly lower yield at zero N compared to other hybrids. It is uncertain why that isoline pair would perform poorly in 2010. Expressing the yield at zero N as a percentage of the yield obtained at 200 lb N/a is called relative yield (RGY_{200}). As with yield at zero N, relative yield was not significantly different between hybrids in 2008 or 2009, though relative yields were generally greater in 2008 compared to 2009. Relative yields in 2009 were generally a little lower than what is typically measured at the Arlington Ag Research Station. Hybrids 1 and 2 had significantly lower relative yield compared to other hybrids in 2010 with values of 49 and 44%, respectively, which are substantially less than expected.

The yield increase (over the yield at zero N) at 200 lb N/a (Δ $yield_{200}$) was not significantly different between hybrids in 2008 and 2009 (Table 3). In 2010 there were significantly different yield increases at 200 lb N/a between hybrids. This is largely the result of hybrids 1 and 2 having low yields at zero N, but having the third and fourth greatest maximum yield. For a given hybrid the yield increase at 200 lb N/a does vary somewhat between years. There is no obvious trend for hybrids with the CRW trait to have greater or less yield increase at 200 lb N/a.

Fertilizer N use efficiency (FNUE) is a measure of the amount of N required per bushel of grain. When FNUE is calculated at the 160 lb N/a rate, there are significant differences between hybrids in all years (Table 3). Hybrids 1 and 5 often have higher $FNUE_{160}$ while hybrids 3 and 6 often have lower $FNUE_{160}$. The FNUE calculated at the EONR for the 0.10 N:corn price ratio are generally lower than $FNUE_{160}$ because the $EONR_{0.10}$ is generally less than 160 lb N/a (Table 2) and the yield at $EONR_{0.10}$ is not much lower than yield at 160 lb N/a. Over all years, the $FNUE_{0.10}$ is often greatest for hybrids 6 and 8 while the $FNUE_{0.10}$ is often in the middle of the range for hybrids 1, 5, and 7. Agronomic efficiency (AE) calculated at 200 lb N/a was not significantly different between hybrids in 2008 or 2009. In 2010, hybrids 1 and 2 had significantly greater AE_{200} compared to most other hybrids, though they were not different than hybrid 6. Hybrids 1, 2, and 6 had greater AE_{200} because they had the largest yield increases at 200 lb N/a (over the yield at zero N).

Fertilizer N recovery efficiency (FNRE) is the percentage of fertilizer N applied that is taken up in the biomass (grain plus stover) minus biomass N uptake in the zero N treatment. FNRE was calculated at each N rate and then averaged over N rates for each hybrid. In 2008 there was no significant difference in FNRE between hybrids (Table 3). In 2009, hybrid 5 had the greatest FNRE but it was not significantly greater than hybrids 1 and 7. Hybrid 3 had the lowest FNRE, but it was not significantly different than hybrids 2 and 4. Samples collected in 2010 have not yet been analyzed for total N content.

In 2010, end-of-season stalk nitrate samples were collected approximately two weeks after black layer. When applied N rates are within 20 lb N/a of the EONR at the 0.10 N:corn price ratio, stalk nitrate values had a range of 650 ppm (Fig. 2). The increase in stalk nitrate values between the N rate that was within 20 lb N/a of the EONR and the next highest N rate varied with hybrid. These data demonstrate that different hybrids may not have very similar stalk nitrate values at the EONR.

Summary

There was some variation in yield levels and EONRs between years and between hybrids. The preliminary results of this data analysis show that regardless of the metric used to assess N use efficiency, there does not appear to be a consistent trend for hybrids with the CRW trait to have greater or lesser N use efficiency, overall yield level, or EONR. As the 2010 data set is completed, additional data analysis will be completed.

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Table 1. Description of corn hybrid used each year of the study. The hybrids include two pairs of hybrid isolines with and without the corn rootworm resistance gene (hybrids 1 and 2; hybrids 3 and 4), two of the overall best non-rootworm resistant hybrids available in Wisconsin (hybrids 5 and 6), and two of the overall best rootworm resistant hybrids available in Wisconsin (hybrids 7 and 8).

Hybrid no.	Hybrid i.d.	Brand	Hybrid	Relative maturity (CRM)	Traits †
1	Bt-CR 1	Pioneer	P35F44	105	HX (CB & CRW); RR2; LL
2	Isoline 1	Pioneer	P35F37	105	RR2
3	Bt-CR 2	DeKalb	DKC52-59	102	YG-VT3 (CB & CRW); RR2
4	Isoline 2	DeKalb	DKC52-62	102	RR2
5	Standard Bt-CB	2008: NK	N58-D1	107	YG (CB)
		2009: NK	N58-D1	107	YG (CB)
		2010: Renk	RK670	103	YG (CB)
6	Standard nontransgenic	2008: Pioneer	35A30	106	None
		2009: Pioneer	35F38	105	None
		2010: Pioneer	35F38	105	None
7	Bt-CR (Mon863) 1	2008: Renk	R698RRYGRW	104	YG (CRW); RR
		2009: DeKalb	DKC55-24 (VT3)	105	YG-VT3 (CB & CRW); RR
		2010: DeKalb	DKC55-24 (VT3)	105	YG-VT3 (CB & CRW); RR
8	Bt-CR (Mon863) 2	Dairyland	Stealth-4006	106	YG (CRW); RR2

† CB, corn borer; CRW, corn rootworm; HX, HerculexXtra; LL, Liberty Link; RR, Roundup Ready; YG, Yield Guard;

Table 2. Nitrogen rate required to achieve maximum yield along with the economic optimum N rate (EONR) and estimated yield at four N:corn price ratios for each hybrid each year along with the average overall hybrids in a given year. These N rates and yield are calculated from the yield response to N regression equations for each hybrid and all hybrids together (average).

Year	Max. yield		N:Corn price ratio † 0.05		0.10		0.15		0.20	
Hybrid	N rate	Yield	EONR	Yield	EONR	Yield	EONR	Yield	EONR	Yield
	lb/a	bu/a	lb/a	bu/a	lb/a	bu/a	lb/a	bu/a	lb/a	bu/a
2008										
1	164	227	155	227	146	226	137	225	128	223
2	131	234	131	234	131	234	131	234	131	234
3	128	250	128	250	128	250	128	250	128	250
4	175	227	163	227	150	226	138	225	126	222
5	130	212	124	211	118	211	112	210	107	209
6	119	239	119	239	119	239	119	239	119	239
7	130	230	130	230	130	230	130	230	130	230
8	185	234	175	234	165	233	155	232	145	230
Ave.	177	233	167	233	157	232	147	231	138	229
2009										
1	149	194	142	194	136	193	130	192	123	191
2	168	205	160	204	152	204	144	203	136	201
3	188	216	178	216	168	215	159	214	149	212
4	172	213	165	213	158	213	150	212	143	210
5	115	188	112	188	108	188	104	187	100	187
6	200	217	200	217	191	216	181	215	171	213
7	172	211	164	210	157	210	149	209	142	207
8	131	201	125	200	120	200	115	199	109	198
Ave.	157	204	150	204	143	203	136	202	129	201
2010										
1	176	246	170	246	164	246	157	245	151	244
2	145	234	141	233	137	233	133	233	129	232
3	156	231	148	231	140	231	132	230	124	228
4	119	224	115	224	111	224	107	223	103	222
5	153	225	146	225	139	224	132	223	125	222
6	200	251	200	251	200	251	200	251	200	251
7	129	233	124	233	120	232	115	232	111	231
8	199	248	188	248	178	247	167	246	157	244
Ave.	164	236	157	236	150	235	144	234	137	233

† Example of N:corn price ratio: $5.00/bu corn grain and $0.25/lb N (0.05), $0.50/lb N (0.10), $0.75/lb N (0.15), or $1.00/lb N (0.20).

Table 3. Effect of corn hybrid on grain yield with no N applied (GY_{noN}), relative grain yield (RGY_{200}†), delta grain yield (Δ $yield_{200}$‡), fertilizer N use efficiency (FNUE¶), agronomic efficiency (AE§), and fertilizer N recovery efficiency (FNRE‡‡)in each year of the study.

Year/ Hybrid	GY_{noN}	RGY_{200}	Δ $yield_{200}$	$FNUE_{160}$	$FNUE_{0.10}$	AE_{200}	$AE_{0.10}$	FNRE
	bu/a	%	bu/a	lb N/bu	lb N/bu	bu/lb N	bu/lb N	%
2008								
1	155	68	74	0.74 abc	0.65	0.37	0.49	63
2	168	72	66	0.70 bcd	0.56	0.33	0.50	42
3	175	70	77	0.67 d	0.51	0.39	0.59	54
4	169	74	58	0.70 bcd	0.66	0.29	0.38	57
5	142	66	74	0.79 a	0.56	0.37	0.58	62
6	144	60	96	0.69 cd	0.50	0.48	0.80	83
7	163	68	77	0.75 ab	0.57	0.38	0.52	61
8	152	66	79	0.70 bcd	0.71	0.40	0.49	78
p	0.22	0.56	0.55	0.04	NA††	0.58	NA	0.11
2009								
1	106	54	91	0.85 a	0.70	0.46	0.64	70 ab
2	117	56	92	0.80 bc	0.75	0.46	0.57	59 bc
3	127	60	88	0.74 d	0.78	0.44	0.52	53 c
4	113	53	102	0.76 d	0.74	0.51	0.63	63 bc
5	102	56	81	0.85 a	0.57	0.41	0.80	81 a
6	106	48	114	0.77 cd	0.88	0.57	0.58	66 b
7	113	54	97	0.76 d	0.75	0.49	0.62	70 ab
8	123	60	81	0.83 ab	0.60	0.40	0.64	67 b
p	0.30	0.46	0.23	<0.01	NA	0.21	NA	0.02
2010								
1	123 bc #	49 cd	129 a	0.67 bc	0.67	0.65 a	0.75	
2	105 c	44 d	136 a	0.70 ab	0.59	0.68 a	0.93	
3	154 a	66 a	79 c	0.71 ab	0.61	0.40 c	0.55	
4	137 ab	60 ab	93 bc	0.70 ab	0.50	0.47 bc	0.78	
5	142 ab	62 ab	88 c	0.73 a	0.62	0.44 c	0.59	
6	136 ab	54 bc	115 ab	0.67 bc	0.80	0.58 ab	0.58	
7	144 ab	63 ab	87 c	0.70 ab	0.52	0.44 c	0.73	
8	157 a	63 ab	91 bc	0.66 c	0.72	0.46 bc	0.51	
p	<0.01	<0.01	<0.01	0.07	NA	<0.01	NA	

† RGY_{200} = (grain yield in unfertilized treatment / yield at the 200 lb N/a rate) x 100.

‡ Δ $yield_{200}$ = grain yield at the 200 lb N/a rate– grain yield at 0 lb N/a.

¶ $FNUE_{160}$ = (lb N/a applied / grain yield) at 160 lb N/a rate.$FNUE_{0.10}$ = (lb N/a / grain yield) at at economic optimum N rate for the 0.01 N:corn price ratio.

§AE_{200} = Δ $yield_{200}$ / 200 lb N/a. $AE_{0.01}$ = Δ $yield_{0.10}$ / economic optimum N rate for the 0.10 N:corn price ratio.

‡‡FNRE = ((total N uptake in fertilized treatment - total N uptake in unfertilized treatment) / N fertilizer rate) x 100. This is the average over all N rates for a given hybrid.

Mean values in columns for each year followed by the same letter are not significantly different at the 0.10 probability level using Fisher's protected LSD test.

†† NA, not applicable. These parameters were calculated from regression response functions and statistical comparisons were not made.

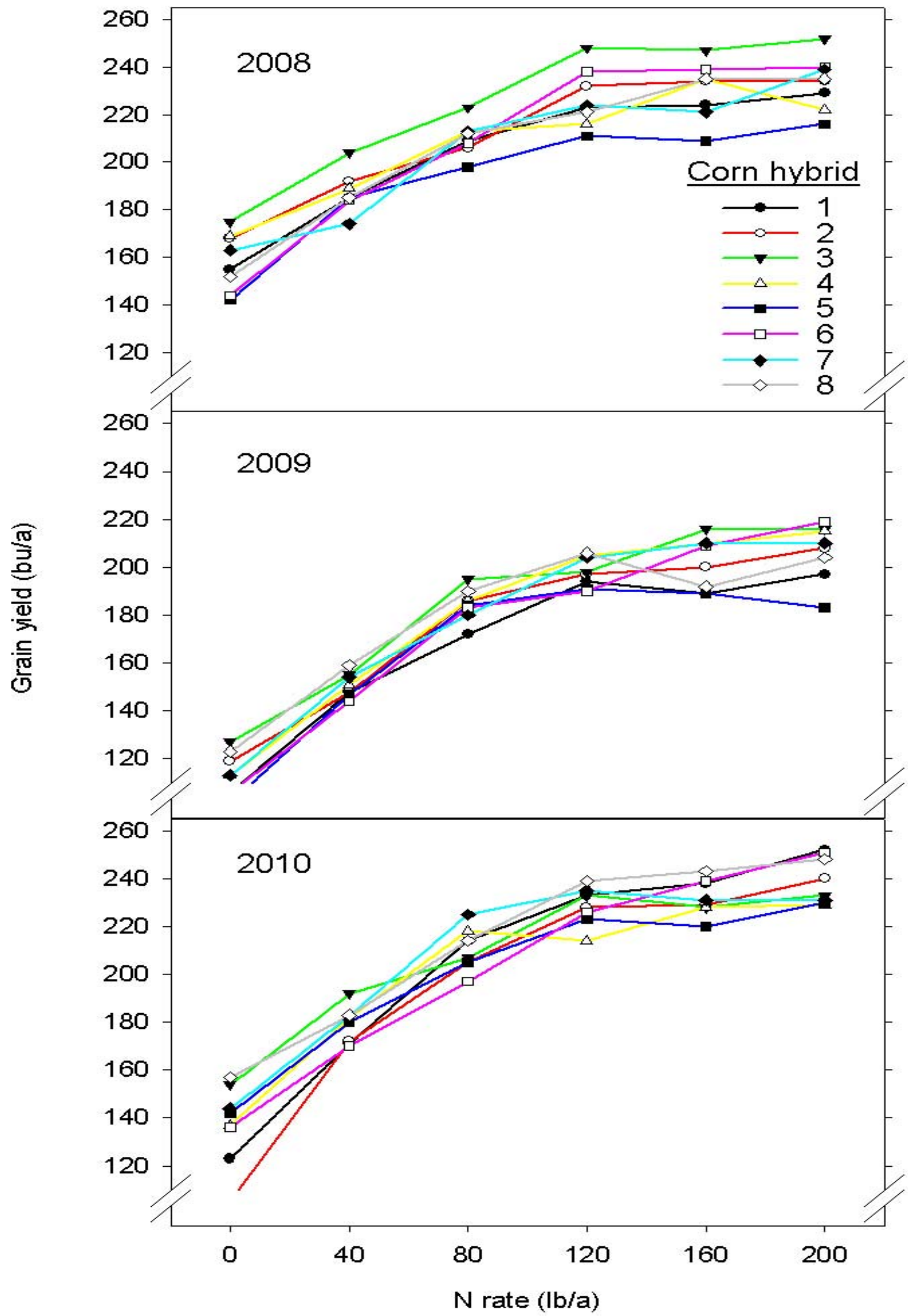

Figure 1. Relationship between N rate and grain yield for eight corn hybrids, 2008 to 2010.

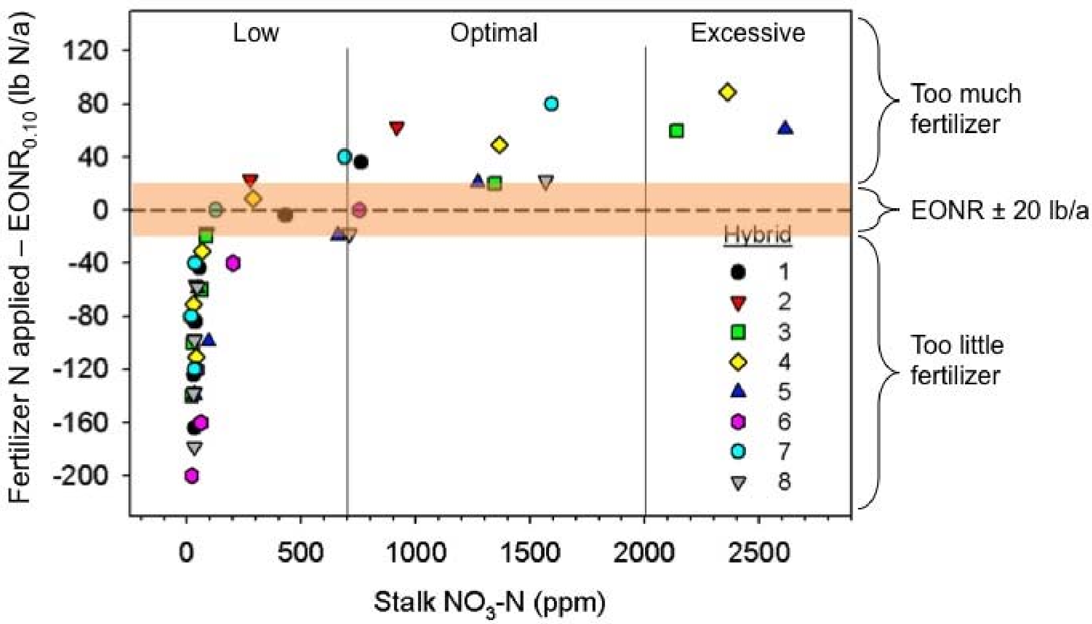

Figure 2. Relationship between over or under application of N compared to the economic optimum N rate at the 0.10 N:corn price ratio ($EONR_{0.10}$) and end-of-season stalk nitrate concentration for each hybrid in 2010.

THE GLOBAL FERTILIZER MARKET OUTLOOK

Al Mulhall[1]

Volatility has been a feature of fertilizer markets over recent years and up to the present. The presentation, "The Global Fertilizer Outlook" addresses the many questions associated with this volatility. What was the effect of the financial crisis on global fertilizer markets? What was the knock-on effect on global crop production? How have global crop markets responded? What does this mean to farmers and to fertilizer dealers? When will things return to normal? Is there still a normal? What is the outlook for the markets for each of the nutrients N, P, and K?

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GRAIN QUALITY: A DAIRY COW'S PERSPECTIVE

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Introduction

Grain quality is a nebulous term that means different things to corn producers, crop consultants, dairy producers or ruminant nutritionist. In commercial grain sales, grain quality is often defined in terms of moisture content, test weight, kernel size, total damaged kernels, heat damage, broken kernels or breakage susceptibility. Foreign material in grain such as molds, mycotoxins, insect fragments, and other foreign material are also used to define grain quality. Likewise, nutritional properties of corn grain such as fat, protein, hardness, density, and starch content define corn quality characteristics. In short corn grain quality is defined primarily by the end users intended use. If the end user of the grain is a dairy cow, then grain quality factors related to milk production best define grain quality.

When fed to lactating dairy cows management practices, such as grinding corn, (Remond et al., 2004), steam flaking corn (Callison et al., 2001), feeding high moisture corn (Oba and Allen, 2003), or feeding floury corn (Allen et al., 2008), have been demonstrated to improve starch digestion and milk production of lactating dairy cows. The aforementioned management practices are commonplace in the dairy industry and are deemed necessary to improve the feeding characteristic of corn grain. The use of these management practices brings to light a broader question—why is corn starch within the native corn kernel only partially digestible by dairy cows? This paper will review the biochemical properties of corn which are potentially related to starch digestibility in dairy cows.

Corn is a Seed

Corn per se is not a feed, it is a seed, and some understanding of corn seed anatomy and physiology are required to better understand chemical factors that potentially influence starch digestibility in ruminants. The corn seed is comprised of three basic morphological parts, pericarp, germ, and endosperm. The endosperm represents approximately 75 to 80% of the corn kernel by weight and is the morphological structure which contains starch. The endosperm contains primarily starch and protein but does contain small amounts of fat as phospholipids and ash. The endosperm of corn is virtually devoid of fiber (ADF or NDF). Specifically, corn endosperm contains < 4% NDF and 0.09% P (phosphorus), as compared to the germ which contains 17% NDF and 0.97% P, and pericarp with 33% NDF and 0.29% P (Van Kempen et al., 2003). Corn endosperm contains abundant storage proteins (albumins, globulins, prolamins, and glutelins) which will be discussed in detail later in this paper.

The endosperm in cereal grains surrounds the germ and serves as the primary nutrient source for the germ which contains living tissue (roots, leaves, etc). Seed germination is initiated by imbibition (water absorption) and the seed undergoes renewal of enzymatic activity that results in cell division and ultimately embryo emergence through the pericarp. The endosperm's biological function is to serve as the primary nutrient source for the embryo until photosynthesis is initiated upon seedling emergence (Mohr and Schopfer, 1995; Buchanan et al., 2000).

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Corn Endosperm

Corn is an annual plant, reproducing only by seed, facilitated by the seed falling onto the ground where germination is reinitiated. Plant reproduction by seed requires protection of the embryo from improper environmental conditions until proper environmental conditions (moisture, temperature, seed coverage, dark) exist for germination. The fibrous pericarp is the primary morphological structure protecting the embryo but the starch in corn endosperm is also protected by hydrophobic (repels water) proteins called prolamins. Pure starch cannot be efficiently stored in corn endosperm because pure starch is highly hydrophilic (attracts water) and premature hydration of the endosperm would not properly facilitate germination. The combination of starch, prolamins and other proteins (albumins, globulins, glutelins) in corn endosperm is often referred to as the starch-protein matrix. Differences in the starch protein matrix can be visibly seen in dissected kernels of yellow dent corn. The visual appearance of all or portions of the starch-protein matrix in corn endosperm have historically been given visually descriptive classifications. Starch-protein matrices appearing white are commonly given the names floury, opaque or soft endosperm. Starch-protein matrices appearing yellow, shinny or glassy are classified as, horny, translucent or vitreous (Kempten, 1921). The word vitreous means to exist in an amorphous, glassy-like state. A common example of something existing in a vitreous state would be a ceramic vase. The term vitreous is presently important because over the past decade animal and dairy scientist have adopted the word to semi-quantitatively define corn endosperm types in ruminant nutrition trials.

Vitreous Endosperm and Negative Effects on Starch Digestibility

Vitreousness of corn can be quantified in whole corn kernels by manual dissection (Correa et al., 2002). Corn kernels are soaked in water, the pericarp and germ are removed with a scalpel and the remaining endosperm is weighed. Using visual judgment the floury (white, opaque) endosperm is separated from vitreous (yellow, glassy) endosperm with a scalpel and the weight of the vitreous endosperm is weighed and expressed as a percentage of the total endosperm.

Recent research has evaluated the relationship between in situ starch or DM degradability of corn (Philippeau and Michalet-Doreau, 1998; Correa et al., 2002; Ngonyamo-Majee et al., 2008) and endosperm vitreousness. All studies have observed a strong negative relationship between endosperm vitreousness and in situ starch or DM degradability, meaning as endosperm vitreousness increases in situ starch or DM degradability decreases. Ngonyamo-Majee et al. (2008) evaluated in situ DM degradability of 31 corns differing in vitreousness. Corn kernels were ground through a 6-mm screen, placed in dacron bags and incubated for 14 h in cannulated steers. The negative relationship ($R^2 = 0.72$) between endosperm vitreousness and in situ DM degradability of corn observed by Ngonyamo-Majee et al. (2008) is presented in Figure 1.

Lebaka et al. (2007) reported the opaque (o2) gene alters vitreousness and endosperm storage protein composition of corn. The less-vitreous kernel texture of *o2* grain directly improved in situ starch degradability, but adversely affected agronomic performance. Lebaka et al. (2007) evaluated 140 recombinant inbred lines of corn for in situ starch degradability in combination with quantitative trait loci markers (QTL) to assess regions of the corn genome negatively or positively related to corn in situ DM degradability. Ruminal starch degradability of corn was negatively related QTLs on two primary chromosomes that have been previously associated with endosperm storage proteins (prolamin-zein) in corn.

Similar results were observed in vivo by Allen et al. (2008). Allen et al. (2008) fed eight ruminally and duodenally cannulated lactating dairy cows, corns with 25 or 66 % vitreous endosperm. Feeding cows 66% vitreous endosperm corn reduced ruminal and total tract starch digestion by 19.1 and 7.1 percentage units respectively (Figure 2).

Prolamins Make Corn Vitreous

Prolamins are endosperm storage proteins high in proline (amino acid) found in the seed of all cereal grains. Prolamins for each cereal grain have specific and historical names: wheat (gliadin), barley (hordein), rye (secalin), corn (zein), sorghum (kafirin) and oats (avenin). The small grains (wheat, oats, barley) have lower prolamin contents as compared to corn although modified endosperm types exist in corn which are low in prolamins. Prolamins are characterized by a high glutamine and proline content. Proline is a highly hydrophobic amino acid capable of complex folding and thus proteins with high proline contents develop tertiary structures that are intensely hydrophobic and are soluble in aqueous alcohol solutions (Lasztity, 1984; Momany et al., 2006).

In corn, prolamin proteins are named zein and comprise 50 to 60% of the total protein in whole corn (Hamaker et al., 1995). Prolamin-zein, defines a class of hydrophobic proteins synthesized on the rough endoplasmic reticulum of the amyloplast (starch producing organelle) envelope consisting of four zein sub-classess (ά,β,γ,δ), (Buchanan et al., 2000). Because prolamin-zein proteins are synthesized on the rough endoplasmic reticulum within the amyloplast without the presence transit genes (Buchanan et al., 2000) prolamin-zein proteins are not intrinsic within the starch granule but are primarily surface localized on the exterior of starch granules (Mu-Forster and Wasserman, 1998). As prolamin-zein proteins enlarge and distend with advancing maturity β- and γ- zeins cross-link and ά- δ-zeins penetrate their network and occupy a more central position encapsulating starch into a starch-hydrophobic protein matrix (Mu-Forster and Wasserman, 1998; Buchanan et al., 2000).

The degree, amount, mechanisms and genetics associated with starch encapsulation by prolamin-zein in corn have been extensively investigated by plant physiologist and cereal chemist (Lasztity, 1984; Mu-Forster and Wasserman, 1998; Buchanan et al., 2000; Landry et al., 2000). It is well defined that floury and opaque corn endosperm types have significantly lower prolamin-zein content as compared to flint or normal dent corn endosperms (Wallace et al., 1990; Hamaker et al., 1995; Landry et al., 2000). The lower prolamin-zein content of floury, opaque or modified opaque corn is regulated by ά, and γ, prolamin-zein gene expression (Wallace et al., 1990). Philippeau et al. (2000) quantified the relationship between vitreousness and prolamin-zein content with vitreous flint corns containing more prolamin-zein than less vitreous dent corns. These data define differences in the chemical composition between vitreous endosperm (glassy, translucent) and floury or opaque endosperm. The starch in vitreous corn endosperm is more extensively encapsulated by prolamin-zein as compared to floury or opaque corn endosperm. Differences in corn starch encapsulation by prolamin-zein can be seen using scanning electron microscopy. Presented in Figure 3 are scanning electron micrographs of corn starch granules, (A) heavily encapsulated in a prolamin-protein matrix and (B) starch granules in opaque corn endosperm with less extensive encapsulation by prolamin-proteins (Gibbon et al., 2003).

The significance of prolamin-zein protein and it's chemistry in corn to ruminant nutrition implies sequential logic. Prolamin-zein is not soluble in water (hydrophobic) nor soluble in soluents normal to the innate rumen environment (Lawton, 2002). Potentially, starch digestion requires rumen bacteria to first degrade prolamin-zein via proteolysis before amylolytic activity in the rumen (Cotta, 1988) can actively hydrolyze starch to glucose. Because glucose uptake by rumen bacteria is momentary (Franklund and Glass, 1987) and the rumen has extensive amylotyic capacity (Cotta, 1988) to hydrolyze starch to glucose, proteolysis of hydrophobic prolamin-zein proteins in the rumen should therefore be a rate limiting step associated with starch digestion. The synergism between prolamin-zein and starch digestion in ruminants is compounded by slow degradation potential of prolamin-zein proteins by rumen bacteria. Romagnolo et al., (1994) observed the ruminal degradation rate of zein to be 0.026 %/h as compared to corn globulin-albumin proteins at 0.06 %/h.

McAllister et al. (1993) coalesced the potential influence of starch protein matrix on starch digestion in a classical study. McAllister et al. (1993) observed that when corn was treated with a protease (pronase E, Sigma Chemical) in vitro starch digestion increased approximately two fold and concluded the protein matrix in corn was a major factor in ruminal starch digestion. Lichtenwalner et al. (1978) executed as similar study treating sorghum (prolamin = kafirin) with a protease followed by incubation with glucoamylase and observed a marked increase in starch hydrolysis.

Measuring Prolamins in Corn

Prolamin-zein was first quantified by its solubility in aqueous ethanol by Osborne (1897). Presently, the methods of Landry and Moureaux (1970) are a recognized, but not the sole method to quantify prolamin-zein in corn endosperm. Modifications of Landry and Moureaux (1970) have been evaluated (Wallace et al., 1990; Hamaker et al., 1995; Landry et al., 2000), resulting in permutations. The basis of Landry and Moureax (1970) and other aforementioned methods consist of sequentially solubilizing corn endosperm proteins with saline, H_2O, aqueous alcohol and an alkali. The methods of Landry and Moureaux (1970) are arduous and designed to divide corn endosperm proteins into multiple fractions (albumins, globulins, prolamins, and glutelins), which may be over extensive for ruminant nutrition because only prolamins have been recognized to be negatively associated with starch degradability (Philippeau et al., 2000) in ruminants.

Due to labor, expense, procedural metamorphosis, and prolamin-zein analysis of isolated corn endosperm, laboratory methods to quantify prolamin-zein (Wallace et al., 1990; Hamaker et al., 1995; Landry et al., 2000) in whole corn for ruminant nutrition trials or for routine feed analysis are not employed. Turbidimetric methods (Paulis et al., 1974; Aboubacar et al., 2003; Olakojo et al., 2007) to quantify prolamin-zein periodically occur in the literature and have been successfully used to singularly quantify prolamins zein or kafirin in ground whole corn or sorghum. Larson and Hoffman (2008) coalesced advances in cereal chemistry and rapid turbidimetric methods to quantify prolamin-zein in dry and high moisture corns. Prolamin-zein(s) were solubilized with 55.0% aqueous isopropyl and turbidity of prolamin-zein(s) was achieved by addition to a turbidity solvent. Degree of turbidity was measured on a spectrophotometer and prolamin-zein was quantified using a standard absorbance curve developed form purified zein. The procedure of Larson and Hoffman (2008) delineated prolamin-zein encapsulation of starch across corn endosperm type. Dry flint and dent corns contained significantly more prolamin-zein/100 g of starch as compared to floury or opaque corns.

Prolamins and High Moisture Corn

The starch-protein matrix in corn has been previously defined as a physio-chemical impediment to starch digestion in ruminants (Owens et al., 1986), but the role of the starch-protein matrix in the digestion of HMC starch in ruminants has only recently been defined.

Because prolamin-zein increases with advancing maturity (Murphy and Dalby, 1971), lower prolamin-zein contents in HMC at ensiling could be expected. This argument is somewhat illogical because Murphy and Dalby (1971) observed that maximum prolamin-zein accretion occurred near black layer formation (±30% moisture), which is similar to typical ensiling moisture contents of HMC. In addition, HMC and dry corn are often harvested (combined) at very similar moisture contents with only post-harvest handling and storage of the corn being different thereafter. Specifically, corn is commonly combined at 25 to 30% moisture and mechanically dried thereafter yielding dry corn.

A more plausible explanation for greater and more rapid starch digestion of HMC starch is that fermentation acids or proteolysis degrade prolamin-zein proteins during the ensiling process. Bacterial proteolysis is an intrinsic mechanism in corn-grain fermentation which induces degradation of corn proteins (Baron et al., 1986). Philippeau and Michalet-Doreau (1998) observed that ensiling grains increased ruminal starch degradability and hypothesized that ensiling increases accessibility of starch granules to rumen microorganisms, because hydrophobic prolamin-zein proteins encapsulating starch granules were partially degraded by proteolysis. Likewise, Jurjanz and Monteils (2005) observed the effective ruminal degradability of starch to be lower in corn kernels before (70.2%) than after (92.3%) ensiling. The ensiling process improved starch degradation by significantly altering the rapidly-degradable starch fraction (80.7 vs. 65.6%) and the starch degradation rate (12.4 vs. 8.0 %/h). Combined, these data (Baron et al., 1986; Philippeau and Michalet-Doreau, 1998; Jurjanz and Monteils, 2005) result in a very plausible hypothesis as to why higher ruminal and total tract starch digestibility is observed for HMC as compared to dry corn (Firkins et al., 2001).

In a recent study, (Hoffman et al., 2010a) we monitored the fate of the starch-protein matrix in HMC across a long storage period (240 days). Two random HMC(s), containing 25.7% and 29.3 % moisture were ground, ensiled and stored for 0, 15, 30, 60, 120, and 240 d. At 0 and 240 d, the α, γ, δ and β zein regions of the starch-protein matrix were profiled using high performance liquid chromatography. The effect of fermentation (storage time) on the starch-protein matrix of HMC after 240 d of storage is presented in Figure 4. Fermentation (0 vs. 240 d) reduced all α, β and δ prolamin-zein subunits of the starch-protein matrix from 10 to 40%. The degradation of the γ prolamin-zein subunits of the starch-protein matrix of HMC was more extensive with a 60% reduction. Because γ prolamin-zeins are surface localized and primarily responsible for cross-linking starch granules together, the degradation of γ zeins in HMC would suggest that clusters of starch granules should disassociate (fall apart) as a result of fermentation since the cross links holding starch granules together are being degraded. This was confirmed by electron microscopy (photos not shown) of HMC starch granules at 0 and 240 d. Upon fermentation and storage for 240 d, the disassociation of starch-granule clusters in HMC could be readily seen using electron microscopy. Fermentation resulted in a greater number of individual starch granules (and surface area) for potential attack by rumen bacteria. Electron micrographs also revealed no alteration in individual starch granules in HMC prior to fermentation or after 240 d of storage. Inferences from this investigation (Hoffman et al., 2010a) also suggested the proteins in the starch-protein matrix were more likely altered by bacterial proteolysis and may not have been simply solubilized by fermentation acids.

In second study (Hoffman et al., 2010b), the digestibility of HMC fermented and stored for 0, 15, 30, 60, 120, and 240 d was evaluated using an in vitro gas production system. Gas production and rate (kd) of gas production by rumen bacteria during the first 12 h of incubation increased with increasing storage time, which indirectly validates the observations of greater ruminal starch digestion of HMC as compared to unfermented corn. Increases in 12 h gas production and rate (kd) of gas production increased chronically over the entire HMC storage periods suggesting that the increase in HMC (DM) digestion is not an acute event. Similar results were reported by Benton et al. (2005) who evaluated in situ DM degradation of two HMC(s) and two reconstituted HMC(s) of varying moisture content; a chronic increase in DM degradation across a 300(+) day ensiling period was observed.

Grain Quality for Dairy Cows: Simple Test

Vitreousness: Vitreousness of corn can be quantified in whole corn kernels by manual dissection but the task is tedious. A semi-quantitative method is to determine vitreousness of whole corn kernels (i.e., from a specific corn hybrid) is use of a light box scoring system. Because vitreous endosperm is translucent, light shines through it as opposed to opaque endosperm which is not translucent. A complete guide to light box scoring of corn grain for vitreousness is available in *Breeding Quality Protein Maize (QPM): Protocols for Developing QPM Cultivars.* **http://ideas.repec.org/p/ags/cimmma/56179.html**

Crude Protein: Crude protein in corn grain is of benefit and detriment to dairy cows. Greater crude protein content in corn grain reduces the need for supplemental protein but proteins in corn grain also serve a lignin like function because hydrophobic prolamin-zein proteins encapsulate starch reducing starch digestibility. Crude protein content of dry corn grain has been demon-strated to be negatively related to starch degradability. It is very simple to measure crude protein in corn grain and crude protein analysis is widely available at numerous commercial feed and forage testing laboratories. The crude protein content of corn grain averages 9.2% but ranges from 7.5 to 11.5%. Crude protein and the amount of starch encapsulating prolamin proteins are highly related. Corn grain from hybrids with crude protein contents > 10.0% are likely more vitreous, may contain more flint genes, or are short relative maturity hybrids (more flint genes). Corns with lower crude protein < 8.0% maybe unique opaque-floury hybrids or have a portion of these endosperm types in their genetic makeup. Nitrogen fertility has also been demonstrated to have an effect on grain crude protein content therefore crude protein content of grains grown under nitrogen deficient growing conditions should be interpreted with caution.

Prolamin Protein: A commercial test is available to determine the concentration of hydro-phobic prolamin proteins that encapsulate corn starch. The prolamin protein assay is available at a number of commercial feed and forage testing laboratories. The prolamin content of dry corns ranges from 2.5 to 5.5% of dry matter. Corns > 4.5% prolamin as a % of DM are likely more vitreous, may contain more flint genes, or are short relative maturity hybrids (more flint genes). Corns with lower prolamin protein < 3.0% maybe unique opaque-floury hybrids or have a portion of these endosperm types in their genetic makeup.

Soluble Protein: The relationships between crude or prolamin protein and starch digestibility in lactating dairy cows applies primarily to dry corn. In ensiled corn (HMC) it is important to ascertain whether the hydrophobic proteins in the starch protein matrix have been degraded in the ensiling process. Prior to ensiling about 20% of the protein in corn is soluble in a buffer solution. In extensively fermented high-moisture corn, over 70% of the protein may be soluble. The change in soluble protein is a marker of the degradation process of the starch matrix proteins. As silage bacteria degrade hydrophobic proteins they become more soluble in buffer solutions.

Ammonia Nitrogen: Ammonia nitrogen may also be a marker of the status of starch-matrix proteins in high-moisture corn. At ensiling, corn has virtually no ammonia nitrogen and the appearance of ammonia in high moisture corn means that amino acids associated with the starch protein matrix are being degraded by silage bacteria. In extensively fermented high-moisture corn, ammonia nitrogen may represent > 7% of the total nitrogen (or protein). High-moisture corns with < 2% of the total nitrogen (or protein) as ammonia nitrogen indicate the degradation of starch-matrix proteins is probably minimal.

Starch: As compared to test weight or density, determination of starch content of corn grain prior to feeding is important. Corns harvested at immature stages due to late planting, early frost or lack of growing degree days will likely be lower in total starch content. High moisture corns harvested with cob or husk as a part of the feed will also be lower in starch content. Starch contents of corn fed to dairy cows ranges from 60 to 74% of DM. Diets can easily be adjusted for starch content if the starch content of the grain is known.

In Vitro Starch Digestibility: Numerous feed and forage testing laboratories offer in vitro starch digestibility. There is no standardized method. Typical whole grains are ground through a mill fit with a 4 to 8 mm screen and incubated in rumen fluid from 6 to 12 h. More specialized in vitro gas production procedures are also available. These procedures result in lab specific numbers but are useful in ranking or indexing relative starch digestibility potential by dairy cows.

Conclusions

- Corn is a seed and is comprised of three basic morphologic parts, pericarp, germ, and endosperm. Starch is contained in the endosperm and the biochemistry of the endosperm influences starch digestibility in dairy cows.
- Vitreous endosperm is negatively related to starch degradability and in vivo starch digestibility in dairy cows.
- Vitreous endosperm, is translucent and can be indexed using a light box scoring system.
- Dry flint and dent corns contain more hydrophobic prolamin-zein as compared to floury or opaque corns.
- The higher starch digestibility of high moisture corn is the result of degradation of starch encapsulating proteins by proteolysis during fermentation and not solely due to moisture or harvest maturity per se.
- The crude protein, prolamin protein or vitreousness of dry corn grain is negatively related to starch degradability in dairy cows.
- In high moisture corn the extent of degradation of the starch protein matrix can be evaluated using soluble crude protein or ammonia nitrogen as a marker.

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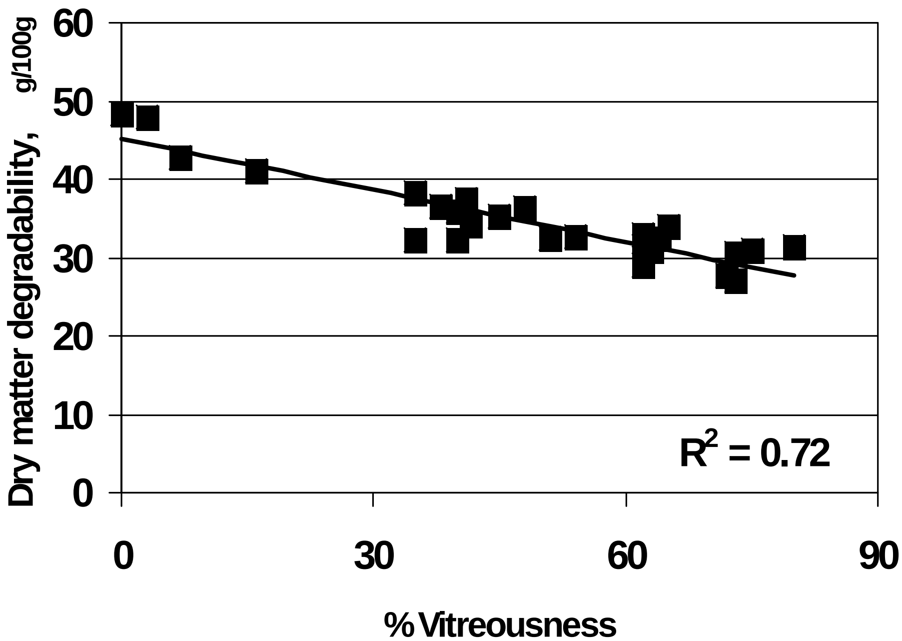

Figure 1. The relationship betwwen kernel vitreousness and in situ DM degradability of corn (Ngonyamo-Majee et al., 2008).

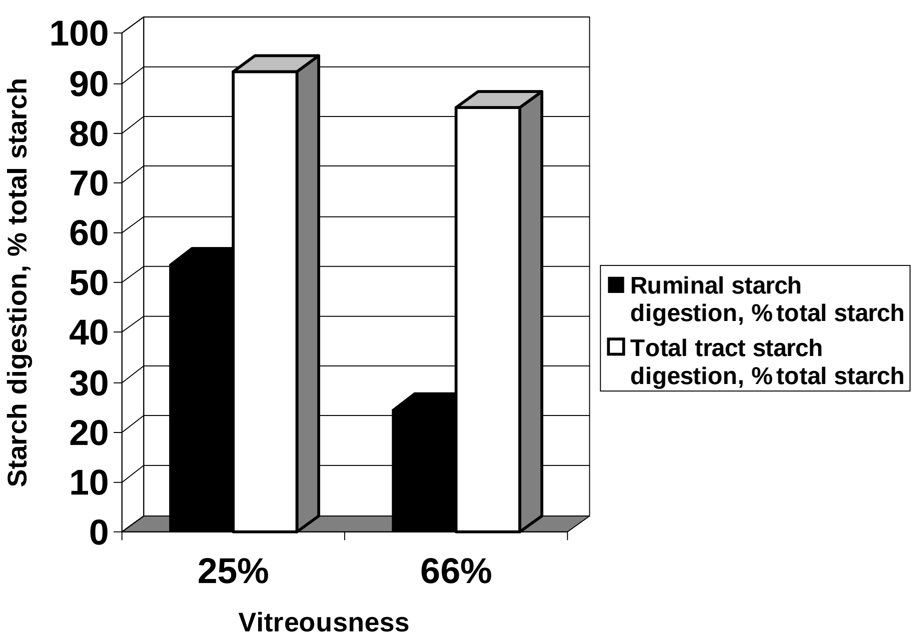

Figure 2. Effect of kernel vitreousness on ruminal and total tract starch digestibility in lactating dairy cows (Allen et al., 2008).

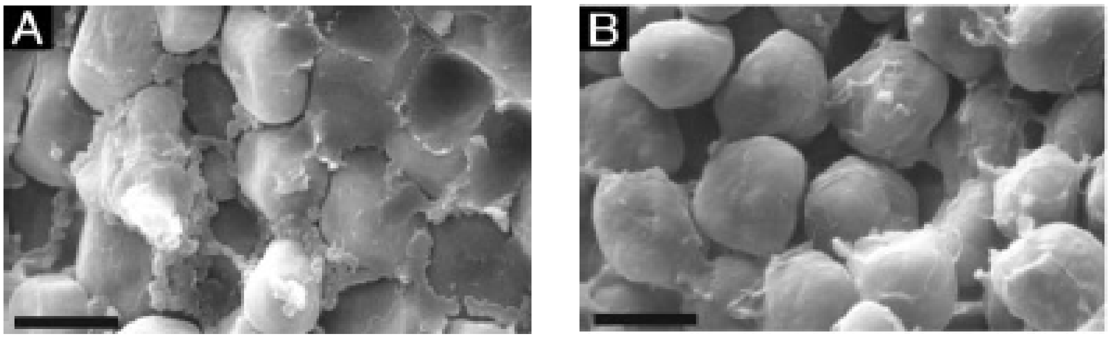

Figure 3. Scanning electron microscopy of starch granules in corn: A) starch granules heavily imbedded in prolamin-protein matrix, B) starch granules in opaque corn endosperm with less extensive encapsulation by prolamin-proteins (Gibbon et al., 2003). Published with permission: *Copyright (2003) National Academy of Sciences, U.S.A.*

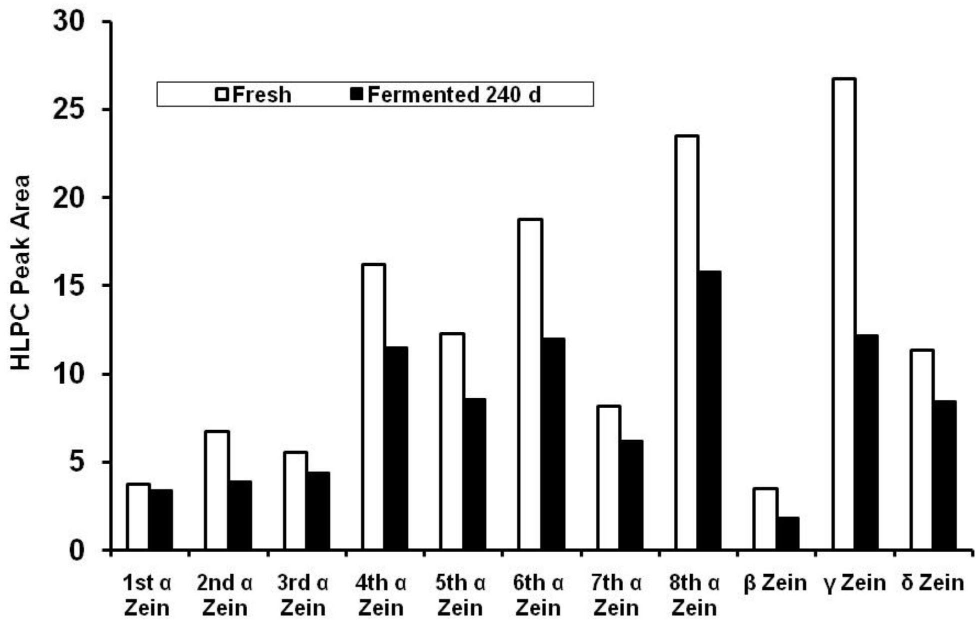

Figure 4. The effect of storage period (240 d) on hydrophobic prolamin-zein proteins in the endosperm of high moisture corn (Hoffman et al., 2010a).

MEASURING ALFALFA YIELD AND PERSISTENCE DURING THE BUSH AND OBAMA ADMINISTRATIONS

Mike Rankin[1/]

Introduction

Ever since the demise of the Wisconsin Green Gold Program in 1996 there has been no public source of on-farm alfalfa yield data. Unlike corn and soybeans, obtaining accurate yield information for forage crops involves considerable planning, time, and effort on behalf of the person collecting the yield data and the farmer. Historically, few producers had the capacity or patience during harvest to undertake such a task. Further, past efforts to measure alfalfa yield were usually limited to the best small area of the best field. In the past ten years, many larger dairies have installed on-farm scales for measuring purchased production of forages and/or feed commodities. These scales now make it relatively easy to weigh production not just from small areas of fields, but entire fields over the course of several years.

Knowing actual alfalfa production offers some unique value beyond just documenting what is being harvested on Wisconsin farms. It allows us to contrast what is being found with current small-plot research trials and identify management areas where improvements can be made. Further, we can document progress over time.

During the early spring of 2007, members of the Univ. of Wisconsin Extension Team Forage decided to initiate the Wisconsin Alfalfa Yield and Persistence Program. The objectives of the program were to:

1. To verify the yield and quality of alfalfa harvested from production fields over the life of the stand beginning with the first production year (year after seeding).
2. To quantify decreases in stand productivity of alfalfa fields as they age.

Data Collection

Each year, interested producer participants with qualifying fields are solicited All fields in the program are entered at the beginning of the first production year (the year following seeding). Further, fields must remain in the program for the life of the stand. For each field, an accurate measure of field size is determined (if not previously calculated). Forage yield from an entire project field is weighed (usually this is done with an on-farm drive over scale). Both empty and full weights for all trucks/wagons used are recorded. Two forage samples from each harvest are taken and submitted to the Marshfield Soil and Forage Analysis Laboratory for NIR analysis (only one sample was submitted per harvest in 2007). Data from the two forage samples is averaged and recorded by the local coordinator. Information is inputted into an Excel spreadsheet program and shared with the producer following each harvest. At the end of the season, all data is collected and summarized. Summary reports are available on the UW-Extension Team Forage web site (www.uwex.edu/ces/crops/uwforage/alfalfa.htm).

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2010 Overview

The year 2010 marked the fourth year of this project. As in previous years, UW-Extension agents were asked to identify forage producers who would be willing to weigh and sample forage from a 2009-seeded field and continue to do so for the life of the stand. Six such fields were identified on two separate farms. As is always the case in these types of studies, there is some attrition of fields over time. This is usually the result of not being able to obtain critical yield or forage quality data for a cutting or multiple cuttings. This year there were six 2006-seeded fields dropped from the project simply because the producers decided not to harvest a fourth production year from the stands. In total, production data was collected for 23 fields in 2010 (the same number as 2009). Over 6500 tons of forage was harvested from the project fields in 2010. A summary of all fields is presented in Table 1.

Table 1. Field background information

Field #	1st Production Year	County	Seeding Mo/Yr.	Seeding Rate (lb/ac)	Field Size (ac)	Notes
107	2007	Outagamie	05/06	15	103.7	dropped in 2010
207	2007	Outagamie	04/06	16	79.3	dropped in 2010
307	2007	Outagamie	04/06	16	37.0	no ’08 1st-cut data
407	2007	Outagamie	04/06	16	156.7	dropped in 2010
507	2007	St. Croix	08/06	NA	51.0	dropped in 2010
607	2007	Waupaca	04/06	15	24.1	dropped in 2008
707	2007	Fond du Lac	04/06	17	15.7	dropped in 2008
807	2007	Fond du Lac	04/06	17	39.7	
108	2008	Chippewa	04/07	15	18.8	dropped in 2010
208	2008	Marathon	04/07	15	5.2	
308	2008	Winnebago	05/07	15	115	
408	2008	Winnebago	08/07	15	36.0	
508	2008	Winnebago	05/07	15	22.0	
608	2008	Outagamie	05/07	20	83.7	
708	2008	Outagamie	04/07	16	147.8	
808	2008	Outagamie	04/07	16	53.0	
908	2008	Outagamie	05/07	15	50.3	
1008	2008	Outagamie	08/07	15	194.8	dropped in 2009
109	2009	St. Croix	08/08	NA	41	
209	2009	Winnebago	04/08	15	67	
309	2009	Winnebago	08/08	15	78	

Table 1 (cont.). Field background information						
Field #	**1st Production Year**	**County**	**Seeding Mo/Yr.**	**Seeding Rate (lb/ac)**	**Field Size (ac)**	**Notes**
409	2009	Brown	08/08	18	75	
509	2009	Chippewa	04/08	15	16.2	dropped in 2010
609	2009	Calumet	04/08	12	15	
709	2009	Outagamie	05/08	20	74.8	
809	2009	Outagamie	05/08	20	63	
110	2010	Outagamie	05/09	16	48	
210	2010	Outagamie	05/09	16	110.2	
310	2010	Outagamie	05/09	16	61.7	
410	2010	Outagamie	05/09	16	111	
510	2010	Fond du Lac	04/09	17	50.3	
610	2010	Fond du Lac	04/09	17	19.3	

Harvest Schedules

Across Years:

Mean cutting dates by year are presented in Table 2. Average first-cut date ranged from May 22 in 2007 and 2010 to June 3 in 2008. Regardless of first-cut date, the average fourth-cut date was generally close to September 1. The vast majority of fields in this study were cut four times. Across years and sites, 8 fields were cut three times, 54 fields were cut four times (generally prior to or soon after September 1), and 8 fields were cut five times (generally four times before September 1 with a final cut in October).

Table 2. Mean cutting dates by year

Year	**1st Cut Date**	**2nd Cut Date**	**3rd Cut Date**	**4th Cut Date**	**5th Cut Date**
2007	22-May	24-June	25-July	30-Aug	21-Oct
2008	3-Jun	3-Jul	3-Aug	29-Aug	29-Oct
2009	31-May	1-Jul	4-Aug	5-Sep	
2010	22-May	28-Jun	2-Aug	29-Aug*	12-Oct

*average excludes data from two fields where a 4th-cut was taken in October

2010

Cutting dates for all project fields harvested in 2010 are presented in Table 3. All of the 23 fields were cut at least four times with two being cut five times. The average first-cut date of May 22 was the earliest since 2007. Unlike 2007, second-cut was delayed by rain in many areas of the state. In some cases, third-cut was also delayed. Contrasting 2007 with 2010, although the average first cut date was the same, the third-cut date was one week later in 2010. Even so, many of the project participants generally took their fourth-cut before September 1, resulting in a very short interval between the third and fourth cuttings. Two fields, 208 and 409, had a fourth-cut harvested in October. These two fields were not considered into the mean of the average fourth cut date.

Table 3. Summary of 2010 Cutting Dates

Field ID#	1st Cut Date	2nd Cut Date	3rd Cut Date	4th Cut Date	5th Cut Date
307	19-May	23-Jun	2-Aug	29-Aug	
807	23-May	28-Jun	28-Jul	29-Aug	
208	31-May	12-Jul	17-Aug	11-Oct	
308	23-May	30-Jun	4-Aug	25-Aug	
408	24-May	30-Jun	4-Aug	27-Aug	
508	23-May	30-Jun	4-Aug	25-Aug	
608	25-May	28-Jun	5-Aug	6-Sep	
708	19-May	24-Jun	3-Aug	29-Aug	
808	19-May	25-Jun	4-Aug	2-Sep	
908	26-May	20-Jun	3-Aug	2-Sep	
109	17-May	18-Jun	13-Jul	15-Aug	
209	23-May	30-Jun	4-Aug	25-Aug	
309	23-May	30-Jun	4-Aug	24-Aug	
409	26-May	2-Jul	17-Aug	15-Oct	
609	24-May	26-Jun	3-Aug	7-Sep	
709	27-May	10-Jul	7-Aug	6-Sep	
809	27-May	10-Jul	6-Aug	7-Sep	
110	18-May	24-Jun	2-Aug	29-Aug	
210	18-May	23-Jun	4-Aug	29-Aug	
310	19-May	24-Jun	3-Aug	3-Sep	
410	19-May	24-Jun	3-Aug	29-Aug	
510	22-May	28-Jun	26-Jul	26-Aug	13-Oct
610	23-May	28-Jun	26-Jul	26-Aug	12-Oct
Mean	**22-May**	**28-Jun**	**2-Aug**	**29-Aug***	**12-Oct**
Earliest	**17-May**	**18-Jun**	**13-Jul**	**15-Aug**	**12-Oct**
Latest	**31-May**	**12-Jul**	**17-Aug**	**7-Sep**	**13-Oct**

*average excludes data from two fields where a 4^{th}-cut was taken in October

Forage Dry Matter at Harvest

Alfalfa was harvested as haylage for all but eight individual cuttings over the four years. Harvest dry matter data from the eight dry hay harvests was not included in the forage dry matter data summary. Average harvested forage dry matter content has consistently been at or slightly below 50 percent (Figure 1). In both 2009 and 2010 only five of the twenty-three fields had total-season forage dry matter levels (weighted average) below 45 percent.

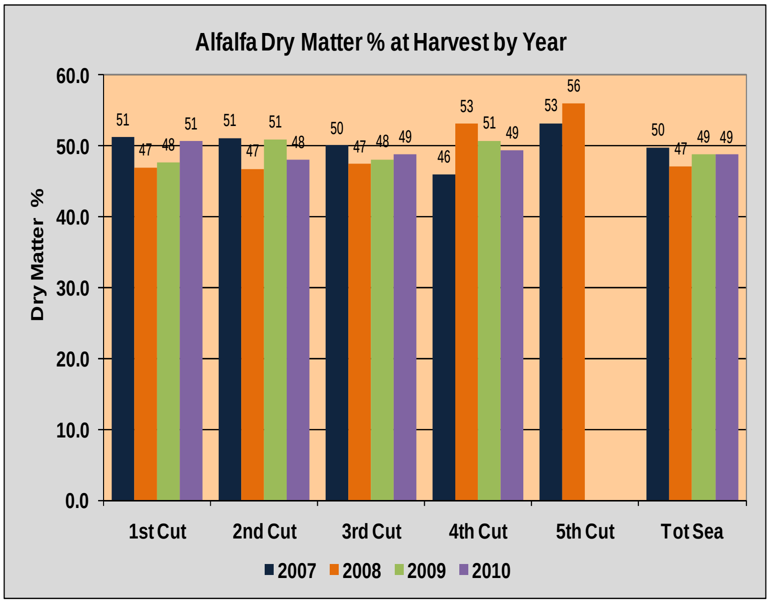

Figure 1. Average dry matter of harvested forage by cutting and as a weighted average for the total season (2007-2010).

Range for individual fields:

2007 (n=8):
For individual cutting:
33.9% - 67.6% DM
For total season:
41.6% - 54.2% DM

2008 (n=16):
For individual cutting:
33.0% - 63.3% DM
For total season:
37.0% - 54.4% DM

2009 (n=23):
For individual cutting:
27.7% - 66.6% DM
For total season:
37.9% - 59.2% DM

2010 (n=23):
For individual cutting:
27.6% - 63.1% DM
For total season:
37.4% - 54.9% DM

Although project participants were not asked about storage structure, there is good reason to believe most of the farms are storing this forage in bunker/pile silos. Dry matter percentage has consistently been near 50 percent throughout the first four years of the project. This is well above that recommended by ag engineers to obtain optimum fermentation and silage porosity. Conversely, many nutritionists are recommending drier alfalfa haylage to offset the wetter corn silage component of the diet, decrease the percentage of soluble protein, and to avoid any chance of butyric acid formation. Clearly, the latter strategy is being followed on these farms and presumably many others.

Forage Dry Matter Yield

Average yield by cutting and for the season in each project year are presented in Figure 2. In 2010, exceptional weather conditions in April and May allowed for the highest average first-cut yield (1.81 tons d.m./A) of any project year. Average second-cut yield (1.49 tons d.m./A) also was higher than any of the previous three years. Third-cut yield was about average (1.08 tons d.m./A), while fourth-cut dropped to 0.64 tons d.m./A. The lower fourth-cut yield can be somewhat be attributed to a relatively short harvest interval (perhaps induced by a need to begin harvesting corn silage in some cases). The mean average total season yield in 2010 was 5.05 tons d.m./A, just slightly higher than 2007 but a full ton higher than 2009. A summary of dry matter yields by cutting and for the total season are presented in Table 4.

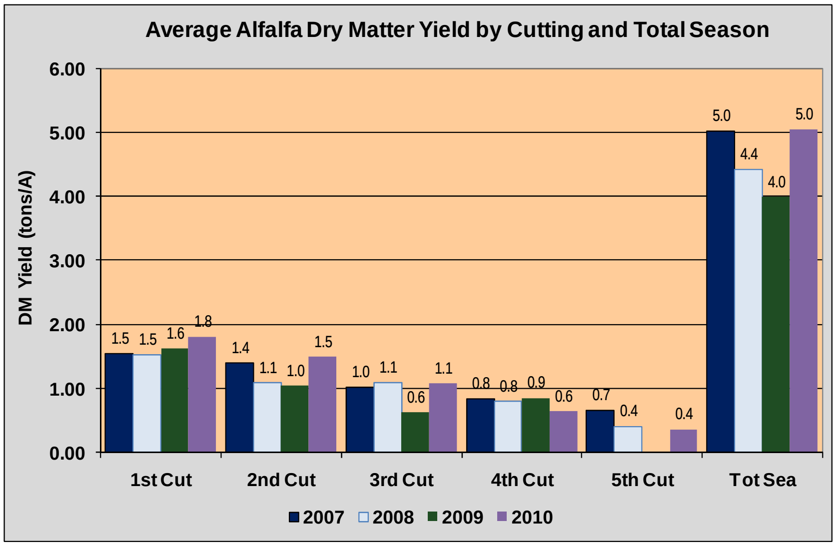

Figure 2. Average dry matter yield by cutting and for the total season. Data is segregated by calendar year.

Table 4. Mean dry matter yield and range by cutting and for the total season in 2007-2010

	1st Cut DM Yld	2nd Cut DM Yld	3rd Cut DM Yld	4th Cut DM Yld	5th Cut DM Yld	Tot Sea DM Yld
	----------------------------------tons d.m./A----------------------------------					
			2007			
Mean	1.55	1.39	1.02	0.84	0.67	5.02
Low	1.00	1.02	0.37	0.59	0.34	2.39
High	1.79	1.77	1.42	1.14	0.88	6.12
			2008			
Mean	1.52	1.08	1.09	0.80	0.41	4.42
Low	0.73	0.49	0.76	0.43	0.37	2.70
High	2.23	1.78	1.54	1.12	0.45	6.08
			2009			
Mean	1.62	1.04	0.63	0.85	NA	3.99
Low	0.57	0.55	0.20	0.32	NA	2.21
High	2.36	1.60	1.33	1.15	NA	5.27
			2010			
Mean	1.81	1.49	1.08	0.64	0.37	5.05
Low	1.16	0.84	0.55	0.39	0.34	3.33
High	2.34	1.85	1.57	1.33	0.39	6.17

A comparison of 1st, 2nd, 3rd, and 4th production year fields cut four times in 2010 (essentially all fields) shows the highest average yield occurred with the 2nd production year fields (5.4 tons d.m./A), followed by the 3rd production year fields (5.1 tons d.m./A), 1st production year fields (4.9 tons d.m./A), and 4th production year fields (4.5 tons d.m./A) (Figure 3). Average first- and second-cut yields were generally lower for the 4th production year fields. As is always the case, there is extreme yield variability between fields that can be attributed to cutting schedule and environment.

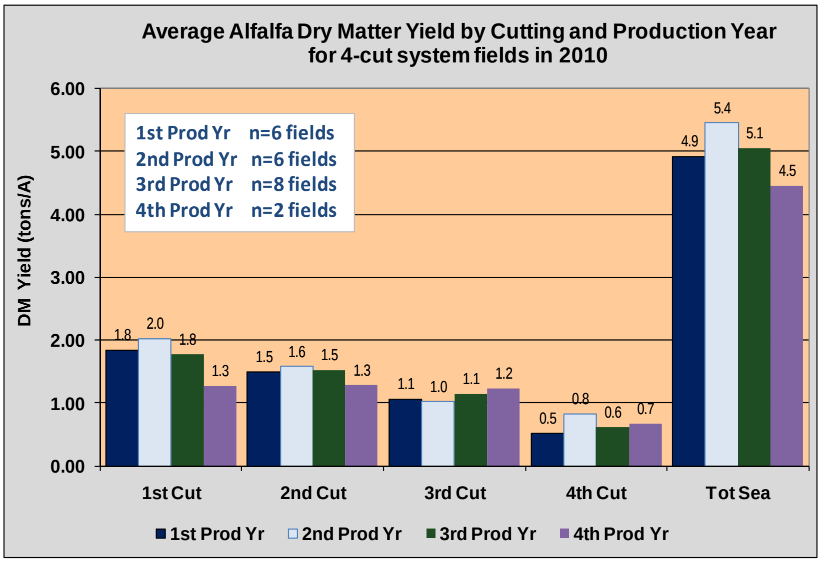

Figure 3. Average dry matter yield by cutting and for the total season. Data is segregated by stand production year.

How profitable is it to take a 5th cutting in October? During 2007-2010, there were eight project fields where this cutting strategy was used. The yield range was from 0.34 to 0.88 tons/A. Given the potential for reduced yield in the subsequent growing season and the cost of harvesting such a small amount of forage per acre, is such a practice viable in Wisconsin? Perhaps the "need for feed" might justify the practice in some years, but long term it's likely not a sustainable or profitable management practice on a routine basis.

Cutting schedule x yield:

It's often interesting to look at cutting schedule as a function of yield. The average yield of alfalfa harvested for fields cut 3, 4, or 5 times per year is presented in Figure 4. Not surprisingly, more harvests per year translated to higher total season yields. It should be noted that this is a simple average that did not take into account the previous year cutting schedule. Further, these comparisons are made across a range of environments and locations.

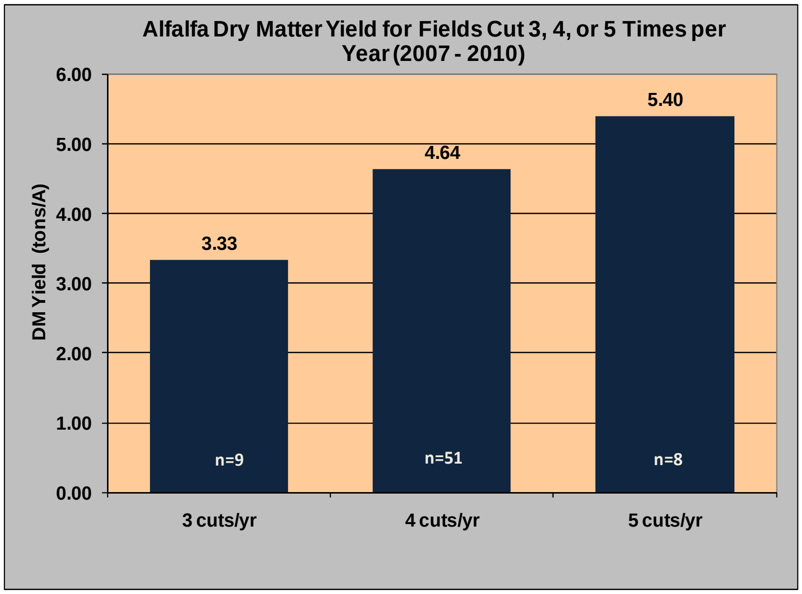

Figure 4. Alfalfa dry matter yield for fields cut 3, 4, or 5 times per year (2007-2010)

Alfalfa Persistence:

<u>In-season</u>

An analysis was done to determine the percent of total season yield for each cutting (Table 5). Data was summarized for 3-, 4-, and 5-cut systems for all project years. Five-cut fields were also included in the 4-cut summary with the final fall harvest not included in the total season yield. It's significant to note the wide variation in percent yield for an individual cutting. In some cases this is the result of environmental conditions (e.g. drought) previous to the harvest while in other situations it's simply a function of cutting date.

<u>Between years</u>

Being four years into the project, it's difficult to draw too many firm conclusions on stand persistence across years. Persistence is influenced over time by the age of the stand, cutting schedule, and environment. For this project, persistence is being measured as a percent of 1st production year dry matter yield. Persistence data in Table 6 consists of 2006 through 2008-seeded fields and is averaged over all cutting schedules. Although ranges indicate a wide variation, yields to date for the 2nd production year fields have usually equaled or exceeded the 1st production year. Production for 3rd-year fields remained equal with 1st-year stands, while the yield for the two 4th-year stands dropped off to 77 percent of their 1st-year production.

When should an alfalfa stand be terminated? Most of the project fields have maintained productivity equal or greater to the 1st production year for three years after the seeding year. Time will tell if this trend continues, but to date it appears that keeping stands for at least three production years seems to be the prudent decision.

Table 5. Average percent of total season yield by cutting for 3, 4 and 5 cut harvest systems*

3-cut system (N=9 site years)

	1st cut	2nd cut	3rd cut
Mean	43	30	26
Low	26	23	16
High	59	43	50

4-cut system (N=58 site years)

	1st cut	2nd cut	3rd cut	4th cut
Mean	36	27	20	17
Low	20	14	5	9
High	58	37	32	30

5-cut system (4+1 fall) (N=8 site years)

	1st cut	2nd cut	3rd cut	4th cut	5th cut
Mean	31	24	21	14	10
Low	25	14	19	9	6
High	39	31	26	19	14

* high and low figures are for individual cuttings and will not add to 100%

Table 6. Percent of 1st production year yield by cutting and total season for 2nd and 3rd production year stands.

2nd Production Year Stands (N=22 site years)

	1st cut	2nd cut	3rd cut	4th cut	Tot Sea
Mean	133	124	117	90	**112**
Low	82	57	23	61	78
High	275	291	491	128	236

3rd Production Year Stands (N=14 site years)

	1st cut	2nd cut	3rd cut	4th cut	Tot Sea
Mean	119	129	88	90	**101**
Low	61	65	32	23	63
High	250	299	150	169	170

4th Production Year Stands (N=2 site years)

	1st cut	2nd cut	3rd cut	4th cut	Tot Sea
Mean	76	97	90	66	**77**
Low	76	83	86	58	68
High	77	111	95	74	86

Forage Quality

Forage quality was measured for harvests but is not the focus of this paper. A summary of forage quality results can be viewed in the annual program summary found at: www.uwex.edu/ces/crops/uwforage/2010WAYPSummary.pdf

Summary

The Wisconsin Alfalfa Yield and Persistence Program is designed to provide forage growers and agricultural professionals a unique look at what is happening at the farm level. As more fields are entered and years pass, the reliability of information will increase. It's important to keep in mind that only four years of data have been collected. Environmental conditions have a profound influence on both yield and quality and during the course of the past four years there have been no two alike. Nevertheless, there certainly is enough information to begin to formulate possible trends and topics for discussion.

Acknowledgments

First and foremost, UW-Extension Team Forage wishes to thank the producers who took the extra time and effort to obtain weights and forage samples for the project fields at each cutting.

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THE VALUE OF GRASS WITH ALFALFA

Dan Undersander [1/]

Generally dairymen have perceived grasses to be too high in fiber for high producing dairy cows since grasses tend to have higher NDF than alfalfa. But, with knowledge of digestible fiber, we have learned that the fiber of grass 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.

Why the interest in grass mixed with alfalfa? 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 grasses head little or not at all after first cutting, therefore regrowth is primarily leaves which change little in 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 – 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.
2) The fiber of grasses is more digestible than alfalfa.
3) Potential to reduce NFC of dairy rations – Increased use of corn silage in dairy rations, which is excellent forage for high producing cows, has nutritional limitations because it is low in protein and high in fermentable carbohydrate (starch). Lameness in dairy cattle has increased dramatically in the Midwest in recent years to 20 to 25% of all dairy cattle. One of major contributors to this problem has been formulation of high starch, low fiber diets (Cook, 2003).

Alfalfa is a good nutritional complement to corn silage because of its high protein content. However, high quality alfalfa is low in fiber and high in non-fiber carbohydrates like corn silage. When high quality alfalfa and corn silage are the only source of forage in diets of high producing cows, it can be difficult to provide adequate levels of digestible fiber without providing excessive levels of highly fermentable non fiber carbohydrate (NFC).

High quality grass silages may be a good fit with diets formulated with high quality corn silage and alfalfa diets. Intensively-managed grass (or grass mixed with alfalfa) is high yielding forage that contains moderate level of fiber (NDF) and a low concentration of NFC (Table 1). The nutrient profile of high quality grass complements the excesses and deficiencies of rations formulated with excellent quality corn silage and alfalfa.

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There are three approaches to using grass in dairy diets. Past research has focused on the first two which have minimized the nutritional value of grasses in dairy diets.

One approach is to replace alfalfa with an equal amount of grass. This increases the total fiber content of the ration. If dietary levels of NDF are high enough to limit feed intake by rumen fill, the cows fed the grass-based diets typically consume less dry matter and produce less milk than those fed an equivalent amount of alfalfa.

A second approach is to balance for an equal level of fiber. Results from experiments designed this way usually find that milk yield and intake of grass-based diets are similar to alfalfa control diets. When grasses are used to replace an equivalent amount of NDF as contained in alfalfa, forage to concentrate ratios of the diets change. These experiments clearly show that grasses can be used in diets for high producing cows, but with increased concentrate levels.

A third, and newer, approach is to use grass as a source of digestible fiber. Grass at early maturity contains more NDF than corn silage or alfalfa but 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 equal or less crude protein than alfalfa forage as shown in Table 1.

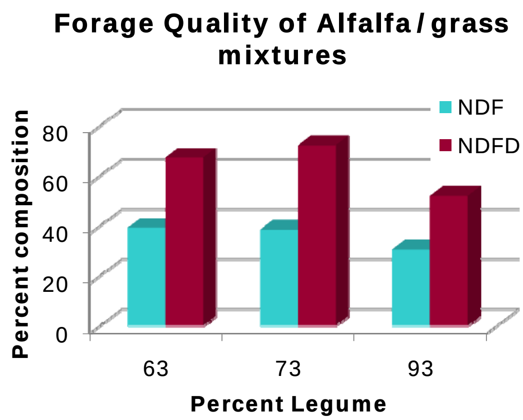
Table 1. typical composition of high quality forages.

Forage	CP	NDF	NDFD	NFC
	% of dry matter			
Corn silage	9	41	68	27.5
Alfalfa	20	40	48	27.5
Annual ryegrass	20	57	65	12.5
Tall fescue	17	60	60	14.5
Orchardgrass	16	60	60	11.5

Diets formulated with high quality corn silage are often marginal in fiber and high in NFC content and it becomes necessary to incorporate feeds that have highly digestible yet contain relatively low amounts of NFC and high amounts of digestible fiber. As alfalfa is brought into high corn silage diets, often the proportion of digested energy from fiber does not change and the proportion of rapidly fermented energy only shifts slightly from NFC to digestible protein.

Nutritionists sometimes add as much as 2 to 4 lb of straw to corn silage based diets to increase the proportion of dietary fiber. Adding straw increases the total fiber content of the diet but decreases the digestible energy intake because it is poorly digested and contributes significantly to rumen fill. Grasses may be a better choice to incorporate into high NFC/low fiber diets because unlike straw, the fiber in grasses is more digestible than fiber in corn silage, alfalfa or wheat straw. A recent feeding trial showed an average of 4 lbs milk/day when grass was used to add fiber rather than straw.

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 not reducing the overall digestibility of the diet. Note (in graph) the decline in NDF as mixtures shifted to more alfalfa while digestible fiber (NDFD) declined. 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.



Initial 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.

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. This will get more grass in second and later cuttings.

Appropriate selection of grass varieties is crucial to success in alfalfa/grass mixtures. Grass varieties should be selected for yield, maturity (want late to have grass head close to when alfalfa is ready to harvest), adequate winterhardiness, rust resistance, and good seasonal distribution of yield.

Information on maturity and seasonal growth distribution are available on my website at www.uwex.edu/ces/forage , then select 'grasses' and then 'historical information on grass yield trials.'

CONTROLLING WEEDS IN A GRASS-LEGUME MIXTURE

Mark J. Renz[1]

Weeds can affect the establishment of any perennial system, especially forages. For example Hoy et al. (2002) found alfalfa fields with high densities of weeds resulted in reduced alfalfa plant densities > 50%, and others have documented similar results (Lanini et al., 1991; Simmons et al. 1995). Researchers attributed the loss in establishment from competition for soil moisture and light (Lanini et al., 1991; Simmons et al., 1995). Fortunately Wisconsin's climate during typical establishment periods is favorable and typically soil moisture is adequate to prevent reductions in establishment. While light can be limiting, mowing/harvesting the first cutting at the appropriate timing can limit this effect. So why do we still manage weeds in establishing forages? These weeds can result in reductions in establishment in abnormally dry years and lower forage quality in the first and sometime second cutting.

This same principle holds when establishing grass-legume mixtures. Although much interest exists in combining legumes and grasses, integrating these two forages limits weed control options. The sections below highlight what the limitations and options are for weed management in establishing and established stands as management decisions will need to be made at each of these timings of the crop.

Establishing Mixture

Currently most producers rely on herbicides to assist in the establishment of perennial grasses or legumes. These herbicides typically target annual and biennial weeds as they are the most common in newly seeded fields. If perennial weeds present, consider managine prior to planting as they are difficult to control while establishing forages. Of the ten herbicides registered for use in establishing legumes, only 2,4-DB (e.g.,Butyrac) and bromoxynil (Buctril) will provide weed control. These herbicides, while effective, should provide limited injury to establishing grasses and legumes depending on the stage of growth of forages at application. 2,4-DB tends to be more injurious to young grasses, therefore applications should be applied to grass seedlings that have >5 leaves or are tillering. Timing of these herbicides with respect to weed size is also critical, with the level of control declining significantly with weeds taller than 3 inches. While these herbicides are effective on most common broadleaf weeds, annual grasses will not be controlled.

Weed management decisions in this situation should be based on weed density, and soil moisture. If weed density is low and soil moisture is adequate then successful establishment should result without the need of any management. Realize that not managing these weeds will result in lower forage quality with high amounts of weeds as a component of the forage in the first one to two cuttings. Thus growers should have a market for this lower quality hay, otherwise weed species should be managed regardless of density.

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Established Mixture

If establishment of grass-legume mixtures is successful, likely little management of weeds will be necessary until stands thin due to age, disease and/or weather. Weeds in established forages are typically perennials and are difficult to remove unless herbicides registered for use in either grass or legume forages are used. Unfortunately these herbicides will typically result in extensive injury to the non-labeled forage species. Therefore few options for weed management exist in mixed grass legume stands besides proper management of forages that promotes healthy growth and competition.

Typically as these mixtures age, the legume component begins to decline and the grass forages dominate. As legumes decline, if forage species cannot fill the void left, perennial weeds will appear and require management with a herbicide. While these can be controlled, typically this results in extensive injury to the remaining legumes. If growers wish to keep the forage grass only field in production they can use a range of herbicides registered for use in pastures to suppress weeds in question. Although this treatment will be effective it will also likely remove the remaining legumes of the field. If a significant legume component is desired field renovation can be conducted to replace this feature, but planting of the legume should wait until after the plant-back interval listing in the herbicide has passed.

Conclusions

Legume-grass mixtures are competitive forages that are a viable option for Wisconsin production, but few options exist for weed management. When these forages are establishing, control of annual and biennial broadleaf weeds can be made with well timed applications of 2,4-DB (e.g. Butyrac) and bromoxynil (Buctril) when weeds are small ($\leq$ 3 inches tall). If difficult to control weeds are present in a field being considered for this crop combination, they should be controlled prior to establishment. Once forages are established they are typically very competitive until the legume component thins. At this point no viable management option exists for common weeds (perennials) that fill this gap without damaging one of the two forages. Thus at this stage it is recommended to either rotate to another crop or apply a herbicide to the target weed and accept the injury to the minor forage present in the field (usually the legume).

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PAIRING GENETICS AND FUNGICIDES IN WHEAT PRODUCTION

Paul Esker and Shawn P. Conley[1]

With the wheat commodity prices staying high, the interest in wheat in the state remains very strong. Over the past few years, we have discussed many issues associated with managing wheat in Wisconsin (Esker et al. 2008), in particular knowledge of the following factors for use of foliar fungicides as part of an IPM program: (i) active scouting of fields, (ii) knowledge of growth stage, (iii) knowledge of disease risk, (iv) knowledge of the variety planted, (v) estimating stand quality post-dormancy, (vi) overall crop development in the spring, (vii) weather, (viii) understanding the different fungicides and targeted diseases, and (ix) commodity prices. However, linking both genetics and fungicides is not a trivial set of research questions. For example, in 2009 and 2010, the winter wheat variety trial at Janesville was duplicated in size thus enabling the application of a fungicide at flag leaf emergence (fungicide: Quilt). However, results from that trial indicated that there was no evidence of an effect of foliar fungicide nor an interaction of variety and fungicide (Lackermann, 2010). One explanation was that the disease intensity at Janesville was relatively low in both years but this also highlights that the appropriate use of a foliar fungicide should be for disease control.

To improve our knowledge of how wheat varieties in the state react to different diseases, we are exploring the use of non-parametric methods to rank wheat varieties in terms of both yield and disease. Based on preliminary analyses with data collected from the Winter Wheat Performance Test locations (http://coolbean.info) in 2009 and 2010, the primary disease of interest was powdery mildew (*Blumeria graminis*, Fig. 1).

The goal with using a rank-based approach to pair disease and yield is to provide a stable method for annual and across-year comparisons since that may then link with other management tactics like the use of foliar fungicides. The general ranking methodology was to rank wheat varieties within each location-year by yield, where a 1 indicated the highest yield, and by disease, where a 1 indicated the least disease. Based on further statistical analyses, results indicated that there were three varieties that had both lower yield and a worse disease reaction (Table 1), while there were 12 varieties that had high yield and a good disease reaction.

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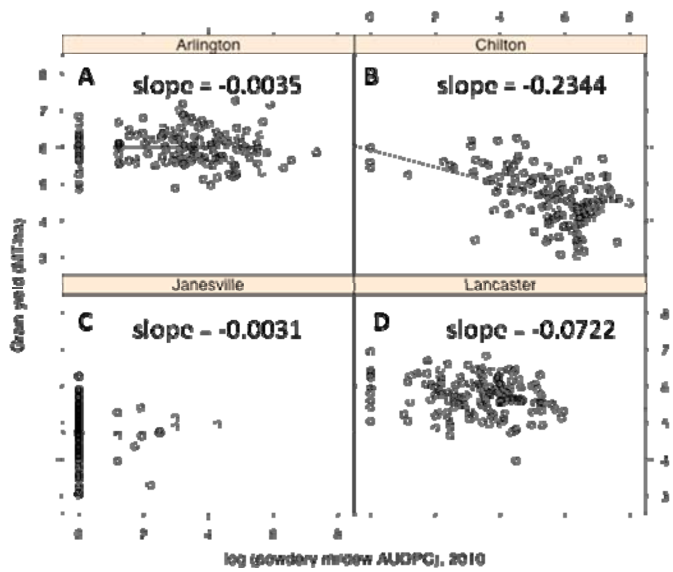

Figure 1. Grain yield as a function of powdery mildew (log-transformed area under disease progress curve). Slope values indicated that there was an effect of powdery mildew at Chilton, while other locations had a much smaller effect.

Table 1. Lowest and highest ranked varieties when examining both yield and disease reaction (powdery mildew) using a non-parametric statistical approach. Varieties within each category were not statistically different from one another (P < 0.05).

Lowest ranked varieties	Highest ranked varieties
P02333A1-23-9	Hopewell
Pro Seed Genetics Pro220	PIP720
Kaskaskia	P25R47
	Sunburst
	PIP760
	LW1050
	IL01-11934
	Branson
	Jung 5988
	LW960
	Jung 5830
	PIP 729

The ability to provide improved management information by pairing genetics and fungicides, we can design controlled trials that target specific diseases and answer fungicide questions. In 2010, we had a trial at the Lancaster ARS targeting Fusarium head blight (FHB; *Fusarium graminearum*) that examined both foliar fungicide and wheat variety (cultivar). The foliar fungicides examined were: (i) untreated check (UTC), (ii) Proline (6.5 fl oz/A) @ Feekes 10.5.1, and (iii) Proline (3.0 fl oz/A) + Folicur (3.0 fl oz/A) @ Feekes @ 10.5.1). Wheat varieties were (with relative FHB resistance, where MR = moderately resistant, MS = moderately susceptible, and S = susceptible): Kaskaskia and Truman (MR) , IL01-11934 and PIP720 (MS), and LW860 and LW863 (S). Results indicated that there were differences in the log-FHB incidence by wheat variety (*P* = 0.0109, Fig. 2A) and an effect of fungicide on Fusarium damaged kernels (*P* = 0.0109, Fig. 2B). While there was an interaction of wheat variety and fungicide (*P* = 0.0446), grain yield differed among public versus private varieties and the greatest response to a foliar fungicide application was for public varieties.

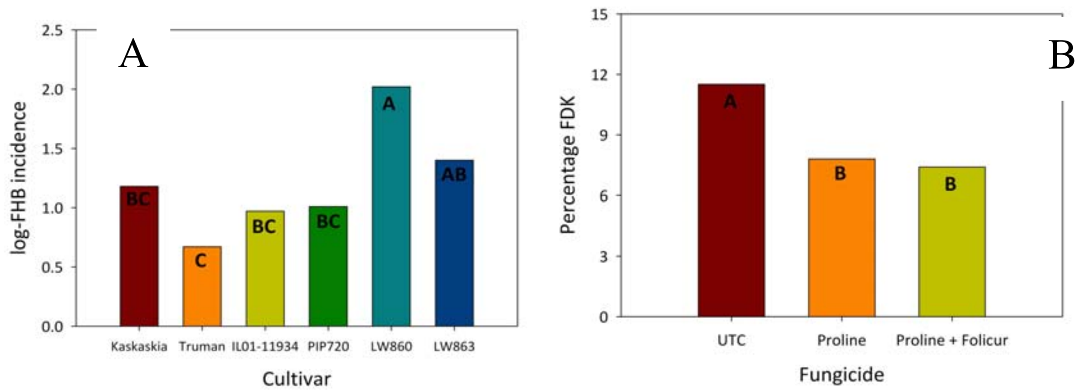

Figure 2. Effect of wheat variety (cultivar) (A) on the log-Fusarium head blight incidence and fungicide (B) on the percentage of Fusarium damaged kernels (FDK). Means with the same letters are not statistically different based on Fisher's protected LSD (alpha = 0.05).

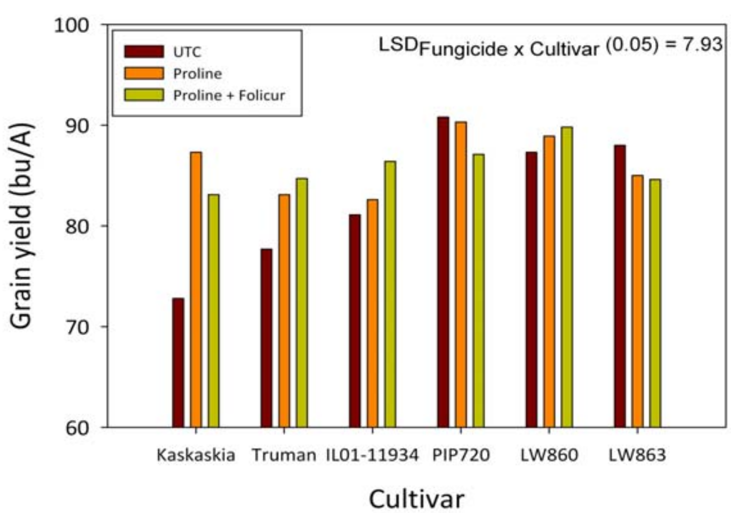

Figure 3. Interaction of wheat variety (cultivar) and foliar fungicide on grain yield at Lancaster in 2010. The P-value was 0.0446 and the Fisher's protected LSD (5% level) was 7.93.

Overall, our current research in Wisconsin has shown that improved management decisions can be made by examining both grain yield and disease reaction. Grain yield is still the key primary component but integrated disease related information can greatly influence if a foliar fungicide will be warranted.

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WATER MOLDS 101: UNDERSTANDING AND MANAGING THE PATHOGENS CAUSING LATE BLIGHT, DOWNY MILDEW, AND PHYTOPHTHORA FRUIT AND CROWN ROT

Amanda J. Gevens[1]

Introduction

The group "water molds," or oomycetous plant pathogens, is comprised of both foliar and soilborne organisms with the potential to cause great destruction of a number of economically valuable crops when environmental conditions are wet and warm. Water molds are distinguished from true fungi, the classification of most plant pathogenic organisms, by several features including 1) lack of cell walls in hyphae resulting in the coenocytic condition, 2) diploid nuclei of vegetative cells, 3) cell walls composed of beta-1,3 and beta-1,6 glucans rather than chitin in true fungi, and 4) many species produce biflagellated swimming spores termed zoospores in structures called sporangia (3). The distinguishing features of water molds make their control on agricultural crops a challenge unique from that of true fungi. On vegetable and potato crops, the water molds which threaten the greatest crop losses include *Phytophthora infestans* (causal agent of late blight on potatoes and tomatoes), *Phytophthora capsici* (causal agent of Phytophthora crown and fruit rot on tomatoes, peppers, squash, and cucumbers), and *Pseudoperonospora cubensis* (causal agent of downy mildew on cucumbers).

Late blight and downy mildew 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. Phytophthora crown and fruit rot is a soilborne oomycete and is not known to be aerially dispersed over long distances (2). The Phytophthora crown and fruit rot pathogen is most often spread by movement of infected fruit, plant material, or infested soil or water. Populations of *Phytophthora capsici* in field soils have been shown to contain two mating types, or sexually compatible types, which result in the production of soil persistent oospores.

Results and Discussion

In the 2010 growing season in most of Wisconsin, wet (30 in rainfall from May-Oct 2010) and warm (growing degree days base 50 of 2381) weather conditions promoted the initiation and development of epidemic levels of late blight, Phytophthora crown and fruit rot, and downy mildew in vegetable and potato crops (Fig. 1).

Symptoms of 'water mold' vegetable diseases were first noted in Central Wisconsin in July of 2010 with the confirmation of late blight on potato and tomato (Table 1). Phytophthora crown and fruit rot and downy mildew diseases were observed in Central and Southern Wisconsin during the month of August (Table 1). Once the water mold diseases were identified in fields, disease progressed rapidly and was persistent throughout the rest of the growing season. Management recommendations for water molds are limited in season and include repeated application of

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effective fungicides such as: chlorothalonil, mancozeb, zoxamide, copper, propamocarb hydrochloride, fenamidone, cymoxanil + famoxadone, dimethomorph, cyazofamid, cymoxanil, fluazinam, metiram (potatoes), triphenyltin hydroxide (potatoes), mefenoxam, mandipropamid, difenoconazole, and fluopicolide (tomatoes). This is a comprehensive list of active ingredients across host crops and diseases. For specific crop allowances and uses, see fungicide labels for both federal and state-specific allowances. Wisconsin fungicide recommendations for water molds 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).

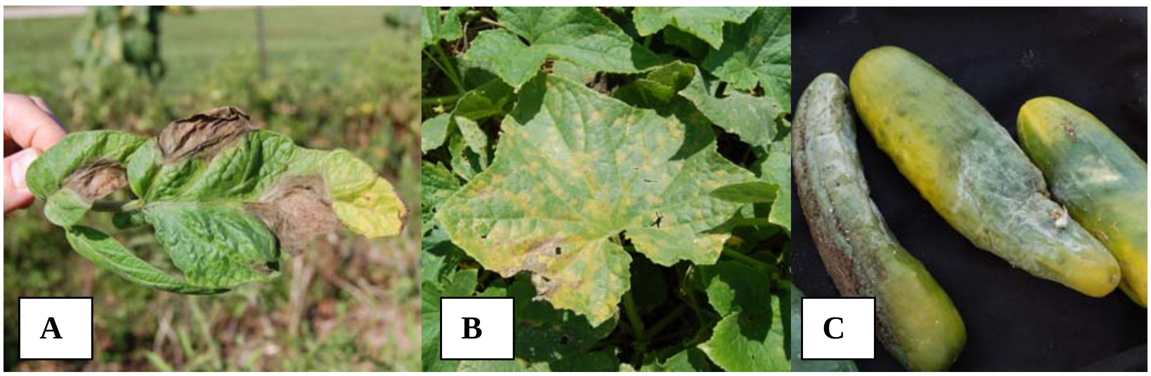

Figure 1. Disease symptoms on vegetable crops. A. Late blight on tomato leaf. B. Downy mildew on cucumber leaf. C. Phytophthora crown and fruit rot on cucumber fruit.

Table 1. Symptoms associated with oomycete plant pathogens diagnosed in Wisconsin, 2010.

Disease	Host crop	Symptoms
Late blight	potato and tomato	Foliage: Olive green to brown circular to irregularly-shaped lesions on leaves and stems, white fuzzy pathogen sporulation on foliar lesions with warm and wet conditions. Potato tuber: Internal brown, corky textured tuber tissue; External brown to purple, water-soaked yet firm lesion. Tomato fruit: firm, circular, brown or golden lesions often exhibiting rings, white fuzzy pathogen sporulation on fruit lesions with warm and wet conditions.
Downy mildew	cucumber, squash, melon	Pale green, yellow, or brown angular (contained within veins) lesions on leaves. Pathogen sporulation appears brown, gray, or purple and fuzzy or dirty on leaf underside only. Lesions can expand and coalesce to give an entirely yellow or necrotic leaf. Severe infection looks like plant experienced frost. No direct fruit infection.
Phytophthora crown and fruit rot	cucumber, pepper, tomato, squash, pumpkin	Foliage: wilting of cucurbit vines, lower stem water-soaked lesions with white pathogen sporulation. Fruit: water-soaked circular or irregularly shaped lesions. Under warm, wet conditions, lesions contain white pathogen sporulation that looks like powdered sugar.

Additional recommendations for managing water mold diseases in vegetable crops include: selection of varieties with resistance, planting or transplanting of clean, disease-free seeds or plants, crop rotation away from susceptible hosts, management of water in field and judicious irrigation (drip irrigation), increased plant spacing, effective fungicides applied when disease forecasting tool indicates time of risk, raised beds, and soil fumigation.

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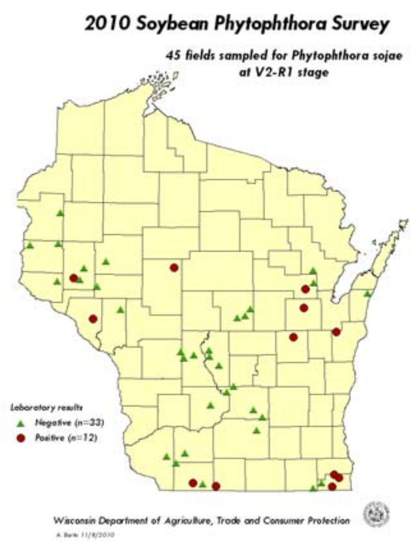
2010 WISCONSIN CROP DISEASE SURVEY

Adrian Barta[1] and Anette Phibbs[2]

This is a summary of disease surveys conducted by plant pathologists at the Department of Agriculture, Trade & Consumer Protection (DATCP). In 2010, field surveys focused on the following crops and diseases: Phytophthora Root Rot of seedling soybeans, Viruses of snap beans and soybeans, foliar diseases of winter wheat; and Stewart's wilt of Seed Corn. Laboratory diagnosis was provided by DATCP's Plant Industry Laboratory.

Phytophthora Root Rot of seedling soybeans

2010 was the third consecutive year in which the pest survey team conducted a statewide survey for Phytophthora root rot (*Phytophthora sojae*) of soybeans. From June 16 to July 9th, 45 randomly selected soybean fields in early vegetative stages were sampled throughout Wisconsin. While fields were selected randomly, surveyors chose seedlings from areas within each field that showed declining soybean seedlings. Symptomatic seedlings were carefully dug up and transported to DATCP's Plant Industry Laboratory for testing.



Seedling roots were tested for the presence of the root rot pathogen *Phytophthora* by molecular testing (PCR=polymerase chain reaction) of DNA extracted from cleaned root tissue. Testing showed 12 of 45 samples (27%) tested positive for *P. sojae*.

P. sojae infected fields were 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.

Viruses of Soybeans and Snap Beans

The DATCP pest survey team, in cooperation with processors and fresh market producers conducted a survey for snap bean diseases caused by plant viruses. A total of 78 snap bean fields were sampled between July 23 and August 24, and 174 soybean fields were sampled between July 20 and August 23, 2010.

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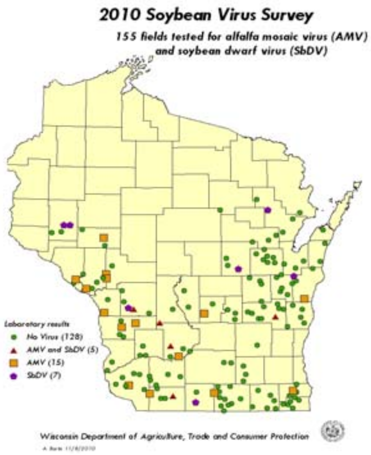
[2]Wis. DATCP, Plant Industry Laboratory Director, 4702 University Ave, Madison, WI 53702, anette.phibbs@wi.gov.



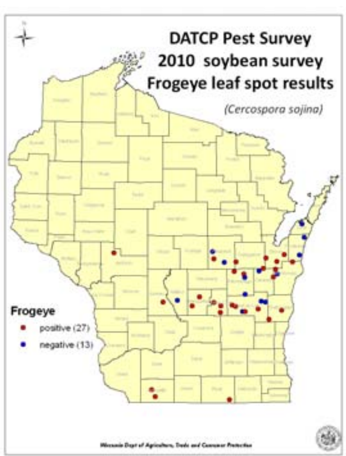
Snap bean fields were sampled at approximately 48 days post-planting, while the target growth stage for soybeans was R2-R4. Ten leaves (five from the top of the plants and five mature leaves) were collected at each of four locations, in each sampled field. Notes were made on disease symptoms present, and counts of aphids were made on ten additional plants at each location. Leaf tissue was kept on ice and promptly transported to DATCP Plant Industry Laboratory for testing.

Table 1. Snap bean virus summary from 2003 to 2010

Year	Total No. of Fields Surveyed	AMV (%)	BPMV (%)	CMV (%)	Potyvirus group (%)
2003	25	NA	0	**72**	**4**
2005	33	NA	0	**3**	**9**
2006	62	NA	0	0	0
2008	25	**4**	0	**8**	0
2009	101	**7**	0	**4**	**2**
2010	78	0	0	**5**	0

Soybean foliage was tested for the following viruses: alfalfa mosaic virus (AMV), bean pod mottle virus (BPMV), cucumber mosaic virus (CMV), soybean dwarf virus (SbDV) and the potyvirus group that includes bean common mosaic virus and bean yellow mosaic virus. Snap bean foliage was tested for alfalfa mosaic virus (AMV), bean pod mottle virus (BPMV), cucumber mosaic virus (CMV), the above-mentioned potyvirus group, southern bean mottle virus (SBMV), and tobacco ringspot virus (TRSV).

Laboratory analysis was conducted using reverse-transcription polymerase chain reaction (RT-PCR) for AMV, and enzyme-linked immunosorbent assay (ELISA) for all others.

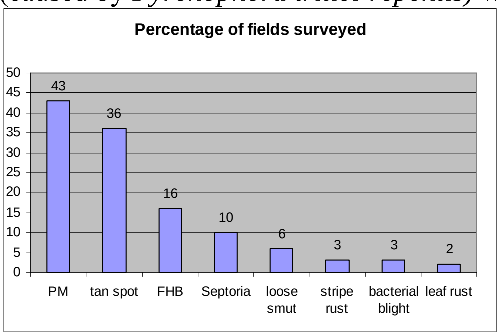


Laboratory results for snap bean showed 20 fields positive for AMV and 12 positive for SbDV. Snap bean results yielded four fields positive for CMV and no detections of AMV, BPMV, SBMV, TRSV or the poty group. (Table 1). As in past years, laboratory results for snap beans differ from field observations of potential virus symptoms; speculation is that observed symptoms may be caused by a virus not included in testing. TRSV was added to the survey in 2010 as a candidate, but was not apparently the causal agent. Further investigation is warranted.

Notable in the field observations was the dramatic increase in symptoms of frogeye leaf spot, caused by *Cercospora sojina*. Frogeye was confirmed in 27 fields visited by DATCP surveyors.

Foliar Diseases of Winter Wheat Survey

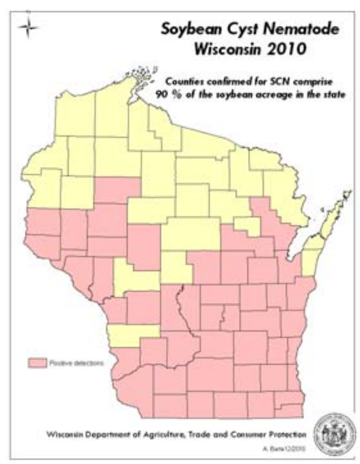
Between May 5 and June 17, 70 wheat fields in 16 Wisconsin counties were surveyed for disease presence. Wheat fields ranged in maturity from Feekes Stage 5 (leaf sheath strongly erected) to Feekes 10.5.3 (flowering complete to base of spike). Powdery mildew (*Blumeria graminis)* was the most commonly observed disease, detected in 30 fields. Symptoms of tan spot (caused by *Pyrenophora tritici-repentis)* was found in 25 fields; Fusarium head blight was detected in 11 fields. Stripe rust, Puccinia striiformis, was found in two fields. Traces of leaf rust (*Puccinia triticina*) was found in one field. No stem rust (*P. graminis*) was detected.



Other diseases observed included loose smut (*Ustilago tritici*) in two fields, and bacterial blight, caused by *Pseudomonas syringae*, in two fields. Damaging populations of the cereal leaf beetle, *Oulema melanopus* (L.) were found in two fields.

Seed Corn Survey

Corn field inspections for export regulatory pests were performed on 57 fields in Columbia, Dane, Eau Claire, Grant, Rock, Portage and Pierce Counties. Goss's wilt, caused by *Clavibacter michiganensis* subsp. *nebraskensis* was detected in 35 of the 57 fields, far above the historical average of the seed field inspection program. The other diseases of common regulatory concern, Stewart's wilt (*Pantoea stewartii*) and maize dwarf mosaic virus (MDMV), were found in seven and five fields respectively.

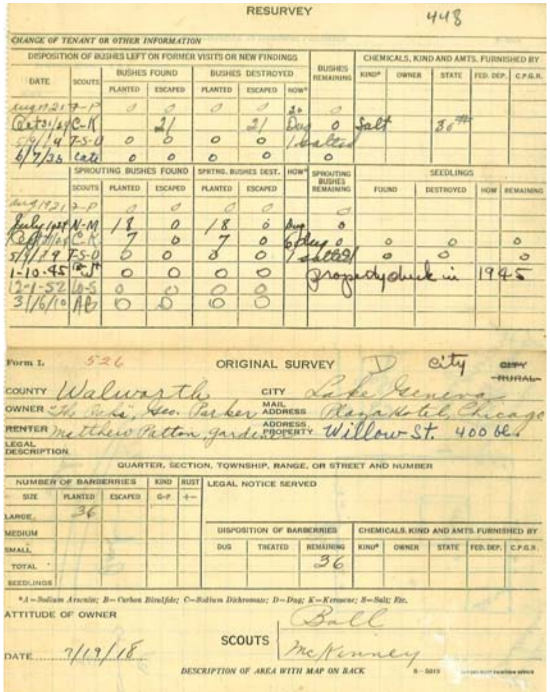


Soybean cyst nematode

Soil sampling in 2010 led to the detection of soybean cyst nematode (*Heterodera glycines*) in Oconto county, bringing the number of Wisconsin counties where the nematode is known to occur to 52, comprising 90% of the soybean acreage in the state. Growers are strongly urged to test fields for the presence of soybean cyst nematode.

Barberry survey

In an attempt to stabilize the race structure of the population of stem rust (Puccinia graminis) in North America, USDA and midwestern states conducted widespread eradication of common barberry, Berberis vulgaris, the alternate host of the rust fungus, from 1918 to 1980. In Wisconsin, an estimated one million barberry bushes were destroyed on some 8000 sites in that period, in a program that had 350 workers in Wisconsin during the height of the Great Depression. Races of stem rust have remained reasonably stable over the years, allowing plant breeders to utilize resistance genes effectively over a long period of time.



RESURVEY 448

CHANGE OF TENANT OR OTHER INFORMATION

DATE	SCOUTS	BUSHES FOUND PLANTED	BUSHES FOUND ESCAPED	BUSHES DESTROYED PLANTED	BUSHES DESTROYED ESCAPED	HOW*	BUSHES REMAINING	KIND*	OWNER	STATE	FED. DEP.	C.P.G.R.
Aug 19 21	7-P	0	0	0	0	2+	0					
Oct 31/24	C-K		21		21	Dug	0	Salt		36#		
5/9/[illegible]4	T-S-O	0	0	0	0	1 salted						
6/7/35	Cate	0	0	0	0		0					

DATE	SCOUTS	SPROUTING BUSHES FOUND PLANTED	SPROUTING BUSHES FOUND ESCAPED	SPRTNG. BUSHES DEST. PLANTED	SPRTNG. BUSHES DEST. ESCAPED	HOW*	SPROUTING BUSHES REMAINING	SEEDLINGS FOUND	SEEDLINGS DESTROYED	HOW	REMAINING
Aug 19 21	7-P	0	0	0	0		0				
July 1924	N-M	18	0	18	0	Dug	0				
[illegible]	C-K	7	0	7	0	6 dug	0	0	0		0
5/9/29	T-S-O	0	0	0	0	1 salted		0	0		0
1-10-45	[illegible]	0	0	0	0	property check in 1945					
12-1-52	[illegible]	0	0	0	0						
3/16/10	AB	0	0	0	0						

Form 1. 526 ORIGINAL SURVEY City ~~CITY~~ ~~RURAL~~

COUNTY Walworth CITY Lake Geneva

OWNER "[illegible]", Geo. Parker MAIL ADDRESS Plaza Hotel, Chicago

RENTER Matthew Patton, gardener ADDRESS PROPERTY Willow St. 400 bl.

LEGAL DESCRIPTION

QUARTER, SECTION, TOWNSHIP, RANGE, OR STREET AND NUMBER

NUMBER OF BARBERRIES SIZE	PLANTED	ESCAPED	KIND G-P	RUST + -
LARGE	36			
MEDIUM				
SMALL				
TOTAL				
SEEDLINGS				

LEGAL NOTICE SERVED

DISPOSITION OF BARBERRIES DUG	TREATED	REMAINING	CHEMICALS, KIND AND AMTS. FURNISHED BY KIND*	OWNER	STATE	FED. DEP.	C.P.G.R.
		36					

*A—Sodium Arsenite; B—Carbon Bisulfide; C—Sodium Dichromate; D—Dug; K—Kerosene; S—Salt; Etc.

ATTITUDE OF OWNER

DATE 7/19/18 SCOUTS Ball, McKinney

DESCRIPTION OF AREA WITH MAP ON BACK

The recent emergence of the Ug99 race of stem rust in the Middle East has raised concerns about new races of stem rust, either introduced or arising endogenously. To assess the effectiveness of the 62-year-long eradication effort, DATCP staff have drawn samples from the USDA records for revisiting, as time allows. To date, 117 former barberry sites have been located and resurveyed; common barberry has been found at only three sites. This would suggest that the threat to wheat from recombination of rust virulence on barberries is currently minimal.

FUNGICIDE APPLICATIONS ON V5 CORN

Paul Esker, Nancy Koval, and Bryan Jensen[1]

Foliar fungicide applications on corn remain a controversial topic. There continues to be debate regarding the economic use of foliar fungicides, and more recently, discussions have ensued about the use of foliar fungicides during vegetative growth stages, specifically at the V5 to V6 growth period coinciding with post-emergence herbicides applications. In soybean, the use of tank mixes has been discussed extensively in terms of avoiding the mixing of herbicides-insecticides-fungicides based on several factors like application equipment (nozzle type), coverage, and timing as well as the use of thresholds for insects like aphids (see: http://www.planthealth.info/pdf_docs/trimix_05.pdf). We feel that these same considerations need to be made about the use of tank mixes for corn. However, in corn less is known about the effect of early-season fungicide applications on disease development and late season stalk health.

Regional Summary 2009

In 2009, several states conducted trials to examine the effect of foliar fungicides applied early, late, or in a combination of timings. A general summary of that research can be found here: http://bulletin.ipm.illinois.edu/article.php?id=1284. In particular, results indicated that only one of eight trials (Nebraska) was there a response of > 10 bushels per acre. Interestingly, the greatest responses were observed with applications made at VT-R1 in trials in Nebraska and Iowa. In Nebraska, the primary disease that was being controlled was southern rust. Averaged across trials, the mean response was 1.5 bushels per acre with V5-V6 applications compared to 8 bushels per acre with the VT-R1 applications, although variability was high in the trial.

2009 Lancaster ARS Trial

To examine the effect of fungicide, application timing, and rate, an experiment was conducted at the Lancaster ARS in a field previously cropped to corn with a history of anthracnose. The experimental design was a randomized complete block with four replications, with a single hybrid (P37Y14) used. The trial was planted on 11 May 2009 at 33,000 plants per acre and was harvested on 27 October 2009. The general growing conditions were cool and wet the entire season. The treatments are listed in Table 1. Fungicide application dates were 17 June and 29 July and were made using a CO_2-backpack sprayer calibrated to 20 gallons per acre and 40 PSI. Prior to the 29 July fungicide application, hail occurred in these plots and ranged in size from pea to marble sized. Due to the hail damage, disease ratings focused on measures associated with ear mold development, common smut, anthracnose top dieback and stalk health. Yield measures included grain moisture, test weight, and grain yield. Data were analyzed using SAS PROC MIXED and mean comparisons were based on the least significant difference (LSD) at the 10% level.

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Table 1. Treatments in the 2009 foliar fungicide trial at the Lancaster ARS that examined fungicide active ingredient, timing, and application rate.

Product	Active ingredient	Timing	Rate
UTC	-	-	-
Quilt	Azoxystrobin + Propioconazole	R1	14 fl oz/A
Quilt Xcel	Azoxystrobin + Propioconazole	R1	10 oz/A
Quilt Xcel	Azoxystrobin + Propioconazole	R1	14 oz/A
Quilt Xcel	Azoxystrobin + Propioconazole	V6	10.5 oz/A
Headline	Pyraclostrobin	R1	6 oz/A
Headline (+NIS)	Pyraclostrobin	R1	6 oz/A (+0.25% v/v)
Headline fb Headline (+NIS)	Pyraclostrobin	V6&R1	3 oz/A fb 6 oz/A (+0.25% v/v)
Headline	Pyraclostrobin	V6	3 oz/A
Headline (+NIS)	Pyraclostrobin	R1	6 oz/A (+0.25% v/v)
Headline fb Headline (+NIS)	Pyraclostrobin	V6&R1	6 oz/A fb 6 oz/A (+0.25% v/v)
Headline	Pyraclostrobin	V6	6 oz/A
Stratego	Propiconazole + Trifloxystrobin	R1	10 oz/A

Results for the 2009 trial are provided in Tables 2 and 3. Overall, there was no evidence of an effect of foliar fungicide application on any of the late season disease measures or yield measures.

Table 2. Summary of late season disease assessments and stalk health, for the foliar fungicide trial conducted at the Lancaster ARS in 2009.

Treatment	Ear mold	Top dieback	Push test	Stalk rating
	(%)	(%)	(%)	(0-5)
UTC	5	10	25	1.7
Quilt, R1, 14 oz/A	15	20	40	2.7
Quilt Xcel, R1, 10.5 oz/A	10	20	20	1.7
Quilt Xcel, R1, 14 oz/A	13	18	58	2.4
Quilt Xcel, V6, 10.5 oz/A	15	15	25	1.3
Headline, R1, 6 oz/A	8	10	25	1.2
Headline, R1, 6 oz/A (plus NIS)	3	8	43	1.0
Headline, V6, 3 oz/A	5	18	33	2.8
Headline, V6, 3 oz/A fb Headline, R1, 6 oz/A (plus NIS)	8	13	28	1.5
Headline, V6, 6 oz/A fb Headline, R1, 6 oz/A (plus NIS)	13	13	40	1.9
Headline, V6, 6 oz/A	15	10	35	1.1
Stratego, R1, 10 oz/A	15	8	25	1.4
LSD (10%)	NSD	NSD	NSD	NSD

Table 3. Summary of yield measures for the foliar fungicide trial conducted at the Lancaster ARS in 2009.

Treatment	Grain moisture	Test weight	Grain yield
	(%)	(lb/bu)	(bu/A)
UTC	25.4	50.7	107
Quilt, R1, 14 oz/A	23.8	51.4	109
Quilt Xcel, R1, 10.5 oz/A	23.8	51.4	119
Quilt Xcel, R1, 14 oz/A	22.8	52.7	93
Quilt Xcel, V6, 10.5 oz/A	25.7	51.1	117
Headline, R1, 6 oz/A	25.1	51.6	93
Headline, R1, 6 oz/A (plus NIS)	25.6	52.0	128
Headline, V6, 3 oz/A	23.4	51.4	107
Headline, V6, 3 oz/A fb Headline, R1, 6 oz/A (plus NIS)	26.7	51.4	117
Headline, V6, 6 oz/A fb Headline, R1, 6 oz/A (plus NIS)	25.0	52.0	110
Headline, V6, 6 oz/A	25.0	51.7	115
Stratego, R1, 10 oz/A	24.9	51.2	141
LSD (10%)	NSD	NSD	NSD

2010 Lancaster ARS Trial

In 2010, a similar trial was conducted again at the Lancaster ARS in the same field. The experimental design was a randomized complete block with four replications, and a single hybrid (NK N51T-3000GT) was used. The trial was planted on 10 May at 33,000 plants per acre and was harvested on 22 October. The general weather conditions were warm, humid, and rainy throughout the growing season. Treatments are listed in Table 4. Fungicide application dates were 16 June and 19 July, and were made using a CO_2-backpack sprayer calibrated to 20 gallons per acre and 40 PSI. Disease assessments were made between the two fungicide applications (8 July), shortly after the second application (21 July), and at kernel dent (10 September). Ratings on 8 July and 21 July were at the whole plant level and on 10 plants per plot, while the 10 September rating was on the ear leaf for 10 plants per plot. Stalk ratings were made on 22 September using both a push testing on 20 plants per plot as well as a stalk rating (0-5) on 10 plants per plot. Yield measures included grain moisture, test weight, and grain yield. Data were analyzed using SAS PROC MIXED and mean comparisons were based on the least significant difference (LSD) at the 10% level.

Table 4. Treatments in the 2010 foliar fungicide trial at the Lancaster ARS that examined fungicide active ingredient, timing, and application rate.

Product	Active ingredient	Timing	Rate
UTC	-	-	-
Stratego YLD (+Induce)	Prothioconazole + Trifloxystrobin	R1	5 oz/A (+ 0.125% v/v)
Stratego YLD (+Induce)	Prothioconazole + Trifloxystrobin	V5-V6	2.5 oz/A (+ 0.125% v/v)
Stratego YLD (+Induce) fb Stratego YLD (+Induce)	Prothioconazole + Trifloxystrobin	V5-V6 fb R1	2.5 oz/A (+ 0.125% v/v) fb 5 oz/A (+ 0.125% v/v)
Quadris	Azoxystrobin	V5-V6	6 oz/A
Quadris fb Quilt Xcel	Azoxystrobin fb Azoxystrobin + Propioconazole	V5-V6 fb R1	6 oz/A fb 10.5 oz/A
Quilt Xcel	Azoxystrobin + Propioconazole	R1	10.5 oz/A

Results for the 2010 trial are provided in Fig. 1 and 2. In this trial, there was a low level of disease at V5-V6 and there was no evidence of differences among treatments when plants were assessed on 8 July (data not shown). As shown in Fig. 1A, there was evidence of differences among treatments for both eyespot and anthracnose, although the effect of a fungicide application on anthracnose was difficult to quantify due to low disease pressure in the untreated control. Eyespot was reduced, however, with all treatments applied early. Late in the growing season (Fig. 1B), differences were also noted among fungicide treatments on disease severity assessments made on the ear leaf. The severity of anthracnose was high, consistent with field history of this disease. There were also differences noted for common rust, gray leaf spot, and northern corn leaf blight, although the severity was very low making inference difficult (data not shown). However, as shown in Fig. 2A, there was no evidence of an effect of foliar fungicide application on either stalk lodging (push test) or stalk rating, respectively. There were differences in grain moisture (Fig. 2B) with all fungicide treatments greater than the UTC ($P = 0.81$). While there was no evidence of an effect of fungicide treatment on grain yield, there was a trend towards higher yield in fungicide treated plots. Further research is needed to determine if this is a consistent response and/or a response due to control of eyespot or anthracnose leaf blight.

The current results on the early application of a foliar fungicide in corn are inconclusive. Conditions were more favorable in 2010 for disease development than in previous years, and we saw efficacy against several diseases. While there were some trend results for grain yield in 2010, further research is needed to quantify what the primary factor(s) may be driving such a response.

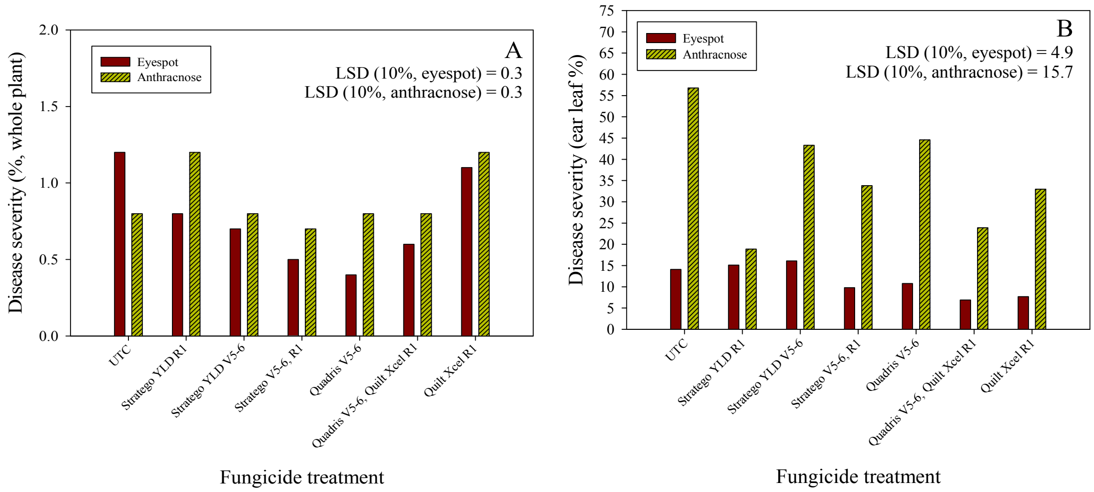

Figure 1. Disease severity at the whole plant level for eyespot and anthracnose on (A) 21 July and on the ear leaf on (B) 10 September 2010. The P-values for the statistical analysis were 0.0016 (eyespot) and 0.0228 (anthracnose), respectively.

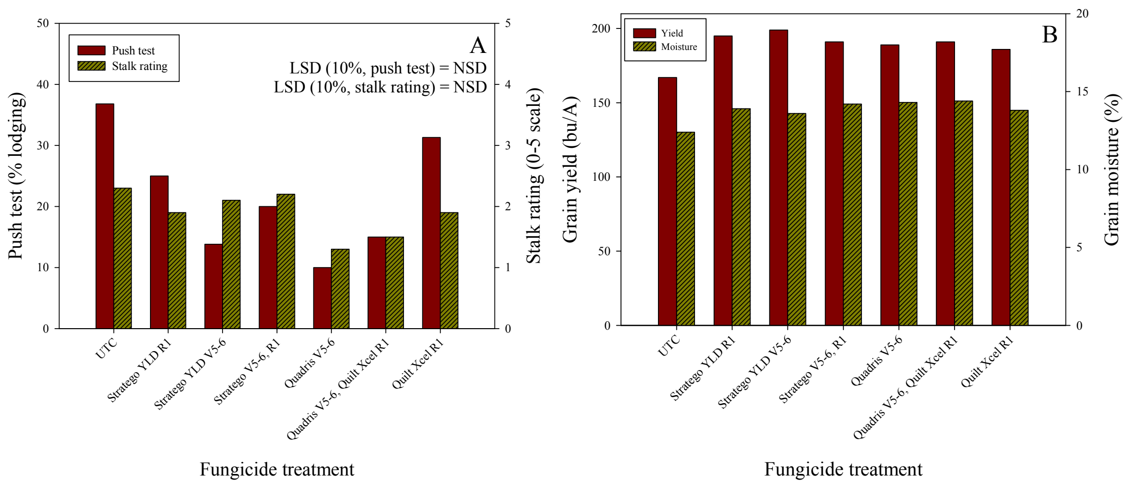

Figure 2. (A) Stalk lodging based on push test and stalk rating and (B) grain yield and grain moisture in the 2010 trial. Differences were noted for grain moisture (B) (P = 0.0097, LSD (10%) = 0.81) and while there was no evidence of a difference in grain yield (P = 0.1012), there was trend toward higher grain yields in fungicide treated plots.

2010 ON FARM CORN FOLIAR FUNGICIDE TRIALS RESULTS

Paul Esker, Mike Ballweg, Bob Cropp Bill Halfman, Richard Halopka, Matt Hanson, Steve Huntzicker, Jon Zander and Paul Sturgis [1]

With corn prices high, the use of foliar fungicides as a means to enhance corn yield remains a topic of great debate. In our previous trial years that have included both small and large strip trials, there has not been a consistent benefit from the use of a foliar fungicides (Grau et al., 2008; Esker et al., 2009). In order to provide the most comprehensive data to stakeholders in the state, staff at the University of Wisconsin Cooperative Extension Service and UW College of Agricultural and Life Sciences have continued a coordinated effort to generate data from replicated large on-farm strip trials and small plot trials.

We used both small plot and large strip trials in our on-farm studies. Both methods have advantages and disadvantages. Some advantages of small plot research include the ability to control variables such as soil type/texture, drainage, soil compaction and pest interactions. It also allows the researcher to evaluate several different treatments in a small area. However, the value of large scale on-farm research is that the previously mentioned variables are not singled out and those results better represent "real world" scenarios. It is this combination of approaches that are important for improving the research process.

Plot Design

Large Strip Trials

Trials were conducted in Clark, Dodge, and Washington counties using cooperating grower production practices and equipment. Foliar fungicides were applied at R1 and no adjuvants were used. Field histories and additional baseline information can be found in Table 1. All plots were randomized and sized to fit within the grower's field and replicated a minimum of 3 times. Data collected included foliar and stalk disease severity ratings and grain yield. Grain moisture and test weight were also collected, however, this data was not always available for all trials on a plot basis.

Small Plot Trials

Small plot trials were conducted using the cooperating grower's production practices in Monroe (2 sites), La Crosse, Pepin and Trempealeau counties. Treatments at each site included Headline AMP (10 ounces per acre), Quilt Xcel (10.5 ounces per acre) and Stratego YLD (5 ounces per acre) applied at R1. Adjuvants were not used. Foliar and stalk health disease severity ratings, yield, grain moisture and test weight data were collected for all plots. Each plot measure 10 ft. (4 rows) wide by 50 feet long and were sprayed using a CO_2 powered backpack sprayer calibrated to deliver 23.7 gallons per acre at 36 PSI while walking at 3.0 miles per hours. Each plot was hand harvested.

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Results for Large Strip Trials

Summary results are available in Table 2. Disease severity prior to application was <1% in all trials. The late season foliar disease severity ratings were only statistically different in the Washington County trial (14% for UTC and 4% for Quilt Xcel treated). There was almost no stalk lodging in all trials and stalk ratings were typically very low (<2). There was no evidence of an effect for foliar fungicide on grain yield in all trials. In the Washington County trial, grain moisture was higher in plots that had received Quilt Xcel (18.7% versus 18.0%).

Results for Small Plot Trials

Summary results are available in Table 2. Overall, there was no evidence of an effect of foliar fungicide on disease severity, stalk lodging, stalk rating, test weight, and grain yield. There were grain moisture differences in the Monroe 1 and Pepin County trials, respectively. In Monroe County, grain moisture was highest for plots that have received Quilt Xcel. In the Pepin County trial, the highest grain moisture was in the UTC.

Recommendations for the Use of Foliar Fungicides on Corn

Since 2007, approximately 35 small and large plot trials have been conducted. Results from trials have not shown a consistent response to the application of foliar fungicides. The best management tactic for reducing the risk of corn diseases is the use of an IPM strategy that starts with hybrid selection for resistance to specific corn diseases. In addition, growers should consider using other factors like crop rotation and residue management as part of their overall program. The best results to date (both within Wisconsin and across the region) for use of foliar fungicides is when there have been when disease severity has been higher. Further more, timely field scouting and an assessment of environmental conditions (relative humidity, leaf wetness and temperature) are necessary to determine if the need for a fungicide is warranted. Also, economic considerations should be made prior to an application of foliar fungicides. With prices in the $25-30 per acre range for product plus application, approximately 5 to 6 bushels per acre are necessary to cover the cost of a foliar fungicide application.

Acknowledgments

The authors would like to thank the growers for use of their fields, equipment and time. We would also like to thank the agronomists and custom applicators who assisted with field timing and operations.

Table 1. Field histories for on-farm foliar fungicide trials, 2010.

Information	Dodge	Clark	Washington	Monroe 1	La Crosse	Trempealeau	Monroe 2	Pepin
Trial type	Large	Large	Large	Small	Small	Small	Small	Small
Planting date	22 April	28 April	20 May	6 May	1 May	26 April	10 May	26 April
Harvest data	15 October	11 November	13 October	30 September	30 September	20 September	13 October	2 September
Previous crop	Corn	Grass sod	Soybean	Alfalfa	Corn	Alfalfa	Corn	Soybean
Residue @ planting	60%	5%	25%	75%	15%	NA	5%	10%
Primary tillage	Fall chisel; spring field cultivator	Moldboard plow	No-tillage	No-tillage	Chisel	Chisel plow	Moldboard plow	No-tillage
Hybrid	Jung 78555	NKII N22-C2	Croplan 3514RR	Croplan 3114VT	DeKalb 4660	DeKalb 491VT	DeKalb 46-50	Pioneer 35F40
Fungicide(s)	Quilt Xcel	Stratego YLD	Quilt Xcel	Headline AMP; Quilt Xcel; Statego YLD	Headline AMP; Quilt Xcel; Statego YLD	Headline AMP; Quilt Xcel; Statego YLD	Headline AMP; Quilt Xcel; Statego YLD	
Rate(s) (fl oz/A)	10.5	5	10.5	10; 10.5; 5	10; 10.5; 5	10; 10.5; 5	10; 10.5; 5	
Date – pre spray disease assessment	29 July	4 August	26 July	18 July	18 July	16 July	2 August	16 July
Date – post spray disease assessment	31 August	16 September	2 September	9 September	9 September	12 September	9 September	20 September

Table 2. Summary results for large strip and small foliar fungicide trials in 2010.

County	Treatment	Grain yield	Grain moisture	Test weight	Pre-spray disease[3]	Post-spray disease	Stalk lodging[4]	**Stalk rating**
		(bu/A)	(%)	(lb/bu)	(%)	(%)	(%)	(0-5)
Clark	UTC	177 a[1]	NA[2]	NA	<1	6 a	0 a	0.1 a
	Stratego YLD	182 a	NA	NA		11 a	1 a	0.2 a
Dodge (large)	UTC	200 a	NA	NA	NA	NA	NA	NA
	Quilt Xcel	203 a	NA	NA		NA	NA	NA
Monroe 1 (small)	UTC	157 a	**23.0 b**	53.3 a	<1	1 a	0 a	1.3 a
	Headline AMP	159 a	**23.6 ab**	53.7 a		1 a	0 a	0.8 a
	Quilt Xcel	163 a	**24.5 a**	53.3 a		1 a	0 a	0.7 a
	Stratego YLD	162 a	**22.6 b**	54.0 a		1 a	0 a	0.9 a
Monroe 2 (small)	UTC	151 a	23.5 a	52.0 a	<1	4 a	0 a	0.7 a
	Headline AMP	163 a	23.9 a	51.0 a		4 a	0 a	0.6 a
	Quilt Xcel	157 a	23.9 a	51.0 a		3 a	0 a	0.4 a
	Stratego YLD	154 a	23.7 a	51.3 a		3 a	0 a	0.7 a
La Crosse (small)	UTC	165 a	22.9 a	52.0 a	<1	8 a	0 a	1.0 a
	Headline AMP	163 a	24.8 a	53.3 a		6 a	0 a	0.9 a
	Quilt Xcel	157 a	24.3 a	52.5 a		7 a	0 a	1.2 a
	Stratego YLD	154 a	24.3 a	52.7 a		7 a	0 a	1.0 a
Pepin (small)	UTC	152 a	**27.2 a**	50.8 a	<1	NA	0 a	0.8 a
	Headline AMP	141 a	**25.4 ab**	51.5 a		NA	0 a	0.7 a
	Quilt Xcel	152 a	**24.3 b**	50.9 a		NA	0 a	1.1 a
	Stratego YLD	138 a	**23.5 b**	51.4 a		NA	0 a	1.0 a
Trempealeau (small)	UTC	145 a	30.0 a	51.3 a	<1	25 a	0 a	0 a
	Headline AMP	150 a	29.7 a	50.8 a		25 a	0 a	0 a
	Quilt Xcel	151 a	31.0 a	49.8 a		25 a	0 a	0 a
	Stratego YLD	141 a	29.9 a	50.3 a		25 a	0 a	0 a
Washington (large)	UTC	154 a	**18.0 b**	55.1 a	<1	**14 a**	0 a	1.7 a
	Quilt Xcel	157 a	**18.7 a**	54.9 a		**4 b**	0 a	1.1 a

[1] Means followed by the same letter within a trial are not statistically different based on Duncan's multiple range test (*P* = 0.10).
[2] NA = data not available.
[3] Disease assessments were based on a composite severity rating for all diseases (both pre- and post-spray).
[4] Stalk lodging was based on a push test of 30 stalks per plot.

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SUSTAINABLE MANAGEMENT OF WATER IN VEGETABLE PRODUCTION SYSTEMS

Alvin J. Bussan[1]

Water is one of the most essential resources necessary for crop production and its stewardship is becoming more critical with continued population growth and shifts in land management. Agriculture, or food production, is responsible for 70 to 80% of the water consumption across the landscape. Even in Wisconsin with annual precipitation in excess of 30" on average, sustainable water use is becoming more critical. Increasing number of irrigation pivots and more acres of irrigated vegetable production across Wisconsin have led some to believe that increased irrigation pumping is impacting depth to groundwater. Declines in water table can have adverse effects on surface waters and lakes.

Sustainable water management can be defined by multiple metrics, including energy use in irrigation, impacts of irrigation on water quality, and amount of water used in crop production. Irrigated vegetable growers have adopted multiple strategies to decrease energy use in irrigation. Use of low pressure wells and drop nozzles greatly reduces energy required for pumping water. Irrigation systems are typically managed on schedules to minimize electricity use during peak demand periods as well. We are currently working with growers to assess current strategies to optimize energy efficiency in the operation of irrigation systems in Wisconsin.

Due to concerns about water use by vegetable crop producers in Central Wisconsin, we have initiated research to evaluate means for improving water use efficiency. We have conducted trials on snap bean and potato with intermittent drought stresses. These trials serve two purposes: (1) identify ways to reduce water use in production of irrigated crops, and (2) determine the yield and quality impacts of reduced irrigation and increased drought stress on vegetable crops. Preliminary results in snap beans showed that drought stress during flowering and pod development had negative impacts on yield. Yield reductions led to poorer nutrient use efficiency and potential for increase nitrogen losses. In potato, several varieties seemed to have less yield response to drought stress than others.

We are also evaluating use of drip irrigation in field scale trials in potato. Previous research suggested drip irrigation led to improved water use efficiency and decreased need for irrigation. However, irrigation efficiency in Wisconsin is quite high suggesting minimal benefits for use of drip irrigation. Precise placement of water in the potato hill allows for placement of fertilizers in the crop production zone as well. Potato crops yielded similarly between drip and sprinkler irrigated treatments with 40 to 60 lb/a less nitrogen fertilizer.

One thing is clear, if crops are irrigated, the water should be managed to maximize crop productivity. Failing to do so will lead to decreased resource use efficiency and require planting of addition acres. This leads to increased costs to the grower, processor, and dramatically impacts production efficiency.

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IRRIGATION DELIVERY OF WATER-SOLUBLE INSECTICIDES

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Abstract

Wisconsin has a history in the production of fresh market and processing fruits and vegetables including cucurbit crops, succulent beans, sweet corn, peas, carrots, and potatoes. While acreages and crops have changed over the years, growers have adapted and remained leaders in several of these primary crops. The goal of this project is to replace current insect management programs in key segments of the production region, which rely on frequent foliar applications of broad spectrum insecticides, with an economically viable reduced-risk system. This system has focused on EPA classified reduced-risk (RR) and organophosphate (OP)-replacement insecticides and application technology to minimize worker exposure to pesticides and mitigate adverse effects on human health, the environment, and non-target organisms, including biological control agents and pollinators. Specifically, this project focuses on potato in field production systems and is transferable to other fresh and direct market segments. Focus on this crop results from their heavy reliance on high insecticide inputs, the high degree of oversight and management needed to grow and harvest crops, and their economic importance in the region. Outcomes of the work include new pest management strategies devised for the potato crop to improve production efficiency and profitability, reduce human health and societal costs associated with pest management, and increase the long-term sustainability of these crops.

Background and Rationale

Wisconsin Agricultural Statistics report vegetable production on over 112,000 acres in Wisconsin with a total of 2,850 reported processed and fresh market growers. Fresh market vegetables are grown and packaged for direct market sales (road-side stands & farmers markets); produce auctions throughout the state, and for large emerging produce cooperatives emphasizing locally sourced, value-added products. While acreages and crops continue to evolve in response to market demands and production limitations, growers have adapted and remained leaders in several crops. Because there is a very low tolerance for insect damage on potatoes, growers rely on frequent and often foliar applications of insecticides to manage insect pests. 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. In Wisconsin, ca. 24,000 lbs of insecticide active ingredient were applied to potatoes in 2002 (most recent year for which pesticide data are available); of which approximately 60% consisted of OP, carbamate, and cyclodiene products. Only 27% comprised EPA classified RR or OP replacement products. Among the most commonly used insecticides based on total pounds of active ingredient were methomyl and endosulfan. Methomyl, a carbamate, is one of the most toxic insecticides registered for agricultural use. Endosulfan, a cyclodiene, is a suspected endocrine disruptor and has recently been slated for cancellation on several vegetable crops. Other widely used chemicals in WI include the OP acephate on snap beans, and the pyrethroids lambda-cyhalothrin and bifenthrin on all crops. Despite their relatively low use rates, pyrethroids have high impacts on non-target organisms and can negatively impact the surrounding environment.

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Vegetable growers rely almost exclusively on high pressure sprayers for insecticide applications. Depending on equipment and weather conditions, it is estimated that <20% of pesticides reach the target site and as much as 60% drifts hundreds of yards or even miles from the application site (Cox, 1995; Yao et al., 2006). Pesticide drift has been documented to adversely affect human health, water resources and aquatic organisms, pollinators, and natural enemies of pest. Accumulation of insecticides on soil surfaces, where they bind to organic matter and run off following rain, is of particular concern where vegetables are grown near water resources. In central Wisconsin, a large number of surface water sites have been identified as impaired due to specialty crop production in the watershed. Similar concerns exist in other portions of the US including NY, VA, NC, FL, and TX where numerous creeks and estuarine habitats border intense commercial vegetable production. There is also a history of and concern over insecticides leaching into the groundwater in central WI. Effects of agricultural pesticides on pollinators have long been a concern, and the importance of understanding these effects has increased with the recent widespread die-offs of honey bees. Foliar applications of broad-spectrum insecticides are known to have negative consequences for pollinator diversity and survival. Many new chemistries and product labels specifically address toxicity to non-target arthropods, using pollinators in general and honey bees in particular as model organisms and the basis for recommendations. The low toxicity of newer, RR insecticides to pollinators has the potential to mitigate the adverse effects of pesticide use on pollinators.

Insecticides will remain the primary tool used to manage insects for the foreseeable future, particularly for quality driven crops such as commercial and processing vegetables. Recognition of this and the need for new chemistry that reduces risks to humans and the environment led to the Conventional Reduced-Risk Pesticide Program within EPA to expedite the review and registration of pesticides classified as RR or OP alternatives that pose a lower risk to humans and the environment compared with older pesticides. Recent registration of several RR insecticides on fruiting vegetables, cucurbits, and potatoes, many of which move systemically within the plant when taken up by roots, has the potential to mitigate many of the adverse effects associated with current insect management practices. Chlorantraniliprole represents a new class of insecticide chemistry (anthranilic diamides) and was registered as a RR insecticide in 2008. It poses minimal risk to both vertebrate and invertebrate, non-target organisms, including honey bees, and has a narrow spectrum of pest activity, primarily affecting lepidopteran larvae, certain beetles, and whiteflies. A group of neonicotinoid insecticides classified as OP-alternatives, including imidacloprid, thiamethoxam and dinotefuran, is active against a different complex of insects including aphids, thrips, whiteflies, certain beetles and stink bugs. Additional RR insecticides that can play a role in vegetable IPM programs include a group of tetronic acids (spiromesifen and spirotetramat) that affect aphids, whiteflies, and mites, and the spinosyns (spinetoram) that are active against lepidopterans, thrips, and certain beetles.

Recent research has helped develop a system that promises to create an economic incentive for widespread adoption of their use, and a delivery system that mitigates farm worker safety issues related to pesticide exposure and environmental issues associated with pesticide drift and runoff. Drip irrigation, often in combination with plastic mulch, is common in commercial vegetable production to use water and fertilizers more efficiently. When used to deliver the systemic chlorantraniliprole to tomatoes, producers obtained >50 days residual control of tomato fruitworm (Kuhar et al., 2010). The addition of a single neonicotinod, such as imidacloprid or thiamethoxam, expanded the spectrum of pests controlled to include aphids and whiteflies as well as flea beetles and tobacco thrips. Excellent lepidopteran control with drip applications of chlorantraniliprole also has been observed on broccoli and leaf lettuce in the desert southwest. In on-farm tests in central Wisconsin in 2010 that compared drip to conventional application of insecticides on potato, a single, early season drip application of imidacloprid combined with one chlorantraniliprole application resulted in improved insect control, reduced insecticide use, and increased profitability. Other application methods may also be appropriate for these insecticides, including seed treatments. Seed treatments are particularly attractive, because they offer the opportunity to reduce insecticide inputs >80% compared to drip or in-furrow applications. Thiamethoxam treated cucurbit seed is now registered (FarMore DI400®) for early season insect control, but it is unclear if its residual activity is sufficient to eliminate the need for supplemental foliar sprays.

Drip irrigation (and potentially seed treatments) for delivery of insecticides represents a dramatic reduction in risks to farm workers, the environment, and non-target organisms compared to foliar applications. With insecticide residues contained within the vascular system of plants, farm workers are not in direct contact with pesticide residues on plant surfaces, a major route of pesticide exposure. Pesticide drift and runoff from residues on foliage and soil surfaces are largely responsible for contamination of water resources and effects on wildlife (US-EPA, 2005). Because insecticides applied through drip systems are delivered directly to the root zone and are taken up by the crop, pesticide drift and run-off are virtually eliminated. Inclusion of potato in this project, a crop not normally associated with drip irrigation, is in response to the expressed desire of growers in Wisconsin to use this efficient irrigation system to mitigate problems associated with overhead irrigation and depletion of the shallow ground water supply in central Wisconsin.

Research Objectives

The primary goals of this research have been to develop and implement cost-effective IPM systems for high-value crops that rely on RR and OP replacement insecticides applied in a manner that minimizes the potential for insecticide exposure to farm workers, non-target organisms, and sensitive environmental resources.

Specific objectives include:

1) Compare the response of pest and beneficial arthropods, crop yield, and economic returns associated with reduced-risk practices versus conventional foliar and soil-applied applied insecticides in potatoes.
2) Determine the effect of different types of systemic insecticides applied to the roots of crops on natural enemies at the individual and population level.
3) Compare the effect of drip irrigation vs. foliar spraying of insecticides on honey bee health and productivity, and pollinator diversity.

Research Outcomes

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 fruiting vegetables, cucurbits and potatoes rely extensively on frequent foliar sprays of older, broad spectrum insecticides. 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 continue to work to refine and implement pest management programs based on RR 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 runoff into water resources; and (3) creates incentives for adoption by the grower community by documenting enhanced profitability.

INTRODUCTION OF SYNTHETIC AUXIN HERBICIDE RESISTANCE IN SOYBEAN: IMPLICATIONS FOR VEGETABLE PROCESSORS

Jed Colquhoun [1]

Soybeans with resistance to synthetic auxin herbicides, such as 2,4-D and dicamba, are currently in development and may be considered for commercial release in some areas in the near future. While these traits may improve the weed control spectrum and options in soybean, concern has been expressed by specialty crop producers that expanded use of synthetic auxin herbicides may increase risk of off-target herbicide movement. The intent of this paper is to review specialty crop production, with a focus on Wisconsin, and to pose potential components of an "ideal" herbicide stewardship program for discussion.

A Review of Specialty Crop Production, with a Focus on Wisconsin

In general, the number of Wisconsin specialty crop producers has increased in recent years, while the number of grain growers has decreased over a similar time period (Table 1). There are a few common threads among these farms that increase risk when considering off-target pesticide movement. The average specialty crop farm is small, ranging from an average size of 0.9 acres in floriculture to 90 acres for vegetables. Given the small acreage, these farms are not often "on the radar." These farms are also interspersed among agronomic crops throughout the state. There is no consolidated specialty crop production area. Finally, specialty crops tend to be tremendously high in value. Cranberries, for example, cost about $35,000 per acre to establish, and production may exceed $24,000 per acre in gross value.

Table 1. Grain and specialty crop production in Wisconsin in 2002 and 2007 according to the 2007 USDA Census of Agriculture.

	2002		2007		
Crop	Farms (#)	Production (A)	Farms (#)	Production (A)	Avg. farm (A)
GRAINS					
Corn	29,021	2.9 million	27,505	3.3 million	120
Soybean	15,245	1.5 million	14,513	1.4 million	96
SPECIALTY CROPS					
Vegetables	2,850	252,693	3,319	297,238	90
Orchards	1,009	9,683	1,135	9,730	9
Floriculture	814	644	953	864	0.9
Nursery	624	14,334	637	12,177	19
Fruit	--	--	1,132	9,719	9
Grape	--	--	253	479	2
Berry	--	--	1,019	20,485	20

The number and acreage of organic farms is also increasing rapidly in Wisconsin. The number of organic farms in Wisconsin increased from 712 in 2005 to 1,099 in 2009. Wisconsin ranks second, behind California, in the number of organic farms. The acreage has similarly increased, from 41,245 acres in 1997 to 147,120 acres in 2007. Herbicide use near certified organic production can be particularly challenging. Herbicide movement to any non-target crop, grown "conventionally" or organically, is illegal. However, organic production can be particularly at risk given that farm certification, and subsequently the ability to sell the crop as organic, can be compromised by synthetic pesticides.

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Landscapes and ornamental production are also sensitive to off-target pesticide movement. The Association of American Pesticide Control Officials (AAPCO) conducted a national survey of suspected pesticide drift cases in 2005 (AAPCO, 2005). Nationally, agricultural crops were the intended target of 70% of confirmed drift cases, and lawns and landscapes were the most frequent recipient (43%) of drift. Fifty-three percent of cases involved commercial applicators for hire, and 22% involved certified private applicators. In Wisconsin, it is worth noting that more confirmed drift cases occurred from applications to non-agricultural land (51%) than agricultural crops (42%). The 5 most common active ingredients involved in 2004 drift cases in Wisconsin were 2,4-D, glyphosate, dicamba, atrazine and mesotrione.

Components of an "Ideal" Herbicide Stewardship Program

Given the breadth and value of specialty crop production in Wisconsin, it seems that all parties involved would desire reasonable steps to mitigate any potential risk of off-target herbicide movement. Off-target herbicide movement could include particle drift at the time of application, herbicide volatilization, or tank-contamination. The following is a list of potential herbicide stewardship program components for consideration and discussion during the presentation:

- Herbicide characteristics:
    - Non-volatile formulations that would reduce risk of off-target movement and allow use at higher air temperature (when weed control is needed in soybean) without increased risk.
    - Pesticide residue tolerances established for specialty crops grown in close proximity to soybeans and field corn.
    - Traceable marker included in the herbicide formulation to discourage use of other more volatile formulations of the same active ingredient or "anonymous" drift. Investigation of potential off-target movement would include a marker test of the suspected target field to ensure that the reduced-risk, labeled formulation was applied.
- Herbicide application requirements
    - Appropriate drift reduction nozzles and drift reduction tank additives.
    - Allow applications by ground only.
    - Specific tank-cleaning instructions included on and required by the label to reduce risk of misapplication through tank contamination.
    - Specific training and educational requirements prior to use of the herbicide. This could possibly be accomplished by making the potential herbicide a restricted-use pesticide, thus requiring purchase and application by a trained and licensed applicator.
- Weather-related and geographic restrictions
    - Include appropriate air temperature, wind speed and direction, and relative humidity restrictions based on the limitations of the herbicide formulation.
    - Possibly restrict temporally during times of nearby sensitive crop growth, or require permits for application during potentially higher-risk time periods.
    - Include appropriate application buffer requirements near sensitive sites.
    - Possibly restrict geographically in consolidated areas of sensitive sites or specialty crops.
    - Increase knowledge of neighboring sensitive sites through participation in awareness programs such as the Driftwatch program in development by Purdue University.

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NITROGEN RATE AND TIMING CONSIDERATIONS FOR SWEET CORN

Matthew D. Ruark [1/]

Introduction

Sweet corn production represents over 80,000 acres of Wisconsin cropland and is grown for processing and fresh market production. In addition, sweet corn is grown on irrigated sandy soils as well as rain-fed fine-textured soils. Our current nitrogen (N) fertilizer recommendations were developed several decades ago and may not fully represent N need of new varieties, seeding densities, use of multiple split applications to improve nitrogen use efficiency and implications toward groundwater quality. The objectives of this research were to: (1) re-evaluate our current N recommendations for sweet corn and (2) evaluate sweet corn response to N rate, N timing, variety, and seeding density.

Materials and Methods

Two projects were conducted: (1) N rate study conducted on-farm and (2) N rate, timing, variety and seeding density conducted at Hancock Agricultural Experiment Stations (HARS). The first project was conducted on four grower fields in 2009 and 2010. Six N fertilizer rates were applied: 105, 130, 155, 180, 205 and 230 lb ac^{-1}. The grower applied 105 lb ac^{-1} through starter fertilizer, two early in-season applications and fertigation. The grower skipped their main N fertilizer application in our study area and we applied additional N (0 to 125 lb N ac^{-1} in 25 lb ac^{-1} increments). Each site represents a different planting/harvest timing. The second project was conducted at HARS in 2009 and 2010. Two studies were conducted. The first study compared seven N fertilizer rates across two sweet corn varieties and the second study evaluated two fertilizer rates across four seeding densities across two varieties (Table 1). Nitrogen was applied by hand and split-applied when rates were above 50 lb ac^{-1}. When N was applied across three applications, 50 lb ac^{-1} was applied at V5 and 30 lb ac^{-1} was applied at tasseling, with the remainder applied at V8 (Table 1). At each site, corn was hand harvested for yield as fresh weight of whole ear (including husk).

Results and Discussion

On-farm Research

In 2009, there was not a significant yield increase above 155 lb ac^{-1}. In 2010, N fertilization rated did not affect yields at two sites and one site showed a significant increase in yield up to 205 lb ac^{-1}. Overall, yields in 2010 were much lower compared to 2009. Based on these eight site-years of data, there appears to be two main factors that will need to be considered if new N recommendations need to be developed. The first is the timing of fertilizer applications. It is clear that high yields can be obtained with 155 lb ac^{-1} (near the UW guideline of 150 lb ac^{-1})

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Table 1. Experimental treatments for the 2009 and 2010 sweet corn experiments at Hancock, WI.

Study	Nitrogen rate	Variety	Seeding density
	------------ lb ac^{-1} ------------		----- seed ac^{-1} -----
1	None	Overland	
	50 (applied at V5)	Experimental	
	100 (applied at V5 and V8)		
	150 (applied at V5 and V8)		
	150 (applied at V5, V8 and tasseling)		
	200 (applied at V5, V8 and tasseling)		
	250 (applied at V5, V8 and tasseling)		
2	130 (applied at V5, V8 and tasseling)	Overland	18,000
	200 (applied at V5, V8 and tasseling)	Experimental	24,000
			30,000
			36,000

when fertilizer is applied over five or six times during the growing season. Applying extra fertilizer as "insurance" has little value in production systems designed for efficient N use. The other factor is the plot-to-plot variability in small plot sweet corn studies. Standard errors were large, causing yield differences of 0.7 ton ac^{-1} to be indistinguishable. Yield gains of this magnitude (0.5 to 1 ton ac^{-1}) would be considerable for a grower and investment in an extra 30 to 50 lb ac^{-1} of N to achieve that yield increase would be an economic risk growers would take. These results suggest that plot size variability, even with 80 ft of harvest row collected, can be large. Additional site years will be required to determine if UW guidelines should be modified.

Variety and Planting Density Research

Research conducted at the Hancock ARS also suggests yields are maximized with 150 lb ac^{-1} of N. This was evident in both 2009 and 2010, as well as in a conventional variety (Overland) and the higher yielding experimental variety. This preliminary research shows that new varieties of sweet corn, while higher yielding, may not require additional inputs of N fertilizer. At N rates of 150 lb ac^{-1} or greater, N was applied over three application timings, further suggesting that multiple applications reduce the perceived need for "insurance" N. In 2009 and in 2010, there was no significant effect of planting density on yield, but again the experimental variety had greater yields compared to Overland. In effort to evaluate claims of greater nitrogen use efficiency, a lower than recommended rate of 130 lb ac^{-1} was used. The lower N rate of 130 lb ac^{-1} had significantly lower yields compared to the 200 lb ac^{-1} rate in 2009 and in 2010. Thus, improvements in nitrogen use efficiency with new varieties will likely come from increased N uptake at current N application rates rather than maintaining yields with lower N rates.

Future Research

Future research will continue to evaluate N response in experimental sweet corn varieties, as well as explore other agronomic components of sweet corn production, such as ears per acre, ear weight and kernel yield. Additional nutrient management parameters are also being evaluated, such as nitrogen uptake efficiency, nitrogen removal efficiency and nitrogen harvest index.

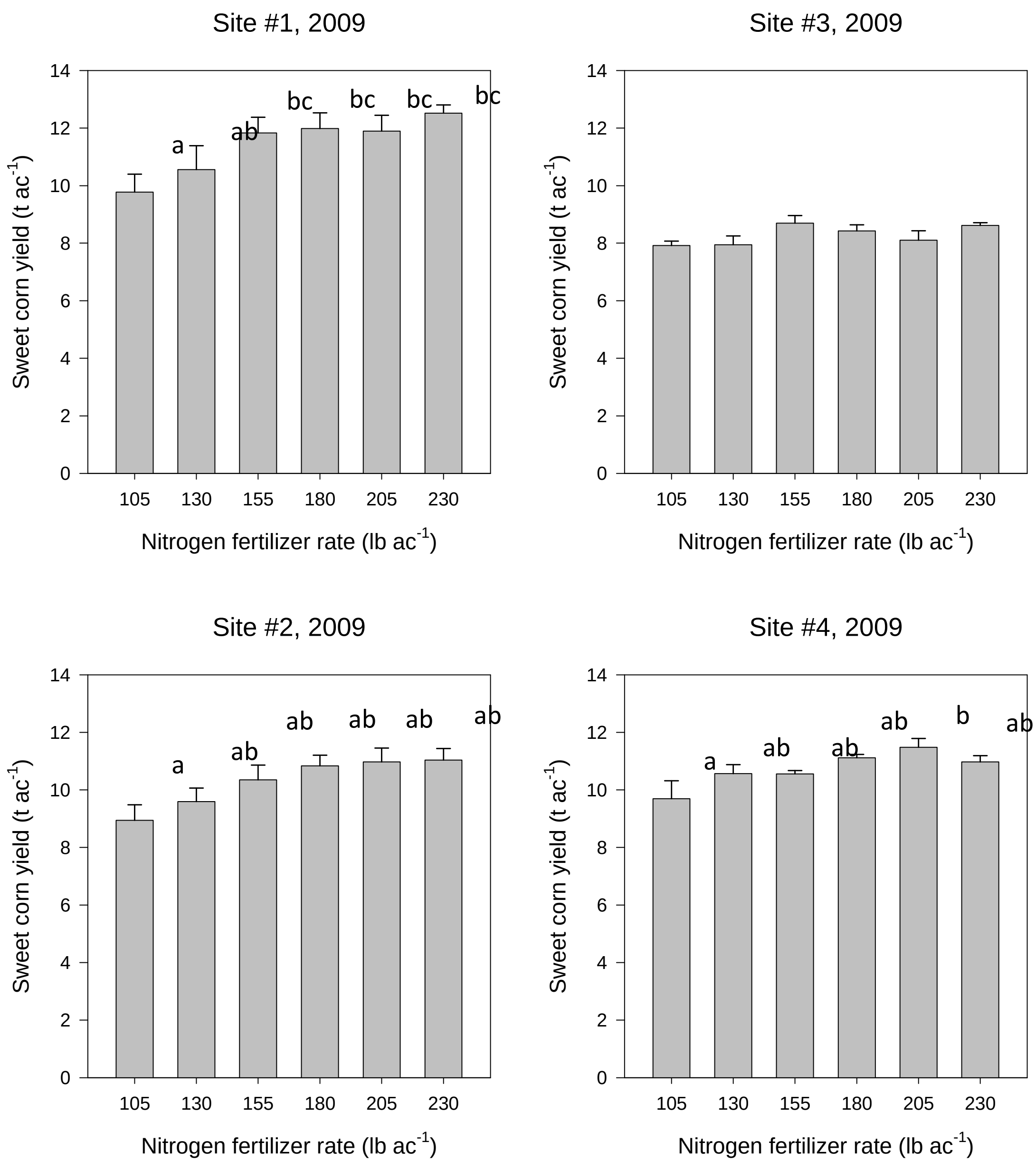

Figure 1. Sweet corn yield response in 2009 to nitrogen (N) fertilizer rates at four grower sites on irrigated sandy soils. Error bars are standard error.

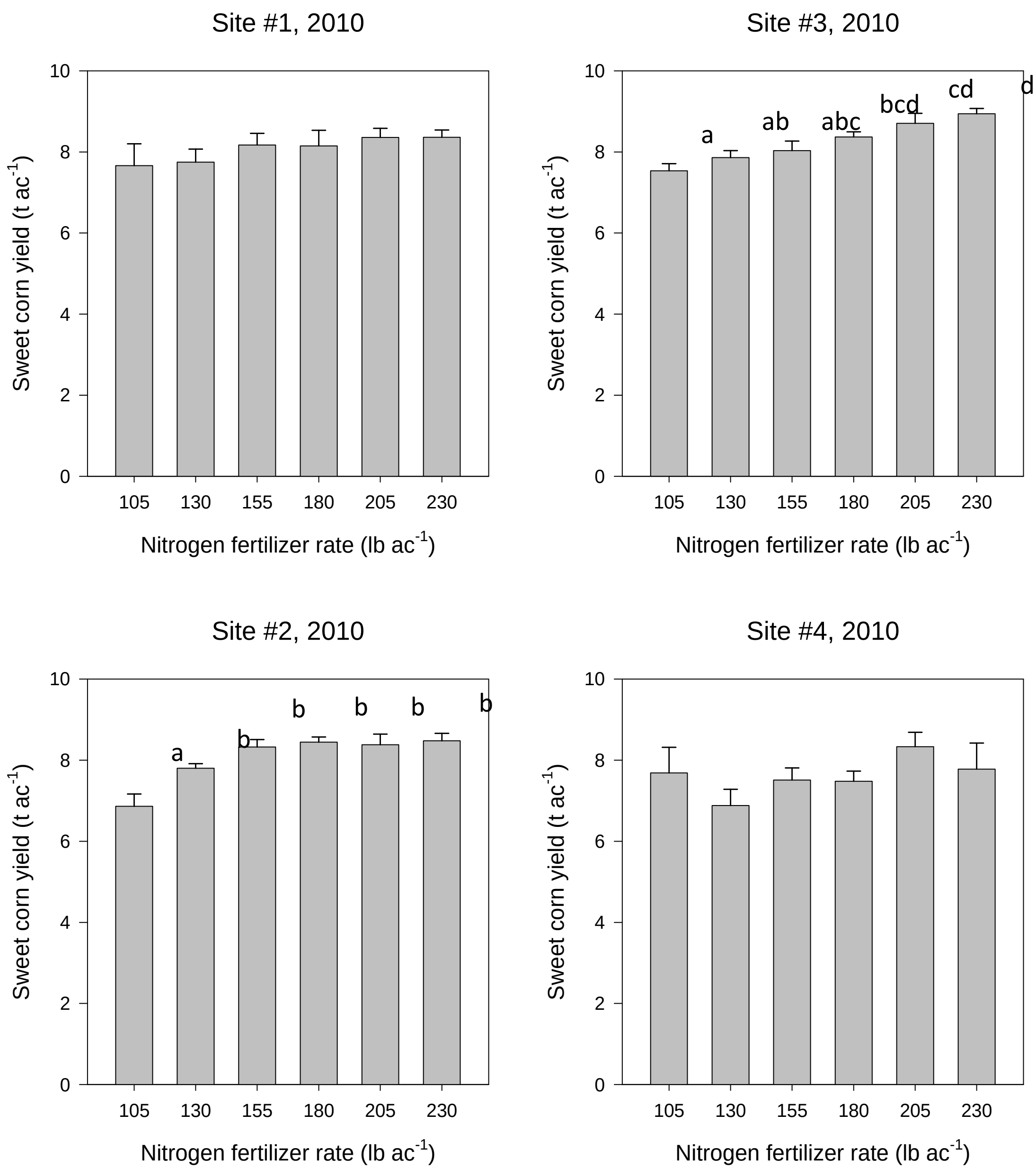

Figure 2. Sweet corn yield response in 2010 to nitrogen (N) fertilizer rates at four grower sites on irrigated sandy soils. Error bars are standard error.

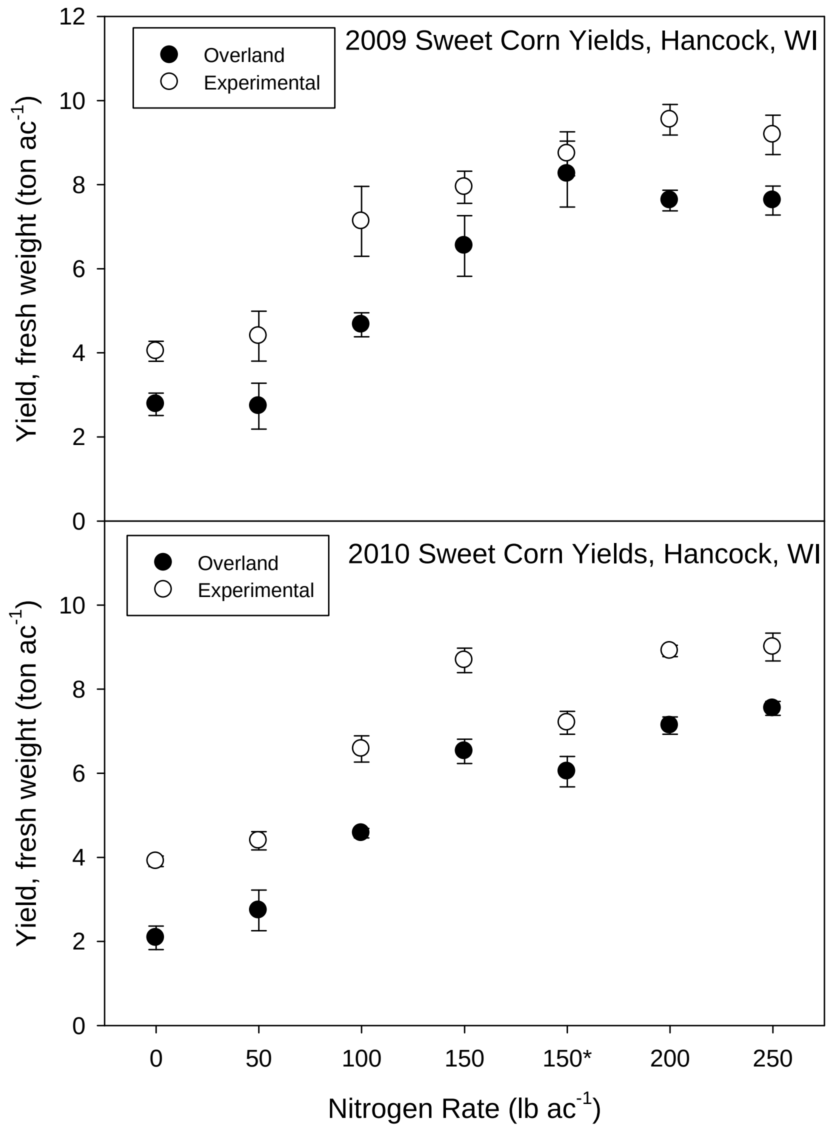

Figure 3. Sweet corn yields from two varieties across different nitrogen rates. Error bars are standard error. * indicates that the 150 lb of N was applied in only two applications.

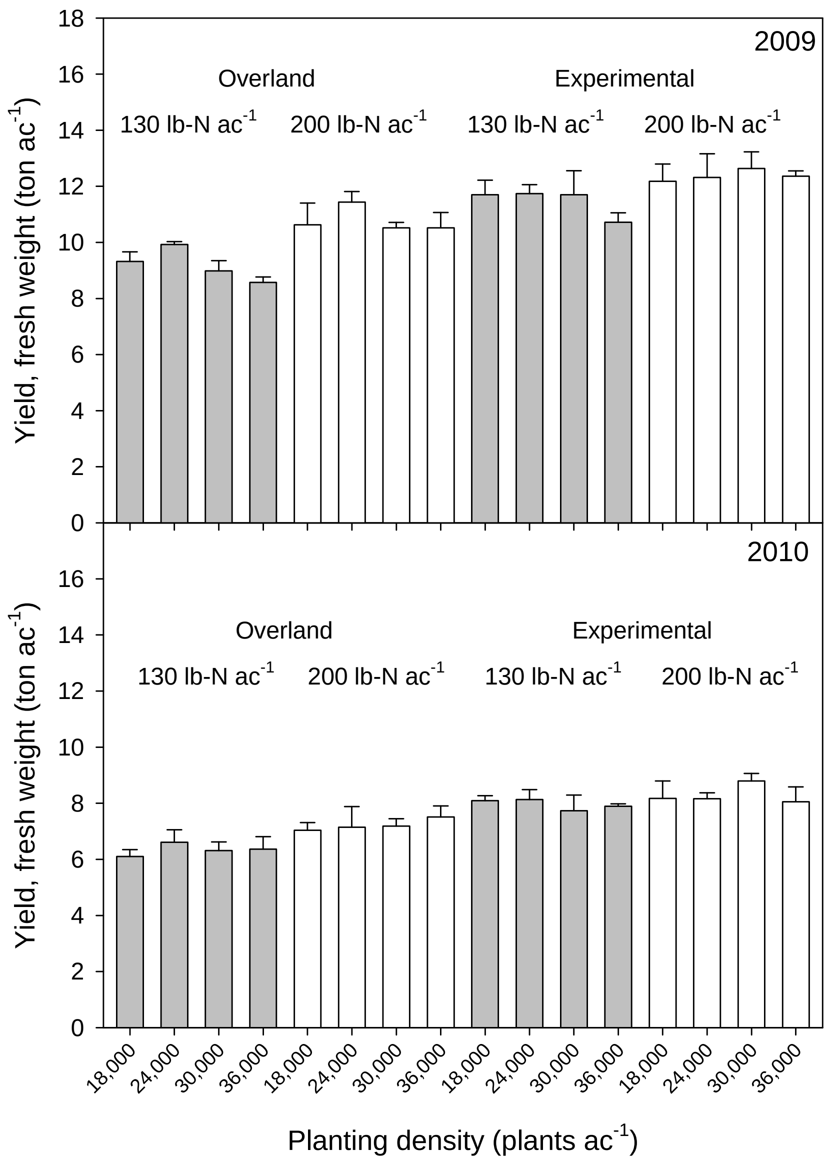

Figure 4. Sweet corn yields of two varieties at two fertilizer N rates across four planting densities. Error bars are standard error.

POTATO AND TOMATO LATE BLIGHT IN WISCONSIN: A NEW TYPE OF LATE BLIGHT IN A NEW DECADE

Amanda J. Gevens, Anna C. Seidl, and Rosemary Clark[1]

Introduction

Late blight is a potentially destructive disease of tomatoes and potatoes caused by the fungal-like organism, *Phytophthora infestans*. This pathogen is referred to as a 'water mold' since it thrives under wet conditions. Symptoms of tomato and potato late blight include leaf lesions beginning as pale green or olive green areas that quickly enlarge to become brown-black, water-soaked, and oily in appearance (Fig. 1 and 2). Lesions on leaves can also produce pathogen sporulation which looks like white-gray fuzzy growth (Fig. 1 and 2). Stems can also exhibit dark brown to black lesions with sporulation (Fig. 2). Tomato fruit symptoms begin small, but quickly develop into golden to chocolate brown firm lesions or spots that can appear sunken with distinct rings within them (Fig. 1); the pathogen can also sporulate on tomato fruit giving the appearance of white, fuzzy growth. On potato tubers, late blight symptoms include firm, brown, corky textured tissue (Fig. 2). The time from first infection to lesion development and sporulation can be as fast as 7 days, depending upon the weather (1). Control of late blight in the field is a critical component of long term disease prevention, as infected plant parts, if unexposed to winter killing frost conditions, can carry the pathogen from one growing season to the next (Fig. 3).

Prior to 2009, there had been no reports of late blight on tomato or potato crops in Wisconsin for 7 years. In 2009 and 2010, late blight was identified on tomatoes and potatoes in a number of U.S. states and Canadian provinces. The 2009 epidemic began early spring in southern U.S. states and was initiated in the northeastern U.S. in June, followed by Midwestern reports in late July-early August. The 2010 epidemic did not follow a spatiotemporal pattern similar to 2009. Rather, isolated reports of late blight emerged at varying times and locations from June to October. In some cases, reports of late blight remained isolated without further spread to greater geographic areas. In Wisconsin, the first reports of late blight came on July 14, 2010 on both tomatoes and potatoes, in Marquette and Waukesha counties. By season's end, additional reports of late blight came from a dozen Wisconsin counties from both tomato and potato. Reports were concentrated in the central Wisconsin region.

Our preliminary work on late blight in 2009 indicated that we had a relatively new genotype of *P. infestans*, US#22, which was sensitive to the fungicide active ingredients mefenoxam and metalaxyl and was likely of the A2 mating or compatibility type. Because of the potential impact of late blight on Wisconsin's potato and tomato crops, we initiated characterization studies to further understand the dynamics of the pathogen population. Results of our work have optimized, and will continue to optimize, disease management recommendations for potato and vegetable growers in the state of Wisconsin.

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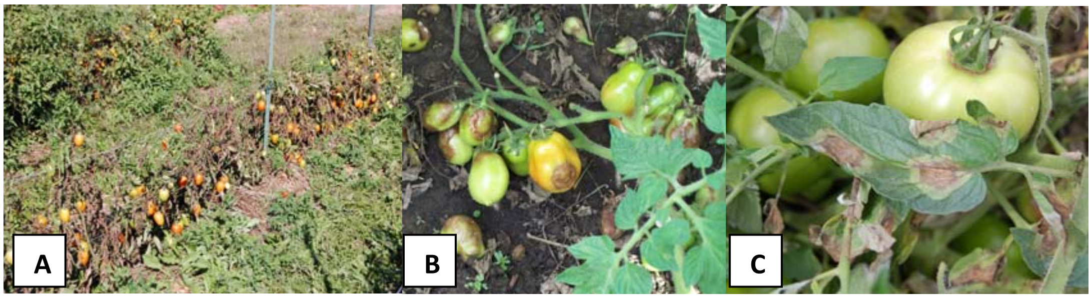

Figure 1. Symptoms of late blight on tomato. A. Dead foliage on a plum tomato variety as a result of severe late blight infection. B. Firm, brown, circular late blight lesions on plum tomato fruit. C and D. Irregularly-shaped pale green-brown late blight lesions on tomato leaves. Note white fuzzy pathogen sporulation surrounding lesions on leaf underside.

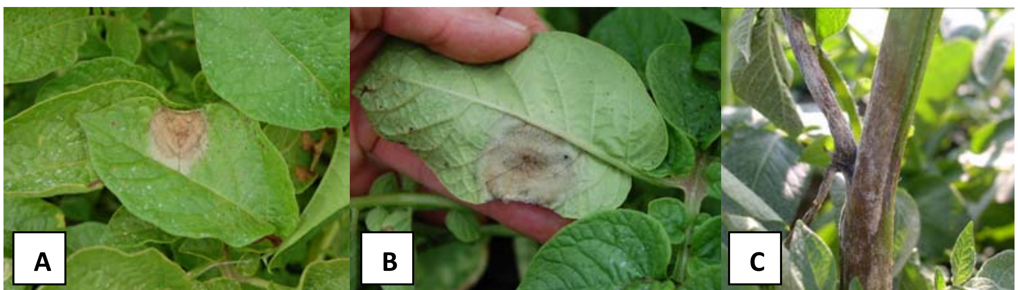

Figure 2. Symptoms of late blight on potato. A and B. Circular brown late blight lesions on potato leaves. Note white fuzzy pathogen sporulation on lesions on leaf underside. C. Water-soaking and white pathogen sporulation on potato stems. D. Water-soaked, brown-purple, firm late blight lesions on potato tubers.

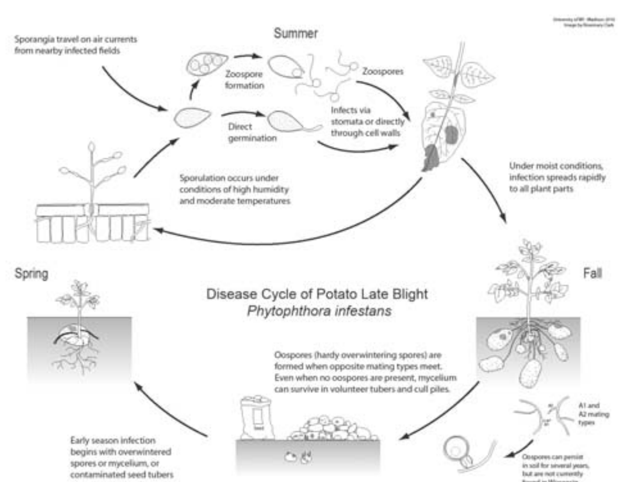

Figure 3. Disease cycle of *Phytophthora infestans*, the pathogen causing late blight of tomato and potato. Cycle depicts disease cycle of potato late blight. Illustration credit to Rosemary Clark, UW-Plant Pathology.

Results and Discussion

Isolates of *Phytophthora infestans* from tomato and potato hosts in Wisconsin were collected in 2009 and 2010 for characterization. Each isolate, or single zoospore-generated axenic culture from a unique sample, was evaluated for a) sensitivity to the fungicide mefenoxam, b) mating or compatibility type, and c) allozymes genotypic profile (Gpi) (2). A smaller group of isolates was further characterized for host range, RFLP profile, and growth optima at different temperatures on artificial media and host tissue. Results of our *P. infestans* characterization work further our understanding of the dynamics of the pathogen population and lend to the development of improved disease management recommendations.

Figure 4. A. Allozymes analyses of 12 *Phytophthora infestans* isolates with putative genotype characterization. B. Distribution of different *P. infestans* genotypes in Wisconsin. Isolates collected from tomato and potato plants during the 2010 growing season.

All isolates were sensitive to the fungicide mefenoxam when tested on amended media. Some isolates exhibited greater sensitivity than others. Further studies will be needed to qualify the media amendment assay. US#22 isolates were of the A2 mating or compatibility type. US#23 and US#24 isolates were of the A1 mating type. Opposite mating types were not isolated from the same fields or from the same counties. We are further evaluating compatibility type features of our *P. infestans* isolates.

There were three predominant *P. infestans* genotypes collected from Wisconsin in 2010: US#22, US#24, and putative US#23. Isolates of the US#22 genotype were collected from 7 counties throughout the state. US#24 isolates were collected from just 2 counties in central Wisconsin and isolates of the putative US#23 genotype were collected from 2 counties in southeastern corner of the state (Fig. 4).

US#22 isolates could infect both tomato and potato leaves. The foliage of several solanaceous plant types was resistant to infection by US#22 *P. infestans* and included tomatillo, eggplant, pepper, ground cherry, and few tomato varieties (e.g., 'Matt's Wild Cherry' and 'Wapsipinicon'). RFLP (rapid fragment length polymorphism) analysis was performed on one US#22 isolate and provided further confirmation of genotype characterization. A single US#22 isolate grew optimally at 20 degrees C on tomato foliage (Fig. 5).

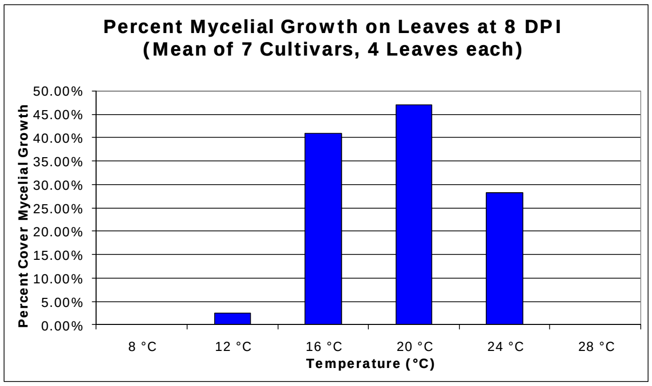

Figure 5. Graph depicting optimal temperatures for the growth of *Phytohpthora infestans* US#22 on tomato leaf tissue at 8 days post inoculation. Data presented is mean growth response on 7 different tomato cultivars.

With the recent presence of the late blight pathogen in the state and likelihood of disease-favorable weather conditions, it is critical that all growers (home gardeners and commercial producers) of tomatoes and potatoes regularly scout their plants for disease symptoms. If late blight is suspected, contact your county extension agent, a crop consultant, the plant disease diagnostic clinic at UW-Madison, or myself. Additionally, protectant fungicides can manage late blight when applied in advance of infection and when re-applied as the crop grows. 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/).

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HOW MUCH NITROGEN IS THERE IN THE SPRING FROM FALL-APPLIED MAP, DAP, AND AMMONIUM SULFATE?

Fabián G. Fernández[1], Robert G. Hoeft[1], and Gyles W. Randall[2]

Introduction

Diammonium phosphate (18-46-0) (DAP) and monoammonium phosphate (11-52-0) (MAP) are the two most common phosphorus (P) fertilizers in the US corn-belt. These granular fertilizers are excellent P sources because they are highly water-soluble, contain a high P concentration, and are easy to handle and store (Fixen, 1990). In addition, they represent a relatively low-cost source of supplemental N.

In much of the Corn Belt, it is a common practice to apply a blend of P and potassium (K) fertilizers during the fall. This time of application is favored because there is less potential for soil compaction (since soils tend to be drier than in the spring) and in general there is more time and equipment availability than during the busy planting season in the spring. One of the potential drawbacks of fall application of N-containing P fertilizers is that soil temperatures are warm (above 50°F) and nitrifying bacteria can quickly convert ammonium (NH_4^+) to nitrate (NO_3^-) (Alexander, 1965). Mulvaney (1994) showed that nitrification occurred in the order of urea [$CO(NH_2)_2$] > DAP > AMS [$(NH_4)_2SO_4$]> ammonium nitrate [NH_4NO_3] > MAP. The conversion to nitrate when fertilizers are applied well before crops will need N increase the risk of N loss through leaching or denitrification when soils are excessively wet in the spring. In laboratory studies, Mulvaney and Khan (1995) determined that denitrification decreased in the order of ammonia [NH_3] > urea > DAP > $(NH_4)_2SO_4$ >NH_4NO_3 > MAP. This differential in nitrification and denitrification rates are brought about by the fact that the hydrolysis (breakdown) of DAP increases soil pH, compared to MAP that lowers soil pH, and the nitrifying and denitrifying bacteria favor alkaline conditions (Lindsay et al., 1962; Allred and Ohlrogge, 1964; Firestone, 1982). Since DAP nitrifies faster than MAP and the resultant nitrate also denitrify faster, it would appear that there would be less potential loss of N from MAP than DAP.

While substantial work has been done to compare the agronomic performance of MAP and DAP (Fixen, 1990), to our knowledge, there has been no attempt to evaluate N availability and efficiency from fall-N applications of MAP and DAP. Frequently, a 200 lb acre^{-1} rate of material is applied which provides 22 lb N acre^{-1} from MAP and 36 lb N acre^{-1} from DAP. Agronomists have generally assumed that all N from fall application of MAP and DAP is fully available to the subsequent crop, but this has not been confirmed with research. Thus, the purpose of this study was to compare the efficacy of N from fall-applied versus spring-applied DAP, MAP, and AMS for corn (*Zea mays* L.) production. In addition, we conducted a laboratory study to measure the effect of soil water content on the rate of nitrification and denitrification of MAP and DAP.

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Materials and Methods

Incubation Study

An incubation study was conducted at Urbana, IL by mixing MAP and DAP with soil [Drummer silty clay loam soil (fine-silty, mixed, superactive, mesic Typic Endoaquolls)] at ratios of 70 and 140 mg N kg^{-1} soil. The soil was collected from the field, sieved to pass a 2-mm screen, and then dried at 25°C for 5 days. The soil was rewet to 80% FC, and allowed to incubate for 2 weeks. The appropriate amount of fertilizer for each treatment was then added and mixed thoroughly. A 100-g sample was weighed into 24 individual plastic bags, enabling three replications and eight sampling dates for each treatment. The fertilizer-amended soil was incubated at constant room temperature (23°C ±2) at 80% FC for 2 weeks, after which half of the soil bags were incubated at 80% FC and the other half were incubated at 120% FC at room temperature. Samples were taken at 2-week intervals and frozen. Frozen samples were oven-dried to constant weight and were analyzed for $NH_4^+$and NO_3^-. Total inorganic N (TIN) was calculated by adding NH_4^+ and NO_3^- concentrations.

Field Study

A 3-year field experiment was conducted at Waseca, MN on Nicollet and Webster clay-loam Mollisols and at Urbana, IL on a Drummer silty clay-loam Mollisol. Both locations were tile-drained. All soil test levels except N were nonlimiting for crop grain yield.

At both locations a full factorial of three N sources (DAP, MAP, and AMS), two application times (fall and spring) and two N rates (40 and 80 lb N $acre^{-1}$) was replicated four times and arranged in a randomized, complete-block design. Treatment plots were 10 ft (4 rows) wide by 50 ft long. A simultaneous N rate study was conducted to develop N response curves. At Minnesota the study consisted of 0, 40, 80, and 170 lb N $acre^{-1}$ in 2004, with the high rate reduced to 120 lb N $acre^{-1}$ in 2005 and 2006. At Illinois, the N rate study consisted of fall- and spring-applied AMS at rates of 0, 40, 80, 120, 160, and 200 lb N $acre^{-1}$. At both locations triple super phosphate (0-46-0) was applied to all non MAP or DAP plots to eliminate the possibility of a differential response to P among the treatments. All treatments were broadcast-applied on fields with soybean [*Glycine max* (L.) Merr.] as the previous crop. In Minnesota, treatments were applied on 10 Nov. 2003, 24 Apr. 2004, 26 Oct. 2004, 4 May 2005, 1 Nov. 2005, and 12 Apr. 2006. In Illinois, treatments were applied 3 Nov. 2003, 5 Apr. 2004, 10 Nov. 2004, 6 Apr. 2005, 2 Nov. 2005, and 5 Apr. 2006. After treatment application the entire plot area was disked to 3-inch depth in the fall and field cultivated in the spring. Corn was planted on 30-inch row spacing. In Minnesota planting was done on 28 Apr. 2004, 4 May 2005, and 23 Apr. 2006. Corn hybrid and final plant populations were: NK N50-P5 at 34,000 plants $acre^{-1}$ in 2004; and Mycogen 2E522 at 33,000 plants $acre^{-1}$ in 2005 and 2006. In Illinois corn hybrid Pioneer 34B24 with final plant population of 30,200 plants $acre^{-1}$ for 2004 and 2005 and 29,600 plants $acre^{-1}$ for 2006 was planted on 29 Apr. 2004, 2 May 2005, and 8 May 2006. Corn was harvested on 19 Oct. 2004, 11 Oct. 2005, and 6 Oct. 2006 in Minnesota and on 17 Sep. 2004, 23 Sep. 2005, and 27 Sep. 2006 in Illinois.

Soil samples were collected from the top 6 inches approximately every 2 weeks after fall applications until soils froze. Sampling resumed after soils thawed, and continued until the middle of June, with spring samples taken at depths of 0 to 6 and 6 to 12 inches. The soil samples collected at the end of May were considered most important because this sampling represents the time immediately before the rapid N-uptake period of corn. Samples were analyzed for NO_3^--N and NH_4^+-N concentration. Percent recovery of the applied N was estimated by subtracting N in the control plot from that of the treated plots and dividing by the applied N rate (Pomares-Garcia and Pratt, 1978).

Soil N and grain yield data were analyzed using the MIXED procedure of SAS (SAS Institute, 2003) with year as random effect and location, N source, time of application, and N rate as fixed effects. The optimum N rate and yield at the optimum N rate was determined from the N rate study by regression analysis using PROC REG and PROC NLIN models (SAS Institute, 2003). Economic-optimum N rates (EONR) were calculated with an N: corn price ratio of 0.13. Statistical significance was declared at $p<0.1$ unless otherwise indicated.

Results and Discussion

Incubation Study

Within the first 2 weeks of incubation at 80% FC, 74 and 87% of the N was nitrified for MAP and DAP, respectively (Fig. 1). Irrespective of N source, when soil moisture was below FC, the amount of NO_3^- was fairly constant for the rest of the incubation period. On the other hand, under water-saturated conditions, NO_3^- recovery dropped rapidly, especially during the first 2 weeks after soils were saturated. Similar results were observed for the 70 mg N kg^{-1} soil rate. These data indicate that N in MAP and DAP nitrified quickly at warm temperatures, and once N is nitrified, denitrification proceeded rapidly when soils are saturated with water.

Field Study

Weather and Soil Nitrogen

In Minnesota the soils were frozen from early December through late March in all 3 years while in Illinois, soils were frozen or at near freezing temperatures at the 4-inch depth during January and February of each year and in December 2004 and 2005 (Table 1). Temperature and precipitation were variable from year to year during the early spring and summer which impacted N loss potential and crop performance differently from year-to-year. A combination of warmer temperatures and wetter conditions than the average during some of the springs created very good conditions for leaching and denitrification, as it will be discussed later, while in other years the potential was very low.

Soil N levels in the field were largely unaffected by source of N or rate, thus the soil N recovery data presented were averaged across these variables (Fig. 2). Prevailing weather conditions in the early portion of the growing season were most important in determining N availability from the different times of fertilizer application, especially for fall applications. In general the spring application had greater potential for N recovery than the fall-applied treatments. For example, in Minnesota NH_4^+ recovery in early April from fall applications was very low in 2004, whereas recovery was approximately 30% in 2005 and 2006 (data not shown). Ammonium levels were low by late April in both 2005 and 2006, likely due to rapid nitrification under warm temperatures (Table 1), but NO_3^- recovery did not increase concomitantly, due to denitrification under warm, wet conditions or to leaching of nitrate to below sampling depth. Spring applications showed greater TIN recovery compared to fall applications, especially in 2005 when the spring application occurred in early May, later than in 2004 and 2006 (Fig. 2A). These findings indicate that reducing the amount of time between application and plant uptake could result in greater N recovery.

In Illinois, during the fall of 2003 there were low soil NH_4^+ and high soil NO_3^- levels (data not shown). In contrast, under similar average monthly temperatures in 2004 as in 2003, only 6 mg NO_3^- kg^{-1} was released during the first 20 days after application in 2004, compared to a release of 16 mg NO_3^- kg^{-1} in 2003, averaged across forms and rates of fertilizer. This differential carried through into April, with more NH_4^+ recovered in the top 6 inches of soil in the spring of 2005 than in the spring of 2004. Since by spring 2004 virtually all the fertilizer was nitrified, the trend in TIN recovery in Figure 2B mimics that for NO_3^-. Despite these differences in nitrification trends from the fall through the winter before the 2004 and 2005 cropping seasons, spring conditions were more important than winter conditions in determining recovery of applied N. March and April 2004 had excessive precipitation (Table 1) and little NO_3^- was recovered by mid-April; while drier conditions in 2005 provided low potential for denitrification and leaching and enhanced recovery of NO_3^- at a time when nitrification was taking place. Recovery trends for spring-applied fertilizer during the three years showed a rapid decline in NH_4^+ recovery concomitantly with an increase in NO_3^- recovery, reflecting nitrification (data not shown). Nitrification of the spring-applied fertilizer appeared to be essentially completed by the end of May in 2004 and 2006, while in 2005 nitrification continued into early June. Recovery of TIN by early June was low in 2004 and 2006 for both application times, probably as a result of substantial N uptake by the crop (Fig. 2B). In 2005, very low precipitation in May likely reduced both plant uptake of N and nitrate loss, resulting in greater TIN recovery in June. Greater NH_4^+ recovery in late April of all three years from spring- compared to fall-applied fertilizers seems to indicate that fertilizer applications in the spring could reduce the potential for denitrification or leaching by keeping the fertilizer in the NH_4^+ form during the spring, when N loss is typically most likely in the Midwest.

Nitrate recovery at the end of May from fall applications was about twice as great in a dry spring in 2006 relative to the previous two years (Fig. 3A). The dry spring in 2006 also improved relative recovery of the fall application compared to the spring application. Although no differences in percent TIN recovery were observed between fall applications in 2004 and 2005, substantially higher recovery of spring-applied N occurred in 2005 compared to 2004. Even though both years had periods with wet to saturated water conditions, the large difference was the result of less nitrification in 2005 since the soil remained mostly wet and cool between the time of N application and measurement of TIN. An additional factor may be that in 2005 the time elapsed between N application and soil TIN measurement was 15 days less than 2004. Nonetheless, these data show the impact early season weather conditions can have in the overall efficiency of fertilizers. The fact that N recovery was greater than 100% for the spring application in 2005 may also indicate that the fertilizer application had a priming effect in the mineralization of organic N present in the soil.

Soil TIN recovery was consistently greater for spring than for fall applications in Illinois (Fig. 3B). Regardless of the time of application, the largest fraction of the TIN recovered was NO_3^-. Although the early spring in 2004 was much wetter than in 2005, N recovery from the spring applications was similar for both years. Since 2005 was dryer, there was less nitrification potential as reflected in the larger proportion of NH_4^+ in TIN. Nonetheless, the fact that 2004 and 2005 had similar TIN is indicative of the fact that spring applications have greater potential for N recovery even when substantial nitrification had taken place. Conversely, wet conditions in 2004 likely caused nominal recovery of the fall-applied N, while dry conditions in 2005 helped increase recovery of the N applied in the fall. This finding indicates that spring-applied N has greater potential for recovery than fall-applications, and precipitation patterns in the spring have an important impact on the efficiency of fall N applications. Averaged across 3 years in Illinois, 35% of the fall-applied N was recovered as inorganic N compared to 90% for the spring application.

Grain Yield

In Minnesota, response curves generated from the full N rate studies indicated that the EONR from a spring application of AMS averaged across all 3 years was 137 lb N acre^{-1}, which produced a yield of 181 bu acre^{-1}. At this location, typical application rates (200 lb acre^{-1}) of MAP or DAP would have produced no yield reduction compared to the yield at the EONR, given that there was full recovery of TIN from the soil at the end of May. In Illinois, the EONR and the yield at the EONR were 138 lb N acre^{-1} and 179 bu acre^{-1} for fall AMS application and 158 lb N acre^{-1} and 192 bu acre^{-1} for spring AMS application. In typical field situations, in which MAP or DAP are a minor source of N, unrecovered N from the use of fall-applied MAP or DAP would reduce N supply at the flatter portion of the response curve. For this reason, N loss from fall-applied MAP or DAP would typically result in minimal impact on yield. Averaging percent soil N recovery in Illinois (data in Fig. 3B) indicated that from a typical application, 23 lb from a 36 lb DAP-N acre^{-1} application and 14lb from a 22 lb MAP-N acre^{-1} application were not recovered by the end of May following fall applications. Subtracting 23 and 14 lb of N from the EONR translated into a yield loss of 4 bu acre^{-1} (2.4% of the yield at EONR) for DAP and 2 bu acre^{-1} (1.3% of the yield at EONR) for MAP. Yield losses from loss of N from spring-applied MAP and DAP were very minor.

In Minnesota, source of N produced no significant yield difference. Yields were higher with N than without N, indicating that N was limiting in the study (Fig. 4). Averaged over the 3 years, the 80 lb N acre^{-1} rate produced 14% greater yield than the 40 lb N acre^{-1} rate. The response to application time was influenced by year. Spring applications resulted in 8% greater yield relative to fall applications in 2004 and 13% greater yields for the spring compared to the fall application in 2005. On the other hand, in 2006 fall-N application produced a 5% greater yield than spring application. Low precipitation during the early spring, when potential for N loss is typically greater, likely improved N recovery from the fall-applied fertilizers in 2006. Further, good growing season conditions likely induced substantial mineralization of organic nitrogen throughout the growing season resulting in the highest yields during this 3-year study. Percent TIN recovery at the end of May for the spring application in 2005 was 2.2 times higher than that of 2006 (Fig. 3A). However, the 2006 crop had overall better growing season conditions resulting in 24% greater yield for spring-N applications than the 2005 season (Fig. 4). This illustrates the fact that overall growing season conditions can overwhelm any N management effects or what may be expected in terms of grain yield by measurements of soil TIN recovery before rapid crop growth.

Corn grain yield in Illinois was not affected by N source or any of the interactions of main effects, but significant differences were observed for rate and time of application, thus the data were averaged across N source (Fig. 4). The 80 lb N acre^{-1} rate produced 15% greater yield than the 40 lb N acre^{-1} rate. Averaged over N rate and source, spring-N application resulted in a 7% yield increase relative to fall application. The fact that the 40 lb N acre^{-1} rate applied in the spring produced similar yields to the 80 lb N acre^{-1} rate applied in the fall for 2005 and 2006 indicates an advantage for spring applications. On the other hand, there was no yield difference for time of application in 2004. In 2004, growing-season conditions likely induced ample N availability by increasing mineralization of soil N. This likely compensated for the low N recovered from the fall application. The yield and TIN recovery data (Fig. 4 and Fig. 3B, respectively) illustrate that overall growing season conditions can overshadow the effect of early-season soil N status. For the spring application in 2004 and 2005, percent TIN recovery was very similar; but overall better growing season conditions in 2004 resulted in 46 bu acre^{-1} (32%) greater yields for spring-N applications than in 2005.

Conclusions

The incubation study showed rapid nitrification rates, regardless of whether the NH_4^+ was in MAP or DAP. Once in NO_3^- form, the rate of denitrification was influenced by soil water conditions. Nitrate concentrations remained constant in the soil if water content was below FC, but denitrification proceeded quickly once soils were saturated.

Soil inorganic N and grain yield were not affected differently by N source (DAP, MAP, and AMS) at both field locations. The fact that grain yield increased with increasing N rates clearly indicated that N was limiting in the study.

In general, agronomists have assumed that most or the entire amount of N from ammoniated phosphates is available to the crop the following year when applications are done late in the fall, when soil temperatures are low enough to slow nitrification rates. This study indicates that such an assumption is inaccurate in most years. At the end of May, fall-applied N recovery as inorganic N from the soil prior to the rapid N uptake period of corn was 31% in Minnesota and 35% in Illinois. In years in which soils are warm and become water-saturated after substantial nitrification of NH_4^+, leaching and denitrification can result in nearly all of the N from fall-applied MAP or DAP to be unrecovered. However, since a typical 200 lb acre^{-1} rate of MAP and DAP amounts to only 22 and 36 lb N acre^{-1}, respectively, the low recovery of N from a fall application would reduce N supply at the less responsive portion of the N response curve. Our results indicated that at most, the reduction from EONR yield is close to 3%. This study provides evidence that regardless of rate or source, the fate of fall- and spring-applied N is mostly impacted by weather conditions in early spring. Further, even if the early spring was conducive to lower N recovery, adequate crop-growing conditions for most of the remainder of the season compensated in part, likely through mineralization, for some of the unrecovered N from ammoniated phosphates in the early season.

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Table 1. Air temperature and rainfall for a 30-year period (averaged from1971 to 2000) and for the period fall-summer from fall 2003 to summer 2006 in Minnesota and Illinois.

	Minnesota								Illinois							
	Air temperature (°F)				Precipitation (inch)				Air temperature (°F)				Precipitation (inch)			
Month	30-yr	03-04	04-05	05-06	30-yr	03-04	04-05	05-06	30-yr	03-04	04-05	05-06	30-yr	03-04	04-05	05-06
Oct.	48.0	49.3	49.6	52.0	2.5	0.7	2.4	1.3	54.9	54.9	54.9	56.3	2.8	1.3	3.7	1.3
Nov.	31.8	32.0	37.4	36.3	2.3	1.2	1.2	1.8	41.9	45.1	45.5	44.1	3.5	5.0	5.2	3.7
Dec.	17.2	23.4	22.5	14.7	1.4	1.3	0.2	1.1	30.2	33.4	32.4	25.2	2.8	3.1	2.0	1.9
Jan.	11.3	17.2	14.4	26.6	1.4	0.4	1.1	1.0	25.0	24.4	28.2	38.3	1.9	2.2	6.2	1.8
Feb.	18.3	18.5	25.3	17.8	0.9	1.6	1.4	0.5	30.2	30.4	35.1	31.3	2.0	0.6	2.0	0.5
Mar.	30.7	36.3	29.8	31.8	2.5	2.8	2.9	2.8	41.0	44.4	38.7	42.3	3.2	7.8	1.7	3.5
Apr.	45.3	49.1	51.6	51.4	3.2	1.8	3.4	4.4	52.0	54.3	55.0	57.0	3.7	10.9	4.0	4.4
May	58.8	57.4	55.4	60.1	4.0	5.6	5.9	2.8	63.3	66.0	61.7	62.4	4.8	4.4	1.0	3.1
June	68.2	65.3	73.0	69.1	4.2	6.4	5.7	5.2	72.3	70.0	75.4	71.8	4.2	3.8	2.4	1.7
July	71.6	70.0	73.9	75.0	4.5	7.1	3.1	3.7	75.6	73.0	76.5	77.0	4.7	5.7	4.3	7.8
Aug.	69.3	64.6	69.6	71.1	4.6	5.7	4.5	5.1	73.6	68.7	76.1	74.3	4.4	3.6	2.2	3.0
Sep.	60.6	66.0	65.5	58.5	3.2	6.9	7.0	4.4	66.7	68.9	71.2	64.9	3.2	2.2	5.7	3.2
Total					34.7	41.5	38.8	34.2					41.1	50.4	40.4	35.8

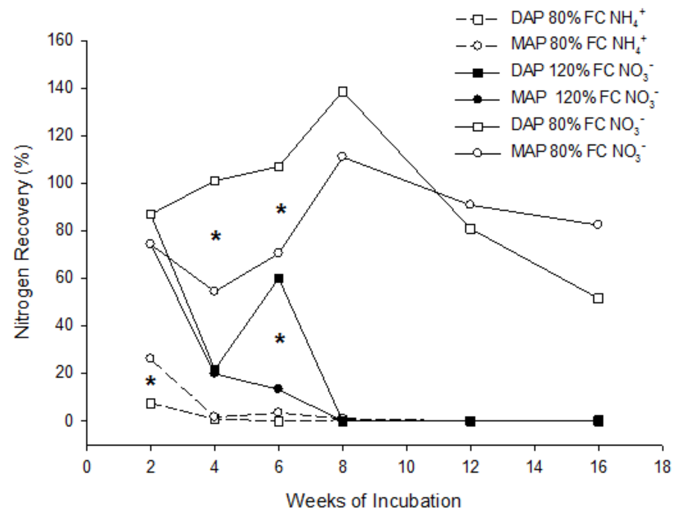

Figure 1. Apparent recovery of ammonium-N (NH_4^+-N) and nitrate-N (NO_3^--N) from soil receiving 140 mg N kg^{-1} from MAP or DAP incubated at room temperature at 80% or 120% field capacity (FC) water content. * Between two N recovery levels at a specific sampling time indicates a significant difference.

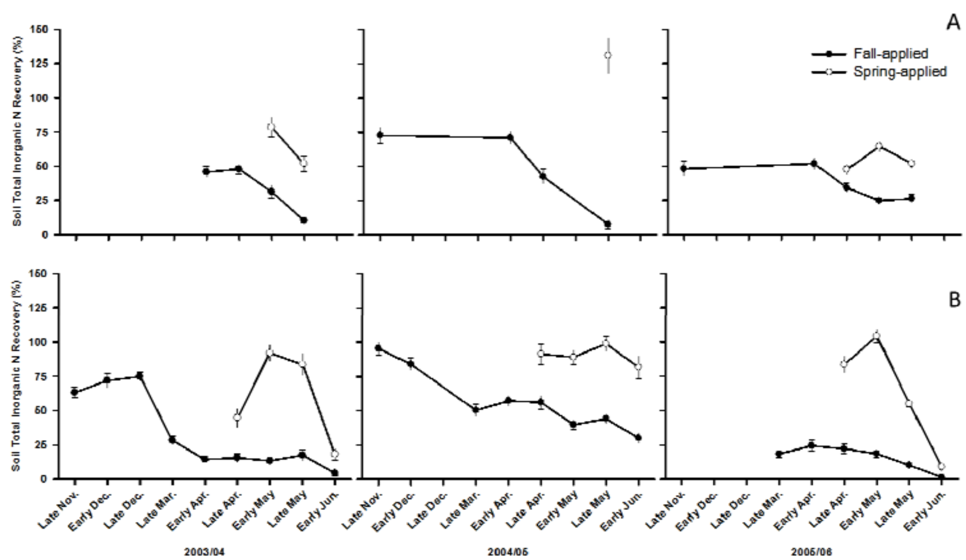

Figure 2. Apparent recovery of total inorganic N (ammonium plus nitrate) at different sampling times in the top 6 inches of the soil for three growing seasons averaged across N source and rate for fall and spring application times for Minnesota (A) and Illinois (B). Bars represent standard error of the mean (*n*=24).

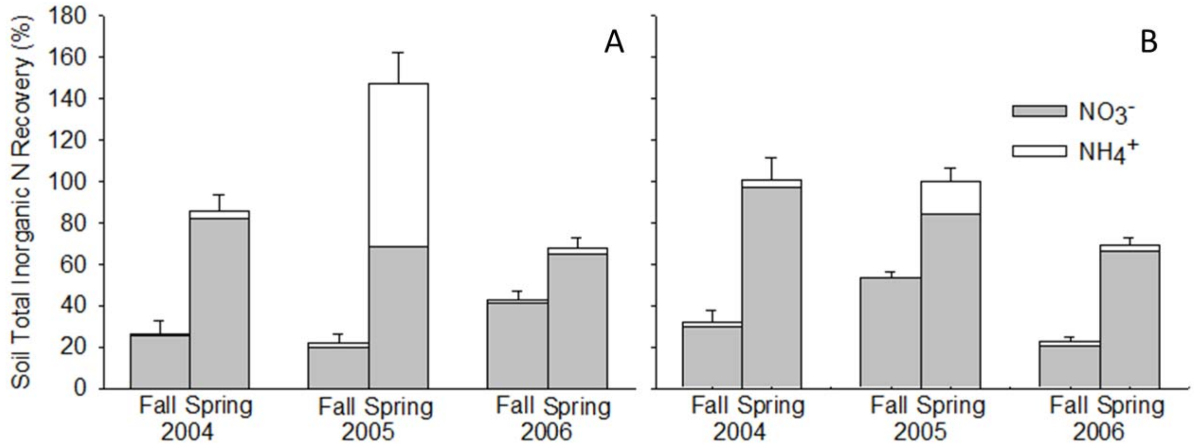

Figure 3. Apparent recovery of total inorganic N (ammonium plus nitrate) in the top 12 inches of the soil at the end of May for three growing seasons averaged across N source and rate for fall and spring application times for Minnesota (A) and Illinois (B). Bars represent standard error of the mean (*n*=24).

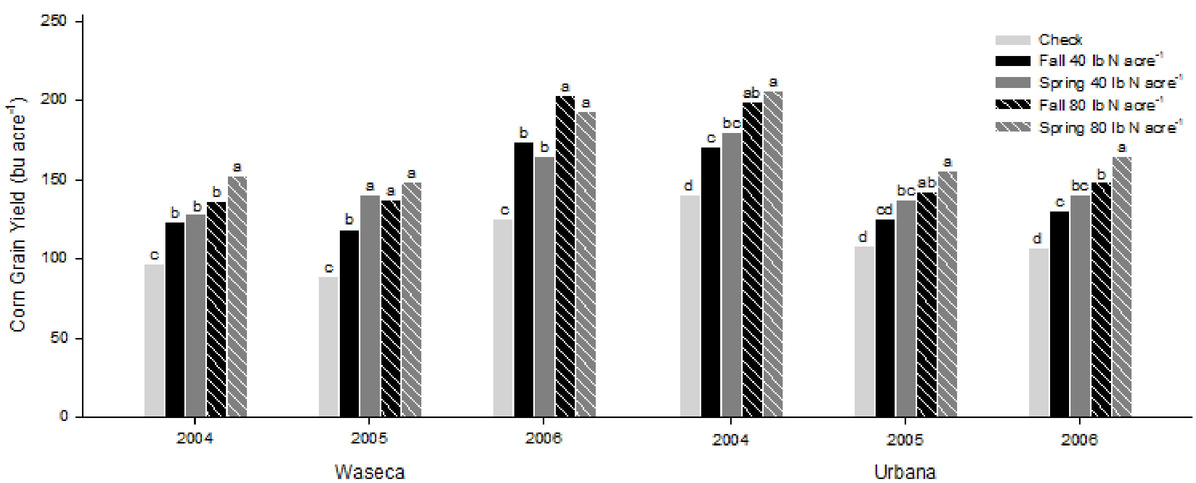

Figure 4. Corn grain yield in each year and location averaged across N source for the 40 and 80 lb N acre^{-1} rate and the fall and spring application times. Within location and year, yields with the same letter are not significantly different (p>0.05).

WATERSHED P INDEX INVENTORIES: AN EXAMPLE OF RUNOFF P LOSS RISK DISTRIBUTION IN TWO DRIFTLESS AREA AGRICULTURAL WATERSHEDS

Laura Ward Good[1], Pat Sutter[2], Curt Diehl[2], Katie Songer[3], Kim Meyer[4]

There are a number of projects underway in Wisconsin to investigate the relationship between field management and runoff phosphorus (P) losses and P loads from agricultural watersheds. This paper focuses on the field runoff P loss risk distribution found in one of those projects located in two similar watersheds within the Pecatonica River Basin.

The Pecatonica River pilot project is testing Wisconsin Buffer Initiative recommendations for using targeted strategies in small agricultural watersheds (5,000 to 25,000 acres) to achieve water-quality improvement goals (http://www.nelson.wisc.edu/people/nowak/wbi/). This small watershed scale was chosen as optimal for identifying nonpoint pollution sources, implementing strategies, and measuring success.

This is a paired watershed project with an experimental treatment and reference watershed. Both watersheds are approximately 19 mi^2 and have similar soils and topography. Within the treatment watershed, changes in management are being applied to a small percentage of area that is identified as contributing comparatively high levels of sediment or phosphorus to the stream. A second nearby agricultural watershed with similar soils and topography is being monitored as a reference. Although P losses from these two watersheds are not exactly the same, they are close enough to have similar weather and they have a similar pattern of P load response to rainfall and snowmelt. By comparing P losses at the watershed outlet over time, we will be able to determine whether field-level management changes on targeted areas produce significant changes in P loading in the treatment watershed. Monitoring is complemented with multi-disciplinary measurements and modeling to better quantify overland flow and in-stream delivery processes between fields and watershed outlets (http://wi.water.usgs.gov/surface-water/9ko46/) .

The first step in the project was to identify fields and pastures contributing high levels of dissolved or sediment-bound nutrients via runoff to streams using the Wisconsin Phosphorus Index (WPI, http://wpindex.soils.wisc.edu). The WPI uses routine soil test and field management information to estimate runoff phosphorus delivery from a field to a stream or lake under average weather conditions. It is calculated with software developed by the UW-Madison Soil Science Dept. (SNAP-Plus, http://www.snapplus.net) that also computes field erosion using the Natural Resources Conservation Service RUSLE2 model. To get the information needed to calculate the WPI required collecting soil samples on all fields and interviewing farmers to document field management. In the treatment watershed, a full inventory was completed and the WPI calculated on approximately 80% of the agricultural land in the watershed. A similar coverage was obtained for the reference watershed.

Wisconsin PI calculations of runoff P loss risk uses soil P, manure and fertilizer P application rates and timing, and estimated runoff and erosion. In these Driftless Area watersheds, most of the high runoff P loss risk areas resulted from a combination of comparatively high comparatively high soil test P and erosion. A broad range of soil test P values were found in both watersheds, with the highest values associated with cropland with a history of manure applications, continuously grazed pastures, and dry lots or night pastures (Tables 1). Erosion rates calculated with RUSLE2 also varied widely (Table 2). Many of the fields in these watersheds are on highly erodible land and the highest erosion rates were on tilled fields with rotations that included

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multiple continuous years of low residue crops such as corn silage. Many of the continuously grazed areas show evidence of erosion, but erosion estimates for these areas are not included in Table 2 because RUSLE2 calculations are not currently as accurate for them as for cropland.

Table 1. Average and range of soil test P by land use for two agricultural watersheds in southwestern Wisconsin.

Land use	Treatment watershed Acres soil sampled	Treatment watershed Average soil test P (Range)	Reference watershed Acres soil sampled	Reference watershed Average soil test P (Range)
		ppm		ppm
Cropland	3368	37 (5 - 384)	2623	36 (4 - 236)
Managed rotational grazing	57	42 (25 -72)	523	27 (8 - 97)
Continuous grazing	609	39 (7 - 348)	524	77 (9 -247)
Dry lots, night pastures	20	155 (32 – 348)	-	-
Grasslands	1048	23 (6 – 83)	191	23 (5 - 87)
Woods (may include grazed areas)	94	31 (13 – 59)	112	22 (18 -23)

Table 2. Average and range of estimated annual erosion rates for inventoried cropland and grasslands in two agricultural watersheds in southwestern Wisconsin.

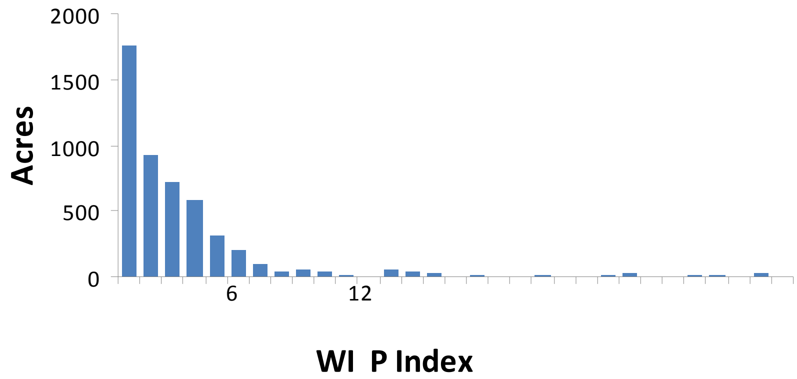
	Treatment watershed	Erosion (T/a) †		Reference watershed	Erosion (T/a) †	
Land use	Inventoried acres	Area weighted average	Range	Inventoried acres	Area weighted average	Range
Cropland	3400	2.4	0.1 – 19.9	2630	3.2	0.1 – 17.9
Grasslands-not grazed	1050	<0.1	0 – 0.2	190	<0.1	0 – 0.1

† Erosion was calculated on a field basis with the Natural Resource Conservation Service (NRCS) RUSLE2 program embedded in SNAP-Plus software (www.snapplus.net), following NRCS conservation planning guidelines.

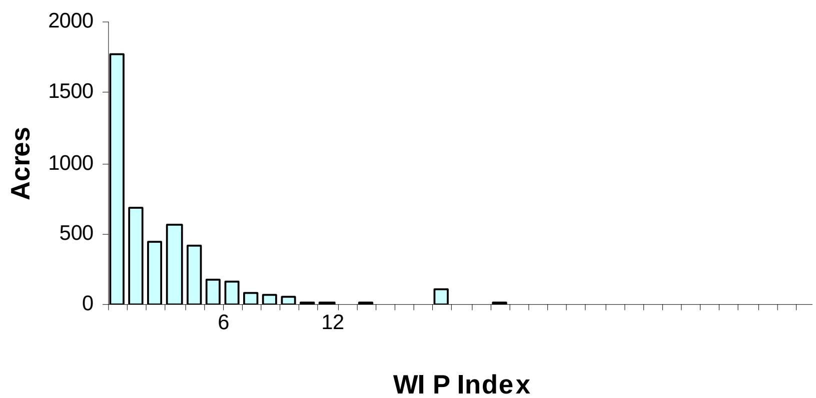
Only a comparatively small percentage of the inventoried lands in both watersheds had WPI values above the Wisconsin standard of 6, while the majority was below 3 (Fig. 1). This year, 2010, implementation of management practices to reduce erosion and P loss began on fields in the treatment watershed with WPI values above the standard.

Figure 1. Distribution of acres by baseline[1] rotational P Index values in the (a) treatment (5018 acres[2]) and (b) reference (4576 acres[2]) watersheds.

(a)



(b)



WI P Index category	Treatment watershed proportion of acres	Reference watershed proportion of acres
< 3	68 %	63%
3- 6	21 %	25%
> 6	10 %	12%

[1] Crop rotations in place for crop year 2007, the first year the watersheds were monitored.
[2] This includes all acres with complete inventories and soil sampling except for woods and continuously grazed (not rotational) pastures.

SOME THINGS TO CONSIDER FOR SHALLOW PLACEMENT OF ANHYDROUS AMMONIA

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Introduction

Correct nitrogen (N) management is essential for sustainable corn (*Zea mays* L.) production. While N fertilizer is an expensive input, this nutrient is critical since corn is in general very responsive to N fertilization. Proper N management is important not only in terms of profitability but also environmental protection. Anhydrous ammonia (NH_3) is an important source of N fertilizer in much of the US Corn Belt, with some states applying close to fifty percent of their N in this form. This source of N is injected in the soil during fertilization to reduce losses to the atmosphere. Nitrogen losses to the atmosphere have negative effects to the environment and represent a lost input to the farmer. For these reasons, there have been many studies conducted to determine the appropriate depth, speed, and soil conditions to minimize losses (Jackson and Change, 1947; Stanley and Smith, 1956; Baker et al., 1959; Wagner and Smith, 1958; Abo-Abda, 1985). There is growing pressure to move N application from fall to spring and sidedress times to try to reduce the potential of N loss. This pressure (which also shrinks time of application to a smaller time-frame) comes at a period when farm size is increasing, the use of no-till or other tillage systems with minimal crop-residue disturbance is desired for soil conservation purposes, and reduction in fuel consumption is important to reduce production costs and carbon emissions. All these factors makes it necessary to investigate the possibility of applying anhydrous ammonia with equipment that allows faster application, lower fuel consumption, and minimal disturbance of the soil. Applications at shallow depths, as long as ammonia losses are maintained at an acceptable low level, may be a possible way to achieve these desired outcomes. Recently, a high speed low draft (HSLD) applicator, most commonly known as John Deere 2510H, was developed to inject anhydrous ammonia at shallow depth with minimal soil disturbance. Our objectives were to: compare a prototype of the HSLD injection system to a John Deere conventional till knife (TRAD) applicator; to compare corn plant stand, growth, and grain yield response to the two application systems; and to evaluate the impact of ammonia application method, timing, and rate on plant N status and grain yield.

Materials and Methods

This study was conducted over three growing seasons (2007-2009), at three locations (Illinois, Iowa, and Kansas) in loam to clay loam soils depending on the year and location, with soybean (*Glycine max*. L. Merr.) as the previous crop. Corn was planted on 30-inch row spacing in plots 10 ft. wide by 50 ft. long with an additional 50 to 100 ft. to ramp-up tractor speed and

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ammonia flow to operating condi-tions before the treatment area. A factorial arrangement of the two anhydrous ammonia systems (TRAD and HSLD), three application times [late fall after bare soil temperatures at 4 inches below the surface were <50°F (FA) only in 2008-09, spring pre-plant (SP), and sidedress (SD)], and five N rates (0, 80, 120, 160, and 200 lb N acre^{-1}) was replicated four times in a split-plot arrangement with time of application as the main plot in a randomized complete block design. FA and SP applications were in-row (future corn row), while SD was between every other row around V4 development stage. It is important to note that since the sidedress was between alternate rows, the N rate was double per injection system knife. Anhydrous ammonia was applied at 7 inch depth and 6 miles hr^{-1} with the TRAD system and 4 inches and 8 to 10 miles hr^{-1} with the HSLD system.

Plant population was determined before sidedress application and again approximately 14 days after application in the same row areas as before. Plant height was also measured at that time. At approximately V10 development stage leaf N status was determined by different methods: SPAD meter (Minolta SPAD-502 meter), and NDVI (normalized difference vegetative index) with a Holland Scientific Crop Circle ACS-210 optical, active light, canopy sensor. In Kansas, N status was measured by chemical analysis of ear leaves collected at R1. Corn grain yield was determined by harvesting the center two rows of each plot with a plot combine, with yields adjusted to 15.5% moisture. Data were analyzed statistically using PROC MIXED of SAS (SAS, 2004) with location and year as random factors.

Results and Discussion

Across all site-years, corn was highly responsive to N fertilization (Fig. 1). The economic optimum N rate (EONR) calculated at 0.1 N:corn price ratio was 145 lb N acre^{-1} and the yield at EONR was188 bu acre^{-1}. We also observed that time of application has an important effect on corn yield. The EONR and yield at EONR was very similar between spring pre-plant and side-dress N applications (Fig. 2). These two application timings produced higher yields with lower N rates relative to the fall application time. This is likely because the longer the period between N application and absorption by the crop, the greater the chance that N will not be available for the crop. However, fall applications are often less expensive because they require less transportation and storage. They also provide logistical advantages such as generally better soil physical conditions in the fall to protect soils from compaction during fertilizer application, saving time in the spring and allowing early planting, and better distribution of labor and equipment. Since the loss potential of N is often greater with fall applications, measures should be taken to minimize such losses. Fall applications should be done only in soils and regions where potential for N loss are low. Fall N applications should not be done in soils that are sandy, organic, very poorly drained or excessively drained, or in regions where soils rarely freeze or the time lapse between 50°F and soil freezing is too long (Fernández et al., 2009). Also, nitrification inhibitors can provide additional protection against loss. However, the length of time that inhibitors remain effective in the soil also depends partly on soil temperature since warmer temperatures breakdown nitrification inhibitors more quickly. Nitrification inhibitors are normally most effective for fall applications or in wet springs for pre-plant applications (Fernández et al., 2009).

Across all site-years, we observed that the TRAD system allowed higher rates of application with less N loss compared to the HSLD system. While N losses from the highest rate of application produced a significant yield reduction (Fig. 3), the lower yield was not related to insufficient nitrogen availability since the application rate was above the averaged economical optimum N rate of 145 lb acre^{-1}. Further examination of the data indicated that the drop in yield was the result of seedling injury for the spring pre-plant application in 2008 and 2009 in Iowa (Fig. 4) and canopy damage by ammonia losses during sidedress application in Kansas in 2009 (Fig. 5). In Iowa there was visual seedling damage, root burn, and delay emergence due to ammonia toxicity with the HSLD system at the highest three N rates, while no problems were detected with the TRAD system. Thus, anhydrous ammonia applications, especially for spring pre-plant, should be avoided directly under the corn row with the HSLD system. The observed damage is likely the result of a very short distance between the point of ammonia release (4 inches) and the seed depth (2 inches). In the shallow anhydrous ammonia placement treatment it is possible that planting was done within the ammonia retention zone. Also, excavation of injection tracks visually showed less fracture of the soil and a smaller "void" at the point of injection with the HSLD system relative to the TRAD system. This would also increase the tendency of ammonia to move upward with the HSLD system. Ammonia losses with the HSLD system during sidedress application in Kansas were related to excessively high soil moisture content and smearing of the soil sidewall during application. These conditions produced substantial visual anhydrous ammonia gassing during application and plant tissue damage. In general, ammonia volatilization losses occur during—or soon after— application when the application is not fully retained in the soil by organic matter and soil water. Because anhydrous ammonia moves out into the soil until it is all dissolved in soil water, it is lost more easily from shallow placement. This problem was probably exacerbated by the fact that N rates per knife were doubled for the sidedress application (due to injection between alternate rows). Also, whenever there is a direct opening from the point of injection to the soil surface, some ammonia will escape to the atmosphere; thus, it is important to apply into soil conditions that allow full closure of the applicator track. In Kansas, post-application ammonia losses were quantified. Regardless of the time of application, the HSLD system had consistently greater post application emission losses at higher N rates than the TRAD system, especially when soil conditions were dry. Finally, in-season plant measurements across all site-years produced similar results to those previously noted for grain yield, thus these data are not shown.

Conclusions

We observed that while the HSLD allows faster speed of application and less horsepower requirements per opener, the shallow depth of injection could cause N loss and yield reduction when soil conditions are not near ideal for the application. Thus, while the HSLD system provides an alternative to the TRAD system, soil conditions and placement with respect to the crop row are important considerations, especially at high N rates. Applications should not be done near the seed-row and high N rates should be avoided, especially when applications are done on every other row.

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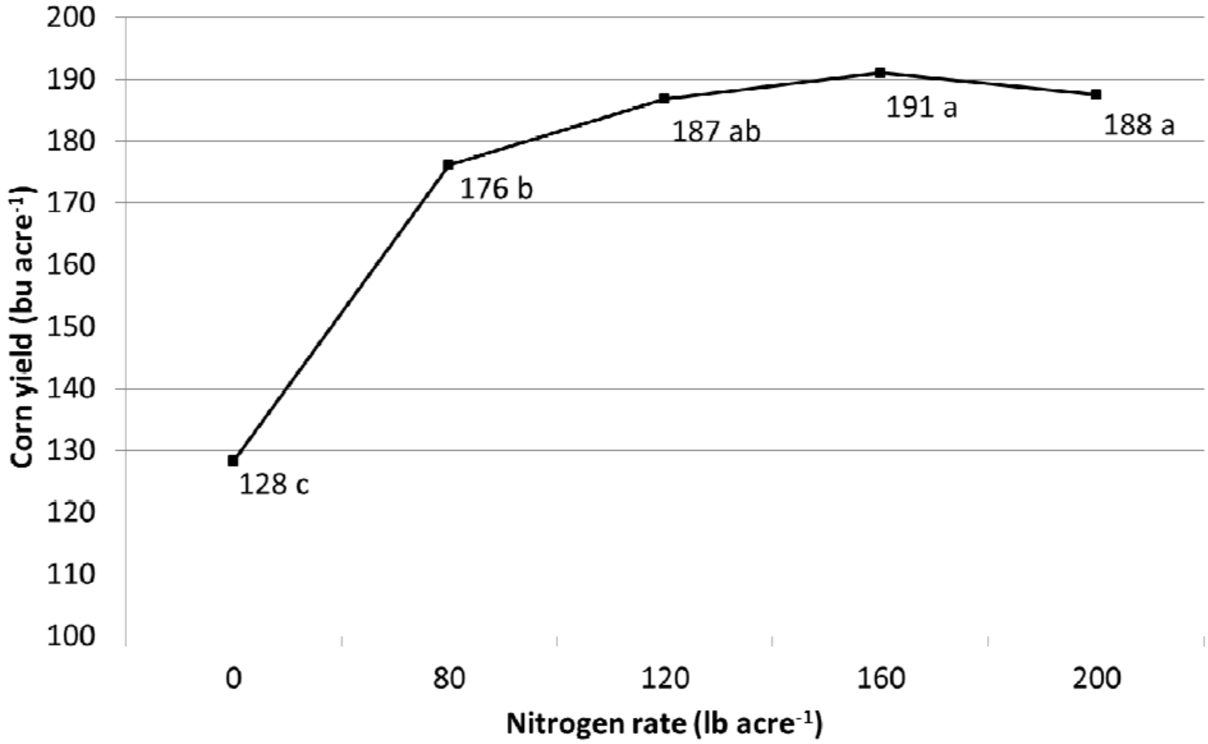


Figure 1. Corn response to nitrogen rate averaged over three years (2007-2009) and three locations (Illinois, Iowa, and Kansas). Values followed by the same letter are not significantly different *P*>0.05.

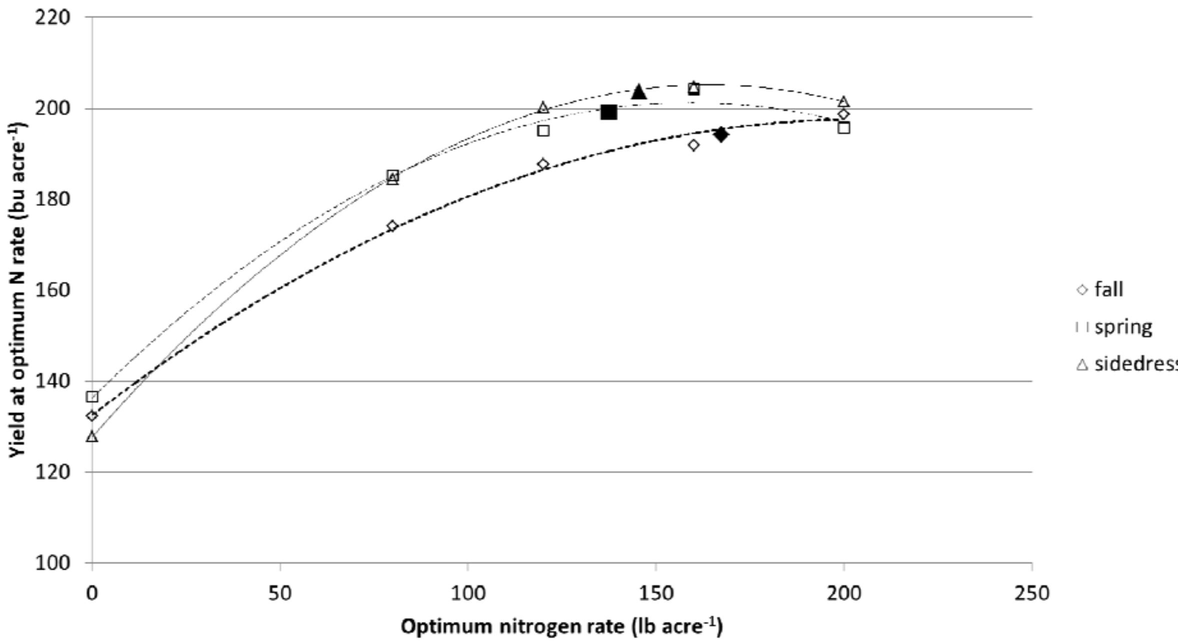


Figure 2. Corn response to nitrogen rate averaged over a 2-year period (2008-2009) as impacted by time of application. Open symbols represent actual data and closed symbols represent optimum points for the different application times calculated at a 0.1 nitrogen price:corn price ratio.

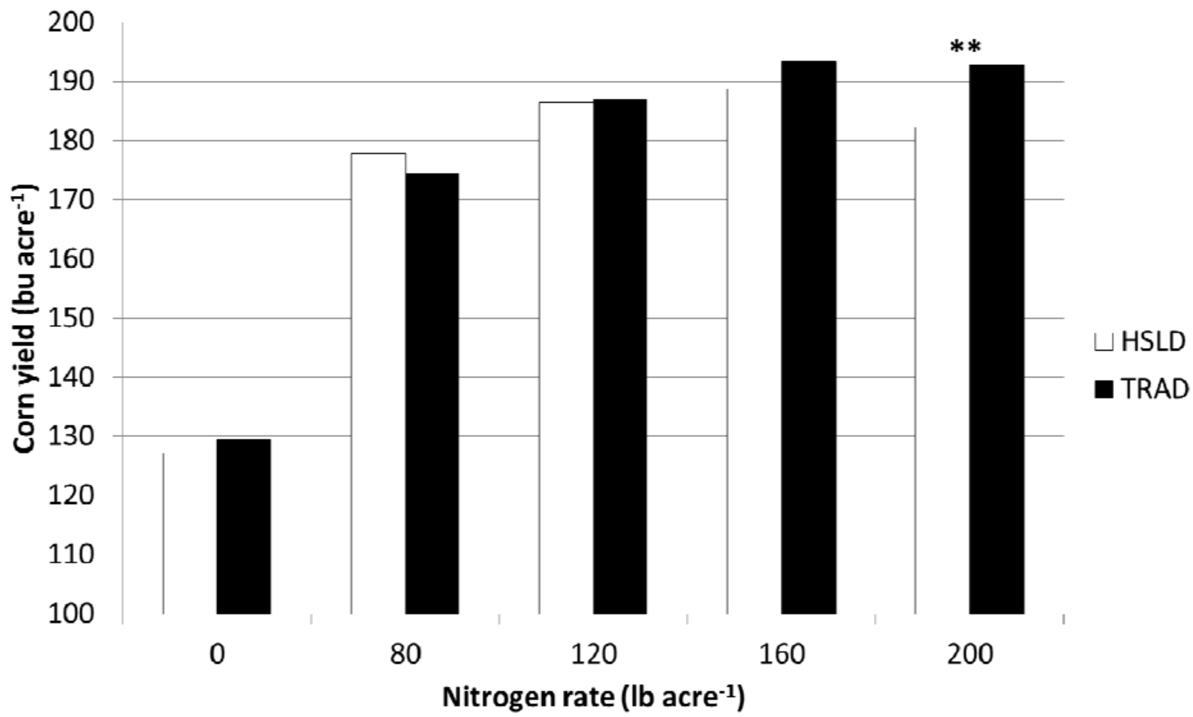


Figure 3. Corn yield averaged over 3 years (2007-2009) and three locations (Illinois, Iowa, and Kansas) as impacted by nitrogen rate and anhydrous ammonia application system [high speed low draft (HSLD) applicator and traditional anhydrous ammonia mole-knife injection (TRAD) applicator]. **Indicate treatment difference for the specific set of bars at *P*<0.05.

Figure 4. Seedling injury and root burn caused by spring pre-plant shallow placement of anhydrous ammonia with the high speed low draft (HSLD) applicator.

Figure 5. Gaseous losses of anhydrous ammonia during sidedress application with the high speed low draft (HSLD) applicator at the rate of 200 lb N $acre^{-1}$.

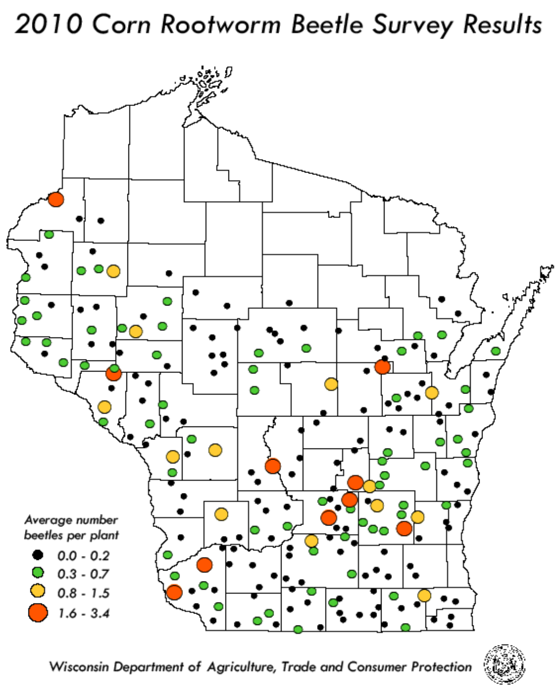
WISCONSIN INSECT SURVEY RESULTS 2010 AND OUTLOOK FOR 2011

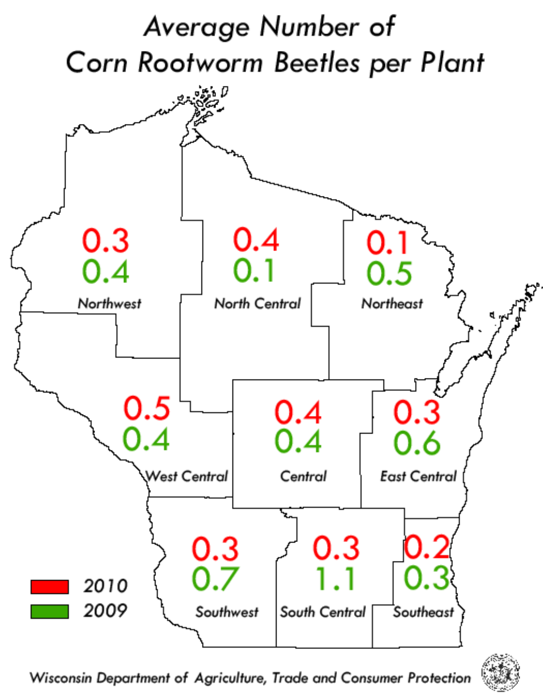
Krista L. Hamilton[1/]

Corn Rootworm

Beetle populations were the lowest in 40 years, according to the results of the annual survey in August. The state average of 0.3 beetle per plant is about half that of last season and the lowest since prior to 1970. District averages were uniformly low and did not exceed 0.4 beetle per plant. The most drastic reduction occurred in the south-central area, where the count decreased from 1.1 beetle per plant last year to 0.3 per plant in 2010. Economic populations of 0.75 or more beetle per plant were found in only 10% of the 229 evaluated fields, compared to 23% in 2009.

Excessive rainfall and dramatically increased use of Bt-rootworm corn hybrids accounted for part of this historic decline in beetle numbers. Aerial treatments of both corn and soybean fields with insecticides and fungicides for other pests also may have contributed to the decrease. The accompanying maps show the locations of the surveyed fields and the 2010 district averages.





European Corn Borer

Larval populations increased slightly in 2010. The fall abundance survey found a state average of 0.07 borer per plant in grain corn, a minor increase from 0.06 in 2009, but the third lowest average since 1942. The northeast, northwest, south-central and southwest were the only districts to show higher larval numbers. Population reductions were charted in the east-central,

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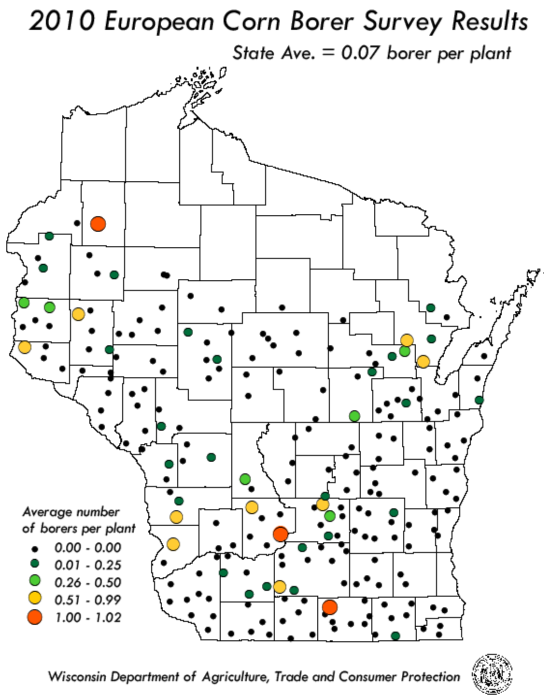
north-central and west-central areas, while averages in the central and southeast districts remained unchanged. The largest decline, from 0.09 per plant in 2009 to 0.01 per plant in 2010, occurred in the east-central district. Non-economic infestations were observed in 99% of 229 fields surveyed this fall and only 1% of sites had economic counts of 1.0 or more borer per plant. The low population entering the winter of 2010-11 serves as the base for a potentially small flight of moths next spring.



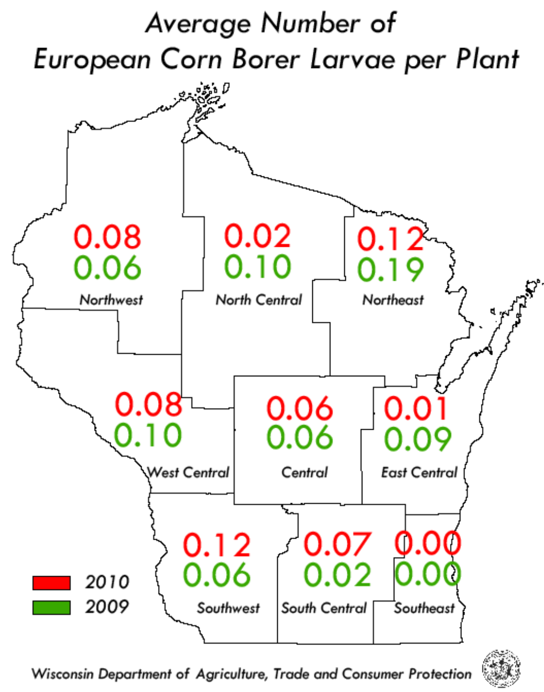


Table 1. European corn borer fall abundance survey results 2001-2010 (Average no. borers per plant).

District	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	10-Yr Ave
NW	0.33	0.44	0.20	0.13	0.01	0.27	0.24	0.12	0.06	0.08	0.19
NC	0.05	0.26	0.14	0.20	0.36	0.16	0.35	0.18	0.10	0.02	0.18
NE	0.07	0.75	0.23	0.22	0.33	0.23	0.07	0.12	0.12	0.19	0.23
WC	0.67	0.71	0.16	0.05	0.24	0.42	0.52	0.04	0.10	0.08	0.30
C	0.48	1.21	0.44	0.06	0.44	0.51	0.42	0.11	0.06	0.06	0.38
EC	0.33	0.44	0.20	0.22	0.25	0.11	0.21	0.20	0.09	0.01	0.21
SW	0.87	0.65	0.34	0.10	0.49	0.20	0.28	0.05	0.06	0.12	0.32
SC	0.48	0.86	0.51	0.05	0.67	0.38	0.33	0.07	0.02	0.07	0.34
SE	0.36	0.61	0.21	0.02	0.35	0.16	0.12	0.04	0.00	0.00	0.19
State Ave.	**0.40**	**0.66**	**0.30**	**0.10**	**0.40**	**0.29**	**0.31**	**0.09**	**0.06**	**0.07**	**0.27**

True Armyworm

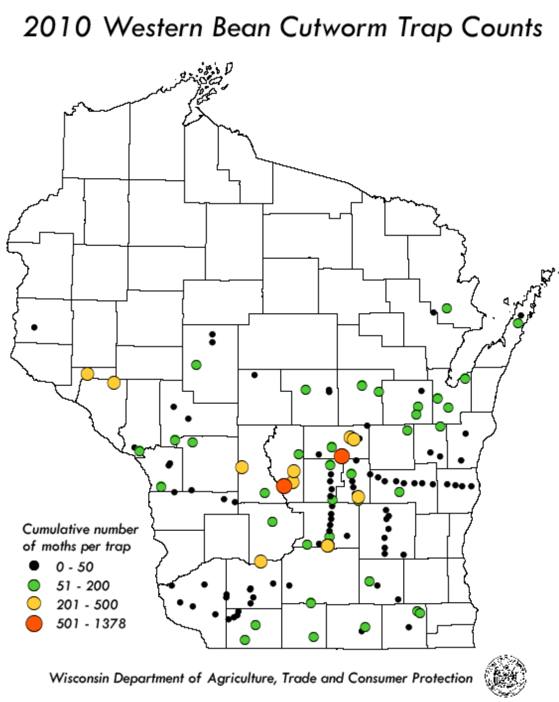
Larvae began concentrating in wheat and corn fields by June 16. Many thousands of acres, principally in the east-central and central counties, were treated with insecticides during the next two weeks. Based on reports from county extension agents and local cooperatives, areas of heaviest infestation occurred in wheat in Brown, Calumet, Fond du Lac, Green Lake, Washington and Winnebago counties, although numerous acres in Dane, Dodge, Manitowoc and Sheboygan counties were also affected. Generally the infested wheat had dense growth of annual grasses and was lodged from heavy rains. The armyworm outbreak subsided by July 2 due to pupation and chemical treatment of many fields. In most instances, the infestations were detected early and sprayed to prevent serious damage.

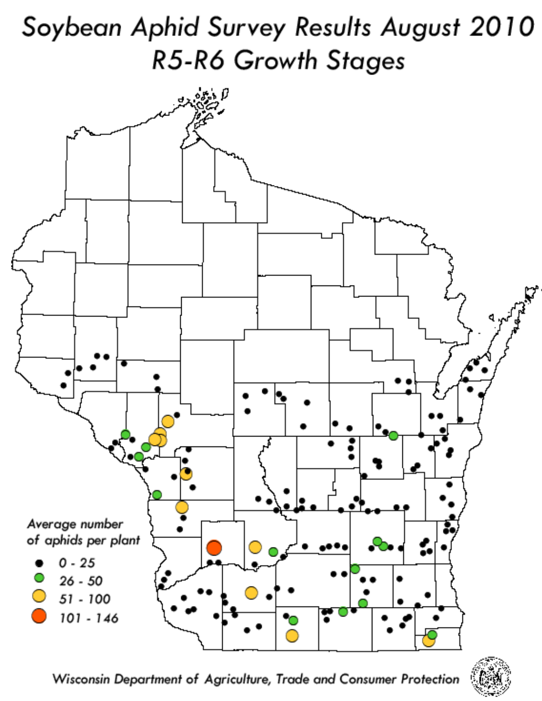
Corn Earworm

Moth collections increased sharply from July 20-27 and peaked by August 20. Four successive weeks of significant flights produced scattered infestations statewide, but control efforts by sweet corn producers mostly kept damage in check. On the basis of pheromone trap counts, the primary migration occurred earlier and was almost five times larger than that of 2009. The cumulative seasonal capture was 4,867 moths in 2010, compared to 990 moths in 2009, 5,624 moths in 2008 and 8,055 moths in 2007.

Western Bean Cutworm

The sixth annual trapping survey documented a 54% increase in western bean cutworm counts in the state, from 4,928 last year to 10,807 this season. Moths appeared in pheromone traps by June 17 and the first egg masses on corn were noted the following week. Larvae were present in scattered fields by mid-July. Approximately 5,000 acres of sweet corn were treated on July 22 in Adams County, where individual fields showed 10 to 32% of plants with eggs and small larvae. Other counties reporting problems were Columbia, Dane, Green Lake, Juneau, Marquette, Marin-ette, Monroe, Portage, Shawano and Waushara. Trap collections for most sites peaked from July 18-22 and activity subsided by mid-August. The western bean cutworm was again the most destructive pest insect of corn in Wisconsin.





Soybean Aphid

Populations in soybeans were the lowest since 2004. The annual survey found very low counts of less than 25 aphids per plant in 85% of fields, while only 15% showed moderate densities ranging from 26-146 per plant. Of the 168 fields examined, none had economic populations of 250 or more aphids per plant in July and August. The state average of 16 aphids per plant compares to 53 in 2009, 72 in 2008, 164 in 2007, 69 in 2006, 118 in 2005, 11 in 2004, and 758 in 2003. As illustrated in the map above, the higher populations were found mostly in the western half of the state. Abundant precipitation from June through August, unfavorably high temperatures, and natural enemies are thought to have suppressed aphid populations this season.

Table 2. Soybean aphid survey results 2003-2010 (Average no. aphids per plant).

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

Green Cloverworm

Damaging populations developed in soybeans throughout Wisconsin and the Midwest in 2010. Defoliation became pronounced by late July, and many fields in Grant, Green, Iowa, Lafayette, Rock and Walworth counties were treated at that time. Less serious infestations were reported or observed in all areas of the state in August. Damage moderated by late summer, and a less destructive brood of larvae occurred in September. Populations were the highest in many years.

A MULTI-TACTIC APPROACH TO MANAGING WESTERN BEAN CUTWORM

Dean S. Volenberg[1]

Since first being detected in 2005, Western Bean Cutworm (WBC), *Striacosta albicosta* (Smith) (Lepidoptera: Noctuidae) has become a pest throughout most of Wisconsin. WBC was first detected in corn in southern Wisconsin and by 2006 WBC had spread into several counties in the state. Populations are most prevalent south of highway 29/Interstate 94 based on 2010 pheremone trap captures (Pestwatch, 2010). Since WBC initial collection and identification (Smith, 1887) in the late 1800s in the western United States, the pest has continued to migrate both to the north and east.

WBC as the name implies was first found damaging dry beans in Colorado (Hoerner 1948). A number of years passed after the pest was identified in beans before WBC was identified as a pest in corn. Even after WBC was identified as pest in these two crops in mid-1940 (Crumb, 1956), migration to the north and east took a period of approximately 50 years. Today, the migration of WBC has hastened with many states each year adding WBC to their lists of new pests. The quickened pace of WBC migration may be the result of corn growers adoption of specific corn hybrids that have favored WBC over other corn earworm pests (Dorhout and Rice 2010). Regardless of migration, once WBC becomes established in an area, a number of tactics should be implemented to manage WBC. Before any management is implemented, a thorough understanding of WBC biology will greatly aid you in management.

Biology and Ecology of Western Bean Cutworm

The first stage of WBC that many corn growers are introduced to is the larval stage in infected ears. Like most other corn insect pests, WBC has four life stages: egg, larvae, pupae, and adult. Eggs are often laid on the upper leaf surface on corn leaves high in the crop canopy. The eggs go through three distinct color changes: creamy white, tan, and purple. WBC eggs in the purple stage will likely hatch within 24 hours. A large amount of variation exists in the number of eggs per egg mass, 20 to 200 is common. Although most egg masses are often found high in the corn canopy, egg masses can sometimes be found on the ear husk.

Newly emerged first instar larvae are extremely small (2 to 3 mm) and remain around the egg chorion for an extended period while feeding on the egg shells. Depending on the corn stage, pre-tassel or post tassel, larvae will either move upwards or downwards on the corn plant. In pre-tassel corn, larvae will move into the plant whorl and feed upon the developing tassel and young leaf tissue. In post-tassel corn, larvae will move downward to feed upon the ear silk. Some larvae will also move to other corn plants, resulting in multiple plant infections from a single egg mass.

Once larvae attain the third instar, they begin to move into and feed on the developing ear tips. If high densities of larvae are present, larvae may bore directly through corn husks and feed on developing corn kernels. At this point in WBC development, other plants can also serve as hosts to complete larval development. For example, the weed black nightshade (*Solanum nigrum*) is a suitable host for late instar development (Blickenstaff and Jolley, 1982).

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At the completion of larvae development in the corn ear, larvae drop to the ground and burrow into the soil and overwinter as mature larvae. Larvae begin to pupate when soil temperatures reach 50°F. Adult moths begin to emerge during the end of June with peak emergence typically occurring during the second and third weeks of July in southern Wisconsin. In northern growing regions, WBC peak emergence will occur in late July or early August.

The success of WBC overwintering is likely dependent on soil type. Anecdotal reports suggest that WBC populations are higher in crop fields planted on sand soils versus loam or clay soils. The greater success of WBC in sandier soils can be attributed to a higher percentage of larvae overwintering at deeper depths in sand type soils compared to soils containing a larger percentage of loam or clay soil types (Hein, 2000).

The Role of Corn Phenology

The life cycle of WBC is synchronized with corn development. Pre-tassel corn is the preferred corn stage selected by gravid adult females for egg laying. The pre-tassel stage can be defined as the period between the last leaf stage and VT. The VT stage is when 50% of the tassels have emerged. At the VT stage of corn development the first reproductive stage (silking) will occur in 2 to 3 days. A number of factors, including corn hybrid, relative maturity, planting date, and climatic conditions will impact when corn plants attain these stages of development. Corn development can be tracked by monitoring the number of growing degree days (GDD) that accumulate at base 50. For example, a corn hybrid with a relative maturity of 105 days planted on May 1 in southern Wisconsin will attain VT when approximately 1,200 growing degree days have accumulated. Although, corn phenology can be used to predict when corn is susceptible to egg laying, more direct techniques can be applied to monitor WBC.

Monitoring and Scouting

The adult moth of male WBC can be monitored using a pheromone trap. The trap attracts male moths using a lure that mimics a natural pheromone secreted by female WBC adults to attract a mate. The trap is easily constructed from a 1 gallon milk jug. For step by step directions for constructing a WBC trap, see A3856 Western bean cutworm: A pest of field and sweet corn (Cullen and Jyotika, 2008).

Traps should be installed on the edge of a cornfield around July 1 and monitored weekly. The trap captures will be more meaningful if the traps are monitored consistently; i.e. check traps on same day of the week. Replenish the trap solution weekly and replace the pheromone lure every 4 weeks.

The objective of monitoring adult moths is to determine peak moth flight. During peak moth flight the greatest number of eggs are laid. The pheromone trap provides a direct method to establish peak flight. An alternative to the pheromone trap is using a GDD model to predict peak moth flight.

Adult moth emergence can be monitored by tracking the number of growing degree days that accumulate. To track WBC emergence, begin counting growing degree days starting on May 1. Although you can calculate GDD simply (see Cullen and Jyotika, 2008) the degree day information is readily available from the University of Wisconsin Agricultural Research Stations online. If you choose to use GDD data from a research station, select GDD data from a research station located closest to your production fields. Relying on GDD data from distant locations will be inaccurate since a large variation in GDD exists between southern and northern corn growing areas. There are two important GDD periods for WBC:

1,320 GDD. Approximately 25% of WBC moths have emerged.
1,422 GDD. Approximately 50% of WBC moths have emerged.

If you are monitoring WBC with a pheromone trap, trap captures should peak at or around 1,422 GDD and this is called peak flight.

A major advantage of the degree day model to track WBC is that emergence can be tracked simply without entering the corn fields. One of the major drawbacks of relying just on the GDD model is that the level of pest pressure is unknown. WBC populations, like many other insect pests are known to pass through cycles. For example, WBC populations may be high one year and low the next. Only by monitoring a pheromone trap will you get an early indication of WBC pressure.

Scouting Corn

Scouting should begin once 1,322 GDD have been accumulated. If pheromone traps have been set out well in advance of 1,322 GDD and moths are present in traps, scouting should commence. In a field, 20 plants should be evaluated in five different locations. Scout fields in different stages of development separately. In pre-tassel corn, look for egg masses on the upper three or four leaves of each plant. Egg masses of WBC are small and vary in the number of eggs per mass. WBC egg masses can be confused with egg masses of some stink bugs. Stink bug egg masses differ from WBC egg masses, Stink bug egg masses start out white and turn brown, whereas WBC egg masses start out white, turn tan, and then purple. Corn fields planted with corn hybrids that are resistant to WBC and associated corn refuges should also be scouted for egg masses or small larvae. Fields should be scouted on a daily basis between 1,320 and 1,422 GDD. This span in GDD occurs normally over 4 to7 calendar days. Scouting should continue for at least another 7 days beyond peak emergence.

Thresholds of WBC in Field and Sweet Corn

Field corn should be treated with an insecticide if 5% or more of the 100 plants had an egg mass or small larvae. In sweet corn, an insecticide should be applied if 4% or more of the plants had egg masses or small larvae. Insecticides for control should be applied when corn is 95% tasseled. A listing of insecticides for managing WBC can be found in A3646 Pest Management in Wisconsin Field Crops. Timing of insecticide applications is critical to attain control of WBC. Corn needs to be treated before larvae enter the corn ear. Once larvae are within the ear, insecticide applications are no longer effective in controlling these larvae.

Conventional corn growers in Door County have been successfully managing WBC by applying insecticides when 1,422 GDD have accumulated and egg mass/small larvae thresholds are 5% or greater. The incidence of WBC ear damage was reduced by 90% in treated versus untreated corn in 2009.

Corn Hybrid Selection in Managing WBC

WBC can be managed by planting corn hybrids that have the Bt trait Cry 1F or Viptera trait Vip3A (DiFonzo and Cullen 2010). The Vip3A (vegetative insecticidal protein) has similarities to the Cry 1F toxin. Both the Cry and Vip toxins are proteins from *Bacillus thuringiensis* (Bt) and work by rupturing the gut of susceptible insects. Corn hybrids containing these traits are still susceptible to attack by WBC, especially when WBC pressure is high. Ear damage in corn hybrids containing Cry 1F is likely the result of loss of the traits being expressed as the plant starts to senesce. In corn, the level of the Cry 1F protein is higher during vegetative growth through pollen shed and declines with corn senescence. The concentration of the Cry 1F protein is highest in the corn stalk, followed by pollen, then leaf, and lastly the corn silk (U.S. Environmental Protection Agency 2001). WBC that hatch late in the vegetative stage or beginning of the reproductive stage of corn development, would likely be exposed to lower concentrations of the Cry 1F protein. Bt toxins targeted against WBC are not 100% effective, corn with the Cry 1F trait is 70 to 90% effective against WBC.

Some Corn is More Susceptible to WBC

All field corn and sweet corn is susceptible to attack by WBC, yet some corn is more susceptible than others. Late planted corn is more prone to a WBC infestation than corn that is planted earlier (Holtzer 1983). Corn planted late will more likely be at the pre-tassel stage of development when WBC is at peak flight. Also, corn with a long relative maturity, planted often for silage in a shorter relative maturity zone, will likely be at the vulnerable pre-tassel stage at or near peak WBC flight. Late plantings of sweet corn are also more prone to WBC attack.

Multi-tactic Management of WBC

Monitoring, scouting, and using corn hybrids with resistance to WBC should be used together to manage WBC. Corn hybrids that are resistant to WBC offer a first line of defense, but these hybrids are still susceptible to WBC attack. High WBC pressure in WBC–resistant corn may need to be treated if pest densities meet or exceed thresholds. Refuge acres also need to be monitored and scouted for WBC. Monitoring pheromone traps will indicate when peak flight has occurred and give an indication of WBC pest pressure. Scouting corn for the presence of WBC egg masses or small larvae will determine whether the corn should receive an insecticide treatment.

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CROPPING SYSTEM EFFECTS ON SOIL QUALITY

Bill Jokela[1]

What is Soil Quality?

Soil quality, or soil health, has been defined as "the capacity of a specific kind of soil to function within natural or managed ecosystem boundaries to sustain plant and animal productivity, maintain or enhance water and air quality, and support human health and habitation" (Karlen et al., 1997) or, more simply, the ability of a soil to perform functions that are essential to people and the environment (D. Karlen, personal communication, 2009). Whatever the specific definition, the goal is to manage soils so as to assure long-term productive and environmental sustainability. Soil does this by performing five essential functions: nutrient cycling, water relations, biodiversity and habitat, filtering and buffering, and physical stability and support (Andrews et al., 2004).

People have different ideas of what a quality soil is. For example (USDA-NRCS, 2010b):

- Farmer: sustaining or enhancing productivity, maximizing profits, and maintaining the soil resource
- Consumers: producing plentiful, healthful, and inexpensive food
- Naturalists: soil in harmony with the landscape and its surroundings;
- Environmentalist: soil functioning at its potential in an ecosystem with respect to biodiversity, water quality, nutrient cycling, and biomass production.

These views of soil quality may be too narrowly defined. For example, most farmers recognize the importance of managing soils for conservation and environmental protection, as well as production. But they do point out the different soil functions and individual perspectives on soil quality.

How Can We Assess Soil Quality?

Farmers and others who work with the land often have a personal view of soil quality based on their own experience, for example, the soil is productive, or the soil has "good tilth". Soil scientists in several states have attempted to provide a more systematic approach to experience-based soil quality assessment by developing soil quality score cards. (e.g., the Wisconsin Soil Health Scorecord at http://www.cias.wisc.edu/wp-content/uploads/2008/07/soilhealth_screen.pdf)

For those interested in performing in-field measurements themselves, a Soil Quality Test Kit Guide available from NRCS describes procedures for 12 on-farm tests, an interpretive section for each test, and instructions on how to build your own kit or where to purchase one (USDA-NRCS, 2010c). The UW-Extension Soil Management Team has conducted numerous soil quality field days and demonstrations of the Soil Quality Test Kits in many counties of the state.

Analysis of many soil properties that serve as indicators of soil quality are conducted at a number of university and research labs. Results from selected research studies along with their interpretation for soil quality assessment are summarized in the following sections of this article.

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What Soil Properties Are Indicators of Soil Quality?

Soil quality assessment includes use of standard soil fertility tests for pH and essential nutrients, but it requires a range of other tests to measure physical and biological, as well as chemical, soil properties (Fig. 2).

Chemical (available or harmful)
- pH
- Extractable P, K, other nutrients
- EC (electrical conductivity)
- SAR (sodium adsorption ratio)

Physical – (soil structure, soil strength, water)
- Aggregate stability (water-stable)
- Bulk density, penetration resistance
- Available water capacity
- Water-filled pore space

Biological (biological activity or function)
- Organic matter or total organic carbon
- Active soil carbon
- Potentially mineralizable nitrogen
- Microbial biomass

Figure 1. Typical soil property analyses included in soil quality assessment.

Central to the effects of various cropping systems on soil quality is accumulation of soil organic matter, or soil organic carbon, because it affects many of the other soil properties and processes important for soil quality. Organic matter accumulation can improve soil quality by decreasing bulk density, surface sealing and crust formation, and by increasing aggregate stability, cation exchange capacity, nutrient cycling, and biological activity. Soil organic matter can be affected by the quantity and type of carbon input from crop biomass and manure and by practices such as tillage that affect the decomposition rate and stratification of soil organic matter (Weil and Magdoff, 2004).

How Can We Interpret Soil Property Measurements as Indicators of Soil Quality?

Soil properties can be measured using in-field or laboratory procedures, but soil quality assessment requires quantifiable science-based interpretation. Several soil quality indexes have been developed to interpret individual soil tests and to combine those into an overall soil quality index. Examples are the Soil Conditioning Index (SCI), the Soil Management Assessment Framework (SMAF), and the Cornell Soil Health Assessment.

The Soil Conditioning Index (SCI) is a tool used by the Natural Resources Conservation Service to predict the effect of a particular cropping system and associated practices on change in soil organic matter content (USDA-NRCS, 2010a). An SCI score between -2 and +2 is calculated based on 1) the amount of organic material returned to the soil, 2) the effects of tillage and field operations on soil organic matter decomposition, and 3) predicted erosion. A negative SCI value indicates that a decrease in soil organic matter is expected, whereas a positive value indicates an increase in organic matter over time with that cropping system.

The Soil Management Assessment Framework (SMAF) is a tool for assessing the impact of management practices on soil functions associated with management goals of crop productivity, waste recycling, or environmental protection (Andrews et al., 2004). Specific soil properties, or indicators, are transformed via scoring algorithms into unitless scores (0 to 1) that reflect the level of function of that indicator, with 1 representing the highest potential. The nonlinear scoring algorithms take one of three general shapes—more-is-better, less-is-better, or midpoint optimum (Fig. 2). The SMAF user is directed to select between four and eight indicators, representing physical, chemical, and biological properties.

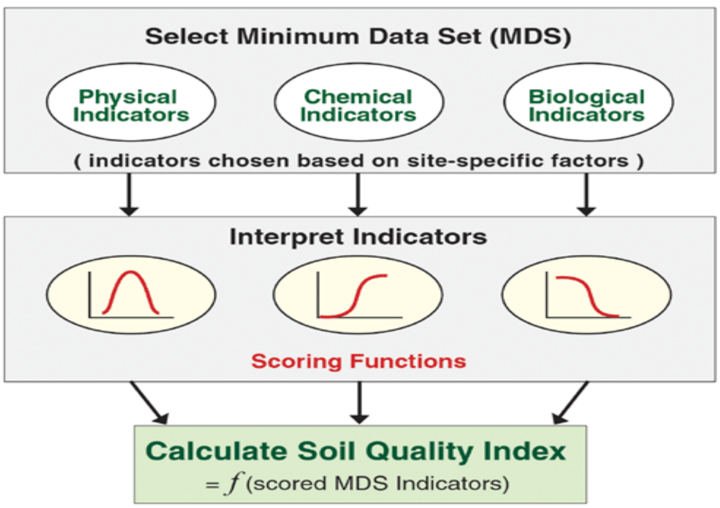

Figure 2. Conceptual framework for the Soil Management Assessment Framework (SMAF; Andrews et al., 2004; D. Karlen, personal communication, 2009).

The Cornell Soil Health Test is a program established in 2007 that includes testing soils for a range of chemical, physical, and biological indicators (particle size distribution and texture, wet aggregate stability, available water capacity, soil hardness, or penetration resistance, organic matter, active carbon, and a standard fertility test) and a comprehensive soil health assessment (Idowu et al., 2009; http://soilhealth.cals.cornell.edu/extension/test.htm).

How Do Different Cropping Systems Affect Soil Quality?

Cropping systems can affect a range of soil properties depending on the specific crop rotation, nutrient amendments, and tillage practices employed. Over time this can result in soil quality degrading, improving, or being maintained. Midwest cropping systems include a variety of crops and crop rotations -- continuous corn, short rotations of corn with soybean or other annual grains, or longer rotations that include multiple years of perennial forages. Karlen et al. (2006) evaluated crop rotations at three locations in Iowa and Wisconsin and found that longer rotations with at least three years of perennial forage and, in some cases, manure application generally had more total organic C, water-stable aggregates, and microbial biomass C than shorter corn-based cropping systems, resulting in higher SMAF soil quality indexes. They found that total organic C was the most sensitive indicator for detecting soil quality differences among cropping systems. In a regional study, Wienhold et al. (2006) found that combining more diverse crop rotations with reduced tillage and less frequent fallow periods improved soil function at several sites throughout the Great Plains.

Two recent studies in Wisconsin evaluated a range of physical, chemical, and microbial soil properties in two separate field experiments – a 4-year trial with various cover/companion crops in no-till silage corn (Jokela et al., 2009) and the long-term (18-year) Wisconsin Integrated Cropping Systems Trial (WICST; Posner et al., 2008; Jokela et al., 2010). Extractable P and K, pH, total organic C, total N, active soil C, potentially mineralizable N, water-stable aggregates, bulk density, penetrometer resistance, and total microbial biomass were measured, and the SMAF soil quality index was calculated.

Corn silage is an integral part of most dairy cattle rations, but removal of both grain and stover for silage increases the risk of soil degradation because of the limited amount of biomass returned to the soil and the lack of crop residue to protect the soil from erosion and runoff. Cover, or companion, crops may be one option to improve the sustainability of silage production. In the no-till silage corn trial referred to above soil samples were collected from treatments of silage corn grown with a living mulch of kura clover, interseeded red clover or Italian ryegrass, September-seeded winter rye, and no cover crop, all with spring-applied liquid dairy manure (Jokela et al., 2009). Use of companion/cover crops in silage corn resulted in more microbial biomass and in improvement in physical conditions, as reflected by more large water-stable macroaggregates and lower bulk density, especially in the surface 2-inch soil layer. Cover crop treatments had more active soil carbon and a nonsignificant trend for greater soil organic matter. These effects on soil quality indicators produced higher SMAF soil quality indexes from most companion/cover crop treatments, especially in the upper soil layer.

In the WICST experiment (Jokela et al., 2010) soil was sampled in the fall following the corn year of three grain-based systems, after both corn and alfalfa in two forage-based systems, and in a grass-legume pasture (Fig. 3). Results showed that different long-term cropping systems had significant effects on most chemical, physical, and microbial soil properties (soil quality indicators), primarily the effect of crop type and rotation, manure addition, and intensity of tillage (primary/secondary tillage and mechanical weed control). In particular, the intensively managed grass-legume pasture was higher in most soil quality indicators (microbial biomass, organic carbon, total nitrogen, readily available nitrogen and carbon, and aggregate stability) than all other corn or forage-based systems and had a significantly higher SMAF soil quality index. The alfalfa-based systems had higher levels of the carbon, nitrogen, and water-stable aggregate variables, but also higher bulk density, in one or both depths than did the grain-based systems. There were only small, nonsignificant differences in soil quality index values. These results suggest that, while there were differences in most soil quality indicators, when well managed, all of the cropping systems maintained acceptable soil quality on these productive, high organic matter, prairie-derived soils.

In summary, results of several Midwest cropping system trials showed that soil organic matter and various other soil properties are affected by the specific management practices and crop rotations of each cropping system. Mixed grass-legume pasture or, in most cases, incorporation of companion/cover crops or perennial forage crops into a grain-based rotation improved soil properties and overall soil quality, as measured by a soil quality index. The management level and inherent soil characteristics are important factors and can affect the sensitivity of soil quality to cropping systems.

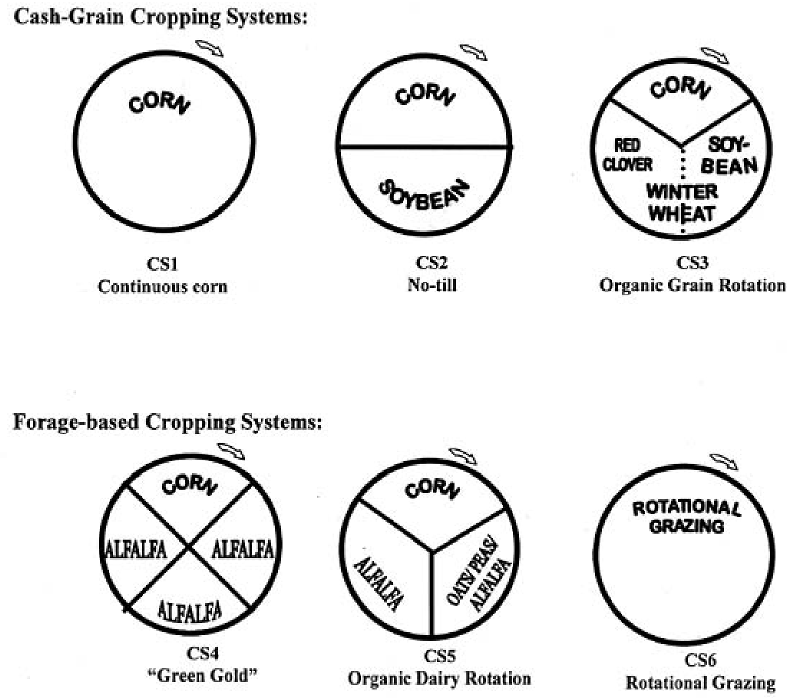

Figure 3. Schematic diagram of the WICST cropping systems (Hedtcke and Posner, 2010).

Management Strategies to Maintain or Improve Soil Quality

Based on practical experience and the results of research trials such as those reported here, several management strategies have been proposed to improve soil productivity, environmental protection, and overall soil quality (USDA-NRCS, 2010b; Magdoff and van Es, 2009).

- Enhance organic matter by adding diverse sources of organic materials to the soil
- Avoid excessive tillage
- Manage soil fertility to maintain optimum pH and nutrient availability
- Prevent soil compaction and maintain good soil structure
- Maintain good ground cover with crop residue, cover crops, or perennial forage rotations
- Diversify cropping systems

The specific practices within each of these management components will vary with the soils, climate, and farming system of a particular situation, but the principles apply to all cropping systems.

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UPDATING WISCONSIN INOCULANT RECOMMENDATIONS[1]

Branden Furseth and Shawn P. Conley[2]

Rhizobia are responsible for biological nitrogen fixation (BNF) when in symbiosis with a host legume such as soybean. Though evidence suggests that legumes prefer to use mineralized sources of nitrogen (N) in the soil before spending energy on a symbiotic relationship with rhizobia, total plant N derived from BNF is typically between 25 and 75% for soybean (Zapata et al., 1987). Rhizobia inoculant application is the primary strategy employed by soybean producers to promote adequate levels of BNF. Inoculant recommendations differ by state and are largely driven by crop history. Conley and Santini (2007) conducted a survey of 1,134 farmers in Indiana and found 18% to use rhizobia inoculants. Wisconsin inoculant use was shown to be much higher, at 85% (n=168) (Conley, unpublished data, 2008).

Inoculants have been thoroughly evaluated during the previous 50 years, but their effectiveness remains unclear. DeBruin et al. (2010) evaluated 51 inoculants across 73 environments (five states) between 2000 and 2008. Yields responded positively to inoculation in 6 environments, negatively in 4 environments, with the remainder showing no response. Across all environments and products, the yield response to inoculation was not different from zero. Upon economic evaluation they found that for the 10 most widely used products, the probability of breaking even on investment ranged from 6 to 85%.

Thies et al. (1991) surveyed rhizobia populations prior to planting and found little to no yield response to inoculation at rhizobia populations above 100 cells g^{-1} soil. Moderate responses were observed between 10 and 100 cells g^{-1} soil, while the greatest responses occurred below 10 rhizobia g^{-1} soil. Rhizobia populations are maintained over time if soybean is regularly incorporated into the crop rotation. Across seven locations in Iowa, soils with a recent history of soybean were been shown to contain an average of 316,000 cells g^{-1} soil (Berg, 1988). With most Midwestern production land in a corn – soybean rotation, the likelihood of positive responses to inoculation decreases. Our goal for this research was to increase the predictability of a positive response to seed inoculation on a site by site basis.

Soybean Response to Rhizobia on Previously Flooded Soil

Prior to planting in 2009, many farmers were concerned with the viability of rhizobia following the long term flooding events of 2008. To address this concern, three rhizobia inoculants were evaluated on soils near Watertown, WI which had been flooded for a minimum of three weeks during 2008. The experiments were conducted at 3 locations, each arranged in a randomized complete block with 6 replications. Due to the unique nature of flooding events, this experiment was only conducted during 2009. Table 1 summarizes the results of this experiment.

Seed yield, protein content, and oil content did not positively respond to the rhizobia seed treatments. Seed treatments did not have any effect on the change in rhizobia population from the spring to fall (data not shown). These results suggest that the flooding events of 2008 were not detrimental to the soil rhizobia population at these sites. Though the use of inoculants did not provide any advantages in our study, farmers need to evaluate each situation by considering the source of any sediments and residue deposited by flood waters.

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[1] Funded by the Wis. Soybean Marketing Board and the Univ. of Wisconsin-Madison College of Agriculture and Life Science.
[2] Research Assistant and State Soybean and Small Grains Extension Specialist; Univ. of Wisconsin-Madison.

Table 1. Mean seed yield, protein and oil content across four rhizobia seed treatments on soil which had been previously flooded

Inoculant[1]	Seed Yield kg ha^{-1}	Protein g kg^{-1}	Oil g kg^{-1}
Untreated	57.8	33.6a[2]	18.9
Cell Tech®	57.7	33.6a	18.8
Excalibre™	57.4	33.5ab	18.8
Optimize®	55.3	33.3b	18.8
LSD(0.05)	NS	0.20	NS

[1] Cell Tech® and Optimize®, EMD Crop BioScience; Excalibre™, Advanced Biological Marketing
[2] Within columns, means followed by the same letter are not significantly different according to LSD (0.05)

Response of Soybean to Rhizobia across Wisconsin

In addition to the study of rhizobia on previously flooded soils, we conducted an evaluation of inoculants at nine locations throughout Wisconsin during 2009 and 2010. Two inoculants, Excalibre™ (Advanced Biological Marketing) and Optimize® (EMD Crop BioScience), were compared to a non-treated control on three soybean varieties each year. Since the 2009 season was quite different from 2010, year and location were merged into one environment variable for data analysis. Therefore, means were evaluated across 18 environments, as opposed to nine locations in each of 2 years.

Across all environments, inoculant treatment did not affect seed yield at the α=0.05 level. However, yield did respond to inoculant treatment at the α=0.10 level. Means were separated using Fisher's least significant difference (α=0.10). Optimize® resulted in yields which were higher than the non-treated control, but not different from Excalibre™. Yields from the Excalibre™ treatment were not different from the non-treated control (Fig. 1). These results suggest that the use of rhizobia inoculants may result in a yield advantage in Wisconsin. We are still evaluating the predictive response of soybean to pre-plant rhizobia populations. These data will be presented at the 2011 WCMC. Ultimately producers need to consider product efficacy, their environment and cropping history when deciding to use inoculants in Wisconsin.

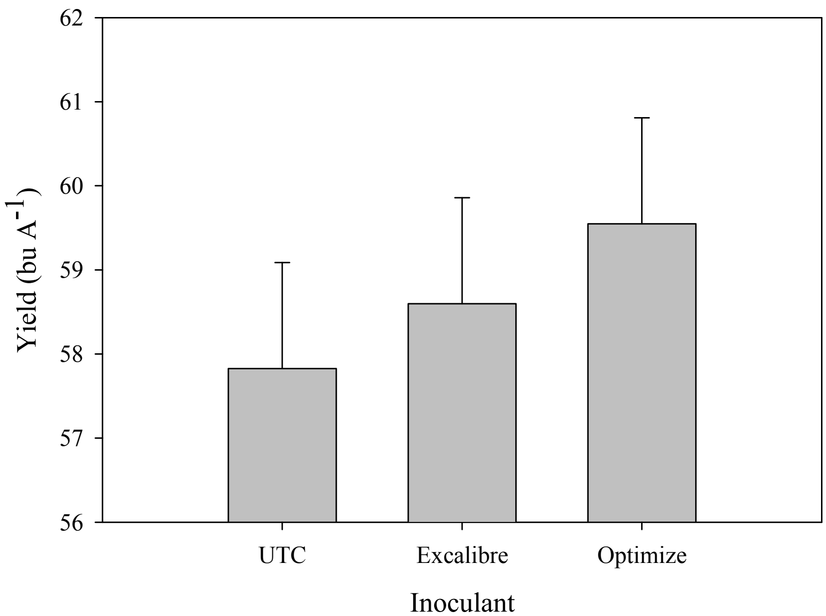

Figure 1. Soybean yield response to rhizobia inoculants. Yield responded to inoculant treatment at α=0.10 (*P*=0.08). Fisher's least significant difference (LSD) (α=0.10) is 1.3 bu A^{-1}

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REFLECTIONS ON 40 YEARS OF PLAYING IN THE DIRT

Fred Madison [1/]

What's changed in 40 years? Certainly not the soils! What about the soil scientist? Let's take a few minutes and review the learning process, the application years and what is there about the soils in Wisconsin that is worth passing on. Has it all been worth it?

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SELLING TRACTORS AND SOIL TESTING IN INDIA

John Peters [1/]

Introduction

The Khorana Program was established by the University of Wisconsin-Madison to promote long-term linkages between the UW and India. The program honors Har Gobind Khorana, the Indian-born scientist who won the Nobel Prize in 1968 while a member of the UW Biochemistry faculty. Under the umbrella of this program the University of Wisconsin-Madison applied for and received a grant of $950,000 from the United States Agency for International Development. The grant allowed the UW to partner with Mahindra and Mahindra and the Rajiv Gandhi Charitable Trust to promote rural development in India. In addition to the funding received by the UW, the two partners provided over three million dollars. "This represents the latest approach to development, linking university expertise with the private sector's financial power and on-the-ground experience," says project leader Kenneth Shapiro, former associate dean in the UW College of Agricultural and Life Sciences and professor of Agricultural and Applied Economics. "This approach is especially appropriate for India, where rapid economic growth has benefited 300 million, but 800 million, mostly rural residents, are left behind, and over 25% of children are malnourished, leading to tragically high rates of infant mortality and mental and physical stunting."

Mahindra and Mahindra is one of the world's leading tractor producers, with operations in India, the U.S., China, and elsewhere. Their vision is to aid rural development and poverty alleviation by becoming a comprehensive provider of agricultural inputs, services and advice. As the rural economy prospers, so will the company. The Rajiv Gandhi Charitable Trust, named for the former Indian Prime Minister (1984-1989), has a broad program to aid women and their families in one of India's poorest states. Women's self-help groups have proven very effective in empowering women and creating income opportunities. The Trust's programs reach well over 100,000 families in Uttar Pradesh. A linkage was also established with Tasty Bite, India's largest exporter of processed food, and with the Agricultural Consultancy Management Foundation near Chennai.

Background

The acquisition of a tractor is considered the first step in the direction of farm mechanization and it is a lifetime investment for an average Indian farmer. There are 130 million farm families in India but the total number of tractors sold by all of the tractor companies in the country since 1964 is only about 500,000 tractors. Though the Indian tractor industry is the largest in the world and accounts for one third of the global production, Indian agriculture is still deprived of farm mechanization, and crop productivity levels are far below the world average.

In India, the main usage of tractors is largely limited to sowing and post harvesting activities. Intercultural operations are crop specific in nature and as a result, demand crop knowledge, which is often lacking. As M&M is an engineering company, the crop knowledge component was completely missing in the organization. Realizing the significance of the need in this area, M&M decided to enhance the competency level in the organization with a special focus on crop knowledge. The company has therefore taken the lead in bringing about a paradigm shift by creating a synergy between engineering and agronomy. It is hoped this will have far reaching

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effects on improving farm productivity, building better economic prosperity in rural areas, and reducing migration of the youth to urban areas. This innovative community-driven initiative is called "Samriddhi," a Hindi word for prosperity. Mahindra Samriddhi was conceptualized in 2008 with the goal of offering innovative farming technologies to increase productivity and thereby enhance rural prosperity. The focus is to drive positive change in rural society with the inclusion of tractor dealers in the movement to look beyond tractors to agricultural solutions. Samriddhi Centers also provide farm mechanization solutions, crop protection and crop production guidance. This Samriddhi concept also involves making formal linkages with leading agricultural universities in India as well as the private industry.

Before this transformation was begun, M&M conducted a thorough evaluation of the situation. It was discovered that the sale of tractors can be positively impacted by developing strong relationships and a long-term bond with farmers and considering a tractor not to be just an engineering product but a component in providing crop specific mechanization solutions. Currently tractors are mainly used in land preparation, harvesting, post harvest and haulage (transportation of agricultural produce), but there is a huge potential to position tractors for various crop specific intercultural operations such as seed sowing, transplanting, irrigation, weeding, fertilizer application, pesticide application and pruning.

Traditionally, farmers have had very limited access to new and innovative technologies which has affected their income earning capacity, which in turn affects their ability to acquire mechanized equipment to till their land. It is therefore necessary to provide them with end–to-end solutions from crop production to protection as well as crop specific mechanization solutions. There are fifty-three major crops in India. To start with, it was necessary for M&M as an engineering company, to acquire knowledge on predominant rainy season (Kharif) and winter season (Rabi) crops in all of the relevant states. Nationwide, the company's focus is on rice, sugarcane, potato, soybean, cotton, wheat, maize and pulses. If a tractor dealer acquires crop knowledge he can provide agricultural solutions to the farming community and thereby will also have an opportunity to develop long-term relationships with the farmers in his area. The company also looked at the most common stress factors of Indian farmers. Typically, these were related to the lack of technical know-how on crop production and protection, limited availability of affordable financial products at the right time, and the ability to sell produce at the right price and right time to have an increased net income. The agricultural universities in India are conducting much research but despite the efforts of extension departments the information dissemination is very peripheral across the country. Hence, farmers are not able to reap the benefits of the new innovative farming technologies.

The Mahindra Samriddhi Program

There are more than 1000 Mahindra tractor dealerships located throughout India. A Samriddhi center is a transformed tractor dealership, which includes a soil and irrigation water testing laboratory. The transformation of these dealerships began in 2008 with the first ones chosen among the most progressive and successful locations. There were ten centers started in 2008 and an additional twenty were added in 2009. In the 2010 fiscal year this number grew from thirty to seventy-five and has reached over one hundred in the current fiscal year. The long-term goal is to impact the lives of ten million farmers by 2020 by delivering farm tech prosperity.

This transformation has a number of components. The first is the establishment of soil and water testing laboratories. Soil testing is a basic necessity to determine the quantity of nutrients to be applied and has a key position under the new nutrient-based subsidy regime for fertilizers. The country has only about 700 soil testing labs with an analyzing capacity of seven million soil samples per annum. This is not nearly adequate as the total land available is nearly 329 million hectares of which 48% is under cultivation.

Crop specific fertilizer recommendations are provided to the farmer based on the soil test results. The farmer is charged a nominal fee of Rs60 ($1.50) towards the cost of the testing, and the results are available in about seven days. Soil is analyzed for pH, EC (electrical conductivity), organic carbon, phosphorous and potassium, and in some cases secondary nutrients such as calcium and sulfur. Water is analyzed for its pH, EC, total dissolved solids, carbonate, bicarbonate, chloride, fluoride, sodium, calcium, magnesium, potassium and sulfur content. Recommendations for the most appropriate crops based on the soil and available water supply include the amount of nutrients to be applied with the appropriate timing and number of applications. The next step in the transformation is the establishment of productivity demonstration farms affiliated with each Samriddhi Center. The goal is to demonstrate suitable technologies ranging from land preparation to post harvest strategies by establishing demonstrations at different stages of crop development. Another key component in the process is the establishment of a strong tech interface. This is used mainly to disseminate the knowledge on technologies and success stories and make farmers aware of weather forecasts, demand and price status of crops, warehousing, cold storage and transportation facilities for their produce and government policies on finance, subsidies and insurance. A Samriddhi Center also has agricultural counseling facilities available, which are used to update the farming community on various agricultural practices by bringing in experts and scientists from agricultural universities and research institutions. A transformed center also serves as a one-stop finance and insurance shop. They offer various finance products such as micro finance as well as vehicle, crop and personal loans. They also provide insurance products for crops, animals, as well as life insurance.

Outreach

One of the key components of the Samriddhi Program is the dissemination of improved farming practices through the delivery channels developed by M&M. The first is to provide recommendations directly to the farmer on quantity, method and time of application of organic or inorganic fertilizers as well as water and soil reclamation methods. Another channel involves using subject matter specialists from agricultural institutions to provide crop specific mechanization, production and protection solutions that are based on the productivity issues identified from farmers. Productivity demonstration farms are attached to Samriddhi Centers to provide farmers with a firsthand look at new technologies.

The purchase of crop specific farm implements is generally not affordable by most of the farmers in India as it would not be economically viable if it were to be used only on his own land. These implements are being made available for rent through Samriddhi Centers for farmers who wish to implement the recommended mechanical solutions. The information on innovative farming technologies is being disseminated in regional languages through crop related magazines. A website is maintained (www.mahindrakisanmitra.com) that provides updated information in regional languages on cultivation practices for over fifty crops, weather forecasts, commodity prices, market availability, loan and insurance schemes, global agricultural news, upcoming events, and success stories of farmers.

To help motivate farmers an award named, “Kisan No.1 Mahindra Samriddhi Samman,” has been instituted to recognize and reward the farmers who have successfully adopted innovative farming technologies and registered the highest productivity increase. In 2010 there were thirty Samriddhi Samman program contests initiated. Mahindra Samriddhi Samman winners are given cash awards of the equivalent of over U.S. $500 with lower awards for second and third place finishers. Consolation prizes are also given to all participants.

Another shift in philosophy that the Samriddhi concept brought to rural India was the inclusion of different players in the process for the first time, so as to bring about a holistic solution. Besides farmers and dealers, previously unassociated constituents were included as stakeholders in the game plan. Inclusion of agriculture universities through industry–institution tie-ups, financiers and insurers and other agricultural input companies, enabled inclusive growth as well as a meaningful and positive change in the rural landscape. The relationship between all these stakeholders has now culminated into improved business relationships and brought about a win-win for all.

The Samriddhi Centers broadened the horizon of farmers by engaging not only Mahindra tractor owning farmers but also other competitive tractor owners as well as farmers without tractors and introduced them to innovative farming technologies.

Seeing the value in this initiative, the United States Agency for International Development (USAID) supported Samriddhi through the University of Wisconsin-Madison by funding John Peters, Soil Scientist, who was based in Mumbai for twenty-one months to support soil testing services. As part of the knowledge enhancement program, the University of Wisconsin plans to send agriculture students to India to work in Samriddhi centers and Samriddhi executives are coming to the University of Wisconsin for short-term interactions.

Samriddhi has signed memorandums of understanding with ten leading agricultural universities. In addition, M&M has also launched Mahindra Samriddhi grants worth Rs 1.01 crores (over ten million U.S. dollars) towards IFT development and dissemination. Under this program, selected postgraduate students, scientists and undergraduate students will receive a stipend for their work. This program is already under way at ten agricultural universities. The goal is to take advantage of the expertise from agricultural universities, Krishi Vigyan Kendras, research stations, agriculture colleges, and agriculture departments.

Challenges Ahead

Some of the key challenges faced by M&M in the Samriddhi program include personnel recruitment and retention, offering Mahindra Insurance Brokers Limited Insurance products to farmers, manpower shortage in team Samriddhi, and the need for continuous competency development for soil testing due to manpower attrition and new joinees. Additional challenges include the selection of target crops for the demonstration farms and the identification of key productivity issues. Participating dealers are also further challenged by the need to organize result and method demonstrations, to organize Mahindra Samriddhi Samman programs, to keep up the farmer libraries and to bear the operating expense of the labs.

In the future Samriddhi Centers will be upgraded to a Crop Specific Samriddhi Center to provide end-to-end crop specific mechanization solutions. The staff at a CSSC will include a crop expert plus a trained demonstrator to conduct method demonstrations and promote farm implements. This will allow Samriddhi centers an opportunity to participate in an agricultural value chain and thereby generate additional revenue. These centers will focus on key crops including rice, soybeans, sugarcane, cotton, potato and wheat.

Conclusion

In conclusion, I would like to express my gratitude to Mahindra and Mahindra, USAID, and UW-Madison for the opportunity to connect tractors and soil science in this unique program of

prosperity, Samriddhi. Portions of this text were taken from various Samriddhi documents including the application for the Golden Peacock Award for Social Responsibility.

ORGANICS: NEW OPPORTUNITIES IN CROP CONSULTING

Laura Paine[1]

Introduction

Wisconsin is a national leader in the small, but rapidly growing organic sector of agriculture. The number of organic farms in the state has more than tripled since 2002 to over 1200 farms today (Figure 1). We are second in numbers of organic farms after California, and first in the nation in numbers of organic dairy farms (National Agricultural Statistics Service 2008). We are also in the top ten in numbers of organic farms producing livestock, vegetables, grain, and forages. In 2008, farmgate sales totaled over $132 million (Table 1).

Wisconsin's certified organic farms represent a community that has traditionally been outside the communication system that serves most of the rest of agriculture. For some organic producers this is by choice, but many are looking for information to help them in their transition or to help them improve their existing systems. They also have some of the same technical assistance needs as conventional farmers such as meeting nutrient management planning requirements.

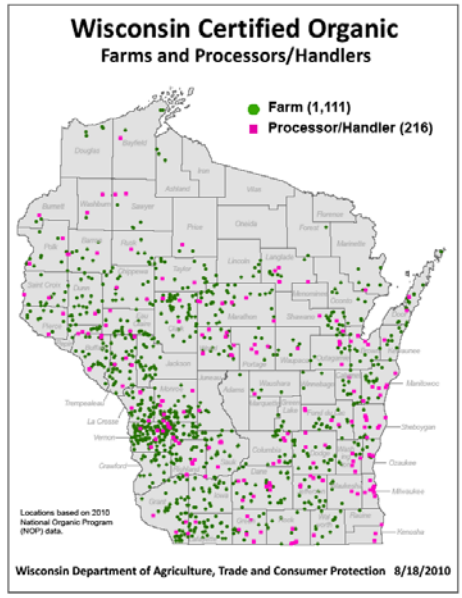

Figure 1. Map of WI organic farms and processors.

Table 1. Wisconsin organic farm statistics from the 2008 National Agriculture Statistics Service Organic Production Survey (www.agcensus.usda.gov).	
Number of organic farms	1222
Number of acres	195,603
Total value of farmgate sales	$132,764,000
Wisconsin rank among states	
Number of farms	2 (after CA)
Value of sales	2 (after CA)
Number of acres	4 (after CA, TX, MT)
Number of organic dairy farms (455)	1

Although there has historically been a dearth of research-based information on organic farming systems, that is changing rapidly. Recent federal Farm Bills have provided increased funding for organic research, as well as additional funding for direct cost-sharing to farmers for transitioning or maintaining organic certification. The papers in this session will summarize these new programs and some of the research that is being conducted to support this growing industry.

What's fueling the growth?

Consumer Demand: The growth in organic agriculture is being fueled by several related factors. Consumer demand is one. Consumer spending on organic foods grew more than 20% per year from 1988 to 2008. With the recession, growth slowed to about 11% in 2009, with 2010 growth

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predicted to be about 6%. Although it represents less than four percent of the entire U.S. food economy, the $23 billion organic sector is the only segment of the food industry that has seen significant, consistent growth for so many years (Mintel 2009).

Among all of the 'ecolabels' consumers see in the grocery store, the organic seal (Figure 2) is the only one that has a comprehensive legal framework behind it. The National Organic Program (NOP), an agency of the United States Department of Agriculture (USDA), is tasked with managing organic certification. The organic seal assures the buyer that the product was produced by a farm or processor using organic practices, is third-party certified, and is inspected annually.

Figure 2. USDA Organic Seal.

Approximately 60 percent of consumers purchase organic foods at least occasionally, with about 10% being regular buyers (Mintel 2009). The organic seal provides consumers more specific information about how the product was produced than other ecolabels because of the enforcement capacity of the National Organic Standard. And while consumer surveys indicate significant confusion about what the organic seal stands for, these surveys also suggest that many consumers are motivated to buy organic foods by an interest in supporting agriculture that reduces use of pesticides, antibiotics and artificial hormones (60%). Fifty-seven percent feel they are helping small and local farmers with their purchases. A growing number of consumers are turning to organic foods because they feel it is better for their health (68%). Avoiding pesticide residues in foods is a motivating factor for many of these consumers (Mintel 2009). In addition, several studies have shown that some organic fruits and vegetables have higher amounts of vitamins and antioxidants in them (Lairon 2009).

<u>Farmer and Processor Interest:</u> The dramatic growth in demand for organic foods has put pressure on the agricultural community to produce for this market. In response, many retailers have turned to overseas markets to keep their shelves stocked. This situation represents an opportunity for U.S. farmers. Wisconsin is positioned well to contribute to this growing market, especially with the growing complimentary consumer interest in local foods. The number of companies processing organic raw materials in Wisconsin increased by 70% between 2005 and 2010 and now stands at 217 (NOP, unpublished data).

Farmers who convert to an organic system do so for many reasons. In a 2004 national survey of organic farmers, Walz (2004) found that four of the top five responses to the question, "Why do you choose to farm organically?" were related to land stewardship and reducing pesticides in the environment. The second most important reason was reducing pesticide exposure for their families and farm workers.

Economics was another consideration for many farmers. Organic crops and livestock products command a substantial premium in the market (Table 2). Although organic grain prices are at historically low levels and conventional prices are historically high in 2010, organic producers averaged a 16% premium for their corn and a 33% premium for their soybeans. Organic milk prices average about 70% higher than conventional farmgate prices and remained above $20/hundredweight (CWT) during the recent downturn in conventional milk prices (NODPA 2010, UW Center for Dairy Profitability 2010). Respondents to the Walz survey also reported that they were able to significantly reduce purchased inputs and that they can generate a higher income on fewer acres than they did when they were farming conventionally (Walz 2004).

Table 2. Comparison of current conventional and organic prices (Fall 2010).		
Commodity	Organic	Conventional
Corn (bu)	$6.25	$5.38
Soybeans (bu)	$16.75	$12.63
Milk (cwt)	$25.85	$15.44

Agency Support: The 2002 and 2008 Farm Bill contained a significant increase in resources for organic farmers. The Natural Resource Conservation Service (NRCS) provides Environmental Quality Incentives Program (EQIP) cost sharing for adoption of organic practices as well as funding for hiring a consultant to assist in writing an organic transition plan and/or an organic system plan. Approximately $50 million was set aside in the 2008 Farm Bill for this program nationally. Wisconsin led the country with 363 applications when the program was first announced in 2009 (National Sustainable Agriculture Coalition, unpublished report).

The NOP provides funds to reimburse farmers for 75% of their certification costs up to $750 per farm. The program, administered by DATCP, provides nearly $400,000 per year in cost-share funds to over 700 organic farmers, input suppliers and processors (Paine 2010).

In addition, funding for research has supported establishment of organic research programs at universities across the country. Several universities, including the University of Wisconsin, have hired organic research coordinators. Dr. Erin Silva, with the UW Agronomy Department serves in that capacity (Contact information: 608-890-1503; emsilva@wisc.edu).

The Missing Link

The missing link in this picture of a rapidly growing agricultural sector is a bridge between farmers interested in organic practices and sources of research-based information and technical assistance. What the organic sector needs is a system of crop consultants and technical service providers (TSPs) similar to what exists for mainstream agriculture.

Many people in both the organic world and the conventional world view organic farming as a separate system. For the purposes of providing technical assistance to organic farmers, it might be more effective to picture it as part of a continuum with certified organic at one end, integrated pest management in the middle, and farming that relies heavily on synthetic fertilizers and pesticides at the other end. The primary goal, no matter who we're helping, is to meet producers where they are and move them toward more economically and environmentally sound practices.

Many practices that are part of the organic toolbox are also included in IPM recommendations. Some examples include cover crops and green manures, diversifying crop rotations and increasing rotation length, and utilizing pest and disease resistant crop varieties. All of these practices are effective because they work with the checks and balances that exist in nature, breaking up pest and disease cycles and utilizing nitrogen fixation and organic matter to enhance fertility. While there are approved 'natural' products available for pest control and fertility, organic farming places emphasis on mechanical and cultural tools to optimize the system.

Opportunities for Crop Consultants

Existing Organic Farmers: One goal of the new NRCS Organic EQIP program is to reach out to existing organic farmers who may not have previously worked with government agencies. Crop consultants can serve as a bridge for these farmers to help them access research-based information as well as assisting with bringing their farms into compliance with state and federal regulations for environmental performance. Ironically, the NRCS and NOP, two agencies within

USDA, have developed parallel, but different standards for nutrient management planning, soil erosion control, water quality, and other environmental standards. Efforts are currently being made to correlate the two sets of practices and provide guidance on NRCS practices to utilize to meet NOP requirements.

Farmers Transitioning to Organic: With cost-share funding available, many farmers new to organics need assistance in developing transition plans and organic system plans. Most farmers who transition to an organic system have farmed conventionally. One of the errors often made is simply attempting to substitute a few organic practices for their current conventional ones. Successful organic farms employ multiple layers of cultural and mechanical practices to help keep their crops and livestock healthy and productive. These farmers need assistance not just in writing their plans, but in learning how best to manage their farms and their crop rotations as they make the three year transition to organic production.

Organic certification provides a framework for farmers to do the kind of whole farm, system-based planning that we as crop consultants and agriculture educators encourage farmers to engage in. The organic farmer must develop and annually update an organic system plan for his or her farm. This involves establishing crop rotations, monitoring soil health, documenting crop varieties used, developing pest, weed, and disease thresholds and control practices to be used, and nutrient management planning, among other things.

The new EQIP organic program requires farmers to work with a NRCS certified planner to complete their organic transition plans and organic system plans, similar to the way nutrient management planning cost share works. Congress provided the funding for this program without first having TSPs in place. Since the farm bill was passed in 2008, agencies have worked together in Wisconsin to provide training for this certification, but there is still a great need for TSPs for this program and in general, to provide research-based information to this growing sector of agriculture.

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A CROP CONSULTANT'S GUIDE TO ORGANIC TRANSITION

Kevin B. Shelley[1/]

What is organic crop production?

Organic farming, when done correctly, is more than just producing crops and livestock without synthetic chemicals, fertilizers and pharmaceuticals. Most definitions of organic farming emphasize production practices that conserve, protect and enhance natural resources, encourage biological diversity, foster cycling of nutrients, build soil organic matter and minimize use of off-farm inputs. I like to think of organic crop production as an integrated system of **cultural**, **biological**, **ecological** and **mechanical** practices, much like the traditional definition of *integrated pest management*, without most, or usually any, of the **chemical** practices. With very limited chemical tools at their disposal, organic farmers have to develop and continually hone their skills and practices in these other management areas.

To market farm products as "organic," the farm, or portion thereof, must undergo a process of certification. Organic certification ensures buyers of the farm's products that they have been produced according to organic standards, which are defined by federal statute: US Code of Federal Regulations, Title 7 = Agriculture (USDA), Part 205 = *National Organic Program* http://www.ams.usda.gov/AMSv1.0/nop.

The National Organic Program (NOP) establishes the legal rules for certified organic products and production. At the farm level, this includes what production inputs can be used (allowed materials) and what cannot be used (prohibited materials). The NOP requires that an annual organic production plan be prepared by each certified organic farm that includes detailed whole-farm information about strategies employed to manage pests, assess and provide required crop nutrients and ensure that contamination of produce with prohibited materials is prevented. Individual field plans and records are required that include crops planted, previous crop, tillage and all practices and inputs used including manures, fertilizers and the organic seed variety or hybrid. In the plan, farmers must also show how environmental management criteria are being met in the areas of soil quality, soil conservation and protection of surface and groundwater resources. In addition, detailed records must be maintained as to the harvest, transport and sales of all organic products to ensure the integrity of organic products sold and that no co-mingling with prohibited materials or non-organic products has occurred.

The NOP establishes the certification process through public or private third-party certification agencies. Certifiers are responsible for ensuring that the client farm's practices and production conforms to the standards of the NOP. A farm's certification agency will collect and review their organic plans, perform an annual inspection of the farm and its records and issue transaction certificates to buyers of the farm's production certifying it as organic.

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Why would a farmer be interested in transitioning to organic production?

1. Environmental stewardship: farm without (or with fewer) inputs that cause pollution and are toxic to the environment and human health

In general, organic farms provide environmental benefits to society by not using large quantities of highly soluble, processed fertilizers and toxic pesticides. Use of these products, with traditional management and best practices, still, often results in some losses from the crop to the environment.

2. Add value to their products by producing for a higher value market (organic premiums)

Traditionally, markets for organically produced grains have offered premium prices of two to three times those of conventional markets. Consumers of organic food products have offered higher payments to reward producer's efforts and compensate for increased labor and management costs as well as slightly lower yields and greater risks. In reality, cost of production is often lower per-unit produced due to less purchased input use and crop yields are comparable. Corn yields are usually less, but only due to later planting.

In past years organic premiums have also been supported by a tight demand-supply environment. However, over the last 2 years, supplies of organic grains have met demand from organic livestock producers and food processors and premiums have declined. Together with the current strength in conventional commodity markets, the potential for achieving profitability advantages with organic production are more challenged.

3. Independence: More emphasis on their own labor and management and less reliance on purchased inputs

What are the foundations of organic crop production management?

1. Diverse crop rotations (bio-diversity, agro-ecology)

Successful approaches to organic production recognize principles of plant, soil and farm ecology as important to managing pests and building soil fertility. Ecology refers to relationships between organisms and their environment. So, organic crop production, as an agro-ecological approach to farming, uses cultural practices like crop rotation in attempt to create a growing environment favorable to the competitiveness of each crop in the rotation against pest damage.

Two common Wisconsin organic crop rotations (agronomic crops):

1. Corn - Soybeans - Oats/Alfalfa+grass - Alfalfa+grass - Alfalfa+grass – Corn (5-year rotation)

2. Corn – Soybeans – Small grain/Red clover – Corn (3-year rot., less sustainable for organic)

What are the foundations of organic crop production management ? – *cont.*

Functions of crop rotations

Pest Management: When crops of different species and life cycles are rotated within a field from year-to-year, pressure from soil-borne weed, insect and disease pests particularly suited to narrow crop mixes on a farm are reduced. This is especially true when short-term perennial crops (2 to 4 years) like legume-grass hay or pasture forage are rotated with annual crops. Winter-annual cereal grains in the rotation provide additional biological diversity. For example, 2 to 4 years of alfalfa-grass harvested as hay or silage will create an environment less-well suited to annual weeds over this time. Competition from the ground-covering perennial forage plants and the repeated cutting and harvesting selects against annual weeds as they cannot thrive and develop seed. Annual weed seeds in the soil are then depleted and/or become dormant until more favorable conditions arise for their ecological niche. When the forage crop is later terminated and followed by an annual row crop, such as corn or soybeans, it usually takes a while for the annual weed seeds to respond, giving a temporary (1-year, sometimes more, sometimes less) competitive edge to the corn or soybeans planted.

Similarly, changing crops in a field from one year to the next means that soil-based disease and insect pests, such as soybean cyst nematode and northern and western corn rootworms, cannot establish with their host crop in one year, build populations, and infest the same host crop in the next year (or the year after). Rotating crops, particularly of different species and/or life cycles, breaks-up life cycles of pests. Crop diversity across years is also said to encourage beneficial organisms (insects, nematodes, bacteria, fungi, etc.) which prey on or parasitize insect pests and disease pathogens. In addition to three or more harvested crops in rotation, most organic farms will plant non-harvested cover crops. Winter cereal rye, red clover or vetches planted in-between the harvest of one commodity crop and the planting of the next, will increase crop diversity as well as fix or trap soil nitrogen, suppress weeds and add bio-degradable organic matter.

Soil Fertility Management: When leguminous crops like alfalfa, clovers and soybeans are included in the rotation, nitrogen is fixed (biological nitrification) into the crop's seeds (fruit), stems, leaves and roots. Surplus nitrogen, not removed in un-harvested portions of the crop residue, is then left to mineralize in the soil and become available to non-legume, nitrogen demanding crops such as corn, cereal grains or grass forages. For example, depending on plant density (plants/ft^2), a stand of alfalfa hay can provide all of the nitrogen necessary for a following corn crop.

2. Organic and naturally mined (not chemically processed) sources of plant nutrients

Sources of soil fertility nutrients allowed (NOP): "The producer must manage crop nutrients and soil fertility through crop rotations, cover crops, and the application of plant and animal materials." Animal and plant materials include: raw animal manure, which must be composted unless it is:

- Used for a crop not intended for human consumption
- Incorporated into the soil not less than 120 days prior to the harvest of a product whose edible portion has direct contact with the soil surface or soil particles; or
- Incorporated into the soil not less than 90 days prior to the harvest of a product whose edible portion does not have direct contact with the soil surface or soil particles.

Manures can come from other farms and do not have to be from organically raised livestock. Dairy and poultry manure from large producers with little land of their own are popular sources of purchased organic nutrients by organic farmers in Wisconsin. At least two southern Wisconsin egg producers pelletize some of their chicken manure for sale as licensed fertilizer.

There are very specific provisions as to what is "compost" in terms of C:N ratio and the process used to make it. In general, mineral fertilizer materials that are mined, and not synthetically processed, such as rock phosphate, are allowed. However, some processes are allowed such as those used to make potassium sulfate fertilizer and SOME potassium chloride fertilizers (see the national list of synthetic substances allowed in the NOP). The producer must not use any fertilizer or composted plant and animal material that contains a synthetic substance not included on the national list of synthetic substances allowed for use in organic crop production such as sewage sludge (biosolids).

3. Additional cultural practices:
    - Preplant and post-plant tillage: Tillage regimes for organic crop production are often intensive. There are often two to four passes of pre-plant tillage to uproot and dry-out roots and rhizomes of perennial weeds. Annual weed seeds are repeatedly germinated and killed by subsequent tillage passes in attempt at creating a sterile seed-bed. Crop residues are buried to facilitate post-plant mechanical weeding operations such as rotary hoeing, flex tine weeding and inter-row cultivation.
    - Timing of planting: Without the aid of chemical fungicide seed treatments, organic soybeans need to be planted into warmer soil than their conventional neighbors – about one month. However, allowed natural seed treatment products are available, with new ones under development and testing. Warmer soils allow for faster germination and emergence of crop seeds which also aids in competition against weeds. Pre-plant and post-plant tillage.
    - Selection of adapted varieties and hybrids: Traits such as quick emergence and canopy closing, ear flex, strong roots, tolerance to drought and pest influence are particularly important.

4. Biological methods of insect pest management and allowed bio-control agents and "natural" products

Certain natural and biological products and materials are allowed for use against economic insect pest infestations in certified organic production. The Organic Materials Review Institute (OMRI) reviews and tests products for compliance with the NOP and publishes a list of those considered to meet the rules. For example, some things on OMRI the list applicable for control of soybean aphid and other insects include:

Examples of natural insecticides*

• **Azadirachtin (neem) (e.g., Dagger ®)**

• **Insecticidal soap (e.g., M-Pede ®)**

• **Plant essential oils** – garlic cinnamon Plant essential oils garlic, cinnamon, peppermint, rosemary, clove, citronella, coriander, etc (e.g., NaturesTM)

• Seed oils (canola, cotton, other ?)

• **pyrethrum (e.g., Pyganic ®)**

• Rotenone

• Citric acid

• **Fish** oil / **emulsion**

• **Compost tea**

• **cola / soda pop**

• **Hydrogen peroxide**

Products in bold type have been tried in the field against soybean aphid at some scale. Unfortunately, field testing of these materials has revealed poor performance against soybean aphid thus far.

*Source: *Soybean aphid in Organic Production Systems: "It's not easy being green."*
By Phillip Glogoza, Ph.D. Regional Extension Educator –Crops, University of Minnesota

Classical biological control uses the introduction of beneficial insects that are predators or parasitoids of targeted pest insects, or fungal pathogens specifically targeting a pest. A biological control agent of these types may be able to establish permanently, or may need re-introduction for each bio-control event. For example, entomologists introduced a parasitic wasp (non-stinging) on Wisconsin farms in the 1980s that took-up residence and has kept alfalfa weevil under control in most years since then. Currently, research is underway in Wisconsin to try to establish populations of Binodoxys communis, a parasitic wasp with potential for acting against soybean aphids. Thus far, success has been limited.

5. Enterprise diversification

Organic farms often include crop and livestock enterprises. Crop and livestock enterprises include components that have relationship to one another, complement each other and function as a system. Even with crops-only organic farms, perennial forages are often included in the crop rotation and manure is brought-in from other farms.

What are some of the main considerations for a decision on whether to pursue a transition to organic?

1. What is the farm producing, or capable of producing, and are there accessible, profitable markets for those products? Is on-farm storage necessary, available?

2. What are the characteristics of the farmland available for organic production. Intensive tillage-based organic crops WILL REQUIRE soils that can handle it:
   a. Relatively flat or gently sloping topography with deep, non-eroded soils and relatively few rocks
   b. Conservation practices and structures must be in place to control concentrated flow of surface runoff waters: waterways, diversions, terraces, upland and streambank vegetative buffers, to compliment contour planting, use of cover crops and residue management to prevent ephemeral and gully erosion in years where intensive tillage is used.

3. Access to affordable organic sources of crop nutrients
   a. Livestock manure, fresh, processed, composted
   b. Allowed mineral fertilizers that are economical
   c. Allowed organic waste materials or by-products
   d. Purchased feed and bedding (nutrients imported to a farm which, if not for organic livestock, do not have to be from organic sources)

4. Access to occasional hand labor (weed pulling, chopping or hoeing)

Cultural practices aimed at controlling weeds will not always provide adequate control, and manual weeding will provide economic benefit. This can range from less than an hour per-acre for spot hoeing thistles, to over 10 hours per-acre for chopping or pulling annual broadleaves in a low-growing, high value crop such as organic soybeans. A farmer should be prepared to occasionally locate, assemble and manage a crew for short-term work of this nature.

What are the needs of organic farmers from consultants?

There are several areas where crop and farm management consultants could provide services particularly useful to organic farm businesses, including, but not limited to the following:

1. Development of plans and recommendations in the areas of soil fertility nutrients and crop pest management, within the constraints and guidelines of the NOP. This includes making soil fertility recommendations based on soil test results and scouting crops to identify pests and their likely significance. It is important for organic farms to know the efficacy of the cultural practices they employ in managing weed, insect and disease pests, and whether changes need to be made. This is usually more of a long-term strategy on organic farms, but occasionally a re-planting decision will need to be made, or there may be a decision as to whether a cultivation is warranted or whether to use an organically approved pesticide. Determining the economics of these options is sometimes particularly challenging in organic production. Such planning services may also include preparation of the client farm's annual

organic systems plan required by the NOP and the farm's certifier for annual certification purposes.

2. Record-keeping consistent with the requirements of the NOP and the farm's certifier. This includes detailed field-by field records on field operations and inputs used, annual updates of field and farm maps showing fields, crops, crop storage facilities, adjoining and adjacent land uses, associated organic buffer areas, equipment cleaning and purging logs if equipment is also used for conventional crops, organic and non-organic seed search and purchase logs, and records of organic crop sales including a lot numbering system, clean truck affidavits and organic product transaction certificates.

3. Development of organic transition plans (conservation activity plans) for farmers participating in the **USDA NRCS' Organic Initiative through the Environmental Quality Incentives Program (EQIP)**. Through the 2008 Farm Bill, NRCS is providing significant incentive payments to interested farms for development and implementation of plans for transitioning all or some of their farmland to certified organic production. This includes farms that are new to organic production as well as existing organic farms desiring to expand by transitioning additional acreage. In addition, NRCS offers higher per-acre incentive payments to organic farms for conservation practices such as nutrient management planning and pest management planning. In 2010, including transition plans and conservation practices, Wisconsin NRCS approved 91 contracts for over $1.1 million with existing organic and transitioning farmers.

   A transition to organic conservation activity plan must be developed by certified technical service providers (TSPs). The specific TSP certification requirements for *Transition to Organic Farming Activity Plan* is located on the TSP registry (Tech Reg) web site at: http://techreg.usda.gov/. The conservation activity plan may be used by producers to help support their efforts to become a certified operation, but this plan may not be used as a replacement for an organic system plan (OSP) as required by the National Organic Program.

   The conservation activity plan, theoretically, compliments an organic system plan, helping to ensure the organic farm's production system meets NRCS quality criteria for soil erosion, water quality, and other identified natural resource concerns. Assisting a farm business in meeting soil and water conservation requirements could be a very important role for agricultural consultants. An organic farm's practices in areas such as storage, handling and field applications of livestock manure, or intensive tillage often associated with weed management in organic row cropping, may not always receive sufficient monitoring and review by an organic certifier to ensure environmental sustainability. In my experience, the certification agencies do an excellent job of ensuring that the products an organic farm sells have, indeed, been produced without prohibited materials and that they are handled and marketed in an identity preserved fashion, without co-mingling or contamination. However, inspectors of these agencies seldom have the time or the expertise to adequately assess whether a client's farm is meeting the provisions of an updated nutrient management or soil conservation plan such as would be prescribed by county, state or federal conservation agencies.

4. Evaluating and adopting precision farming technology and tools that would be useful in:
    a. Field mapping for planning, record keeping and evaluation
    b. Yield monitoring – aid decisions whether to continue planting end rows/ headlands for certain fields and crops, shallow areas where weeds are difficult to control or intensive tillage depletes organic matter and reduces yield to levels below economic profitability as well as guiding input use
    c. Precision guidance of nutrient applications, planting and inter-row tillage (row cultivation).

    Demand for and economic feasibility of these services for organic farmers is currently undetermined.

What are some sources of information and assistance on organic farming and certification?

Midwest Organic & Sustainable Education Service http://www.mosesorganic.org A Wisconsin-based, farmer-run nonprofit educational outreach organization dedicated to organic farming. MOSES provides trainings and hosts a website that serves as a resource for information on a variety of topics around organic farming and food. They publish the *Upper Midwest Organic Resource Directory*, a guide to resource groups, educational programs, certification agencies, suppliers of equipment, seed and inputs, as well as brokers and buyers of organic commodities and products. MOSES organizes the *Organic Farming Conference* held in La Crosse, WI each February, with over 1500 attendees, over 70 workshops and a large organic farming trade show (150 exhibitors).

ATTRA – National Sustainable Agricultural Information Service http://attra.ncat.org/ ATTRA provides "the latest in sustainable agriculture and organic farming news, events and funding opportunities? The National Sustainable Agriculture Information Service covers these topics, plus offers in-depth publications on production practices, alternative crop and livestock enterprises, innovative marketing, organic certification, and highlights of local, regional, USDA and other federal sustainable agriculture activities."

Organic Farming Research Foundation (OFRF) http://ofrf.org/index.html 'Sponsors organic farming research and education & outreach projects through a competitive grant-making program; Disseminates the results of OFRF-funded research and education projects to organic farmers and to growers interested in adopting organic production systems; and educates the public and decision-makers about organic farming issues.'

Wisconsin Department of Agriculture, Trade and Consumer Protection – Organic Farming Resources for Wisconsin http://www.organic.wisc.edu/ "The DATCP organic agriculture program provides information, support and coordination for organic farmers, businesses and organizations across Wisconsin. We are also working to increase marketing opportunities for organic foods."

The Organic Materials Review Institute (OMRI) http://www.omri.org/home OMRI "is a national nonprofit organization that determines which input products are allowed for use in organic production and processing. OMRI Listed—or approved—products may be used on operations that are certified organic under the USDA National Organic Program. OMRI's funding comes from a variety of sources, including sales of publications, grants, donations, and subscriptions. Mainly, however, the organization generates income through fees collected for the review of products intended for use in organic production or processing. Also, OMRI operates an organic seed information service to help growers find organic seeds."

MANAGEMENT CHALLENGES OF RUNNING PARALLEL ORGANIC AND CONVENTIONAL SYSTEMS

Darwin L Frye[1]

Introduction

The Arlington Agricultural Research Station (AARS) is the largest of 12 UW-Madison Research Stations. It supports a wide cross section of research and programs for 10 different departments in the College of Agricultural and Life Sciences (CALS).

The station consists of approximately 2100 acres of cropland and 14 different crop and livestock units. Approximately 1000 acres is devoted to crop research and the remaining 1100 acres is used as feed for the research livestock units. AARS annually grows approximately 600 acres of corn, 400 acres of forages, 200 acres of soybeans and 100 acres of small grains. This includes the ~80 acres of Certified Organic land.

The AARS staff provides services to CALS researchers which include growing feed for animals, preparing feed rations, performing field operations for crop researchers, removing animal wastes, mowing lawns and research alleyways, trucking, and maintenance and repair of facilities and equipment. The AARS staff also helps facilitate approximately 100 events at our 500-seat Public Events Building and Headquarters meeting room each year.

History of Certified Organic Land at UW Arlington

I certainly want to thank Josh Posner (Professor, Agronomy, UW-Madison) and Janet Hedtcke (Sr Research Specialist, Agronomy, UW-Madison) for their work on getting this organic area, now called the "organic corner" established. Josh has over the years been very supportive of AARS and without Janet guiding us through the certification process we would not have this valuable research area.

The WICST (Wisconsin Integrated Cropping Systems Trial) started in the early 90s by Josh Posner, had an organic rotation for one of the systems. Since each plot was only seven tenths of an acre it would be hard to certify because of the inadequate buffer but all other organic rules are followed. In 2003, to meet the expanded research needs of Josh and other researchers, it was decided that an area across the road from headquarters, the organic corner, would be a good site. A hybrid of the WICST 3-yr organic dairy system was used to integrate crop diversity and manure which is vital to the success of most organic systems. These 45 acres were certified organic in 2007; 3 years after the last non-organic inputs were used. This area has been used by over a dozen researchers over its short existence.

In 2006, Eileen Cullen (Associate Professor, UW-Madison Entomology) started another organic area in what we call the 500 fields. This added another 35 acres that became certified in 2009. With this addition we now have a total of 80 acres of certified organic land.

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Our organic land is certified with MOSA (Midwest Organic Service Association), which also provides forms to facilitate record keeping (available for free download). We pay an annual fee, an inspection fee and .75% of sales to MOSA. The MOSA website is www.mosaorganic.org.

Corn, soybeans, and wheat are marketed to local growers or vendors when possible. The forages are used on the station at livestock units. We receive a good organic premium for the grains that offset the extra labor and tillage required.

Different Way of Thinking – Timing and Timeliness

I think one of the hardest challenges for me was to think of doing things a different way from the way we handled conventional crops. As I will talk about later, this is where the good field plan comes into play. By having this plan in place you will know what and when things are expected to be done.

Planting Date

We start planting conventional corn by the third week of April. With organic crops we wait until the third week of May. We need to wait for a couple reasons:

(1) We needed warmer temperatures to get a couple flushes of weed growth and a couple tillage passes, usually staggered a week apart, before planting.

(2) We also needed warmer temperatures to get the crop out of the ground fast. You need to create that differential between crop growth and weed growth so you can use mechanical tools.

Dedicate Manpower and Time to Manage

Understand that if you don't control weeds you will get significant yield loss. You have a small window to do things correctly the first time.

- With a conventional tillage system 4 passes across the field including fall tillage, digger, plant and harvest. With organic system we can make as many as 8 passes across the field. These include fall tillage, digger, digger, planter, tine weeder or rotary hoe, cultivator, cultivator, and harvest.
- Be prepared to do some hand weeding. Hot spots will pop up and they will need to be taken care of.

Get control of the Weeds

Crop rotation and a healthy vigorous stand will help with weed control. In addition, having the diversity of equipment available, starting early and staying aggressive are the keys to success. In data from WICST yields are 95 to 100% of conventional crops with good weed control but let weeds get the upper hand and yields can fall to 60 to 70% of conventional.

Selection of an Organic Site

Some criteria that we used for site selection that has helped us and could save you trouble:

1. Close to our Public Events facility where most field days are held, easy access
2. Close to an area very visible on a daily basis. You need to know what's happening on a daily basis as far as weeds and crop growth, to name a few. Timing in an organic system is very important. Miss something and you will probably pay directly out of the pocket as lost revenue. Second, have it as an area everyone can see. If everyone sees it you will take care of it better.
3. Find an isolated piece of land with naturally existing borders of roads. It is required to have at least a 30-ft border and if surrounded by naturally occurring borders, less land waste.
4. Select an area that is level or at least has a good conservation plan in place. With the amount of tillage required the leveler the better. Due to the rains of 2008 we needed to add waterways and diversions to our organic corner because of heavy erosion.
5. Allow room for access roads or strips. You will need to drive in several times with tillage tools.

Dirty Sheets and Field Plan Sheets

With the experience gained from the WICST we started a new record keeping process with the organic corner. The WICST had record sheets with a yearly plan guide for each rotation and a map with crops to be grown in each rotation. The organic corner "dirty sheets" contain the same layout as the WICST, and with the addition of the 500 fields we adopted the same scheme.

We use the dirty sheets to provide instructions to employees doing each task. When the task is completed, the dirty sheet is modified if needed, signed by the employee and returned to management. Later the information is added to our field records database and the cleaning information is entered into the cleaning log.

The Critical Parts to "Dirty Sheets" include:

*Map with field acres	*Date & Operation
*Instructions	*Cleaning Procedures
*Operator (have operator sign)	*Notes and Measure

The second part of the organization is the Field Operation Plan Sheets. Going into each year a plan is put together for all activities that are planned on a field or plot basis.

The Critical Parts to Plan Sheets include:

*Crop
*Tillage
*Fertilizer (manure or other)
*Harvest
*Plot or Field Numbers
*Planting (including varieties and rates)
*Post Plant Tillage and other Operations
*Fall Practices

Forms and Records

Access Records (data base of complete farm records)
Cleaning Log
Organic Seed Search
Seed Tags and Receipts
Crop Input Inventory
Seeds, Seedlings and Planting Stock
Farm: Update Organic Plan Long Form (every 3 years)
Update Farm Plan Questionnaire – Short Form
TCA (Transaction Certificate Authorization)
Off-Site Transportation Cleaning Affidavit
User Fee Billing (quarterly)

Summary of Other Suggestions

Get Employees to Buy into the System

By having the employees doing each process, in detail, from beginning to end, they learn what to do and why it is important. They should know how to properly clean equipment, document and record all information, save a seed sample and the seed label. If this is done each time it saves a lot of scrambling later to figure out what was actually done.

Dedicated Cleaning Site

Cleaning equipment is so important not only for organic but all equipment. We used to do it in front of shop but it would run down across the parking lot next to our headquarters and make a mess. We now have built a new wash pad with a new pressure washer on the back of a building further away from headquarters.

Dedicated Room for Seed Storage

Sometimes it was difficult to tell if the seed was organic approved or not and which researcher purchased the seed. Now we know if it's in the seed room we should have all the paperwork needed. If seed was used in 2009 it should be able to use in 2010 because it was already approved.

Dedicated Equipment

If you think you have all the equipment you need for organic you are wrong. Some specialized equipment will be needed and the equipment will need to be in good shape. Things like a crimper, tine weeder, a couple cultivators, and an aggressive rotary hoe. We also purchased a dedicated corn planter. Going from a conventional planter to an organic planter takes a good 4 hours of cleanup.

Order Same Varieties and Coordinate Planting Dates

We try to order the same varieties for all three sites. This way we can share seed and don't have so many partial bags left over. Emptying seed boxes and cleaning always takes extra time. We also try to plant similar dates where possible to get done with the planter at the same time.

INSECT RESPONSE TO APPLIED NUTRIENT INPUTS IN ORGANIC FIELD CROP PRODUCTION[1/]

Robin E. Mittenthal and Eileen M. Cullen[2/]

Soil Fertility, Plant Health, and Insect Responses – An Overview

Because organic farmers have relatively few control options when insect pest populations reach problem levels, a preventive approach to pest management is essential in organic systems. However, given the limited research base regarding relationships between soil fertility, plant health, and insect growth and reproduction, it's unclear in many situations exactly what this should mean to farmers in terms of inputs and practices.

What do we know so far? In general, mineral nutrition status is known to influence factors such as growth and yield of crop plants by affecting changes in growth pattern, plant morphology and anatomy, and particularly chemical composition. For example, thickness of epidermal cells, degree of lignification, sugar concentrations, amino acid content in phloem sap, and levels of defensive compounds are all influenced by nutritional status of the plant, and in turn either affect or are presumed to affect resistance to insects (Marschner, 1995, Patriquin et al., 1995). Much of the work done to explore plant-insect relationships has involved aphids and nitrogen. For example, there is substantial evidence that aphid reproduction is increased by high levels of soluble N (e.g., amines, amides, amino acids) in host plant leaves (McKee 1962; Auclair, 1963, 1965; van Emden et al., 1969).

We can also say at least a few specific things about the connections between soil fertility management and insect pest problems at the farm scale. For example, both overfertilization with N (Mattson, 1980; Koritsas and Garsed, 1985) and insufficient soil K (Myers et al., 2005; Myers and Gratton, 2006, Walter and DiFonzo, 2007) seem to make crops more susceptible to aphids and other pests by increasing free amino acids in plant tissue.

Overall, the state of research so far with respect to soil fertility management and prevention of insect pest problems doesn't suggest a clear course of action in most cropping systems other than regular soil testing and fertilization as needed to meet the needs of each crop. There are anecdotal observations that a "healthy" soil makes for "healthy" plants capable of repelling (or at least tolerating) feeding by insects, but "healthy" can be defined many ways. Both organic and conventional growers have proposed managing pests through the addition of livestock manure, green manures, compost, mineral fertilizers, and a host of other measures. Researchers have found hints regarding which of these methods might contribute to insect pest suppression (e.g., Chaboussou, 1976; Eigenbrode and Pimentel, 1988; Listinger, 1993; Phelan et al., 1995; Alyokhin et al., 2005; Arancon et al., 2007), but the work of teasing apart how they work and how best to make use of them has largely not been done. When evaluating nutrient management practices as a researcher in field trials, it is important (but difficult) to separate effects on pest populations that occur as a result of changes in levels of plant-available nutrients from effects observed as a result of other simultaneous changes such as an increase in crop residues that might harbor predators (e.g., Schmidt et al., 2007).

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The Base Cation Saturation Ratio (BCSR) approach

One specific fertility management approach that has been advocated to help plants repel or tolerate feeding by insects is the "basic cation saturation ratio" (BCSR) concept (sometimes referred to as the "soil balance" approach). The BCSR concept, use of which is not limited to organic agriculture, proposes that chemical, physical, and biological soil conditions are optimal for plant growth when the negatively charged exchange sites on soil clay and humus are filled with particular proportions of the cations Ca, Mg, and K (Exner, 2007). For Bear et al. (1945, 1948, 1951), on whose work the idea primarily rests, these proportions were 65% Ca, 10% Mg, and 5% K, with protons filling the remaining exchange sites. Graham (1959) and Albrecht (1975), important proponents of the concept, later gave ranges from 65 to 85% Ca, 6 to 20% Mg, and 2 to 5% K that they felt were acceptable. As a practical matter, since many soils of the Upper Midwest have Ca saturation levels lower than these target ratios, growers interested in the BCSR approach usually try to add Ca ions to their soil (and, consequently, displace Mg and K ions) by fertilizing with either calcitic limestone [calcium carbonate, $CaCO_3$], or gypsum [calcium sulfate, $CaSO_4 \cdot (H_2O)_2$].

As a guide to fertilizer application, the BCSR concept is often contrasted in the literature and in recommendations made by soil testing labs with the "sufficient levels of available nutrients" (SLAN) concept (McLean, 1977; Eckert, 1987; Exner,2007). Under the sufficiency level concept, there are "Definable levels of individual nutrients in the soil below which crops will respond to added fertilizers with some probability and above which they likely will not respond" (Eckert, 1987).

Reviews of early work by Bear, Albrecht, and others on the BCSR concept reveal significant methodological flaws. In particular, the method by which given Ca saturations were obtained resulted in changes in pH such that what was actually being measured was plants' response to pH and not Ca or ratios of cations (Kopittke and Menzies, 2007). Dozens of studies reviewed by Kelling and Peters (2004) and Kopittke and Menzies (2007), including a series of field and laboratory experiments by McLean, one of Albrecht's students, failed to find significant benefits in yield or tissue composition by using the BCSR concept as a guide to fertilization rather the SLAN concept. Work by Olson et al. (1982), Exner (2007) and others has also demonstrated higher costs to the BCSR approach relative to the SLAN concept.

Despite the lack of definitive research support for the BCSR concept, McLean (1977) and Kopittke and Menzies (2007) document that it remains popular around the world among both conventional and organic growers, as well as consultants and some private soil testing labs. With the exception of Schonbeck (2000), working in vegetable systems in the southeastern U.S., no one has explored the impact of BCSR-based fertilization in certified organic production or with respect to insect pest problems. As a result, with the encouragement and participation of seven certified organic growers throughout southern Wisconsin (three of whom use the BCSR approach as a guide to fertility management), we are conducting a long-term field study with the primary objective of evaluating the role of the BCSR concept in crop plant nutrient uptake and insect pest and natural enemy response in an organic field and forage crop rotation.

BCSR, Plants, and Insects – Introduction to Field and Greenhouse Experiments

Working in a Plano silt loam at the Arlington Agricultural Research Station near Madison, Wisconsin, we have been comparing two different organic soil fertility systems for their impact on a variety of insect pests since 2007. The first of these two systems, the standard organic fertility (SOF) system, relies on livestock manure, alfalfa hay in the rotation, and cover crop green manures for nitrogen and most other crop nutrients. The second (BCSR) system involves all of the management practices just described but also entails addition of either high-calcium aglime (a single application averaging 3,000 lb per acre in spring 2007) or gypsum (average of 2,600 lbs per acre in spring 2008, and average of 3,000 lb per acre in late fall 2009) regardless of soil pH levels. There are 32 0.77-acre plots, 16 of each organic fertility treatment, and each plot is being moved through a four-year rotation (alfalfa/forage grass plus small grain, alfalfa/forage grass, corn, soybeans) typical of many farms in the region. The plots received formal organic certification in fall 2009.

Plant tissue mineral analyses and standard tests of soil physical and chemical properties (including organic matter, pH, and ratios of exchangeable cations) have been conducted at appropriate times (for example, after exposure to a full season's rainfall, in the case of calcium inputs) either annually or as needed to choose levels of inputs. Weed management has involved delayed planting dates typical of organic field crop production, pre-plant flushing of weeds with shallow cultivation (average of three separate operations), and post-plant cultivation with rotary hoes, tine weeders, hilling cultivators, and other tillage implements common to both organic and conventional production (average of 5-6 total separate operations). Data on weed populations and weed species composition (not presented here) have now been collected for four growing seasons.

Beginning in 2008, we also added a set of conventionally managed plots (rotated between corn and soybeans) in an adjacent field of the same soil type. These plots receive urea and other synthetic fertilizers as dictated by soil tests and crop removal. They also receive preplant application of appropriate herbicides but no insecticides. Rather than comparing organic and conventional systems *per se*, the purpose of these plots is to help determine whether any plant or insect effects seen in the organic plots are a function of organic management in general as opposed to the BCSR method in particular.

In all three systems, we have focused our data collection on three crop-pest associations: soybean aphid on soybeans, potato leafhopper on alfalfa, and a set of Lepidopteran larvae (European corn borer, corn earworm, and western bean cutworm) on corn. Phelan et al. (1995, 1996) found that the history of soil fertility management (standard organic versus conventional, in their studies) affected egglaying preferences by European corn borers. Together with differences in population densities and timing of population establishment, this represents the kind of changes we might expect to find.

Because it is possible that one or another of our fertility management approaches might help plants regulate pests to levels that naturally occurring predators are better able to suppress, we are measuring both pest populations and the interactions between pests and natural enemies. Work with natural enemies thus far has focused largely on predators of the soybean aphid.

To complement the long-term field experiments, we have also conducted a set of greenhouse studies. These studies involved rearing two different insects (soybean aphids and beet armyworm larvae) on soybean plants grown in soil modified in the laboratory to a set of different cation ratios. These studies allowed us to explore possible effects of the BCSR fertility management approach on insect feeding and population growth under controlled conditions, and also to compare and contrast these response variables for chewing and sucking insect pests. Soybean tissue from these experiments was also sampled for its concentrations of calcium oxalate. Calcium oxalate is a mineral that most vascular plants accumulate in crystalline form in their tissue. In some studies by other researchers (e.g., Korth et al., 2006**)**, calcium oxalate appears to help plants defend themselves against predators. As a result, possible increases in calcium oxalate concentration as a result of BCSR fertility management could provide a mechanism to explain insect pest effects observed in the field.

BCSR, Plants, and Insects – Field and Greenhouse Results and Discussion

Selected characteristics of soil from the standard organic and BCSR organic treatments are presented in Tables 1 and 2. Values from before the start of the experiment (fall 2006) are contrasted with values obtained in late summer 2010. Values from conventional plots from 2010 are shown for comparison purposes.

Table 1. Selected characteristics of soil from two organic treatments and a conventional comparison before (2006) and after (2010) several years of amendments as discussed in the text. Conventional plots were added to the experimental design in 2008 and are in a field directly adjacent to the field containing the long-term organic fertility systems trial. Values shown are means of four replicates of each treatment. If no letters are present within a column, values in that column do not differ. If letters are present, values not sharing a lower-case letter are significantly different within each column by ANOVA and Tukey's HSD at the P = 0.05 level.[¶]

	Percent organic matter*		pH		P ppm		K ppm		Ca ppm		Mg ppm	
	2006	2010	2006	2010	2006	2010	2006	2010	2006	2010	2006	2010
Standard organic fertility	3.4	3.6	6.7	6.6	76	65	207	199 a	1629	1991 a	559	600 a
BCSR organic fertility	3.1	3.5	6.7	6.9	72	64	183	173 b	1598	2321 b	552	492 bc
Conventional fertility	N/A	3.6	N/A	6.7	N/A	74	N/A	329 b	N/A	1809 c	N/A	527 c

[¶] While these data meet assumptions for ANOVA, results represent preliminary analysis. Proper analysis may involve building models that incorporate a block effect for each variable within each year.
* Analytical methods used: organic matter, loss on ignition; pH, water (1:1); P, weak Bray (Bray 1); K, Ca, Mg, extracted with 1 *M* NH_4OAc at pH 7. Analyses performed Midwest Laboratories, Omaha, NE.

Statistical analysis across years within each treatment will likely prove informative (for example, both soil organic matter and total cation exchange capacity may have increased in both organic treatments), but these analyses have not been completed. Comparisons within years and across treatments are also preliminary and will need to be adjusted for block effects and other factors. However, at present it seems that the BCSR organic plots have significantly higher levels of exchangeable soil calcium than standard organic plots (an average of 2321 ppm Ca for BCSR in 2010 compared to 1991 ppm Ca for standard). At the same time, BCSR plots also have significantly lower levels of exchangeable Mg and K than standard plots (492 ppm Mg for BCSR in 2010 compared to 600 ppm Mg for standard, and 173 ppm K for BCSR compared to 199 ppm

K for standard). These results are consistent with the replacement of Mg and K by Ca on surfaces of soil clay and organic matter. In all treatments, however, quantities of Ca, Mg, and K are above deficiency ranges defined for Wisconsin according to the SLAN concept (Laboski et al., 2006).

Table 2. Cation-related characteristics of soil from two organic treatments and a conventional comparison before (2006) and after (2010) several years of amendments as discussed in the text. Conventional plots were added to the experimental design in 2008 and are in a field directly adjacent to the field containing the long-term organic fertility systems trial. Values shown are means of four replicates of each treatment. If no letters are present within a column, values in that column do not differ. If letters are present, values not sharing a lower-case letter are significantly different within each column by ANOVA and Tukey's HSD at the P = 0.05 level.¶

	Cation exchange capacity ($cmol_c$ per kg)		Percent saturation with Ca		Percent saturation with Mg		Percent saturation with K		Ratio of percent Ca saturation to percent Mg saturation	
	2006	2010	2006	2010	2006	2010	2006	2010	2006	2010
Standard organic fertility	13.9	16.4 a	58.9	61.0 a	33.6	30.6 a	3.8	3.1 a	1.75	2.00 a
BCSR organic fertility	13.6	16.4 a	58.7	70.7 b	33.9	25.0 b	3.4	2.7 a	1.74	2.84 b
Conventional fertility	N/A	14.5 b	N/A	62.3 a	N/A	30.3 a	N/A	5.8 b	N/A	2.06 a

¶ While these data meet assumptions for ANOVA, results represent preliminary analysis. Proper analysis will likely involve building models that incorporate a block effect for each variable within each year.

*Analytical methods used: K, Ca, Mg, and Na extracted with 1 *M* NH_4OAc at pH 7 (Na not shown; levels were very low), protons (H, not shown, present at low levels) estimated from buffer pH. Analyses performed Midwest Laboratories, Omaha, NE.

The ratio of percent saturation with Ca to percent saturation with Mg appears to be significantly higher for the BCSR organic soil than for the standard organic soil (2.84 compared to 2.00 in 2010). The BCSR plots have significantly higher percent saturation with Ca than the standard plots (70.7% compared to 61.0% for the standard plots in 2010), and this percentage brings the soil into the range suggested by advocates of the BCSR approach.

Despite approaching the target cation ratios in the field BCSR organic plots, few measures of yield or insect pest response have differed significantly by treatment thus far. Yields of corn in 2010, for example, averaged 192 bushels per acre for all treatments, while soybean yields ranged insignificantly between 63 and 65 bushels per acre for the three treatments (soil balance, standard organic, conventional). Data on grain quality and forage quality have been collected and statistical analyses of these data are underway.

One representative set of insect data is the graph of soybean aphid population growth shown in Figure 1. As with a similar set of data from 2008 (not shown), aphid populations appeared to diverge between the three treatments near the end of the season, with populations lowest in the BCSR organic plots, next lowest in the standard organic plots, and highest in the conventional plots. However, due to wide variation in aphid counts between plants, populations did not differ significantly by treatment except on the final sampling date, when plants in conventional plots harbored significantly more aphids than plants in either of the two organic treatments. We have not yet analyzed the analogous 2010 data, but preliminary summaries suggest that the pattern of data is the same as in the previous two years. We are now analyzing a corresponding set of plant tissue data for each pest (mineral content of soybean leaves at R1-R2, in the case of soybean aphids) that may allow us to establish soil-plant-insect interaction effects.

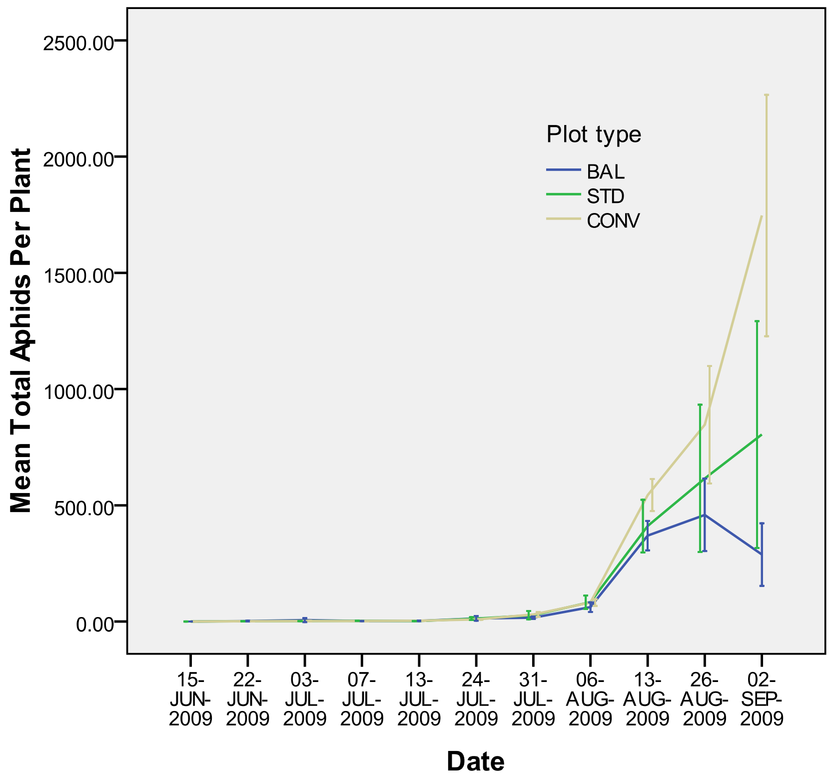

Figure 1. Aphid populations in plots of three treatments (BAL = BCSR organic, STD = Standard organic, CONV = Conventional) in summer 2009. Error bars represent +/- 2 SE.

Research results from the greenhouse largely mirror those obtained in the field. Using methods modified from Favoretto et al. (2006), we did successfully create soils with ratios of exchangeable Ca:Mg as high as 4.65:1. There was a significant difference between soil treatments in the length of time it took for beet armyworm larvae to reach pupation, with the larvae on plants grown in 4.65:1 soil pupating slightly faster than larvae in other treatments. However, weight gain and final pupal weight do not appear to have been significantly affected by feeding on soybeans grown in soils of different cation ratios. Soybean aphids feeding on similar soybean plants similarly did not differ in lifespan or total lifetime reproduction.

Though there was no apparent response by insects to the cation ratios in which their soybean host plants were grown, leaf tissue from the plants themselves did vary in content of calcium oxalate (see Fig. 2). Plants grown in soil modified to Ca:Mg ratios of either 2.95:1 or

4.65:1 contained significantly more calcium oxalate than plants grown in unmodified control soil with a Ca:Mg ratio of 2.0:1. Plants grown in soil of the 2.95:1 ratio also had more calcium oxalate than plants from a second control group grown in soil rinsed with water in a way that mimicked the cation ratio modification process, though this was not true of plants grown in soil with a 4.65:1 ratio.

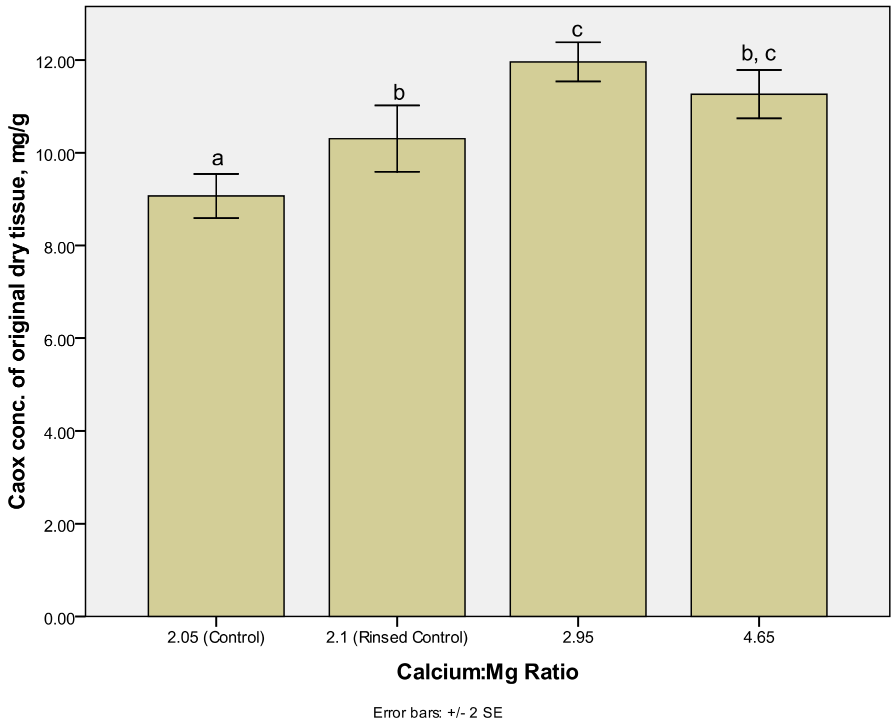

Figure 2. Calcium oxalate content of dry leaf tissue from soybean plants grown in soil of varying cation ratios. The "rinsed control" treatment involved soil that had been repeatedly saturated with water in a way that mimicked the modification process but did not involve concentrated calcium and magnesium salts. Columns not sharing a letter are significantly different by ANOVA and Tukey's HSD at the $P = 0.05$ level. Calcium oxalate levels were determined using a kit and protocol (available from Trinity Biotech, Dublin, Ireland).

BCSR, Plants, and Insects – Take-Home Points

- Changing cation ratios on a field scale appears possible, but the amounts of inputs required are large.
- In greenhouse experiments, use of the BCSR approach does not appear to have had significant effects on insect pests.
- Though aphid data hints at a possible difference in insect response between the two organic treatments, the BCSR approach has overall not shown significant effects on either crop yield or insect pest populations in four years of a large-scale field trial. However, the high Ca:Mg ratios advocated by BCSR proponents have only been achieved recently and may not yet have had time to affect plants or insects.

- By comparison with adjacent conventional plots, there is suggestive evidence that organic fertility management (with or without BCSR-related inputs) might result in lower pest populations than a conventional fertility system without insecticides.
- Our goal is to develop research-based information on how different organic fertility management practices affect crop resistance to insect pests, and what (if any) particular soil fertility management practices are most helpful. The practices described here represent only one possible fertility management variant with one set of crops and pests on a particular soil type and should not be interpreted as conclusive for any other production system.

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