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2006 Wisconsin Fertilizer and Chemical Association Distinguished Service Awards

Distinguished Organization Award
Greg's Feed and Seed
Greg Seffrood
{For Exemplary Industry Professionalism}

Education
Fox Valley Technical College
Randy Tenpas
Dave Gerlach
{For Leadership & Commitment to Educational Excellence}

Outstanding Service to Industry
Dave Crass
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{For Dedication & Support of Legislative Issues}

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***Dan Zierke*, Olsen's Mill**
***Jim Beach*, Syngenta**
***Kent Syth*, AG Systems**
***Doug Yapp*, Van Diest Supply Co.**
{For Full-Term Board of Director Service}

President's Service Award
Vince Michalski
Agriliance
{For Dedication, Service, and Leadership}

2005 – 2006
Scholarship Recipients

Wisconsin Fertilizer & Chemical Association Scholarships

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Marcus Portz, Southwest Wisconsin Tech
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Ronald E. Doersch WFCA Member Scholarship

Cody Kanable, UW-Platteville

R.D. Powell Memorial Scholarship

Nancy Bohl, UW-Madison

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MANURE RUNOFF: IT CAN HAPPEN TO YOU

Karl Klessig [1/]

{This page provided for taking notes}

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WHEN TWO WORLDS COLLIDE
THE FISH-MEETS-MANURE EXPERIENCE

Kurt I. Welke [1/]

2005 was a year when the worlds of fisheries and agriculture met too frequently under less than ideal conditions. The delivery of animal waste to the ground and surface water resources of the state resulted in widespread impacts to the public trust. These impacts included private drinking water contamination, fish kills, and chronic effects that impair habitat, recreation, aesthetics, and systemic health of public resources.

These events elevated manure management to a Governors' priority. Recommendations set forth by an appointed task force have raised public awareness and jump-started a long overdue dialogue between the agricultural community and regular citizens. Long held beliefs and practices concerning the volume, timing, and location of winter-spread manure are being discussed and challenged. The Departments of Natural Resources and Agriculture, Trade and Consumer Protection are advancing a suite of actions that seek to balance economic, logistic, and environmental concerns.

The mechanisms of how manure is delivered to surface waters are discussed in respect to components that drive an event. The vulnerability of fisheries resources to ammonia toxicity in relation to pH, slope, application rate, and distance from water are examined using a case study from winter 2005. Strategies to mitigate a manure spill once it occurs are presented.

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ANATOMY OF A RUNOFF EVENT

Laura Ward Good [1/] and John Panuska[2/]

How Water Runs Off a Field

When rain or snowmelt water accumulates on a field faster than it can flow into the soil, or *infiltrate*, it will begin to fill up all the depressions in the soil surface. If there is enough water that all the indentations fill up and spill over, runoff will begin. Initially, runoff can flow down hill as very thin sheets of water. It does not have to travel very far, sometimes just a few feet, before it starts to form very small but visible channels, called rills. As the water continues to flow down slope with more water flowing into them, the channels become bigger until they flow into gullies or intermittent streams.

What Determines How Much Water Runs Off

The rate and length of time that water is applied to a field as rainfall or snowmelt has an obvious effect on the amount of runoff resulting from a particular storm or snowmelt event. Soil and field conditions also affect runoff volumes – often a storm that produces a large amount of runoff on one field will not produce any runoff at all from adjacent fields. Many factors affect runoff volumes, including:

- Soil texture – heavier soils generally have lower infiltration rates than sandier ones
- Slope and landscape configuration – runoff flows and forms channels more quickly on steeper slopes
- Soil structure – compacted soils have few pore spaces for water to enter
- Soil moisture – if soil pores are already partially filled with water, infiltration is slowed
- Frozen soil – the presence of ice in soil pores can block infiltration
- Plants – stems and leaves near the soil surface trap runoff or slow it down, reducing the formation of channels and allowing for more infiltration
- Residue – crop residue left on the surface also traps and slows runoff
- Surface depressions – the higher the volume of depressions, such as tillage furrows, the more water will be stored there before running off. Direction of the depressions on a slope is very important – furrows on the contour will capture and hold runoff, while furrows running up-and-down slope can act as flow channels.

The last three items above vary with crops and tillage, while soil moisture and freezing are a function of weather and the season. To show how these factors can interact to cause differences in runoff amounts, we can compare the runoff generated on three fields during spring and winter events at the UW-Platteville's Pioneer Farm. (Note: These fields have similar soils and topography, but are not exactly the same, and we know that some of the variability in runoff volumes shown below has to do with the shape of the slopes rather than crops and tillage.)

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Example 1: Total runoff inches generated by a series of rainstorms, June 12 – June 16, 2004.
Field A. Alfalfa/brome – 0.07
Field B. First year corn for grain following fall-killed alfalfa (low residue, smooth field, crop not up yet) – 0.6
Field C. Second year corn for grain, fall-chisel plowed – 0.11

Example 2: Total runoff inches generated by snowmelt and rain on snow, Feb. 12- Feb. 16, 2005.
Field A. Alfalfa/brome – 1.0
Field B. Corn for grain, following fall chisel-plowing on contour, some winter-applied manure- 0.6
Field C. Corn field, following fall chisel-plowing on contour – 0.8

The alfalfa/brome field had much less runoff than the first year corn field in June when the corn crop had just emerged, but more in the winter. Depressions remaining after fall tillage stored some snowmelt runoff in the corn fields.

How Manure Runs Off a Field

Manure constituents like nitrogen, phosphorus, and organic carbon can be lost from fields by dissolving into runoff or as manure particles carried by flowing water. A critical factor in how much of a manure application's nutrients are removed in runoff is the amount of time between the application and the runoff event. It is likely that any water running off of a field within several days of a manure application is going to be very dark and have a high concentration of phosphorus, nitrogen and manure particulates. As a general rule, the longer the time between the application and runoff, the more the manure becomes part of the soil and less susceptible it is to loss. Another critical factor in determining losses is the total volume of runoff. The effect on water quality of nearby surface water is determined by both the nutrient concentrations and quantity of manure-carrying runoff water.

Runoff amounts from fields with manure are affected by the same factors as fields without manure. A manure application can be thought of as a mixture of residue (dry matter) and water. The more liquid the manure is, the more it adds to surface soil moisture. On the other hand, dry matter added as manure can act like residue in slowing and trapping runoff.

Runoff events that have occurred soon after manure application on monitored fields provide examples of how much manure can be lost from the field in runoff. At the Arlington Research Station, 8500 gallons per acre dairy manure were applied to a field in continuous corn silage on 10/29/03. Rainfall started on 11/1/03 before a planned chisel plowing to incorporate the manure could take place and continued off-and-on for several days. Approximately 3% of the applied manure ran off during this period. Another example is a no-till corn field which received 6000 gallons per acre liquid dairy manure in early October of this year. Within three hours of application there was an unexpected storm with 0.55 inches rainfall. About 4% of the applied manure ran off. Manure on snow is at risk of loss in snowmelt, particularly if it is applied within a short time period before the thaw. At the Pioneer Farm, about 3% of the solid beef manure applied in early February ran off during the first series of snowmelt events after application to a fall-chiseled corn field (Field B in Example 2 above). While 3 or 4% may seem like a relatively small proportionate loss, it can have a substantial impact on water quality if the runoff reaches a stream without substantial dilution. An adjacent stream turned black immediately following the October event described above.

SUBSURFACE FLOW OF MANURE AND WATER

Liz Heinen [1/]

{This page provided for taking notes}

[1/] Wis. Department of Natural Resources.

SOIL STRUCTURE: FRIEND OR FOE?

Birl Lowery [1/]

Soil structure controls many soil functions including water and air (gas) flow in soil. Although soil structure has received considerable attention by soil scientists, structure is one of a limited number of soil properties that have not been sufficiently quantified, and to date there are no good methods or techniques for doing so. Soil structure is generally unstable in time and it is nonuniform in space, and it is affected by changes in climate, biological activity, and soil management practices (Hillel, 2004).

Soil structure is defined by the Soil Science Society of America (SSSA) (1996) as the combination or arrangement of primary soil particles (sand, silt and clay) into secondary units or peds. Soil structure can be granular, blocky, prismatic, platy, or it could be structureless and classified as single grain or massive (Fig. 1). These secondary units, which are generally referred to as aggregates are further described based on their size, shape and grade. Grade is the degree on distinctness expressed by aggregates. Soil aggregates are formed as a part of natural soil forming processes. Soil structure is classified as *structureless*, *weak*, *moderate*, or *strong*. This classification is based on soil aggregation. Again according to SSSA (1996) *structureless* soil has no observable aggregation, *weak* has poorly formed indistinct peds, *moderate* has well-formed distinct peds, and for *strong* the peds are distinct and easily separated.

Soil porosity or pore spaces, which is the space between and within aggregates, is that part of soil that houses soil water and/or air. Water and air flow through interconnecting soil pores. Sandy soils permit rapid air and water flow but these soils are often characterized as *structureless* (Fig. 1 and 2A). Sandy soils are classified as having single grains with large pore spaces which are responsible for the good water and air fluxes (Plaster, 2003) (Fig. 2A). Similar flow conditions are found in granular soils (Fig. 2B). Like sandy soils, some fine textured soils can be *structureless* as well, but unlike sandy soils they tend to have massive structure and have limited capacity to transmit water and air (Fig. 3). While massive clayey soils have extensive porosity, the pores are very small and not generally well connected, and as such they do not transmit water or air readily. Platy is another structure that limits water and air movement through the soil profile (Fig. 1). On the other hand, soils with *moderate* or *strong* prismatic or blocky structure, or a combination of both, will have good water and air transmitting capacity and are well drained, yet they have good water holding capacity (Figs.1 and 4). In the past, we have viewed these as excellent soils with ideal hydrological properties for any land use. However, we are now coming to the realization that these soils can be subject to extremely rapid water movement resulting in possible contamination of groundwater when they are located in certain landscape positions such as closed basins (Samuelson, 1999).

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References

Hillel, D. 2004. Introduction to environmental soil physics. Elsevier, Academic Press, New York. 494 p.

Plaster, E.J. 2003. Soil science and management. Thomson, Delmar Learning, Clifton Park, NJ. 384 p.

Samuelson, J.R. 1999. Atrazine and nitrate leaching in a glacial landscape. M.S. thesis, Univ. of Wisconsin, Madison, WI.

Soil Science Society of America. 1996. Glossary of soil science terms. Soil Science Society of America, Madison, WI.

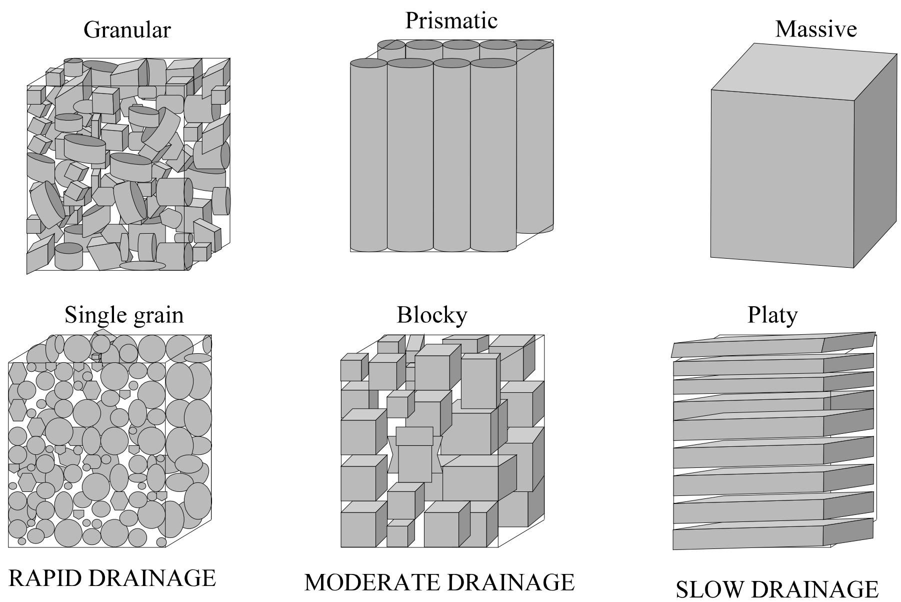
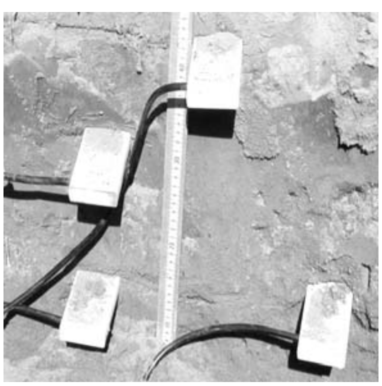


Figure 1. Illustration of different types of soil structure and indication of structure impact on drainage.



A B

Figure 2. Example of single grain (A) and granular (B) soils.

Figure 3. Example of massive soil.

A

B

Figure 4. Example of blocky structure (A) and macropore (B) (Courtesy Brian Lepore, 2005).

SMOKING TILE LINES: A DEMONSTRATION OF SOIL STRUTURE

Ted Bay[1], Jerry Clark[2], Carla Heiman[3], and Kevin Erb[4]

Introduction

Soil structure is a key component to soil quality. Substitution of conservation tillage and no-till for conventional tillage practices greatly affects soil structure and decrease runoff and losses of soil, nutrients, and agrochemicals in overland flow. However, enhanced infiltration increases the potential for sub surface flow, especially in tile lines. Earthworm burrows, root holes, cracks and structural porosity in the soil surface can allow for rapid transport of nutrients and chemicals to tile lines.

Liquid manure has become the norm on many livestock operations. These liquid wastes are applied by surface application or incorporated with tillage or by direct injection. Because of concerns with odor and surface runoff, subsurface injection is becoming more widely used by livestock operations. The issue of liquid manure entering subsurface drainage systems is being increasingly recognized as an important environmental issue throughout drained areas in the U.S. Midwest. The combination of increased conservation tillage, increasing use of liquid manure, and deeper incorporation of liquid manure, transport of manure through soil to tile lines has become an issue.

Transport to Tile Lines

Field research indicates that the amount of rainfall transmitted by earthworm burrows increases with storm intensity and is as much as 10% of total rainfall. Laboratory studies indicate that if a heavy, intense storm occurs shortly after surface application of liquid manure or chemicals, the water transmitted to the subsoil by earthworm burrows may contain significant amounts of that which was applied, up to a few percent. Transport of nutrients can be reduced with the passage of time or if light rainstorms precede the first major leaching event. In the case of fields with subsurface drainage, however, close association of earthworm burrows to tile drains may substantially increase the risk of surface water contamination by surface-applied agrochemicals and injected animal wastes. Likewise, earthworm burrows may connect to subsoil fractures and contribute to rapid water and chemical movement to drains and ground water.

The residue cover on no-till soil significantly reduces the effects of raindrop impact and the propensity for the soil to crust. The residue also produces a more favorable environment for earthworms by keeping the soil cool and moist and providing a continuous supply of food for surface-feeding earthworms. Since they can ingest and process a large amount of soil and residue on a yearly basis, earthworms have the potential to greatly affect how water moves through the soil.

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Ohio Study Determines Transport to Tile Lines

In a study to determine the effect of earthworm burrows to tile line, Frank Gibbs, NRCS Ohio, and Martin Shipitalo, USDA-ARS, used dyed water to measure the infiltration in individual burrows. The infiltration rates in burrows that did not emit smoke were also measured using water dyed a different color. The dyed water quickly entered the burrows where smoke was observed and appeared in the outlet more than 12 m downstream from the nearest burrow only 14 minutes after infiltration measurements were begun and after only a total of only 9.3 L of water had been added to the burrows, even though the drain was not flowing at the time the experiment was begun. The dyed water added to the burrows that did not emit smoke was never observed in the drain. In this study, smoke was observed up to 7 m away from the tile line. Earthworm burrows are not solely responsible for this as burrows tend to be vertical. Burrows connected to cracks, root holes, and soil structure was other probable causes. Using melted plastic to mold earthworm burrows, it was determined that some burrows approach within a few cm of tile line but never entering it (Shipitalo and Gibbs, 2000).

Tile Line Smoking Demonstration

In 2005, the UW-Extension Nutrient Management Team and Grains Team collaborated to host Soil Quality Field Days at four locations across Wisconsin. Field days were held in Fond du Lac, Chippewa, Adams, and Columbia counties. The tile line smoking demonstration was included at the Fond du Lac County site. This demonstration was designed to show how soil structure and specifically, earthworm burrows can affect water and liquid manure movement.

At the field day, Frank Gibbs, USDA-NRCS, Ohio presented information on earthworm burrows and how the tile line smoking demonstration is set up. A pit was opened to expose a short segment of the tile line and the line was temporarily severed. The 200-foot tile line was hooked up to a gasoline powered turbine blower. Once the blower was started, an ignited smoke cartridge was placed on the intake portion of the blower. Within seconds of smoke intake, smoke could be seen escaping through earthworm middens. In most cases, middens emitting smoke were in line with the tile line but there were cases where emission points were 18 to 24 inches outside of the tile line. Eventually, all portions of the tile line were emitting smoke.

A surface application of water was applied to a section of soil above the tile line two hours before the demonstration. The area that was watered had increased earthworm activity and was emitting an increase of smoke compared to the non-watered section.

Control Measures

With the potential for liquid animal wastes to adversely affect water quality when applied to land that has subsurface drainage, both immediately after application and when mobilized by subsequent rainfalls, control measures exist that might reduce these concerns. If tillage is necessary, tilling as high above the tile line as possible will disrupt burrows and leave more area for liquid dispersion in the sub soil. Using precision farming technology to apply liquid manure away from drains may avoid drainage to tile lines. In many instances, however, this will be impractical because of uncertainty in locating the drains, the random nature of the drainage network, and the size of the area that needs to be avoided or tilled.

Inflatable plugs or shut-off valves might be used to block the drains when liquid animal wastes are being applied, thereby allowing any wastes that enter the drain time to reenter the soil. These may not work because of their in ability to withstand pressure heads. Use of shut off valves and catch basins can reduce the failure rate encounter with plugs and valves alone, but still does not address the issue of rainfall-mobilized wastes. The use of application equipment that disrupts the continuity of macropores to the drains can promote diffusion of liquid animal wastes into the soil matrix and thereby reduce both immediate movement to the drains and rainfall-mobilized movement, but probably will not eliminate these losses. Likewise, tillage will probably reduce losses by disrupting macropores and promoting diffusion, but has undesirable consequences of negating the beneficial soil and water quality aspects of conservation tillage. (Shipitalo and Gibbs, 2005).

Gibbs indicated at the field day that liquid manure with more than 5% solids does not enter tile line as readily as manure with less than 5% solids. Agitation of manure storage units and bedding materials can greatly effect liquid manure composition. Managing agitation and bedding are ways to control liquid manure reaching tile lines.

Future Demonstrations

Tile line smoking demonstrations are planned for Wisconsin and northern Illinois in June 2006. Contact the authors below for more information.

References

Shipitalo, M.J., and F. Gibbs. 2000. Potential of earthworm burrows to transmit injected animal wastes to tile drains. Soil Sci. Soc. Am. J. 64:2103-2109.

Shipitalo, M.J., and F. Gibbs. 2005. Preferential flow of liquid manure in macropores and cracks. Paper for 2005 ASAE Annual International Meeting. Tampa, Florida.

INSECTICIDE BASICS–101

Phil Pellitteri [1]

People and insects have more in common than you might think. Insects need to breath oxygen, convert food to energy and regulate their movement and body functions with a nervous system that is very similar to ours. It should come as no surprise the chemicals that kill insects by asphyxiation, stopping energy production or affecting nerves can be toxic to humans. Insecticides can function as stomach poisons, contact and residual contact poisons, and as gasses that are taking in during respiration (fumigants). For contact insecticides it helps to be lipo-philic (fat loving).Insects adsorb these liphilic compounds through their skin. Understanding how insecticides work is important to help select products that are less toxic and also prevent or slow down the development of insecticide resistance in insect populations.

Insecticides are defined as products that kill an insect. These products can be classified by chemical family, how they kill, or by their mode of action. The mode of action (MoA) is the "how and where" a product works. Chemicals may be unrelated but if they have the same mode of action, both can become ineffective when resistance develops. Since over 90% of the insecticides affect the nervous system, it is helpful to have some understanding of the how nerves work. In simple terms, nerves are composed of axons, neurotransmitters, and receptors. In order to transmit a message, an electrical signal or pulse must travel down the axon, release a neurotransmitter which travels across the synaptic cleft and attaches to a receptor on another nerve or muscle. These receptors can be stimulated or can be made less sensitive. There are also enzymes that degrade the neurotransmitters after they have completed their job. Without these enzymes, nerves would be stimulated continuously.

An analogy is to think of the axon as an arm, the neurotransmitter as a ball, and the receptor as baseball gloves. To get an impulse to travel you must throw the ball and capture it in the glove. Insecticides can prevent the arm (axons) from working-or close the baseball glove (tie up the receptors). The enzymes that breakdown the neuro-transmitters are the clean-up crew that pick up all of the "balls" when they have completed their job.

The sensitivity and type of receptors and neurotransmitters do differ in different parts of the body and in different animals. Neurotransmitters found in humans include acetylcholine, dopamine, serotonin, GABA and epinephrine. Insects can utilize different neurotransmitters or receptors than humans. It is like using different types of balls and gloves. If we can exploit the differences between humans and insects we can develop more selective and less toxic products. Much of the new chemistry has gone this direction, but it has also resulted in products that selectively kill only certain types of insects.

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Insects do have a number of biological properties that are different from us. They must molt their skin in order to grow. Many orders of insects including true flies, beetles and moths must transform from a worm-like larval stage to an adult creature that does not look like or behave like the immature. Insects control their development with unique hormones such as juvenile hormone (JH) or ecdysone. As with any animal, if we can disrupt the hormone system we can cause major problems and often kill or sterilize the insect. Insect skin is made from a plastic-like product called chitin which is unique to arthropods. Chemicals that prevent insects from making chitin will kill the insect yet are relatively non-toxic to other animals and humans.

In all 28 main groups or primary modes of action, sites have been identified in mites and insects. Some of these are specialized products and have not been developed for broad scale agricultural uses. The Insecticide Resistance Action Committee (IRAC)-Insecticide Mode of Action Classification has been developed to provide farmers, growers, consultants, and other crop protection professionals with a guide to select insecticides and acaricides for use in an effective and sustainable resistance management strategy. By rotating to different groups, you delay or prevent resistance problems.

Insecticides That Affect the Nervous System

Group 1 Acetylcholine enzyme inhibitors
    Organophospates (66 active ingredients, ai), carbamates (25 ai)
Group 2 GABA chloride channel antagonist
    Cyclodienes (3 ai), fiproles (2 ai)
Group 3 Sodium channel modulators
    DDT, Synthetic pyrethroids (46 ai), pyrethrin
Group 4 Nicotonic ACH Receptors agonist/antagonists
    Neonictinoids (cloronicotinyls) (7 ai)
Group 5 Nicotonic ACH receptors modulators
    Spinosyns
Group 6 Chlorine channel activators
    Avermectins (3 ai), mibemycins,
Group 22 Voltage dependend sodium channels
    Indoxacarb (Avaunt)

Hormonal Products That Affect Molting and Development

Group 18 Ecdysone agonist
    Tubufenozide, Azadiractin
Group 7 Juvenile Hornome mimics
    Fenoxycarb, methoprene (Flea products)

Cuticle (Skin/Chitin Synthesis)

Groups 15,16,17
    Benzoylurea(Lepidotera) , Buporfenzin(Homoptera)
    Cryomazine (Diptera)

Digestion

Group 11 Microbial disruptors of insect mid-gut
    Toxins of Bacillus thuringiensis-and Cry proteins

Metabolic Process (mostly baits)
Group 12 Inhibitors of oxidative phsophorylation
Diafenthiuon and organotin miticides
Group 13 Uncouplers of oxidative phsophorylation
Chlorfenapyr (Pylon), DNOC
Group 20 Site 11 electron transport inhibitors
Hyramethylon and Dicofol
Group 21 Site l electron transport inhibitors
Rotenone, METI acaracides

Insecticidal SOAPS

Fatty acids that affect permeability and structure of cell membrane- contact only

Oils

Act by asphyxiation (block spriacles)
plus essential plant oils can act as poisons by affecting fatty acids and interfering with metabolism

The IRAC Insecticide Mode of Action Classification can be found at **http://www.irac-online.org/resources/guide.asp**

Resistance can develop in a number of ways. Target site resistance refers to biochemical changes that make a site less sensitive to a chemical. Non target site resistance refers to enzymes or other factors which prevent chemical from getting to the target site. Examples would be: insecticides no longer penetrate the insect skin, or insecticides that are broken down by enzymes before they get to the nerve. Behavioral resistance is also possible. An example would be cockroaches becoming repelled by sugar as a pesticide bait mix – if they do not eat, it cannot kill them. Other factors such as soil degradation also affect how chemicals work

FUNGICIDE BASICS

Walter R. Stevenson[1/]

Fungicides play an important and often critical role in the production of most crops around the world. While fungicide treatments often complement other crop and pest management measures, there are times when the use of fungicidal chemistry provides the deciding factor in economical control of a plant disease. Complementary disease management options often include regulatory measures (quarantines, seed tolerance, seed certification programs), cultural activities (early or delayed planting date, rotation, sanitation to destroy crop debris and sources of inoculum, irrigation and nutrition management), biological and physical controls and host resistance. Developing a fully integrated disease management program utilizing these broad based options including chemical controls helps to greatly reduce the risk of economic losses to plant diseases.

A wide selection of fungicide chemistries are currently available for managing plant diseases. Each of these chemistries has its own unique mode of action affecting critical processes necessary for fungal survival, multiplication and host infection. While some fungicides affect a single enzyme or pathway, other fungicides affect multiple sites within the pathogen targets. Single site toxicants are often prone to pathogen resistance problems while multi-site toxicants are much less prone to resistance and are often effectively used for generations.

There are a variety of methods used for fungicide application. Depending on the target pathogen, the crop and the label registration, fungicides may be applied on seed or propagative units such as potato seedpieces, to the soil as broadcast or in-furrow treatments, as foliar or fruit sprays and dusts, and as post harvest treatments in sprays, dips or aerosols. Fungicide labels provide detailed information on rates, schedules, target pathogens and resistance management guidelines. A thorough knowledge of the plant host, the pathogen and how the environment affects crop development and health is useful in achieving high levels of product efficacy.

The use of fungicide controls dates back to at least 1000 B.C. when sulfur was used for control of wheat rust. Lime sulfur was used in the early 1800s for control of grape downy mildew and in 1883, the use of Bordeau mixture (copper sulfate and quicklime) was reportedly used on grapes for control of downy mildew. The year 1932 is widely regarded as the dawn of the organic fungicide era. Since 1932, significant resources have been invested in developing a wide array of fungicide active ingredients. Today there are literally hundreds of registered fungicidal products on the market, some with broad purpose uses and others with highly specific targets. In an effort to group fungicidal materials by activity, EPA and the FRAC (Fungicide Resistance Action Committee) has developed a fungicide classification system based on fungicide Modes of Action (MOA). In the scheme of organization, there are currently over 40 fungicide groups listed on the FRAC web site (www.frac.info/). New labels are beginning to reflect this classification system, with the Fungicide Group Code prominently displayed on the label.

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When discussing fungicides and the concepts related to their use, there are a few key terms that are useful to understand.

Fungicide Terms

- Preventative – prevents establishment of pathogen
- Curative – interrupts development of established infection which is not showing symptoms
- Eradicant – interrupts further development of established infection which is showing symptoms
- Antisporulant – prevents or decreases inoculum production without stopping vegetative growth
- Systemic – movement of fungicide in plant; locally systemic or translocated through plant via xylem or phloem

Preventative fungicides generally adhere to the plant surface and provide a barrier to invasion of the plant tissues by the pathogen. This group of fungicides must be present on the plant surface before the pathogen arrives or at least before the pathogen begins the germination and plant penetration process. A preventative fungicide is of little value once the pathogen has entered the plant and begins to use the host for nutrients. Since preventative fungicides are not absorbed or translocated by the plant, they are often subject to weathering from UV irradiation or washoff by rain and irrigation. Consequently they must be reapplied during periods of high plant susceptibility and environmental conditions favorable for pathogen dispersal and disease development. Some of the older preventative fungicides such as mancozeb continue to be relatively inexpensive and are often looked at by producers as cheap insurance against unexpected disease development.

In contrast, curative fungicides are usually systemic, entering the plant to protect local areas or in some cases, moving throughout the plant to protect both old and new tissues from infection. The period after plant infection by the pathogen when a fungicide treatment with a curative fungicide is still considered effective, is termed the kickback period. It presents a window of opportunity that is normally 12-48 hours in duration depending on the fungicide, the host, the pathogen and the environmental conditions present during this period. Once a fungicide is systemically dispersed within plant tissues–be it a leaf or group of leaves or the entire plant–these tissues are protected for a finite period against infection depending on the fungicide and the pathogen target. Since many of the newer fungicides with systemic properties are quite specific in terms of their modes of action and are prone to resistance management problems, manufacturers generally recommend that growers should not apply these products once disease symptoms are present and disease progress is observed.

There are many issues related to fungicide efficacy that are common to the management of other pest problems. Fungicide coverage is critical for optimum control, especially when using non systemic protective fungicides. Growers need to consider when the plant is most susceptible to specific pathogens and how to achieve maximum plant coverage. This often entails careful selection of spray equipment including nozzles and precise calibration to insure accurate delivery of the recommended and effective rate of pesticide. It also entails timing issues to maintain coverage during periods of rapid plant growth and adverse weather conditions so that the crop remains protected during critical periods. Resistance management issues continue to be an issue, especially with newer materials having a single targeted mode of action. Growers need to be aware of this issue and carefully read and follow label directions related to resistance management. Finally there are safety issues related to protecting the applicator, consumer and environment. Using the correct fungicide at labeled rates with careful timing for management of economically important diseases goes a long way toward effective and safe disease management.

Finally, there are many useful references on the internet. Some of the references that I commonly consult include the following:

- Greenbook – source of labels and MSDS safety information on all pesticides used in U.S.
  - http://www.greenbook.net/
- CDMS Ag Chem Information Services
  - http:// www.cdms.net/
- Fungicide Resistance Action Committee (FRAC)
  - http://www.frac.info/
- University of Wisconsin – Extension Publications
  - http://www.uwex.edu/topics/publications/

WEED MANAGEMENT WITH UNCERTAIN WEATHER

Ed Luschei[1]

Whether you are a homeowner with a small lawn or custom applicator contracting on thousands of acres in several counties, the success of your weed control efforts can be strongly driven by variability in the weather. If you are the homeowner with a small lawn, you can likely wait until weather conditions are favorable or use the short-term weather forecasts to help plan your weed control efforts. Farmers or custom applicators, however, are usually more severely constrained by a large set of additional responsibilities. Many herbicide products should be applied within a window of time when the crop and/or weed have emerged but are not too large, and their sizes are both strongly correlated to accumulated temperature units. Moisture conditions can also have a major influence on emergence, PRE and POST herbicide application success, as well as most mechanical control techniques. Because of the time and scheduling constraints that accompany larger scale agronomic operations, the current and short-term forecasts may not be sufficient to allow for planning of weed management operations. In order to complete their work, many professionals find themselves having to manage weeds in sub-optimal conditions. To help manage and conduct weed control operations with the greatest possible efficiency, we are in the process of designing a tool that will use a large amount of historical data to assess the likely amount of optimal application time remaining during the critical time of the year. This tool, christened "IPMWatch", will be a free software product and allow users to tune the conditions for optimal application.

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MANAGING WEEDS, TIMING, AND RISK

Timothy L. Trower, Chris Boerboom and Joe Bollman[1]

Maximizing return on investment in corn production is a balance of providing the lowest effective levels of inputs compared to projected returns. Weed control is an input that growers have numerous options to customize a program that fits weed spectrum, application timing, and most importantly cost. One variable that is critical in making herbicide decisions is the degree of risk associated with various herbicide programs. WeedSOFT is a computer program that assists growers in predicting yield loss and economic returns of herbicide programs based on the competitive loads of the weed species present. The competitive load (CL) of a weed species integrates a weed's density (D) and its competitive ability (CI). In a field crop, a weed's competitive ability is adjusted based on its size relative to the crop and becomes the adjusted competitive index (ACI). Then the CL is calculated as: $CL=D_{bi} \times ACI_i$. Total competitive load (TCL) is the sum of all the weed species present and is calculated as: TCL = $\Sigma(Dbi \times ACI_i)$. This TLC plus the length of weed competition is used in WeedSOFT to predict crop yield loss.

Two studies were conducted at the Arlington Research Station in 2005 to quantify the risk of reducing corn yield associated with various herbicide programs. In both studies, Dekalb DKC 50-20 field corn was planted in 30 inch rows on April 26 with preemergence herbicides applied on April 30. Weed species counts and heights were collected for 8 weeks after planting from two permanent quadrats per plot placed over the corn rows. Plots measured 10 by 25 feet with a randomized complete block trial design. Giant foxtail and common lambsquarters were the primary weed species present in both studies.

The first study measured the yield risk of a total postemergence program compared to a sequential preemergence/postemergence program in field corn. Outlook and G-Max Lite were applied preemergence at ½ labeled rates of 10 fl oz/a and 1.5 pt/a, respectively, alone or sequentially with glyphosate at 0.75 lb ae/a. Three postemergence timings were compared: early postemergence on June 13 (3 to 4 inch weeds in the nontreated control), mid-postemergence on June 17 (3 to 4 inch weeds in the Outlook treatment), and late postemergence on June 20 (6 to 8 inch weeds in the Outlook treatment).

Half rates of Outlook reduced TCL values by 75% and G-Max Lite reduced TCL values by 99% compared to the nontreated control when evaluated on June 30 (Table 1). TCL values for the preemergence herbicides remained constant regardless of the postemergence glyphosate timing, ranging from 223 to 279 with Outlook and 0 to 52 with G-Max Lite. This was in contrast to the TCL values of 4416 to 6406 for glyphosate applied postemergence at the early, mid-postemergence, and late postemergence application timings, respectively. Information collected from the study was entered into WeedSOFT to predict early season yield losses. The predicted early-season yield losses with the sequential glyphosate treatments following Outlook and G-Max Lite were less than 2% of the final corn yield. G-Max Lite followed by glyphosate at the mid-postemergence timing yielded the greatest at 207 bu/a compared to 102 bu/a for the nontreated control. All sequential glyphosate applications following Outlook yielded more than Outlook alone. Yields did not differ among G-Max Lite treatments applied alone or sequentially with glyphosate. WeedSOFT predicted early-season yield losses ranging from 19 to 22 bu/a with a

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single postemergence application of glyphosate. Yields did not differ among glyphosate treatments applied alone at the three postemergence timings and were similar to Outlook treatments, but generally less than G-Max Lite treatments.

Table 1. Effect of Weed Removal Timing on Total Competitive Load and Yields at Postemergence Glyphosate Application

Treatment	Application Timing	Weed Density SETFA	Weed Density CHEAL	CL SETFA	CL CHEAL	TCL	Predicted Yield loss[b]	Yield
							(bu/a)	(bu/a)
Nontreated		152	56	2471	3121	5593 [a]		102
Outlook	Pre	8	24	65	1338	1403 [a]		167
Outlook fb	Pre							
Glyphosate	early	0	8	0	223	223	5	188
Glyphosate	mid	4	8	26	223	249	5	206
Glyphosate	late	0	8	0	279	279	5	189
G-MAX Lite	Pre	4	0	33	0	33 [a]		193
G-Max Lite fb	Pre							
Glyphosate	early	0	0	0	0	0	0	203
Glyphosate	mid	4	0	33	0	33	0	207
Glyphosate	late	8	0	52	0	52	1	186
Glyphosate	early	364	48	4734	1672	6406	20	185
Glyphosate	mid	136	76	1769	2648	4416	19	178
Glyphosate	late	80	68	1040	3790	4831	22	171
LSD (P=0.10)								*22*

[a] assessed at June 30

[b] early season yield loss predicted by WeedSOFT

A second study investigated the efficacy of half rates of soil-applied herbicides in a sequential application program to reduce the risk of yield loss with delayed postemergence applications. The soil applied herbicides were Harness at 1.1 pt/a, Define at 10 fl oz/a, atrazine at 1.5 pt/a, Dual II Magnum at 0.8 pt/a, Prowl H_20 at 1.25 pt/a, and Camix at 1.2 qt/a. All herbicide treatments except atrazine reduced giant foxtail height, ranging from a 38% reduction with Prowl H_20 to a 91% reduction with Harness (Figure 1). All soil-applied herbicides reduced giant foxtail density compared to the nontreated control (Figure 2). As expected, atrazine was the least effective on giant foxtail with a 42% reduction in density compared to 97% reduction for Harness at 61 days after application. Weed counts remained fairly constant with all treatments, including the nontreated control, from 32 to 61 days after application indicating only one weed cohort occurred in this study. This implies that controlling the early weed germination is more critical than long residual activity in planned sequential herbicide programs. The height and density of common lambsquarters had a similar to giant foxtail (data not shown).

Figure 1

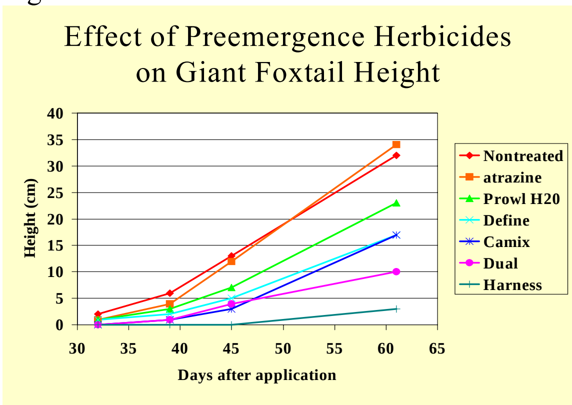


Figure 2

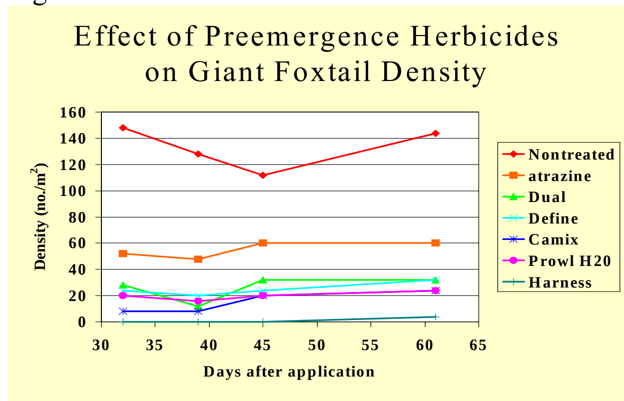
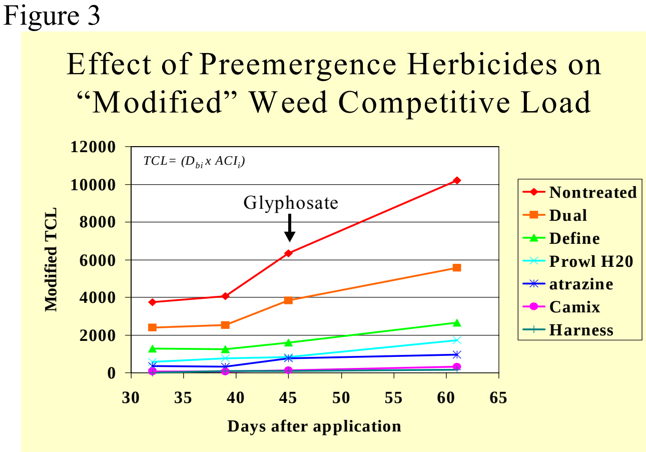


Figure 3 shows the TCLs for the herbicide treatments and the timing of the glyphosate application. Postemergence glyphosate was applied when the corn was at the V6 growth stage.

Figure 3



The increase in TCL values from 32 to 61 days after application is not a function of increasing weed density, but of increasing weed heights. The herbicide treatments reduced TCL values from 40 to 98% at the time of the glyphosate application. The weed and crop information was entered into WeedSOFT to predict early-season yield loss.

The green portion of the bar in Figure 4 indicates the predicted early season yield loss at the time of the postemergence glyphosate timing while the blue indicates the predicted total yield loss if no postemergence glyphosate application was made. All six of the soil-applied herbicides when applied at half rates greatly reduced the predicted corn yield loss compared to the nontreated control.

The light gray portion of the bar in Figure 5 indicates the yield of the herbicide treatment applied alone while the dark gray bar indicates the added yield when postemergence glyphosate was applied. WeedSOFT predicted minimal yield losses with Harness or Camix due to the low TCL values, which was validated by the actual yields. Predicted yield losses for the remaining herbicides ranged from 5 to 6 bu/a from early season competition and 30 to 49 bu/a after total season competition. The light gray bars in Figure 5 correlate with the predicted yield losses in Figure 4. Increasing the TCLs values with soil-applied herbicides measured in Figure 3 corresponded with a decrease in corn yields in Figure 5. No yield differences were noted among the soil-applied herbicides when followed by a postemergence application of glyphosate (Figure 5). The sequential programs generally yielded more than the single postemergence glyphosate application.

Figure 4

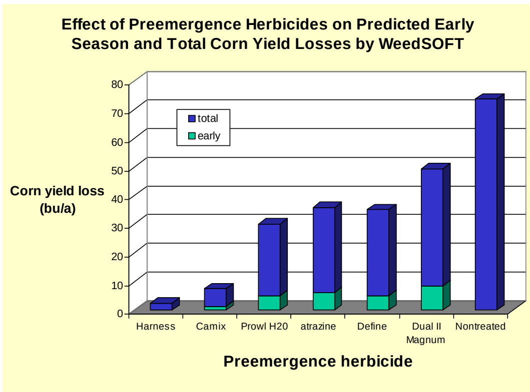
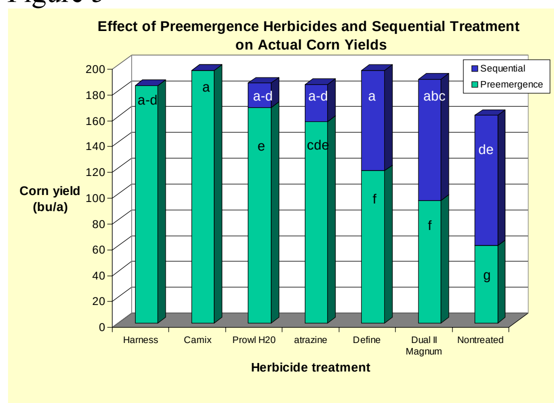


Figure 5



The results from these studies indicate that TCLs are a valid measure of the early season weed competitiveness and the associated risk of various herbicide programs. WeedSOFT proved to be an effective tool in assessing the relative risk of various herbicide programs. The program accurately ranked corn yields of the preemergence herbicides, but did not accurately quantify the yield loss. In this study, the preemergence herbicides differed in their ability to extend the postemergence application window, primarily due to differences in their weed control spectrum. Most importantly, the use of preemergence herbicides can reduce weed density and height which allows for delayed postemergence herbicide applications without increasing the risk of yield loss from early season weed competition.

WEEDSOFT PREDICTIONS OF CORN AND SOYBEAN YIELD LOSS

Mark R. Jeschke, David E. Stoltenberg, J. Anita Dille, Gregg A. Johnson, George O. Kegode, Stevan Z. Knezevic, Shawn M. Hock, and Christy M. Sprague[1]

Introduction

WeedSOFT is a decision support system that brings together a wealth of information on weed biology and management efficacy to improve weed management decision-making (Neeser et al. 2004). An essential part of maintaining WeedSOFT as the state-of-the-art weed management tool is validation and improvement of the crop yield loss model in the ADVISOR module. One of the most novel aspects of the crop yield loss model is the use of an adjusted competitive index (ACI) whereby the competitiveness of a given weed species is adjusted by a competitive index modifier (CIM) based on relative weed and crop growth stages (Tables 1 and 2). In this manner, weeds that emerge at the same time as the crop are considered more competitive than weeds that emerge at a later crop growth stage. The weed CI values are species-specific and differ among the several state versions of WeedSOFT due to regional differences in weed competitiveness. However, the CIM matrix is constant among crops and weed species.

Table 1. WeedSOFT crop and weed growth stages.

Growth stage	Corn	Soybean	Weeds
			inches
1	V1	V1	0-2
2	V2-V4	V2-V3	2-4
3	V5-V8	V4-V5	4-8
4	V9-V14	R1-R8	>8

Table 2. WeedSOFT competitive index modifier (CIM) values.

Crop growth stage	1	2	3	4
Weed Stage 1	1	0.6	0.3	0.1
Weed Stage 2	1.25	0.75	0.35	0.15
Weed Stage 3	2	1.25	0.65	0.25
Weed Stage 4	2.5	1.5	0.75	0.35

The ability of WeedSOFT to model the competitiveness of weeds in mixed-species communities that emerge at different times (i.e., cohorts) relative to the crop has not been assessed across the north central region. Therefore, research was conducted to determine corn

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and soybean yield loss associated with cohorts of mixed-species weed communities. Crop yield loss observed in these experiments was compared to yield loss predicted by WeedSOFT in order to assess model accuracy using current CIM values.

Methods

Research was conducted in corn and soybean at several sites in the north central region in 2004 and 2005. Separate experiments were conducted for corn and soybean. Research sites were chosen based on the presence of natural infestations of at least two species among common lambsquarters, giant ragweed, velvetleaf, redroot pigweed, tall waterhemp, woolly cupgrass, giant foxtail, barnyardgrass, yellow foxtail, and large crabgrass. The experimental design was a randomized complete block with at least four replications of four weed cohorts and a weed-free treatment. Weed cohorts were established relative to crop growth stage (Table 3).

Table 3. Weed cohort establishment timings.

Cohort	Corn growth stage	Soybean growth stage
1	VE	VE
2	V2	VC
3	V4	V1
4	V6	V3

Glyphosate was applied to maintain plots weed-free prior to targeted weed emergence times. Corn was planted at 32,000 seeds/acre in rows spaced 30-inches apart and soybean was planted at 200,000 seeds/acre in rows spaced 7.5-inches apart. Plot size was 10 ft by 30 ft. Weed community data was collected from two 10-inch by 30-inch quadrats in each plot. Corn and soybean were harvested by machine to determine grain yield.

Crop yield data were analyzed using linear mixed-effects models, with a random blocking factor and a fixed cohort factor. Crop yield loss relative to the weed-free treatment was determined by testing linear combinations using Bonferroni adjusted 95% simultaneous confidence intervals. WeedSOFT crop yield loss predictions were based on weed density measurements made 2 weeks following cohort establishment. Crop yield from the season-long weed-free treatment was used as the weed-free yield in WeedSOFT predictions. State-specific versions of WeedSOFT do not exist for Minnesota and North Dakota, so the Wisconsin version was used for data analysis from these sites. Crop growth stage at the time of weed community sampling was input for each cohort timing. All weeds were assumed to be at growth stage 1 at the time of sampling (Table 1).

Results

Weed communities across research sites consisted largely of grass species and moderately competitive broadleaf species (Figures 1 and 2). Foxtail species were among the most abundant grass species. The effect of weed cohort on crop yield was significant in all corn site-years and in four of six soybean site-years for cohort 1, and in one corn and one soybean site-year for cohort 2 (Tables 4 and 5). Crop yield loss due to weed interference occurred only for weed cohorts 1 and 2, although yield loss of up to 83% and 97% occurred in soybean and corn, respectively (Figures 3 and 4).

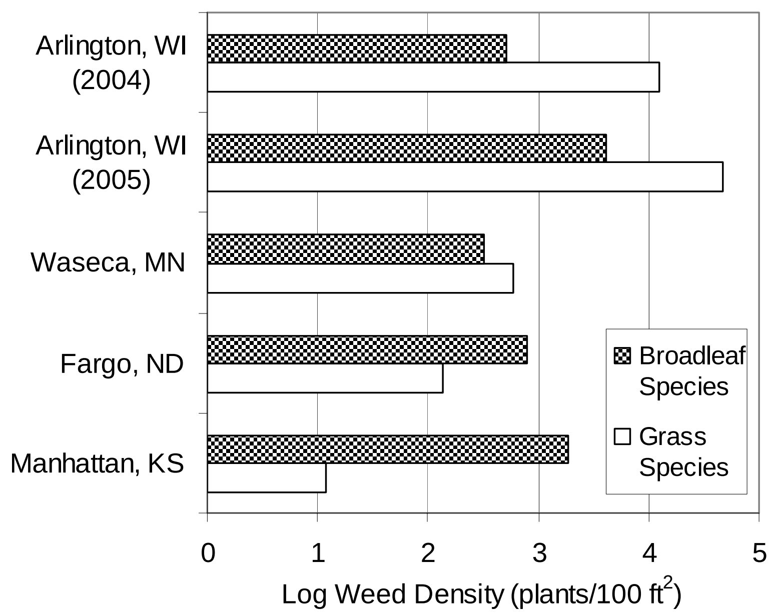


Figure 1. Grass and broadleaf weed communities in corn.

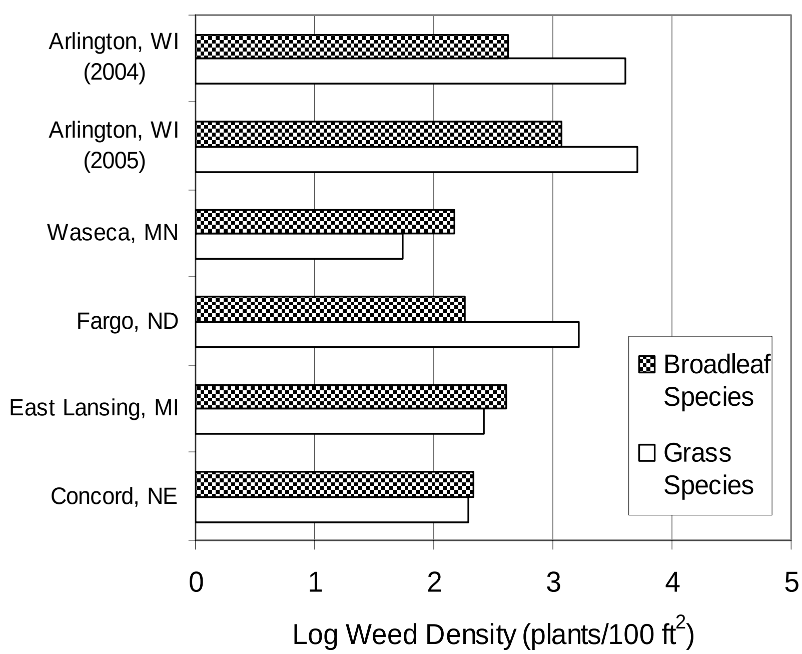


Figure 2. Grass and broadleaf weed communities in soybean.

Table 4. Corn weed-free yield and yield-loss associated with four weed cohorts.

Site	Weed-free yield	Weed cohort effect				
		p-value	Cohort[a]			
	bu/A		1	2	3	4
Arlington, WI (2004)	212	<0.0001	*			
Arlington, WI (2005)	194	<0.0001	*			
Waseca, MN	232	<0.0001	*			
Fargo, ND	100	<0.0001	*			
Manhattan, KS	212	<0.0001	*	*		

[a] An asterisk (*) denotes yield-loss relative to the weed-free yield.

Table 5. Soybean weed-free yield and yield-loss associated with four weed cohorts.

Site	Weed-free yield	Weed Cohort Effect				
		p-value	Cohort[a]			
	bu/A		1	2	3	4
Arlington, WI (2004)	57.3	0.1255				
Arlington, WI (2005)	61.0	<0.0001	*			
Waseca, MN	54.2	<0.0001	*	*		
Fargo, ND	20.7	0.8776				
East Lansing, MI	62.5	<0.0001	*			
Concord, NE	46.3	<0.0001	*			

[a] An asterisk (*) denotes yield-loss relative to the weed-free yield.

WeedSOFT tended to over-predict yield loss in both corn and soybean, with substantial yield loss predicted in many cases where none was observed (Figures 3 and 4). Yield loss was overestimated particularly for weed cohort 2, with an average over-prediction of 31% in corn and 35% in soybean across sites. The greatest over-predictions of yield loss were associated with weed communities composed largely of grasses, indicating that WeedSOFT overestimated the competitiveness of these species at later crop growth stages. In several instances, grass-dominated weed communities were associated with large yield losses for cohort 1, but no yield loss for later cohorts.

Summary

WeedSOFT tended to over-predict both corn and soybean yield losses associated with later weed cohorts (Figures 3 and 4), particularly for weed communities that consisted mostly of grass species (Figures 1 and 2). Different relative competitiveness among weed species is accounted for in WeedSOFT by the use of unique competitive index (CI) values. However, a single set of CI modifier (CIM) values is used for all weed species to account for time of emergence (cohort) effect on competitiveness (Table 2). The accuracy of WeedSOFT crop yield loss predictions may be improved if CIM values were adjusted to account for the apparent differential cohort effect among weed species.

Reference

Neeser, C., J. A. Dille, G. Krishnan, D. A. Mortensen, J. T. Rawlinson, A. R. Martin, and L. B. Bills. 2004. WeedSOFT: A weed management decision support system. Weed Sci. 52:115-122.

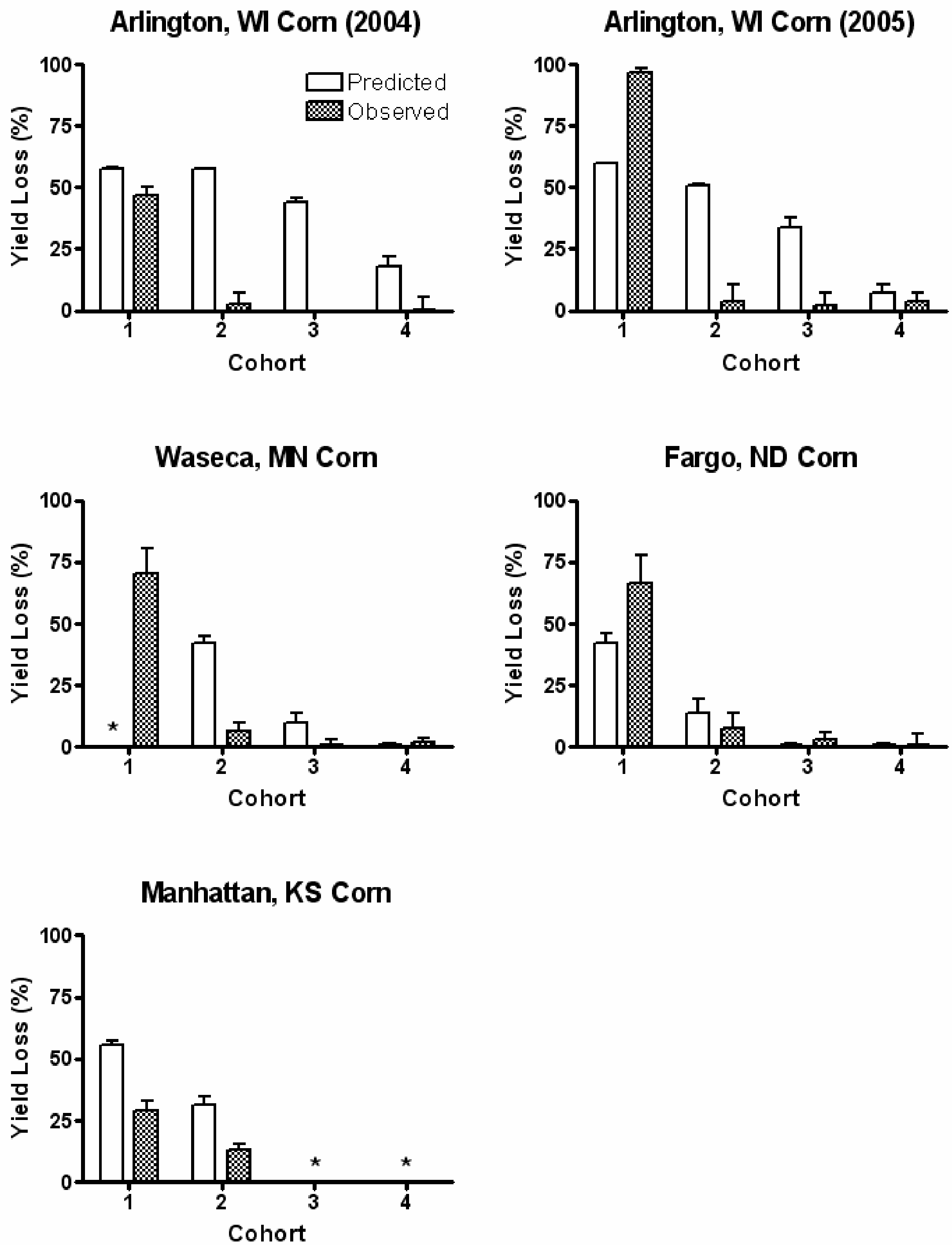


Figure 3. Predicted (WeedSOFT) and observed corn yield loss (± SE) associated with four weed cohorts (emergence times) and five site-years. Corn growth stage for each cohort establishment time is shown in Table 3. An asterisk (*) denotes data not collected.

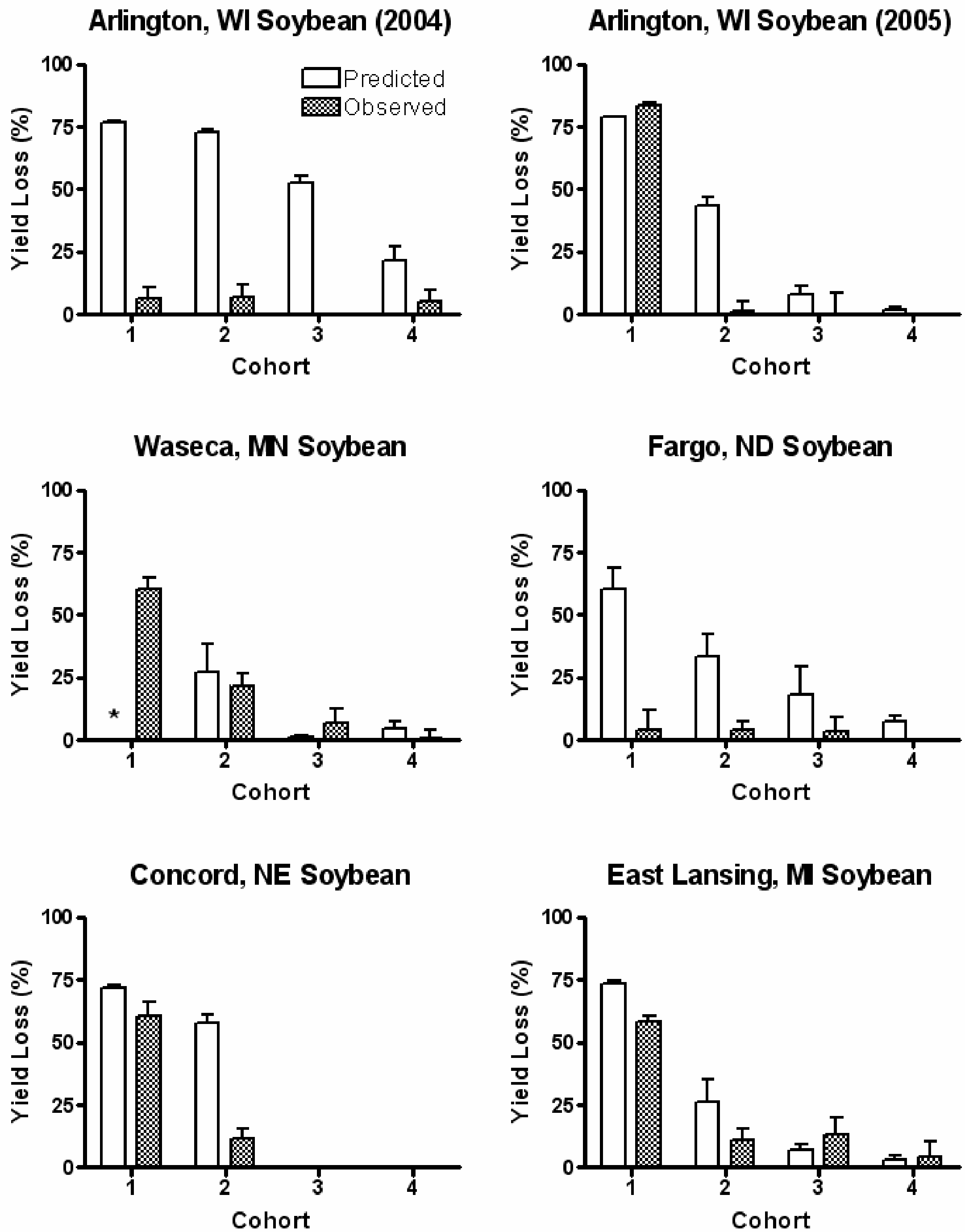


Figure 4. Predicted (WeedSOFT) and observed soybean yield loss (± SE) associated with four weed cohorts (emergence times) and six site-years. Soybean growth stage for each cohort establishment time is shown in Table 3. An asterisk (*) denotes data not collected.

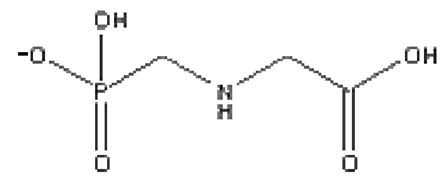
FACTORS AFFECTING GLYPHOSATE PERFORMANCE

Chris Boerboom[1]

Introduction

Glyphosate provides excellent weed control in the vast majority of times that it is applied. However, weeds are not controlled as expected in certain instances. Several factors may be responsible for these control failures. It is important to understand these factors so steps can be taken to avoid poor performance. There are three distinct places where glyphosate interacts with other elements when it is applied: 1) in the spray tank; 2) on the leaf surface; and 3) in the weed. This article reviews the potential for these interactions to reduce glyphosate performance.

Glyphosate in the Spray Tank



Glyphosate is a weak acid herbicide and has a negative charge at typical pHs. As a consequence, glyphosate is formulated with positively charged "salts" like potassium, isopropylamine, or ammonium so it can be dissolved in water during formulation. Since glyphosate has a negative charge, it can interact with other positively charged ions in spray water and form complexes that are not absorbed as readily as the salts included in the formulation. This interaction results in antagonism. The ions that cause problems can be either from the water source or additives to the spray solution.

Hard water is one potential source of antagonism. Hard water is the description of water with high concentrations of minerals like calcium, magnesium, sodium, and iron. These minerals have a positive charge and are attracted to the negative charge of the glyphosate molecule. This interaction results in glyphosate-salt complexes. Unfortunately, some glyphosate-salt complexes are not absorbed easily into leaves. For example, the glyphosate-calcium complex is less readily absorbed than the glyphosate-potassium or glyphosate-isopropylamine complexes that exist in glyphosate formulations.

Micro-nutrient fertilizers are the most likely additives to glyphosate spray solutions that could antagonize glyphosate if not mixed correctly. These products may contain iron, manganese, sodium and other nutrients, which are positive ions that can interact with glyphosate.

Tank-mixed herbicides that are formulated with clay carriers such as herbicides with dry flowable or flowable formulations are another source of antagonism in the spray tank. The clay particles can bind the glyphosate similar to glyphosate binding to soil.

In all three of these cases of antagonism, the solution is the same. Ammonium sulfate is added to the spray water to increase the ammonium salt concentration to reduce the unfavorable glyphosate complexes. The key step is that ammonium sulfate must be added to the water and dissolved before glyphosate is added.

The amount of ammonium sulfate required to overcome hard water depends on the minerals and their concentration. Research in North Dakota has shown that water with 300 ppm

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of sodium or greater than 150 ppm of calcium causes noticeable antagonism to glyphosate. Fortunately, most ground water in Wisconsin has low or moderate mineral concentrations. Examples of the average and the highest mineral concentrations for sampled wells are listed for nine counties from across the state (Table 1). Potassium and iron concentrations averaged less than 3 ppm across the state and were not included in the table.

Table 1. Mineral concentrations for ground water in nine selected counties. Adapted from UWEX Geological and Natural History Survey. 1981. Ground-water-quality atlas of Wisconsin. Information Circular 39.

	Calcium		Magnesium		Sodium	
County	Ave.	High	Ave.	High	Ave.	High
	------------	------------	------------ ppm	------------	------------	------------
Chippewa	15	48	6	18	3	7
Dane	68	110	35	61	4	10
Grant	70	211	34	120	5	63
La Crosse	58	78	22	32	3	12
Manitowoc	81	368	38	101	14	107
Pierce	66	121	25	34	6	8
Rock	69	90	35	52	4	9
Waukesha	82	340	35	73	13	240
Waushara	38	76	20	41	7	19

Although these minerals are generally at concentrations below levels reported to cause antagonism, some wells have mineral concentrations that may antagonize glyphosate activity. This is especially true for some wells in eastern Wisconsin as shown with Manitowoc and Wauskesha counties. Also, the antagonistic effect of minerals on herbicides is additive so water with 150 ppm of calcium and 100 ppm of sodium will cause more antagonism than water with only 150 ppm of calcium. The spray volume also affects the level of antagonism. At the same mineral concentration, minerals will cause more antagonism if glyphosate is sprayed in 20 gal/a than in 10 gal/a of water.

Two ways to determine the amount of ammonium sulfate needed for glyphosate applications are:

1. Use the following equation, which was developed by North Dakota State University.

   AMS (lb/100 gal) = 0.005 x (sodium ppm) + 0.002 x (potassium ppm) + 0.009 x (calcium ppm) + 0.014 x (magnesium ppm)

2. Follow the label recommendations and add 8.5 to 17 lb AMS per 100 gallons of water. Unless severe water quality problems are known, ammonium sulfate at 8.5 lb/100 gallons (or about 1 lb/a) should be sufficient.

Our field tests to measure micro-nutrient interactions with glyphosate did not detect significant antagonism when ammonium sulfate was added to the spray water prior to adding glyphosate and the micro-nutrient. In these trials, glyphosate was applied at a reduced rate to large common lambsquarters to increase the potential for antagonism. Antagonism occurred at the reduced rate, but was minimal when labeled glyphosate rates were used (Table 2).

Table 2. Common lambsquarters control with glyphosate plus ammonium sulfate applied alone or with a micro-nutrient and rated 4 to 7 weeks after application.

Glyphosate	AMS	Max-in†	2004 Early Height	2004 Early Control	2004 Late Height	2004 Late Control	2005 Height	2005 Control
lb ae/a	lb/a	qt/a	inch	%	inch	%	inch	%
0.38	2.5	-	14	100	20	93	18	93
0.38	2.5	1	14	98	20	76	18	88
0.75	2.5	-	14	100	20	100	18	98
0.75	2.5	1	14	100	20	96	18	94

†The Max-in rate was increased to 2 qt/a in 2005.

Glyphosate on the Leaf Surface

After glyphosate is sprayed, it must be absorbed from the spray droplets into the cells of the leaf. In general, only about 30 to 40% of the glyphosate is absorbed from the spray droplets into the leaves. Several factors can affect the total amount of glyphosate absorbed.

Spray volume affects the concentration of glyphosate in the spray solution. Because glyphosate diffuses from the spray droplet into the leaf, higher glyphosate concentrations in the droplets increase the rate of diffusion. Glyphosate is more concentrated in spray droplets at lower spray volumes (Table 3). As a result, glyphosate control is generally greater at lower spray volumes such as at 10 GPA as compared with 20 GPA. (Lower spray volumes also have less potential for antagonism from minerals, which is another benefit).

As a demonstration of this effect, oats and wheat were sprayed with low rates of glyphosate in 2.5, 5, 10, and 20 GPA of water (Ramsdale et al. 2003). Although these low glyphosate rates are not recommended, grass control increased with lower spray volumes at the low glyphosate rate (Table 4). At the higher glyphosate rate, the spray volume did not affect control.

Table 3. Concentration of glyphosate when applied at different rates in increasing spray volumes.

	Glyphosate concentration		
	Glyphosate rate (oz/a)		
Spray volume	8	16	32
gal/a	(grams/liter)		
5	4.4	8.8	17.6
10	2.2	4.4	8.8
20	1.1	2.2	4.4

This assumes a glyphosate formulation with 3 lb ae/gallon.

Table 4. Oat and spring wheat control with glyphosate applied in increasing spray volumes.

	Oat and wheat control	
	Glyphosate rate	
Spray volume	1.3 oz/a	5.3 oz/a
(gal/a)	(%)	(%)
2.5	82	99
5	72	99
10	58	99
20	44	99

Surfactant concentration is also affected by the spray volume when glyphosate formulations are used that are “loaded”. On a relative basis, surfactant concentration is four times higher when spraying at 5 GPA than at 20 GPA with the same glyphosate rate (Table 5). This low surfactant concentration may become limiting under extreme conditions (e.g. low glyphosate rates and high spray volumes). In such cases, it may be beneficial to add additional surfactant to ensure an adequate surfactant concentration in the spray mixture.

Table 5. Surfactant concentration when a preloaded glyphosate formulation is applied at different rates in increasing spray volumes.

	Surfactant concentration Glyphosate rate (oz/a)		
Spray volume	8	16	32
gal/a	(relative to 32 oz/a at 20 GPA)		
5	1X	2X	4X
10	0.5X	1X	2X
20	0.25X	0.5X	1X

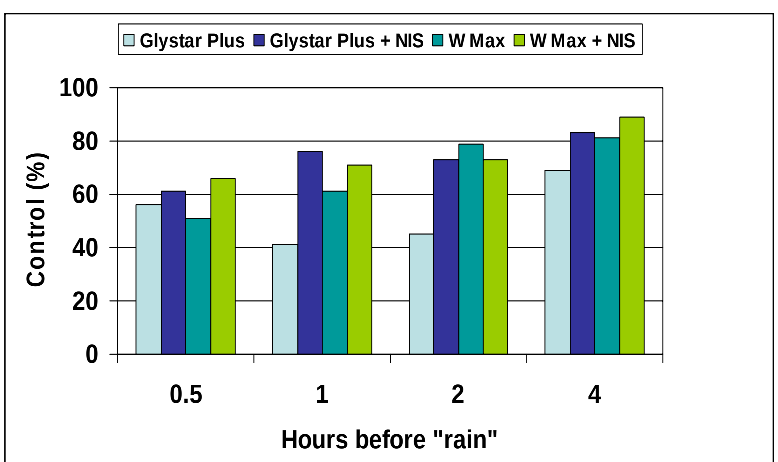
This information means that spraying glyphosate at lower spray volumes should give equal or better weed control than applications at high spray volumes. Using high spray volumes to get more thorough spray coverage of weeds may actually lower the performance of glyphosate in some cases. Glyphosate translocates in weeds so the leaf surface does not need to be uniformly covered by spray droplets for glyphosate to work.

If the "glyphosate science" says that lower spray volumes are better, are there situations where this science fails when glyphosate is applied in the field? This could happen in some situations when spray coverage is not uniform such as when tall weeds prevent spray from reaching shorter weeds. Another case may occur at faster sprayer speeds with low spray volumes. Wind may swirl around the sprayer and displace some of the spray swath if low spray volumes (and small droplet sizes) are being applied. In these cases, higher spray volumes may increase uniformity.

Ammonium sulfate also plays a role on the leaf surface of certain weed species. For example, ammonium sulfate in the spray solution increases glyphosate absorption into velvetleaf (even when hard water antagonism is eliminated) (Young et al. 2003). However, ammonium sulfate made no difference in glyphosate absorption in common lambsquarters. It is suggested that ammonium sulfate is more important with velvetleaf than lambsquarters because velvetleaf has a higher calcium content than other weeds. The calcium ions may form salt complexes with glyphosate, which limit its uptake. In contrast, the addition of ammonium sulfate may lead to ammonium salt complexes with glyphosate that are more readily absorbed by velvetleaf.

Rain after a glyphosate application has the greatest potential to make a glyphosate application fail. Glyphosate is absorbed into the leaf over time. Without adequate time, glyphosate absorption will not reach its full potential. In 2005, we applied 0.75 lb ae/a glyphosate and simulated a rain at 0.5, 1, 2, and 4 hours after the application. At all timings, lambsquarters

Figure 1. Effect of simulated rainfall and glyphosate formulation (Glystar Plus or Roundup Weathermax ± non-ionic surfactant) on common lambsquarters control. Without simulated rainfall, control averaged 96% across treatments.



control was reduced compared to lambsquarters that did not receive the simulated rain (Figure 1). The rain-free period required to achieve a high level of control will depend on the glyphosate rate applied, sensitivity of the weed species, and their size.

Dew. It is logical to question if dew might reduce glyphosate performance because dew could dilute the glyphosate concentration similar to spraying at higher spray volumes. Also, glyphosate spray droplets might run off dew covered leaves. On the positive side, dew could increase the hydration or water content of the cuticle of the leaf and aid glyphosate uptake. Research suggests that moderate or high levels of dew at the low spray volumes does not reduce glyphosate's control (Table 6, Kogan and Zuniga 2001)). This is probably because the cuticle is fully hydrated (e.g. swollen like a sponge) and allows better glyphosate absorption. In this example, the high dew level reduced oat control when glyphosate was sprayed in the highest spray volume, which may have occurred if some spray droplets ran off the leaves due to the large amount of water on the leaves. It appears that moderate levels of dew will likely have little effect on the performance of glyphosate when applied at normal spray volumes. These results are consistent with previous research on quackgrass.

Table 6. Effect of spray volume and dew on oat control by 0.5 lb ae/a glyphosate.

Spray	Dew level		
volume	0%	50%	100%
(gal/a)	(% oat control)		
16	88	89	89
31	82	88	88
47	65	65	59

Dust on the weed leaf surface has the potential to bind and inactivate applied glyphosate. A recent greenhouse experiment found that "dust" or soil sifted onto nightshade leaves at the rate equivalent to 7 lb/a was sufficient to reduce glyphosate activity (Zhou and Messersmith 2005). This rate is apparently similar to the amount of dust that a row cultivation may create. The frequency of problems caused by dusty leaves depends on the frequency of rain and closeness of dusty roads or fields. Similarly, dust that is raised behind sprayers can become a problem. Glyphosate may also be deactivated with the soil that is pressed on the weed leaves in the wheel tracks.

Glyphosate in Weeds

After glyphosate begins to enter the plant, its performance may be affected by several other factors.

Weed species can greatly affect their sensitivity to glyphosate. Differences in glyphosate tolerance among weed species are natural. For instance, annual grass seedlings are much more sensitive to glyphosate than annual broadleaf weeds. Certain annual broadleaf weeds like the morningglories are more tolerant than many other broadleaf weeds. And certain perennial weeds like yellow nutsedge and field horsetail have high levels of natural tolerance. As with any herbicide, weeds become less sensitive as their size increases and the rate of glyphosate should be increased to compensate when spraying larger plants.

Drought is likely the principle environmental stress that may reduce glyphosate's performance. The leaf surface is covered by a wax-like layer called the cuticle. The primary purpose of the cuticle is to reduce water loss. During drought conditions, this purpose becomes even more critical. In response to drought stress, the true waxes on the surface of the cuticle becomes even thicker. The cuticle is also less hydrated by water. Both of these conditions make it more difficult for the glyphosate to diffuse through this barrier. This effect can happen fairly rapidly. For example, glyphosate absorption and translocation was measured in non-stressed in common milkweed (25% soil moisture) as compared to moisture-stressed common milkweed (water withheld for 2 days before glyphosate application; soil moisture decreased from 25 to 13% moisture) (Waldecker and Wyse 1985). The non-stressed milkweed absorbed 44% of the glyphosate whereas the moisture-stressed milkweed only absorbed 29% of the glyphosate. In addition, the moisture-stressed milkweed only translocated half as much glyphosate as the non-stressed plants from the treated leaves.

The time of day when glyphosate is applied can affect the level of weed control. Research has shown reduced glyphosate activity with applications before 6 am and after 9 pm. There are several conditions that change during the day, which affect the plant. Weed leaves at early and late hours may be covered by dew, but this generally should not reduce performance. Leaves of certain weed species (e.g. velvetleaf) move down into vertical positions in the evening, which would reduce the weed's interception of glyphosate spray (Table 7, Sellers et al. 2002). However, even if these leaves are propped up so they receive a full glyphosate dose, control is still reduced at early and late day applications. Light affects many metabolic processes within plants and it is possible that glyphosate's activity (uptake, translocation, and damage to the target site) is being affected by the plant's level of metabolic activity.

Table 7. Effect of velvetleaf leaf angle on spray interception.

Time	Leaf angle	Spray interception
	degrees	% of maximum
4 pm (held flat)	0	100
4 pm	-24	78
6 pm	-34	69
7 pm	-63	44
7:30 pm	-75	42
8 pm (sunset)	-81	42

Summary

Glyphosate's performance is affected by many application, plant, and environmental factors. Applicators can control the application related variables, especially the glyphosate rate and the addition of ammonium sulfate. Applicators cannot control most of the plant or environmental factors with the exception of the size of the weeds and the time of day when glyphosate is applied. Overall, to minimize the risk that the other factors will reduce glyphosate performance, glyphosate applications should be timed so that smaller weeds are treated.

References

Kogan, M. and M. Zuniga. 2001. Dew and spray volume effect on glyphosate efficacy. Weed Technol. 15:590-593.

Ramsdale, B.K., C.G. Messersmith, and J.D. Nalewaja. 2003. Spray volume, formulation, ammonium sulfate, and nozzle effects on glyphosate efficacy. Weed Technol. 17:589-598.

Sellers, B.A., R.J. Smeda, and W.G. Johnson. 2002. Diurnal fluctuations and leaf angle reduce glufosinate efficacy. Weed Technol. 17:302-306

Waldecker, M.A., and D.L. Wyse. 1985. Soil moisture effects on glyphosate absorption and translocation in common milkweed (*Asclepias syriaca*). Weed Sci. 33:299-305.

Young, B.G., A.W. Knepp, L.M. Wax, and S.E. Hart. 2003. Glyphosate translocation in common lambsquarters *(Chenopodium album*) and velvetleaf (*Abutilon theophrasti*) in response to ammonium sulfate. Weed Sci. 51:151-156.

Zhou, J., and C.G. Messersmith. 2005. Dust affects glyphosate efficacy on eastern black nightshade and hairy nightshade. Proc. North Central Weed Sci. Soc. 60:38.

UNDERSTANDING SPRAY NOZZLE PERFORMANCE

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Spray drift is not a new concept. The offsite movement of pesticides during application has been occurring since we began spraying pesticides some 50 years ago. Today's heightened concern over spray drift is a culmination of several factors. Infringing housing development, contamination of neighboring crops with illegal pesticide residues, increased use of "non-selective" herbicides on gmo crops, and a more litigious society have all placed increased demands for caution and safety on today's pesticide applicators.

Weather conditions at the time of application are the primary factor affecting the movement of spray droplets. Wind speed and direction, temperature, humidity and air stability can all play a significant role. But since we have little hope in controlling the weather, our reaction to the weather will determine our success or failure in controlling spray drift.

The movement of spray droplets is a function of spray droplet size. Spray droplets are measured by their diameter which is measured in microns (µm). One micron is approximately 1/25,000 of an inch. For comparison purposes, a human hair is about 100 microns in diameter. Larger spray droplets have greater mass, fall quicker, and therefore have a decreased risk of drift. From Table 1 you can see that while it takes 11 seconds for a 100 micron spray droplet to travel 10 vertical feet, it only takes 2 seconds for a 400 micron droplet to travel the same distance. In general, droplet sizes smaller than 150 microns are considered to pose the greatest drift hazard and should be avoided for most applications.

Table 1. Spray droplet fall rates.

Droplet diameter	20 microns	100 microns	240 microns	400 microns
Time to fall 10 feet	4.2 min	11 sec	6 sec	2 sec

Source: Akesson andYates, 1964.

If small droplets are the problem, then spraying with very large and course droplets must be the answer, right? Not necessarily. The type of pesticide being applied will

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determine the desired spray droplet size. Generally, smaller droplets are more desirable for insecticide and fungicide applications where very thorough coverage may be necessary to maximize crop protection effectiveness. Very large droplet sizes are most suited to soil applied preemergence or preplant incorporated applications where the pesticide is further dispersed by rainfall or mechanical incorporation, therefore requiring less thorough spray coverage. The effectiveness of postemergence applied herbicides can be affected significantly by spray droplet size. Contact herbicides, such as Gramoxone Extra and Liberty which are not translocated well through the plant will require thorough coverage for effective control. Consider spraying droplet sizes from 200-350 microns when applying contact herbicides to minimize drift while maximizing weed control. Translocated herbicides such as Roundup and 2,4-D are moved throughout the plant and therefore do not require as thorough of spray coverage. Larger droplet sizes in the 350-450 micron range can be safely used when applying translocated herbicides without sacrificing control. Because each pesticide has its own limitations, always consult the label for complete guidance on application recommendations.

Because spray nozzles produce a range of droplet sizes, nozzles are classified based on the percentages of the droplet sizes they produce. The term volume median diameter, or VMD is often used to measure a nozzles range of droplet sizes. The VMD represents the droplet size where half of the spray volume is contained in droplets larger than the VMD and half of the spray volume is in droplets smaller than the VMD (Table 2). Nozzle manufacturers use this classification system to indicate the droplet size of their nozzles for different size and pressure combinations. In addition, pesticide labels sometimes use this system to recommend appropriate droplet sizes to be used with their products.

Table 2. Spray droplet classification.

Category	Symbol	Color code	VMD (µm)
Very fine	VF	Red	< 150
Fine	F	Orange	150-250
Medium	M	Yellow	250-350
Coarse	C	Blue	350-450
Very coarse	VC	Green	450-550
Extremely coarse	EC	White	>550

Source: ASAE Standard S-572.

Adjusting spray pressure is perhaps the quickest and simplest way to affect droplet size. Operating any given nozzle at a lower pressure increases the VMD output from that nozzle. Additionally, spray output will be reduced at the lower pressure, potentially requiring a change to larger orifice size to maintain equivalent output. Always operate a nozzle within its manufacturer suggested pressure range. Failure to do so can result in less than optimal spray pattern and ultimately loss of pest control. The aspect of pressure is particularly important with today's pressure compensating spray controllers. If possible, always keep the pressure readout active on your display so that you can verify if you are within the acceptable range for the nozzle you are using. Any increases in speed will require an increase in pressure to compensate output. Just because your spray rig can spray at 18 mph, doesn't mean you should be doing so.

Several new drift reducing nozzle types have been developed to increase droplet size, including:

Pre-orifice Flat Fan Nozzles

Example includes the Driftguard nozzles. These nozzles use a pre-orifice prior to the discharge orifice that ultimately reduces spray pressure, resulting in larger droplets at a given operating pressure. The acceptable pressure range for this nozzle type is generally between 30 and 60 psi, with an optimum operating pressure of 40 psi. The amount of fine droplets are reduced substantially compared to a standard extended range flat fan nozzle. This nozzle type has been a popular choice for soil-applied herbicides.

Turbulence Chamber Nozzles

Examples include the Turbo Teejet and Turbo Floodjet nozzles. These nozzles use a pressure reducing turbulence chamber prior to the orifice that absorbs spray energy within the spray tip, increasing droplet size. These nozzles maintain droplet size and acceptable spray pattern over a very wide range of pressures, making them particularly useful in combination with pressure compensating spray controllers. Optimum operating pressure for these nozzles is about 40 psi.

Air Induction Nozzles

These nozzles contain two orifices, one to control liquid flow into the nozzle and one to form the spray pattern. In between the two orifices a jet is used to draw air into the nozzle body. This air mixes with the liquid and becomes trapped in the liquid droplets, resulting in a course spray of air filled droplets and very few fine droplets. These air filled droplets are intended to shatter on impact with the plant, thereby resulting in improved coverage from the otherwise much larger droplet size. Most air induction nozzles are designed to be operated at higher operating pressures, with optimum performance often in the 60-80 psi range.

Correct nozzle selection is your easiest and quickest tool in preventing spray drift. Remember that no nozzle is meant for all conditions and sometimes the only correct decision is to turn off the key and wait. But knowing the correct uses and limitations of both your nozzles and spray rig are critical when determining the best nozzle for the job.

Reference

Akesson and Yates. 1964. Annual Review of Entomology.

SIDEDRESSING NITROGEN: USEFUL ON ALL SOILS?

Larry G. Bundy[1]

Introduction

Current high nitrogen (N) fertilizer costs and continuing efforts to reduce N losses from cropland have increased interest in use of sidedress or delayed applications in corn production as a method for increasing the effectiveness of applied N and for avoiding adverse environmental impacts from N use. Theoretically, sidedress N has potential for improving N efficiency because N is usually applied just before the period of rapid N uptake by corn so that possible N losses before the application date are avoided. A common expectation is that a lower N rate applied sidedress will achieve the same yield response as a larger amount of N applied earlier in the growing season. Sidedress or delayed N applications have potential allowing reduced N rates only if early season losses of N from preplant applications are significant and can be avoided by applying N later in the growing season. While this is clearly the case on coarse-textured sandy soils where N loss by nitrate leaching from preplant N is likely, the benefits of sidedressing N is less obvious on medium-textured well-drained soils. The purpose of this paper is to review results from research studies and on-farm research and demonstration work that included or evaluated sidedress N applications for corn.

Results and Discussion

In an early review of N timing options for corn production, Bundy (1986) concluded that sidedress N applications were likely to produce large benefits where the risk of N loss by leaching or denitrification from preplant-applied N were high. Alternatively, little benefit should be expected from sidedress N applications relative to preplant additions where the risk of these loss processes are low such as on medium- and fine-textured soils with moderate or better drainage. Research with various times of N application conducted during 1988-1992, mainly on medium and fine-textured soils, in Wisconsin, Minnesota, and Iowa (Table 1), tended to support this conclusion, but this research was hampered by generally below-normal precipitation during the research period and numerous sites that did not respond to N fertilization. The results from all three states show that the most common result of the N timing comparison was no difference between preplant and sidedress application times. The second most common finding in Iowa and Wisconsin was that preplant application was superior to sidedress or split timings, with few or

Table 1. Corn yield response to preplant, sidedress, or split N timing in Iowa, Minnesota, and Wisconsin (1987-1992).

	Location (years)		
Sites	Iowa (1987-1991)	Minnesota (1989-1992)	Wisconsin (1988-1992)
Total	65	32	39
Responsive	25	28	20
Preplant = SD/Split	15	16	17
Preplant > SD/Split	8	4	3
Preplant < SD/Split	2	8	0

Killorn, et al., IA; Randall, MN; Bundy, WI.

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none of the sites showing sidedress applications superior to preplant N. In Minnesota, eight of 28 responsive sites showed that sidedress or split N application timing was superior to preplant N. This group of responses occurred mainly on soils developed in outwash parent material with coarse texture and thus was more prone to N losses by leaching (Randall and Schmitt, 2004). Overall, this comparison of N application timings showed little benefit to sidedress application on medium- and fine- textured soils. Only when soils with relatively coarse texture were considered did sidedress applications provide a benefit.

Recent work with sidedress N application timings on medium- and fine-textured soils have raised interest in the possible benefits of sidedress applications on these soils, specifically, whether sidedress N applications have potential for allowing use of lower N rates than would be recommended with preplant applications. Data from on-farm work conducted in several southern Wisconsin counties (Hanson et al., 2002) found that optimum sidedress N rates for corn following soybean were often substantially lower than the currently recommended N rates for the soils used in these experiments. Results from 12 experiments conducted over three years showed that yields were usually optimized with N rates at least 40 lb N/acre less than the 120 lb N/acre recommended for these situations. This work also showed that relative corn yields ranged between 95 and 100 % at all N rates higher than 50 lb N/acre across all 12 experimental sites, indicating that an application of 50 lb N/acre would result in near-maximum yield levels. In subsequent work, sidedress N applications for corn following soybean continued to optimize yields at relatively low N rates, but where sidedress and preplant applications were compared, yields with the two times of application were similar (Table 2).

Table 2. Corn yield response to preplant and sidedress N in replicated on-farm trials in southern Wisconsin, 2002*

Location	Crop system	N timing	N rate (lb/acre)	Yield (bu/acre)
A	Soybean-corn	Sidedress	103	149
		Preplant	110	144
		Sidedress	143	151
B	Corn-corn	Sidedress	135	130
		Preplant	160	135
		Sidedress	176	134
C	Soybean-corn	Sidedress	90	166
		Preplant	90	167
		Sidedress	150	163

* Data from Matt Hanson, Dodge County Extension

While preplant and sidedress applications produced similar yields at generally equivalent N application rates, yields were optimized at lower N rates than were recommended for these cropping systems. For example, 120 lb N/acre would have been recommended for corn following soybean, and 160 lb N/acre would have been recommended for corn following corn.

It is tempting to conclude from this type of N response data that sidedress N applications are responsible for the lower N rates required to optimize yields. However, results from two experiments conducted in 2005 show that low optimum N rates can also occur without using a sidedress N application time. The first of these experiments was a replicated small plot experiment conducted at the Arlington Agricultural Research Station. Results summarized in Table 3 show that corn yields were optimized at relatively high levels with lower than anticipated preplant N rates. An economic optimum N rate of 54 lb N/acre was obtained from regression analysis of this data and a N:corn price ratio of 0.175 ($0.35/lb of N and $2.00/bu of corn).

Table 3. Corn yield response to preplant N rates in a soybean-corn cropping system. Arlington WI, 2005.

N-rate	Mean yield	Duncan grouping †
(lb/acre)	(bu/acre)	
0	163	B
30	187	A
60	191	A
90	193	A
120	195	A
150	199	A
180	198	A
210	196	A

† Means with the same letter are not significantly different. Data provided by Jeff Osterhaus, Dept. of Soil Science, Univ. of Wisconsin-Madison.

A second trial was conducted as an un-replicated field strip trial in Columbia County, Wisconsin. In this trial, several rates of N were applied to strips of approximately 2.3 acres each using three times of N application: all at planting, all at sidedress, and a split application with 50% of the N at planting and 50% at sidedress. As shown in Table 4, Corn after corn yields appeared to be maximized at the lowest rate of applied N (80 lb N/acre), and there were no apparent responses to time of N application or to higher rates of N even though yields were very good for the 2005 growing season. The standard N rate recommendation for this production situation would be 160 lb N/acre.

Based on recent N response data in Tables 2-4, it appears that the relatively low optimum N rates identified in these and other experiments is probably more related to soil N availability at the experimental location than to the time of fertilizer N application. These results do not provide a clear indication that sidedress N applications are responsible for the low optimum N rates. It should be noted that the two 2005 experiments (Tables 3 and 4) were conducted during a relatively dry growing season where in-season N losses through leaching or denitrification would likely be very low and potential benefits from delayed or sidedress N application times would not be expected.

While the information presented above does not show clear benefits to using sidedress applications on medium- and fine-textured soils, that situation is dramatically different for N timing studies conducted on coarse-textured sandy soils where N loss by leaching from preplant N applications is likely. The expected benefits of sidedress applications on coarse-textured soils with high risk of N loss through leaching are illustrated by the data in Table 5 showing much better performance in terms of yields and N recovery with a split sidedress timing than with preplant applications on a sandy irrigated soil at Hancock, WI.

Table 4. Nitrogen rate and timing effects on corn yield in a field strip trial in Columbia County, WI, 2005.*

N timing			
Preplant	Sidedress	Total N rate	Yield
---------------------------- lb N/acre	--------------------------------		bu/acre
40	40	80	210
80		80	214
	80	80	204
60	60	120	207
120		120	208
	120	120	198
80	80	160	194
160		160	200
	160	160	204
100	100	200	209
200		200	207
	200	200	203

* Un-replicated field strip trial conducted on a Plano silt loam soil, corn after corn, planted 4/23/05, Sidedress N on 6/13/05. Data provided by Laura Paine, Columbia County Extension.

Table 5. Nitrogen rate and timing effects on corn yield and N recovery, Hancock WI, 2003-2004.

N rate	Yield (bu/acre)		N recovery (%)	
(lb/acre)	Preplant	Sidedress*	Preplant	Sidedress*
0	96	96	--	--
50	122	142	47	84
100	145	175	45	79
150	164	194	42	73
200	180	202	40	66
250	193	202	37	57
Average	161	183	42	72

* Split sidedress N applied at 4 and 7 wk after planting.

Summary and Conclusions

Results from N timing experiments conducted in the 1990s and the results of current experiments agree that sidedress N applications are usually not superior to preplant N on medium- and fine-textured soils. Optimum N rates substantially lower than current recommendations have been observed with both preplant and sidedress application times and are probably due to high levels of soil N availability at the experimental site rather than to time of N application. These results also indicate that significant losses of preplant N through leaching or denitrification seldom occur on these soils before crop N use. This statement does not imply that sidedress N applications should not be used on these soils; however, reduced optimum N rates or yield enhancements should not be expected solely from the use of sidedress N. On the other hand, use of sidedress or delayed times of N application on coarse-textured sandy soils is an essential management practice for agronomic efficiency and for avoiding losses of N to the environment. Sidedress N applications are effective on sandy soils because they prevent losses that would likely occur from preplant N applications.

References

Bundy, L.G. 1986. Review - Timing nitrogen applications to maximize fertilizer efficiency and crop response in conventional corn production. J. Fert. Issues 3:99-106.

Hanson, M., T. Novak, and L. Bundy. 2002. Evaluating optimum sidedress N application rates for corn following soybeans. Proc. Wis. Fert. Aglime and Pest Mgmt. Conf. 41:299-303.

Randall G., and M. Schmitt. 2004. Stategies for split N applications in 2004. Proc. Wis. Fert. Aglime and Pest Mgmt. Conf. 43:60-67.

DOES IT PAY TO USE NITRIFICATION AND UREASE INHIBITORS?

Carrie Laboski[1]

Introduction

As nitrogen (N) prices have risen, corn growers are beginning to think about reducing N application rates. Growers are weighing decisions to reduce N rates along with the potential for N losses that may occur because of the form of N used, method of application, and weather conditions. In the past, growers may have increased N application rates to offset the potential for N loss and subsequent yield loss. This practice was considered to be cheap insurance largely because the cost of the extra N fertilizer was cheap. With today's N and corn prices, this type of insurance may not be so cheap. Thus, revisiting the practices and economics of applying nitrification and urease inhibitors to protect against N loss is relevant.

Urease Inhibitors

When urea is applied to the soil, it must breakdown before any of the N is available to plants. The following are the three main reactions of urea in soil.

1. Urea hydrolysis: $\underset{\text{urea}}{(NH_2)_2CO} + \underset{\text{water}}{2H_2O} \xrightarrow{\text{urease}} \underset{\text{ammonium carbonate}}{(NH_4)_2CO_3}$
2. $(NH_4)_2CO_3 + 2H^+ \longrightarrow \underset{\text{ammonium}}{2NH_4^+} + \underset{\text{carbon dioxide}}{CO_2\uparrow} + H_2O$
3. $NH_4^+ + OH^- \leftrightarrow \underset{\text{ammonia}}{NH_3\uparrow} + H_2O$

During the hydrolysis of urea (equation 1), urea acts with water in the presence of an enzyme called urease to produce ammonium carbonate. Ammonium carbonate then reacts with hydrogen ions to produce ammonium (one of the forms of N used by plants), carbon dioxide, and water (equation 2). Depending on the soil pH, the ammonium produced may form ammonia (equation 3) which can be lost through volatilization. If soil conditions do not favor volatilization, ammonium can either be held on the soil's cation exchange or converted to nitrate (which is subject to losses through leaching or denitrification).

Urease is ubiquitous in soil and breakdown of urea will occur within 2 to 3 days. If urea is not incorporated (mechanically or with 0.5 to 0.75 inches of rain/irrigation), then up to 20% of the N applied will be lost through volatilization (Bundy and Oberle, 1988). If urea is surface applied, halting the breakdown of urea (inhibiting the urease enzyme) until adequate rain or irrigation can wash the urea into the soil will reduce N losses through volatilization.

The discussion of urease inhibitors will focus on N-(n-butyl) thiophosphoric triamide (NBPT), the active ingredient in Agrotain. Urease inhibitors act by temporarily stopping/inhibiting the breakdown of urea in urea containing fertilizers.

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Agrotain has been shown to be effective at reducing the conversion of surface applied urea or urea ammonium nitrate solutions (UAN) to ammonium. This can increase corn yields when conditions for ammonia volatilization exist. Hendrickson (1992) compiled data on NBPT use with surface applied urea and UAN from 78 experiments in 17 states over 5 years where 45% of the experiments were on no tilled fields, 45% on reduced tilled fields, and 10% on conventionally tilled fields. A summary of corn yield increases from application of NBPT with surface applied urea and UAN is provided in Table 1. In general yield increases were greater when NBPT was applied with urea compared to UAN. This is to be expected as only 50% of the N in UAN is urea. Yield decreases with application of NBPT also occurred; yield reductions of 10 bu/a or more were seen in 7% of the sites. Consistent crop yield increases are not expected every year or on all fields. Benefits will likely occur 30 to 40% of the time; with negative impacts on yield in 5 to 10% of the time. (Bundy, 1992).

Table 1. Summary of corn yield increases from application of NBPT with surface applied urea and UAN (Hendrickson, 1992). Yield increases were significant ($P < 0.01$).

Experimental sites	Number of sites	—— Yield increase —— Urea	UAN
		———— bu/a ————	
All sites	78	4.3	1.6
N responsive sites†	64	5.0	2.8
Sites with significant ammonia loss	59	6.6	2.7

† Sites where yield increased when fertilizer N was applied.

Bundy (1992) reported on a study assessing the effectiveness of Agrotain at Hancock. Urea, urea plus Agrotain, and ammonium nitrate were applied at several N rates and yield was measured. Results and an economic analysis are provided in Table 2. The N in ammonium nitrate is not subject to volatilization. The yield of corn was the same when 70 or 140 lb N/a was applied as ammonium nitrate. This shows that in this year on this site there was no response to N applied at rates over 70 lb N/a if the N was not lost. 70 lb N/a urea + Agrotain increased yield by 8 bu/a over urea alone at this rate. The increased income from the greater yield more than offset the cost of the Agrotain. When 140 lb N/a was applied, there was no difference in yield when urea was applied with or without Agrotain, because even with some N losses from urea alone, the amount of N applied was enough to reach the yield plateau. Economics for ammonium nitrate were not calculated as this fertilizer material is becoming increasingly unavailable.

Table 2. Effect of N rate, source, and NBPT on corn yield on an irrigated Plainfield sand at Hancock, WI in 1988 (Bundy, 1992).

Material	N rate lb N/a	Yield bu/a	Income * $/a	N Cost * $/a	Agrotain cost $/a	Return $/a
Check	0	88				
Urea	70	127	279.40	26.60	0	252.80
Urea + I †	70	135	297.00	26.60	4.76	268.24
AN ‡	70	140				
Urea	140	134	294.80	53.20	0	241.60
Urea + I †	140	132	290.40	53.20	9.51	232.88
AN ‡	140	138				

† I = inhibitor; Agrotain was applied at a rate of 0.25% by weight of urea (2.27 qt/T of urea).
‡ AN = ammonium nitrate
* Calculations were made using $2.20/bu corn and $0.38/lb N from urea.

Bundy (1992) also reported on other studies with Agrotain in Arlington, Wisconsin. However, there was no benefit to addition of Agrotain because 30 to 40 lb N/a maximized yield both years because of high residual N concentrations in the soil. Overall, these data highlight that when conditions for N loss exist, Agrotain can help prevent N loss. However, yield gains will not necessarily be realized every year.

The decision to use nitrification inhibitors rests with knowing when significant losses of N are likely (surface application of urea containing fertilizers in dry conditions particularly on high pH soils) and the cost benefit. A simple cost-benefit analysis on the use of Agrotain with urea was done. Urea was chosen for this analysis because most of the Agrotain usage in Wisconsin is with urea. The analysis is based on actual corn yield response to applied N in a field experiment; Agrotain was not a treatment. Assumptions in this analysis:

1. The price of corn is $2.20/bu
2. Corn is grown following soybean
3. High yield potential soil
4. Maximum yield achieved is 214 bu/a
5. Yield was maximized at 120 lb N/a
6. Agrotain applied at a rate of 5 qt/T of urea which is supposed to provide 14 days of control.
7. Agrotain costs $50/gal
8. When Agrotain is applied, no N is lost and yield remains the same as when no Argotain is applied and no N is lost. Realistically, this may not occur in all fields.

The analysis was completed using two different prices for N: $0.22/lb N, a price more typical five to ten years ago, and $0.38/lb N, a good estimate of the cost of N from urea in spring 2006. These N prices produce N:corn price ratios of 0.10 and 0.17 for $0.22/lb N and $0.38/lb N, respectively. Four nitrogen application rates were used: 140, 115, 100, 90 lb N/a. These rates were selected as they represent rates a corn grower may choose to apply based on their economic situation (Laboski, 2006). The results of the analysis are provided in Table 3.

Table 3. Cost-benefit analysis of using Agrotain with surface applied urea.

	— No N Loss —		——— Assume 20 % N Loss ———				With Agotain †	
N rate	Yield	Return ‡	N Loss	Yield	Return	Lost return	Agrotain cost	Return
lb N/a	bu/a	$/a	lb N/a	bu/a	$/a	$/a	$/a	$/a
If N costs $0.22/ lb N								
140	214	440.00	28	212	435.60	4.40	9.51	430.49
115	213	443.30	23	209	434.50	8.80	7.81	435.49
100	211	442.20	20	205	429.00	13.20	6.79	435.41
90	208	437.80	18	201	422.40	15.40	6.11	431.69
If N costs $0.38/ lb N								
140	214	417.60	28	212	413.20	4.40	9.51	408.09
115	213	424.90	23	209	416.10	8.80	7.81	417.09
100	211	426.20	20	205	413.00	13.20	6.79	419.41
90	208	423.40	18	201	408.00	15.40	6.11	417.29

† Assume no N was lost when Agrotain was applied.

‡ Return = (yield x price of corn) – (N rate x price of N) – (Agrotain cost if applicable)

These results show that at a relatively inexpensive price of N ($0.22/lb N) the most profitable N rate to apply if no N loss occurred would be 115 lb N/a. If a 20% N loss were to occur, then the most profitable N rate would be 140 lb N/a, because less yield is lost. In this field, the N rate that maximized yield was 120 lb N/a, thus the 140 lb N/a is oversupplying N if no N is loss. So when some N is lost at the 140 lb N/a rate, yield will be impacted little. If Agrotain were applied and no N was lost, then the N rate that would produce the greater return is 115 lb N/a because the cost of Agrotain at this N rate is less than the lost yield. However, if an N loss situation were to occur, return would be maximized by applying 140 lb N/a without Agrotain compared to the return from 115 lb N/a with Agrotain. This difference in these two programs is $0.11/a. Thus, applying extra N is relatively cheap insurance against N loss and subsequent yield losses when N is relatively inexpensive. It should be noted that N losses will contribute to environmental degradation and the practice of applying extra N to offset potential losses is not recommended.

When N is expensive like it is today, $0.38/lb N, the most profitable N rate when no N losses occur is 100 lb N/a. If environmental and management conditions were such that 20% of the N applied as urea was lost, then the most profitable N rate is 115 lb N/a. If Agrotain were applied and no N loss occurred, then 100 lb N/a would be the most profitable. In this situation, N is so expensive that application of extra N to offset yield losses produces a return less than applying 100 lb N/a with Agrotain. For the current economic climate, it is appropriate to reduce N rates to improve profitability. However, if situations for N loss exist, it is also appropriate to maintain a lower N application rate and apply Agrotain to maintain yield.

Nitrification Inhibitors

Nitrification is the process by which ammonium in soils is converted to nitrate. Two bacteria *Nitrosomonas* and *Nitrobacter* mediate this process. Nitrification of ammonium can occur in two to three weeks in most soils when soil temperature is over 50ºF, soil pH is over 5.5, and the soil is aerated (not waterlogged).

The N in ammonium once converted to nitrate can be taken up by plants, leached with excess water (particularly in course-textured soils), or lost through denitrification when warm wet conditions exist in fine-textured soils. In sandy soils, for every one inch of rain/irrigation, nitrate can move two and a half inches down the soil profile; while in fine-textured soils movement is about one inch (Nelson and Huber, 2001). Denitirification is mediated by bacteria and is maximized in soils that are warm (60ºF), have pH near 7.0, have a large concentration of nitrate, and a carbon compound is available. Up to 100 lb N/a can be lost through denitrifcation in waterlogged soils over a five day period if conditions are favorable. If soils are cold (40 ºF) or have pH values near 5.0, denitrification rates are much slower (Nelson and Huber, 2001).

Nitrification inhibitors (NI) interfere with the nitrification process by killing or impeding the metabolism of *Nitrosomonas* bacteria. The advantage of NI is that they maintain N in the ammonium form that is held by the soil and less likely to be lost. NI are effective for three to six weeks depending upon environmental conditions. The purpose of NI to fall applied N is to maintain the N in ammonium form until soil temperatures have dropped below 40ºF and denitrification potential is greatly reduced. For spring preplant applications of N, NI are expected to hold N in the ammonium form during the period when crop demand for N is low and rainfall is high. Past research has shown that the highest probability of yield increases with use of NI are on sandy soils (excessive leaching) and poorly drained fine-textured soils. This is because these situations represent the greatest potential for N loss.

Two examples of the impact of a NI, nitrapyrin (NServe), on yield are provided in Tables 4 and 5. The data in Table 4 show the effect of NServe on a sandy soil. When all of the N was applied preplant, application of NServe increased yield and overall return. However, when all of the N was sidedessed, NServe did not impact yield. Yield when N was sidedressed was greater than preplant N and NServe. This data shows that NServe can be effective in reducing nitrification and subsequent loss of nitrate on sandy soils when the N is applied prior to planting. However, split applications of N on these soils is a better management practice.

Table 4. Four-year average effect of N timing and use of N Serve on corn yield at Hancock (Wolkowski, 1995).

N timing†	NServe	Yield	Income	N Cost	NServe cost	Return
		bu/a	$/a	$/a	$/a	$/a
PP	No	116	255.20	47.60		207.6
SD	No	134	294.80	47.60		247.2
PP	Yes	121	266.20	47.60	8	210.6
SD	Yes	134	294.80	47.60	8	239.2

† 140 lb N/a was applied spring preplant (PP) or sidedressed (SD). NServe was applied at a rate of 2 pt/a.
‡ Calculations were based on $2.20/bu corn, $0.34/lb N, and $32/gal of NServe.

A study in Minnesota shows that fall application of anhydrous ammonia with NServe increases yield and return compared to fall N alone when averaged over seven years. Fall N with NServe produced yields as large as spring applied N, but had a lower return (Table 5). Randall et al. (2003) also found that split applications of N without NServe produced the greatest yields on average. This is because in some years N loss occurred in springs with above normal precipitation. It should be noted that in six of the seven years there was no significant difference between treatments. These data show that on poorly drained fine-textured soils, application of NServe with fall applied anhydrous ammonia can be a profitable practice when averaged over a number of years.

Table 5. Impact on N application timing and use of NServe on corn yield, seven year average on a poorly drained Mollisol in Waseca, MN (Randall et al., 2003).

N timing†	NServe‡	Yield	Income*	N Cost	NServe cost	Return
		bu/a	$/a	$/a	$/a	$/a
Fall	No	131	288.2	45.9		242.3
Fall	Yes	139	305.8	45.9	8	251.9
Spring	No	139	305.8	45.9		259.9
Split	No	145	319	45.9		273.1
LSD (0.01)		4				

† 135 lb N/a was applied as anhydrous ammonia in all treatments. Split application had 40% of the N applied in the spring and 60% sidedressed at V8.
‡ NServe was applied at a rate of 2 pt/a.
* Calculations were based on $2.20/bu corn, $0.34/lb N, and $32/gal of NServe.

Hoeft (1984) summarized results of research with NI in many states. Several trends were found. Soils with a greater potential for N loss through leaching or denitrification have greater probabilities of obtaining economic return through the use of NI. Use of NI in no-till and reduced tillage systems has been shown to conserve N in some regions. Generally, significant yield increases with the use of NI are more often found in fall applied N compared to spring applications. However, NI do not eliminate all potential for N loss on all soils. Some of these principles are demonstrated in Table 6. With the current prices of N, using NServe with fall N applications is cheap insurance against N loss compared with applying more N. For example, return was greater for fall applied N when 150 lb N/a was applied with NServe compared to 200 lb N/a alone ($278.98/a vs. $243.63). Yield with spring applications of N did not vary much with application of NServe. Spring N applications without NServe yielded more than the same amount of N applied in the fall with NServe; showing that while NServe conserved N, some N losses still occurred.

Table 6. Effect of time and rate of N application and NServe on corn yield in Illinois (Hoeft, 1984).

N rate	Nserve	Yield		N cost	Nserve cost	Return[†]	
		Fall application	Spring application			Fall application	Spring application
lb N/a		bu/a	bu/a	$/a	$/a	$/a	$/a
0		66		0		144.86	
100	No	100	144	34		185.47	282.04
100	Yes	124	134	34	8	230.13	252.10
150	No	124	161	51		221.13	302.34
150	Yes	154	159	51	8	278.98	289.93
200	No	142	173	68		243.63	311.66
200	Yes	158	172	68	8	270.76	301.49

[†] Calculations were based on $2.20/bu corn, $0.34/lb N, and $32/gal of NServe.

Summary

In summary, both urease inhibitors and nitrification inhibitors can be tools to manage N loss profitably in today's economic climate. In order to insure the greatest probability of positive economic returns with these materials, it is important to know what environmental and management conditions increase the risk of N loss. As corn growers may reduce N rates because of high N prices, urease and nitrification inhibitors may play a larger role in providing insurance against yield reductions should N losses occur.

Disclaimer

Tradenames are used in this manuscript for the ease of understanding by the reader. These particular products are not necessarily endorsed by the University of Wisconsin-Madison.

References

Bundy, L.G. 1992. Urease inhibitors: NBPT use with surface-applied urea and 28% N solution. New Horizons in Soil Science. no. 2. Dept. of Soil Science, Univ. of Wisconsin-Madison.

Bundy, L.G., and S.L. Oberle, 1988. Evaluation of methods for control of ammonia volatilization from surface-applied urea-containing fertilizers. J. Fert. Issues 5:24-30.

Hendrickson, L.L. 1992. Corn yield response to urease inhibitor NBPT: Five-year summary. J. Prod. Agric. 5:131-137.

Hoeft, R.G. 1984. Current status of nitrification inhibitors use in U.S. agriculture. p. 561-570. In R.D. Hauck (ed.) Nitrogen in crop production. ASA, CSSA, and SSSA, Madison, WI.

Laboski, C.A.M. 2006. Implementation of regional nitrogen fertilization guidelines for corn in Wisconsin. In Proc. 2006 Fert., Aglime, and Pest Mgmt. Conf. Vol. 45.

Nelson, D.W., and D. Huber. 2001. Nitrification inhibitors for corn production. NCH-55. Iowa State University.

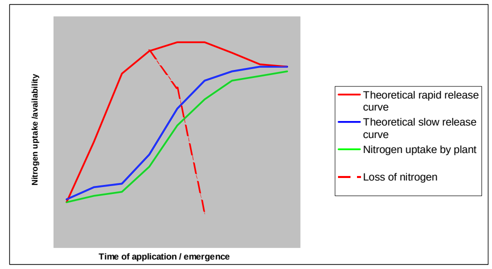
Randall, G.W., J.A. Vetsch, and J.R. Huffman. 2003. Corn production on a subsurface-drained mollisol as affected by time of nitrogen application and nitrapyrin. Agron. J. 95:1213-1219.

Wolkowski, R.P., K.A. Kelling, and L.G. Bundy. 1995. Nitrogen management on sandy soils. UWEX Bulletin A3634. Univ. of Wisconsin-Extension, Madison, WI.

Slow Release N Fertilizers: Are We There Yet?

Donald Genrich
Adams County Agriculture Agent
January 18 2005

Nitrogen Uptake and Release Curves



Benefits of Slow Release N Fertilizers

- Reduce risk of N loss
- Higher crop yields at equal N rates
- Maintain crop yields with lower N rates
- Improve crop quality
- More flexible application of N

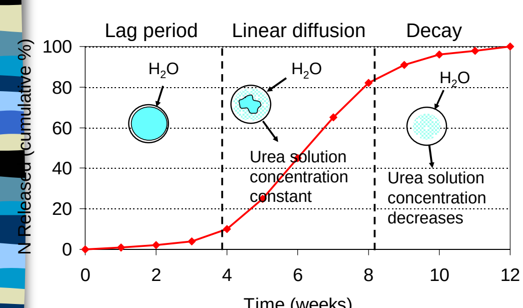
Forms of Slow Release N

- Organic fertilizers
- Sulfur-coated urea
- ESN-a polymer-coated urea from Agrium
- Polyon-a polymer-coated urea developed by Pursell Technologies and marketed by Simplot
- Nitamin-a urea based polymer developed by Georgia-Pacific

How Does the Slow Release Process Work

- Organic fertilizers: by soil microbial action
- Polymer-coated urea: by gradual diffusion of nitrogen through the polymer coating dependant on soil moisture and temperature
- Nitamin: release of nitrogen from the urea-based polymer by soil microbial action

ESN Release Mechanism



Crops Used in Slow Release Nitrogen Trials

- Corn
- Wheat & oats
- Pastures
- Potatoes
- Vegetable crops

Are We There Yet?

- Rates to use
- Placement
- Best timing of application
- Need for combination of fast release and slow release forms of N

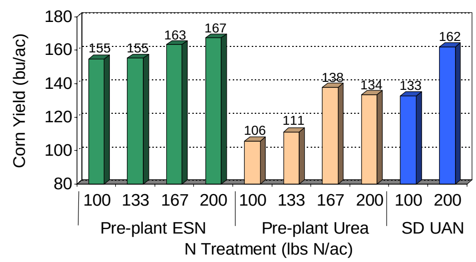
Pre-plant ESN and Urea on Corn Grain Yield at Hancock

Source: Dr. Larry Bundy

Nitrogen Treatment	Nitrogen Rate	Corn Yield
2005 ESN Preplant	100 lbs	174 bu/acre
2005 Urea Preplant	200 lbs	160 bu/acre
2004 ESN Preplant	100 lbs	147 bu/acre
2004 Urea Preplant	200 lbs	148 bu/acre

ESN – A Smarter Nitrogen

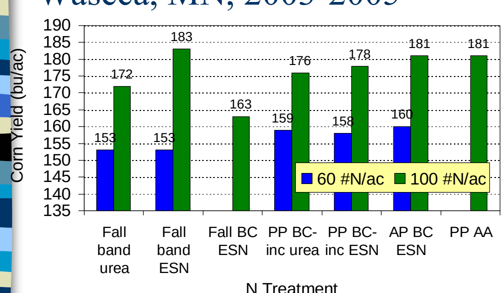
Danville, IL, 2004



ESN and urea broadcast/incorporated before planting

Source: Dr. Randy Simonson, TSM, Danville, IL

Three-Year Average Corn Yields Waseca, MN, 2003-2005



Source: Dr. Gyles Randall, Univ of Minnesota

Summary

- Results are highly weather dependent. You need the right moisture and temperature to get release that matches the plants need for nitrogen
- Slow release products "shine" in wet years, wet sites or sandy soils

HOW CAN WE IMPROVE NITROGEN USE EFFICIENCY?

Larry G. Bundy[1]

Introduction

With escalating nitrogen (N) fertilizer costs and continuing concerns about environmental impacts of N losses from cropland, there is substantial interest in improving the efficiency of nitrogen use by crops. In the Midwest, this interest is focused on corn since that crop receives most of the fertilizer N and most of the non-fertilizer N inputs from manures and previous legume crops. Nitrogen use efficiency (NUE) refers to the proportion of available or applied N that is taken up by the crop. Alternatively, NUE can also be expressed in terms of yield produced per unit of applied N (e.g., bu/lb N). The interest in improving NUE employs the rationale that enhanced NUE could allow less N to be applied without reducing yield, and if less N is used more efficiently, then losses of excess N to the environment should be lowered.

Current Trends in Nitrogen Use Efficiency

The good news is that NUE in the United States has increased since about 1980, and evidence from Wisconsin studies suggests that this increase in NUE is also occurring in this state. Cassman et al. (2002) reported that corn grain yields produced in the USA increased linearly between 1965 and 2000. However, N fertilizer use has leveled off since about 1980 resulting in a linear increase in NUE since that time. A similar observation can be made using data from a long-term (1958 to present) continuous corn N rate experiment at the Arlington Agricultural Research Station (Motavalli et al., 1992; Vanotti et al., 1997). In this experiment, three N rates as anhydrous ammonia have been applied each year, and the rates used since 1984 were 0, 125, and 250 lb N/acre. Yields from the experiment (1958 to 2004) are illustrated in Figure 1 and show that while yields in the control plot (no N) remained relatively constant, yields in the fertilized plots increased linearly throughout the experiment. When NUE is expressed on a bu grain/lb of N basis (Figure 2) for the 1980 through 2004 period, a linear trend toward increasing NUE over time is apparent. This trend is quite similar to that observed for the same time period by Cassman et al. (2002). Although the clear trend is toward increasing NUE for the entire period, substantial variation in NUE among years is apparent. This year-to-year variation in NUE is one of the major problems in developing N recommendation guidelines for corn because no method currently exists for predicting NUE in advance for individual years.

Why is NUE increasing over time? A major source of this improvement is likely due to enhanced crop productivity achieved through genetic modification of corn hybrids. Improvements in cultural practices have accompanied the genetic improvements such as use of higher plant populations with hybrids designed to tolerate increased plant densities and adoption of more effective pest management techniques. To some extent, improved N management practices have probably contributed to enhanced NUE over time by allowing selection of more appropriate N rates and implementation of best management practices (BMPs) to minimize losses of applied N. Efforts to improve NUE could include activities in each of the following three areas: 1) Improving the determination of optimum N rates; 2) Adjusting optimum N rates for non-fertilizer N contributions including those from manures and previous legume crops; soil N mineralization, and residual soil nitrate; and 3) Managing N to avoid losses using appropriate placement and timing methods.

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Selecting Optimum N Rates

Selection of the optimum rate of N to apply in various production conditions is usually the most important factor for improving agronomic NUE and for lowering the potential for N loss to the environment. The importance of selecting the optimum N rate for specific production situations can be seen by considering the shape of the typical corn N response curve and the relationships between maximum yield and the economic optimum yield. The typical N response curve shows that the first increments of added N are the most efficient at increasing yield while N applied as yields approach maximum values is used much less efficiently. To increase yields from the point of optimum economic return to the maximum level requires a significant amount of applied N resulting in very little yield increase and low NUE.

The influence of accurate selection of the optimum N rate on the potential for loss of applied N to the environment can be seen in Figure 3 which shows the relationship between excess N applied (the amount greater than the economic optimum rate) and soil water nitrate concentration below the root zone in a corn N rate experiment. This relationship shows that the soil water nitrate increases dramatically when the rate of N applied exceeds the economic optimum.

Several approaches are in use for selecting optimum N rates for corn production. Many states base corn N recommendations on a yield goal or expected yield approach where the anticipated yield is multiplied by a factor (typically 1.2 lb N/bu) and the result is adjusted for non-fertilizer N sources to arrive at the N application rate. This approach has received criticism because of the poor relationship between yield-based N recommendations and observed economic optimum N rates. This is a particular concern at current high corn yield levels where observed crop N needs are frequently much less than would be predicted using a yield goal approach. Some states including Wisconsin have departed from yield-based N recommendations and instead use a soil-specific approach (Wisconsin) or an approach based on cropping system (Iowa). Recently, a regional effort in the North Central region has resulted in an improved process for making N rate recommendations (Sawyer and Nafziger, 2005). This process, known as the maximum return to N (MRTN) approach, has clear advantages over yield-based strategies and is likely to be employed for making N rate guidelines throughout the North Central region. The MRTN method is based on an economic interpretation of N response data from numerous corn N rate response experiments conducted on soils and in cropping systems relevant for making N rate recommendations in individual states or in multi-state regions with similar soils and cropping patterns (Laboski and Bundy, 2005). This approach can easily account for shifts in corn:N price ratios that must be considered under current economic conditions, and seems promising for avoiding excess N use associated with yield-based N rate guidelines.

Adjustments for Non-fertilizer N Sources

When an optimum N rate is selected for a specific production situation, this rate must be adjusted for non-fertilizer N sources that will contribute to the available N supply. These sources include N from previous forage legume crops, manure applications, N from previous soybean crops, and soil N contributions from residual nitrate and mineralized organic N. It is well established that first-year corn following alfalfa on medium- and fine-textured soils usually needs little or no additional N to achieve optimum yields. Similarly, manure applications can supply part or all of the N needs of corn, depending on the available N content of the manure and the application rate. Historically, corn N needs following soybean have been adjusted using an N crediting approach (usually 40 lb N/acre). However, it is generally accepted that the influence of soybean on the N requirement of a subsequent crop is due to a rotation effect rather than a direct contribution of symbiotically-fixed N as is the case with forage legumes. In the MRTN approach for N rate guidelines (discussed previously), the effect of a previous soybean crop on optimum N rates for corn is handled as a cropping system effect rather than a N credit.

Accounting for soil N contributions is probably the most difficult adjustment to accomplish, due to the transitory nature of nitrate in soils and the lack of a reliable method for assessing N contributions from organic N mineralization. Existing tools such as the preplant soil nitrate test can be used to account for residual or carryover nitrate, and the pre-sidedress test can help assess the N contributions from organic N mineralization. A continuing need is a reliable diagnostic test to predict the amount of available N that will be released from soil organic N mineralization. This need is emphasized by recent findings that 50 to 70% of the corn yield obtained in the North Central region is due to N provided by the soil alone (without added N) (Sawyer, 2006). These substantial soil N contributions have an important effect on the use efficiency of added fertilizer N, indicating that NUE could be substantially improved if a reliable procedure for assessing soil N mineralization was available.

Managing N to Avoid Losses

After determining an optimum N rate through a sound selection process and making appropriate adjustments for non-fertilizer N sources, the N applied must then be managed to avoid losses that could occur prior to plant N uptake. Obviously, direct losses of the applied N will have a negative effect on NUE. The management practices most likely to influence NUE are those related to placement and timing of the fertilizer N application. Fertilizer N placement is critical where urea or urea-containing fertilizers such as urea-ammonium nitrate solutions are used as the fertilizer source. Since surface applications of urea are subject to N loss through ammonia volatilization, and the importance of urea as an N source is increasing rapidly, controlling ammonia volatilization losses are a major factor in improving NUE. Although large losses of urea-N through ammonia volatilization under field conditions are rare, the 20 to 30% (of applied N) losses that can occur are of obvious concern for NUE enhancement. Practices for controlling ammonia volatilization from urea include incorporating or injecting urea-containing fertilizers into the soil, using a soil urease inhibitor with fertilizer urea, or using non-urea fertilizer sources for surface N applications.

Timing of N applications can have important effects on NUE depending on soil characteristics and climate, the N loss mechanisms that are likely to occur, and the timing of N demand by the crop. Ideally, N would be applied just before the period of crop N use, thus providing adequate N to the crop and avoiding N losses that could occur with other times of N application. In practice, other times of N application can be used with equal effectiveness and NUE. Typically, N timing options for corn include fall, preplant, and sidedress or split applications. Fall applications are subject to higher risks of N loss than other timing options, and require use of BMP's to obtain acceptable performance and NUE. In all cases, fall applications should be limited to well-drained, medium- and fine-textured soils, applications should be delayed until soil temperatures remain below 50^{o}F, and N should be applied as anhydrous ammonia containing a nitrification inhibitor. Even when appropriate BMPs are employed, fall applications are usually10 to 15% less effective than the same amount of N applied in the spring. With current N prices and the lower average effectiveness, fall applications are becoming more difficult to justify. The relative performance of fall and spring N timings and their impacts on tile drainage water nitrate-N concentrations is illustrated in Table 1. These results indicate that yields with fall applied N were about 15 bu/acre less than with the same rate of spring applied N even when a nitrification inhibitor (N-Serve) was used with the fall applied N and when the rate of fall N was increased. Economic returns were also much higher with the spring N timing. Although tile drainage nitrate-N was not determined in the spring N treatment, it is clear that nitrate concentrations in drainage water increased as the rate of fall-applied N increased.

Preplant N applications are as effective as other timing options on most medium- and fine-textured soils with moderate or better drainage. Sidedress or split applications are essential for obtaining acceptable NUE on coarse-textured sandy soils and on some poorly drained soils. A comparison of preplant and split sidedress N applications for corn on a sandy irrigated soil at Hancock, WI is shown in Table 2. These results show that yields and plant recovery of applied N (NUE) were higher for the sidedress application than for preplant N at all rates. Yields were maximized at lower N rates with the sidedress timing, and a yield of 194 bu/acre was obtained with 100 lb/acre less N in the sidedress treatment with about 30% more of the applied N being recovered. Applying N just before anticipated N uptake avoids N losses by leaching on the sandy soils and by denitrification on the poorly drained soils, resulting in substantial improvements in NUE. In some situations, use of a nitrification inhibitor with ammonium forms of N or use of slow-release N fertilizers such as polymer-coated urea may also be effective in controlling these losses.

Summary and Conclusions

Improvements in NUE in corn production in the USA since 1980 should be exploited to take advantage of the genetic improvements in crop productivity and improved management practices. This could include use of plant densities to optimize productivity and implementation of improved cultural practices. Additional opportunities for improving NUE include improving the N rate selection process by using N rate guidelines based on N response data and economic considerations such as those offered by the emerging MRTN approach. Further improvements in NUE are possible through complete accounting for non-fertilizer N contributions to the available N supply including legume and manure N as well as the soil N contribution. Accounting for non-fertilizer N is essential for avoiding losses of excess N to the environment. Development of techniques for improved assessment of the soil N contribution to the plant available N supply is a key research need for NUE improvement. Finally, managing applied N to avoid losses through use of appropriate placement and timing practices is critical for improving NUE. These practices include control of ammonia volatilization losses from urea, use of sidedress or delayed N application times on coarse-textured soils, and minimizing the use of fall N applications.

References

Andraski, T.W., L.G. Bundy, and K.R. Brye. 2000. Crop management and corn nitrogen rate effects on nitrate leaching. J. Environ. Qual. 29:1095-1103.

Andraski, T.W., and L.G. Bundy. 2002. Using the PSNT and organic N crediting to improve corn nitrogen recommendations. Agron. J. 94:1411-1418.

Bundy, L.G., and T.W. Andraski. 1995. Soil yield potential effects on performance of soil nitrate tests. J. Prod. Agric. 8:561-568.

Cassman, K.G., A. Dobermann, and D.T. Walters. 2002. Agroecosystems, nitrogen-use efficiency, and nitrogen management. Ambio 31:132-140.

Laboski, C., and L. Bundy. 2005. New nitrogen rate guidelines for corn in Wisconsin using a regional approach. New Horizons in Soil Science no. 3-05. Dept. of Soil Science, Univ. of Wisconsin. 9 p.

Motavalli, P.P., L. G. Bundy, T. W. Andraski, and A. E. Peterson. 1992. Residual effects of long-term nitrogen fertilization on nitrogen availability to corn. J. Prod. Agric. 5:363-368.

Sawyer, J. (ed). 2006. Concepts and rationale for regional N rate guidelines for corn. Iowa State Univ. Extension, Regional Pub. Iowa State Univ., Ames, IA. (In press).

Sawyer, J.E., and E.D. Nafziger. 2005. Regional approach to making nitrogen fertilizer rate decisions for corn. p. 16-24. In Proc. North Central Ext. Industry Soil Fertil. Conf., Des Moines, IA. 16-17-Nov., 2005. Potash and Phosphate Inst., Brookings, SD.

Vanotti, M.B., L.G. Bundy, and A.E. Peterson. 1997. Nitrogen fertilizer and legume-cereal rotation effects on soil productivity and organic matter dynamics in Wisconsin. p. 105-119. In E.A. Paul et al. (ed.) Soil organic matter in temperate agroecosystems: Long-term experiments in North America. CRC Press, Inc., Boca Raton, FL.

Table 1. Nitrogen timing, rate, and N-Serve effects on yield, return and nitrate loss in tile drainage for a soybean-corn rotation in Minnesota (3-year average).

N treatment				Economic	Tile
Rate	Time	N-Serve	Yield	return	nitrate-N
lb/acre			bu/acre	$/acre	ppm
0	--	--	106	--	ND
120	Fall	Yes	160	66	18
160	Fall	Yes	169	74	23
120	Spring	No	175	100	ND

ND = not determined. Randall (2005), see Sawyer (2006).

Table 2. Nitrogen rate and timing effects on corn yield and N recovery, Hancock WI, 2003-2004.

N rate	Yield (bu/acre)		N recovery (%)	
(lb/acre)	Preplant	Sidedress*	Preplant	Sidedress*
0	96	96	--	--
50	122	142	47	84
100	145	175	45	79
150	164	194	42	73
200	180	202	40	66
250	193	202	37	57
Average	161	183	42	72

* Split sidedress N applied at 4 and 7 wk after planting.

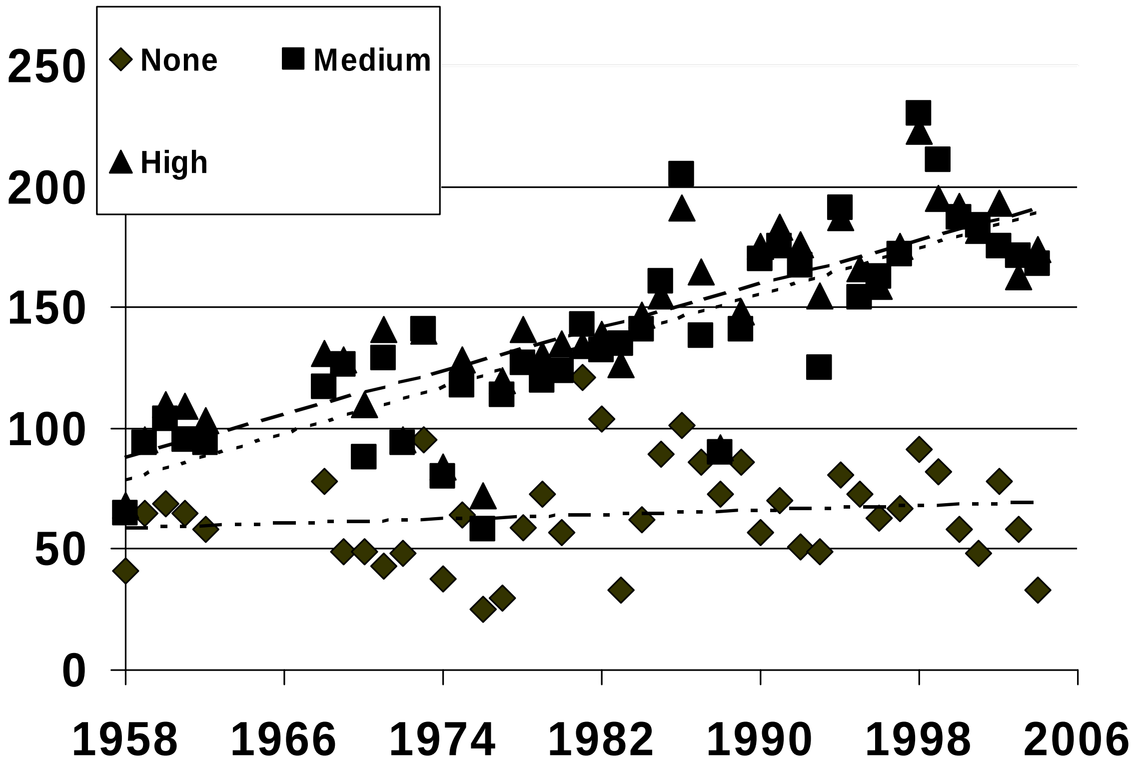

Figure 1. Continuous corn yields with three long-term N fertilizer rates at Arlington, WI, 1958-2004. Current N rates are None, Medium, 125 lb N/acre, and High, 250 lb N/acre.

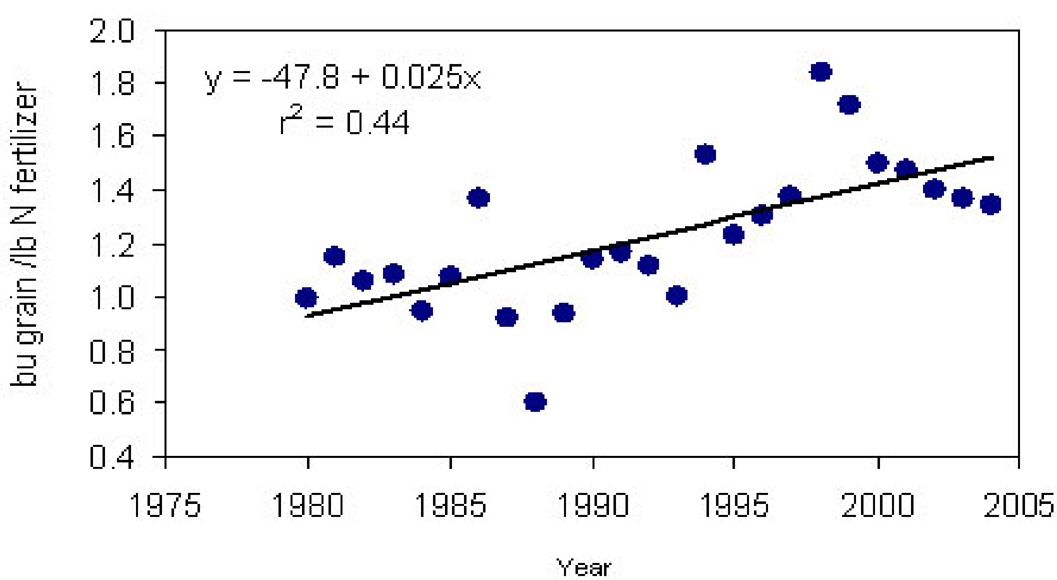

Figure 2. Nitrogen-use efficiency in long-term continuous corn, Arlington, WI, 1980-2004.

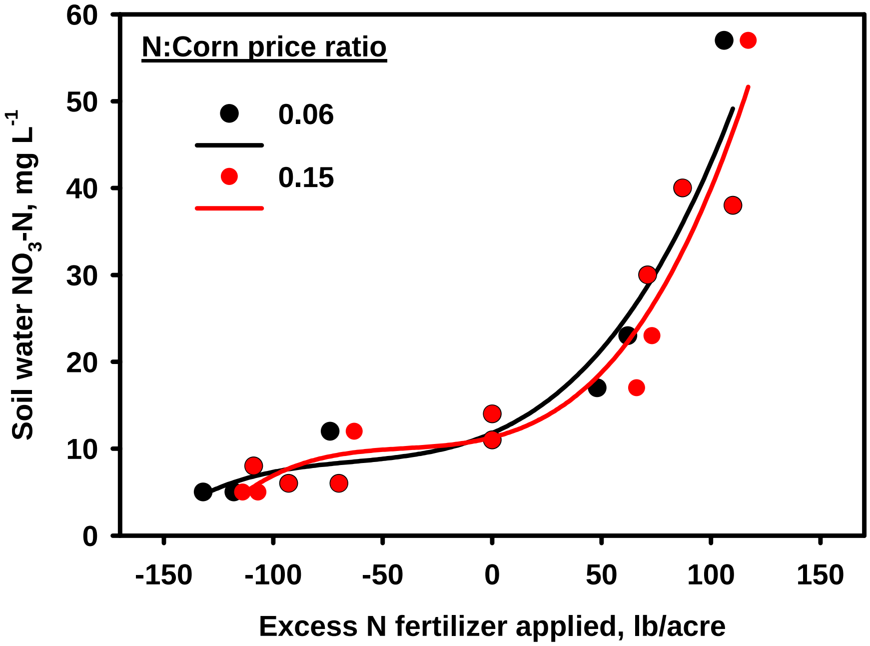

Figure 3. Relationship between the amount of excess N fertilizer applied to corn (at two N:corn price ratios) and average soil water NO_3-N concentrations at Arlington, WI (Andraski et al. 2000).

USING THE ILLINOIS SOIL NITROGEN TEST TO PREDICT OPTIMUM NITROGEN RATES FOR CORN IN WISCONSIN

Jeffrey T. Osterhaus and Larry G. Bundy [1/]

Abstract

Development of a diagnostic test to estimate soil N supplying capability is a continuing research need. The Illinois soil nitrogen test (ISNT) has been proposed as a method for adjusting corn (*Zea mays* L.) N recommendations to account for soil organic N contributions. We evaluated the ISNT as a tool for predicting corn N response in Wisconsin by comparing ISNT values and corn N response data from 80 experiments conducted between 1984 and 2004 with a range of crop rotations, management histories, and soils. Relationships between various hydrolyzable soil N fractions (including amino sugar-N) and corn N response data were evaluated using a subset (13 sites) of the 80 N response experiments selected to obtain a wide range of anticipated soil N availability. Results showed that ISNT values were not related to observed economic optimum N rates (EONR) in the corn N response experiments and that the ISNT had no ability to separate N responsive from non-responsive sites. ISNT values were well correlated ($r^2 = 0.88$) with the soil organic matter content of the experimental sites suggesting that the ISNT is measuring a constant fraction of the soil organic N rather than the readily mineralizable N component. Soil organic N fractions measured in 13 experiments were not related to corn N response although these experiments included cropping systems ranging from first year corn following alfalfa to continuous corn. Results from this work indicate that the ISNT and the soil organic N fractions studied are not reliable predictors of corn N response.

Introduction

Nitrogen recommendations for corn production that avoid yield losses due to under-fertilization and also avoid the economic and environmental problems associated with over-application have been the goal of researchers for decades. Development of improved N recommendations has been hampered by the lack of a reliable method of predicting soil N supplying capability, although many attempts to develop such a method have been made. The accurate assessment of available N production through mineralization of soil organic matter (SOM) is critical for improving corn N recommendations because this component can vary over soils, cropping systems, and years. The Illinois soil nitrogen test (ISNT) has been proposed as a diagnostic tool to predict soil organic N contributions to the available N supply (Kahn et al., 2001), and thus could address the long-standing need for a diagnostic test for assessing the soil organic N mineralization component of the available N budget. In developing this procedure, Kahn et al. (2001) reported a very high correlation between ISNT test values and hydrolyzable amino sugar-N in soils, and Mulvaney et al. (2001) showed that soil concentrations of amino sugar-N were closely related to check plot corn yields and fertilizer N response in field experiments.

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The purpose of this paper is to present the results of an evaluation of the ISNT conducted in Wisconsin to determine if this soil test is an effective tool for predicting corn N requirements. For this evaluation, ISNT values and corn N response data were compared in 80 experiments conducted from 1984-2004 and representing a variety of crop rotations, management histories, and soils. In addition, an evaluation of relationships between various hydrolyzable soil N fractions (including amino sugar-N) and corn N response in field experiments was conducted for a subset of the 80 experiments mentioned above.

Materials and Methods

Laboratory Methods

Soil samples (0- to 12-inch depth) from 80 corn N response experiments were analyzed using the ISNT method of Khan et al. (2001) as described in University of Illinois Technical Note (2002) with the following exceptions. Ammonia evolved from soil during the 5-hr heating period used in the ISNT was sorbed in 0.05 *M* H_2SO_4 and quantified using a colorimetric method described by Mulvaney (1996) with a modified buffer to accommodate the use of 0.05 *M* H_2SO_4 in place of 4% boric acid as the ammonia sorbing solution. The modified buffer consisted of adding 4.08g of NaOH/100 mL instead of the 2.96 g/100 mL specified in the original method.

Soil organic matter (SOM) content was measured on 0- to 12-inch samples from the 80 experimental sites. The loss on ignition method described by Storer (1984) was used for the analysis.

Soil Hydrolysates

Soil samples (0- to 6-inch depth) from 13 of the 80 corn N response experiments (Table 1) were subjected to the soil hydrolysis and organic N fractionation procedure described by Mulvaney and Khan (2001). This procedure provides estimates of the following soil organic N fractions: total hydrolyzable N, ammonium-N (NH_4), (ammonium + amino sugar)-N, and amino acid-N.

Field Methods

Experiments used to evaluate the ISNT for its ability to predict economic optimum N rates (EONR) for corn consisted of N response studies conducted in Wisconsin from 1984 to 2004. In total, information from 80 experiments conducted on a range of soils and eight different cropping systems was included in the evaluation. Cropping systems in this data set ranged from corn following alfalfa to long-term continuous corn and included sites with a history of manure application. These systems would be expected to have major differences in soil N availability. All experiments had multiple rates of applied N including non-limiting N rates to allow for the determination of maximum corn grain yield and calculation of the EONR. Most of the previously conducted N response experiments are described in previous papers (Bundy and Andraski, 1995; Andraski and Bundy 2002). Experiments used for the soil hydrolysis and organic N fractionation study consisted of a subset (n = 13) of the experiments included in the ISNT evaluation.

Soil samples used for the ISNT were collected to a depth of 0 to 12 inches while soils used in the soil hydrolysis and organic N fractionation studies were from the 0- to 6-inch depth. All samples were collected in the spring (April or May) and dried in a forced air dryer at a temperature of 40ºC. Samples were then ground to pass a 2-mm sieve for the ISNT and 150-µm sieve for the soil hydrolysis study.

Economic optimum nitrogen rates were determined using regression analysis with a correction for economic factors (i.e., the cost per pound of N applied and the price paid per bushel of grain) when quadratic and quadratic plateau equations were used for determining N response. Nitrogen fertilizer response was calculated as a percentage and was determined by the equation: 100 x (maximum yield - check yield) / check yield.

Results and Discussion

Illinois Soil Nitrogen Test

The relationship between ISNT values and economic optimum nitrogen rates (EONR) in the 80 experiments used in this evaluation is illustrated in Figure 1. These results indicate that that there is a poor relationship ($r^2 = 0.0013$) between ISNT and EONR. In addition, the ISNT critical value of 225 ppm N identified by Khan et al. (2001) does not separate N responsive from non-responsive sites in this data set. In contrast, a strong correlation ($r^2 = 0.88$) was found between soil SOM and ISNT values (Figure 2). Sawyer et al. (2003) reported a similar strong relationship between ISNT and soil organic matter content in Iowa experiments. These findings suggest that the ISNT probably measures a constant fraction of soil organic N rather than the readily mineralizable portion of soil N. To assess soil N supplying capability on a site specific basis, a diagnostic tool must selectively estimate the size of the readily mineralizable soil N pool. Results to date suggest that the ISNT does not have this ability and therefore, is not providing relevant new information about the N supplying capability of a soil. The poor relationship found between ISNT and EONR in corn N response experiments (Figure 1) is consistent with this conclusion.

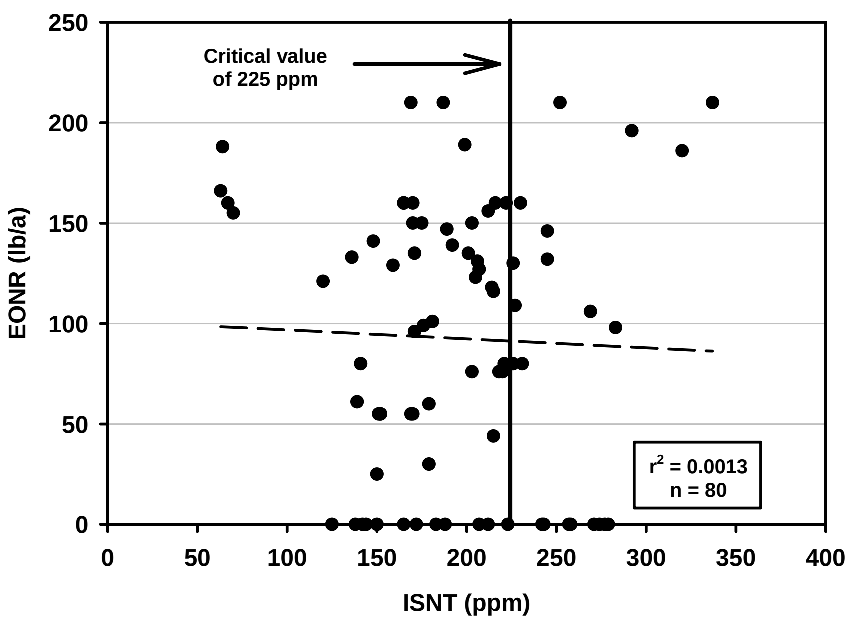

Figure 1. Relationship between Illinois soil nitrogen test (ISNT) values and economic optimum nitrogen rates (EONR) in 80 N-response experiments (1984-2004).

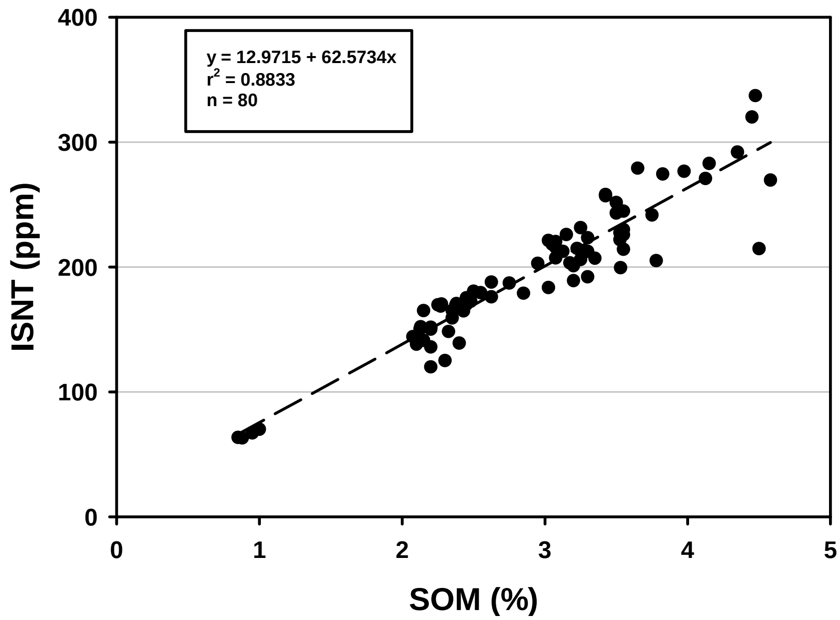

Figure 2. Relationship of Illinois soil nitrogen test (ISNT) values to soil organic matter (SOM) content in 80 N-response experiments (1984-2004).

Soil Hydrolysates

Since Mulvaney et al. (2001) found a strong relationship between soil amino sugar-N content and corn response to N fertilizer, we examined the relationships between several soil organic N fractions and N fertilizer response in field experiments (Table 1). As illustrated in Figure 3, no relationship was found between the soil amino sugar-N content and fertilizer N response in 13 corn N response experiments. Furthermore, none of the soil organic N fractions produced using the Mulvaney and Khan (2001) soil hydrolysis procedure were related to the observed response to N fertilization in the field experiments (Table 2).

Table 1. Site characteristics, soil organic N fractions, and corn N response in 13 Wisconsin experiments.

Location	Year	Crop rotation †	SOM	ISNT	Amino sugar-N	NH_4-N	Amino acid-N	Tot. hyd. N ‡	Check yield	Max. yield
			%	----------	----------	ppm	----------	----------	bu/a	bu/a
Bloomington	1998	CC	2.85	179	190	286	170	1007	190	228
Bloomington	1998	CC	3.98	277	341	458	330	1618	207	223
Bloomington	1998	CC	4.13	271	330	445	234	1388	226	243
Bloomington	1998	CC	3.08	207	315	318	176	1340	203	225
Lancaster	2001	CC	2.20	139	165	215	272	1265	76	104
Lancaster	2001	AC	2.35	180	202	256	479	1560	121	167
Lancaster	2001	ACC	2.55	187	214	291	409	1823	94	132
Lancaster	2001	SC	2.70	173	192	280	463	908	95	162
Arlington	2003	CC	4.35	292	384	441	455	1704	119	192
Arlington	2003	SC	3.55	230	321	423	376	1764	121	207
Arlington	2004	CC	4.50	253	376	364	343	2028	145	194
Arlington	2004	SC	4.58	269	338	362	330	1761	140	200
Arlington	2004	CC	3.53	199	309	327	226	1299	101	208

† Crop rotation where C = corn, A = alfalfa, and S = soybean.

‡ Total hydrolyzable nitrogen.

Table 2. Relationships between soil organic N fractions and corn response to N fertilization.

Fraction	R^2	$p > f$ †
Total hydrolysable N	0.0033	0.8517
NH_4-N	0.0126	0.7153
NH_4+Amino sugar-N	0.0039	0.8384
Amino sugar-N	0.0000	0.9898
Amino acid-N	0.1039	0.2835

† $p > f$ = probability that tabular f ratio exceeds f ratio calculated by analysis of variance.

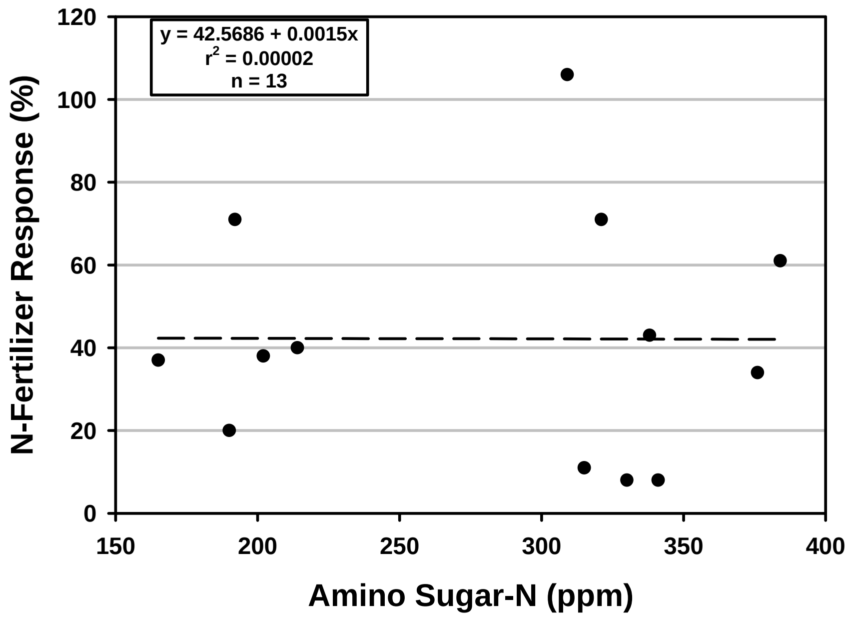

Figure 3. Relationship of hydrolyzable amino sugar-N content to N-fertilizer response.

Relationships between soil organic N fractions and ISNT values (Table 3) show that NH_4-N, (NH_4 + amino sugar)-N, and amino sugar-N fractions were strongly related to ISNT. However, NH_4-N had a stronger correlation with ISNT than amino sugar-N (r^2 = 0.91 and r^2 = 0.79, respectively), and NH_4+amino sugar-N had the strongest correlation of these three fractions. The stronger correlation of NH_4-N to ISNT than amino sugar-N to ISNT suggests that the hydrolyzable NH_4-N fraction represents a substantial portion of the soil organic N measured by the ISNT. Furthermore, comparison of the hydrolysable organic N fractions with ISNT values in Table 1 show that the ISNT recovers only a portion of the various N fractions.

Table 3. Relationship between several soil organic N fractions and ISNT.

Fraction	R^2	$p > f$ †
Total hydrolysable N	0.3017	0.0519
NH_4-N	0.9098	< 0.0001
NH_4+Amino sugar-N	0.9222	< 0.0001
Amino sugar-N	0.7975	< 0.0001
Amino acid-N	0.0139	0.7013

† $p > f$ = probability that tabular f ratio exceeds f ratio calculated by analysis of variance.

Conclusions

Results from 80 corn N response experiments in Wisconsin showed that ISNT values were not related to observed economic optimum N rates (EONR) and that the ISNT had no ability to separate N responsive from non-responsive sites. ISNT values were well correlated ($r^2 = 0.88$) with the soil organic matter content of the experimental sites suggesting that the ISNT is measuring a constant fraction of the soil organic N rather than the readily mineralizable N component. Soil organic N fractions measured in 13 experiments were not related to corn N response although these experiments included cropping systems expected to have major differences in soil N availability. Results from this work indicate that the ISNT or the soil organic N fractions studied are not reliable predictors of corn N response.

References

Andraski, T.W., and L.G. Bundy. 2002. Using the PSNT and organic N crediting to improve corn nitrogen recommendations. Agron. J. 94:1411-1418.

Bundy, L.G., and T. W. Andraski. 1995. Soil yield potential effects on performance of soil nitrate tests. J. Prod. Agric. 8:561-568.

Khan, S. A., R. L. Mulvaney, and R.G. Hoeft. 2001. A simple soil test for detecting sites that are nonresponsive to nitrogen fertilization. Soil Sci. Soc. Am. J. 65:1751-1760.

Mulvaney, R.L. 1996. Nitrogen - Inorganic forms (Chapter 38). p. 1152-1155. In Methods of soil analysis. Part 3. Chemical methods. SSSA Book Series no. 5. SSSA and ASA. Madison, WI.

Mulvaney, R.L., and S.A. Khan. 2001. Diffusion methods to determine different forms of nitrogen in soil hydrolysates. Soil Sci. Soc. Am. J. 65:1284-1292.

Mulvaney, R.L., S.A. Khan, R.G. Hoeft, and H.M. Brown. 2001. A soil organic nitrogen fraction that reduces the need for nitrogen fertilization. Soil Sci. Soc. Am. J. 65:1164-1172.

Sawyer, J. E., D. W. Barker, J.P. Lundvall, and M. Al-Kaisi. 2003. Evaluation of the amino sugar-N based soil test in Iowa corn production. In Proc. 19th North Central Extension-Industry Soil Fertility Conf., Des Moines, IA. 19-20 Nov. 2003. Potash & Phosphate Institute, Brookings, SD.

Storer, D.A. 1984. A simple high sample volume ashing procedure for determining soil organic matter. Commun. Soil. Sci. Plant Anal. 15:759-772.

University of Illinois, Department of NRES. 2002. The Illinois soil nitrogen test for amino sugar N: Estimation of potentially mineralizable soil N and ^{15}N. Technical Note 02-01 (rev. e).

REGIONAL APPROACH TO MAKING NITROGEN FERTILIZER RATE DECISIONS FOR CORN[1]

John E. Sawyer and Emerson D. Nafziger[2]

Introduction

Nitrogen fertilizer is one of the largest input costs for growing corn. Across the Corn Belt, N is typically the most yield-limiting nutrient. Facing record high N fertilizer prices and potential supply problems, producers are concerned about N fertilization rates. Soil fertility researchers and extension specialists from seven states across the Corn Belt (see list in acknowledgements section) have been discussing corn N fertilization needs and evaluating N rate recommendation systems for approximately the past two years. These discussions could not have been timelier considering the current N fertilizer issues.

In recent years N recommendation systems have become more diverse across states in the Corn Belt. Of particular significance has been the movement away from yield goal as a basis of N rate decisions in some states to other methods such as cropping system (Iowa) or soil specific yield potential (Wisconsin). Research from across the Corn Belt has also been indicating that economic optimum N rate (EONR) does not vary according to yield level. At the same time, corn yields have been at historic high levels, leading to increases in yield goal. This has added to concerns that increasing yield-based N rates are often found to be substantially greater than EONR observed in N rate trials. Also, watersheds being targeted to receive incentive and cost-share funds for N rate management sometimes cross state boundaries, which causes problems if suggested rates are not consistent. These issues have increased uncertainty regarding current N rate recommendations.

An outcome of the multi-state discussions has been development of a consistent approach for N rate guideline development that can be utilized on a regional basis. This does not necessarily mean that fertilizer N rates will be the same across states. Rather, there is a common approach to guideline development. Depending upon the research database, rates could be the same or quite different. Another outcome of this approach has been an improved ability to evaluate the economic returns to N, and the ability to estimate the most profitable fertilizer N rates. This has become very valuable information for dealing with today's high N fertilizer prices and water quality issues.

Maximum Return to N Approach (MRTN)

The method utilized for developing the regional approach to N rate guidelines for corn was outlined by Nafziger et al. (2004) in a paper presented at the 2004 North Central Extension-Industry Soil Fertility Conference. The underlying principle is to have rate guidelines based directly from results of many N response trials. Databases of recent response trials represent a population of potential responses to N. Subsets are assembled for specific rotations or other factors that may influence N response. Analysis of economic net return to N across all sites in the datasets provides the basis for N rate guidelines. Net return is calculated from corn yield increase to N minus fertilizer N cost. The point of maximum return to N (MRTN) is the most profitable N

[1] This paper will be presented at various conferences and workshops, including but not limited to the North Central Extension-Industry Soil Fertility Conference, November 16-17, 2005, Des Moines, IA.
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rate. Since net return is relatively constant around the MRTN rate, net return within $1.00/acre of the MRTN defines an N rate range that provides similar profitability.

An example result from MRTN calculation is shown in Fig. 1 for a large corn following soybean (SC) N response trial dataset from Iowa. Net return is influenced by N and corn prices, and the MRTN and profitable N rate range can be easily calculated for different prices. Net return will vary depending upon specific N and corn prices, but the MRTN rate remains constant when the ratio of these prices ($/lb:$/bu) is the same. Details of the MRTN approach can be found in Nafziger et al. (2004) and a recently developed regional publication (see additional information section below). Following is an outline of the steps in the calculation of MRTN.

- ❖ Yield data are collected from replicated, multi-rate N response trials.
- ❖ A computer program is used to fit a line to the yield for the N rates at each site to provide a mathematical equation of that line.
- ❖ Datasets of site response curves are accumulated for specific situations, such as corn in different rotations.
- ❖ For each site in a dataset, values are calculated from the response curve equation at 1-lb N rate increments from zero to 240 lb N/acre. From this information yield increase (above the yield at zero N), gross dollar return from that yield increase, fertilizer cost, and net return are calculated. Economic values are calculated based on specified N fertilizer and corn grain prices.
- ❖ Net return is averaged across all sites in the dataset for each specific rotation.
- ❖ The N rate with the largest net return is the MRTN rate. Nitrogen rates with net return within $1.00/acre of the MRTN provide a range of N rates with similar profitability.

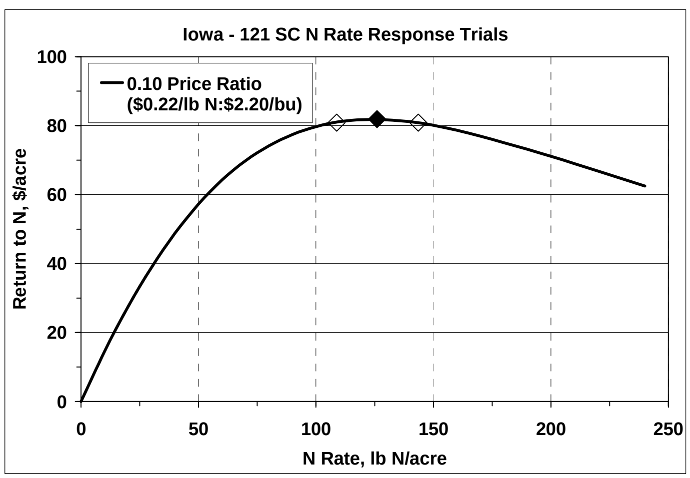

Figure 1. Return to N from 121 Iowa corn following soybean site-years. The MRTN rate is indicated by the closed symbol and the N rates (HIGH and LOW) defining the ends of a range of similar profitability (within $1.00/acre of the MRTN) are indicated by the open symbols.

Regional Database Analysis

Nitrogen response data were assembled from 698 replicated N rate trials conducted from 1983-2004 in Illinois, Iowa, Michigan, Minnesota, Ohio, and Wisconsin (Fig. 2). All sites in the database were non-irrigated and had either spring preplant or sidedress fertilizer N application. Data were accumulated for corn following corn (CC) and SC. The number of sites by state and rotation was: Illinois – 93 CC, 185 SC; Iowa – 60 CC, 136 SC; Minnesota – 73 CC, 55 SC; and

Wisconsin – 39 CC, 34 SC. Grain yield N response curves were determined for all sites and then accumulated into a database. Subsets of the database were sorted by state and rotation. These subsets were analyzed separately using the MRTN approach. The number of sites from Michigan and Ohio was limited; therefore results are not presented separately for those states. Characteristics of sites in the database: approximately 65% of sites were loess parent material soils and 31% had glacial till parent material; 12% were no-tilled and 88% had tillage; 7% had a manure history; 85% were soils classified as very high yield potential and 12% high yield potential.

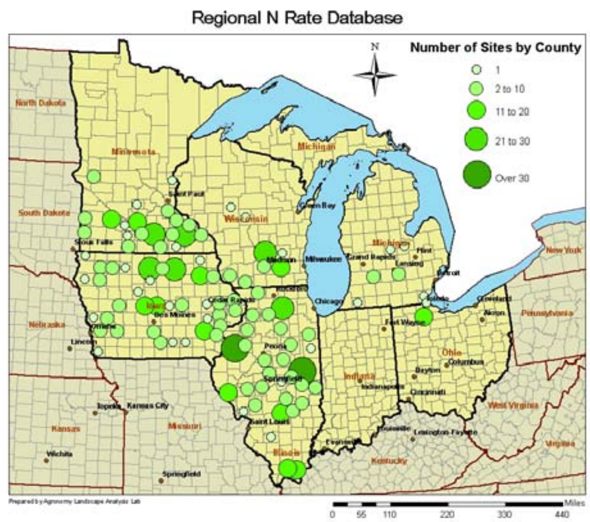

Figure 2. Geographic location and density of N response trial sites.

Across the multi-state database, the MRTN rate (0.10 price ratio, \$0.22/lb N:\$2.20/bu) for SC is 140 lb N/acre (389 sites) and for CC is 161 lb N/acre (244 sites). This calculation does not include non-responsive sites for each rotation (that is, sites with no yield increase from applied N). If the non-responsive sites are included (38 for SC and 27 for CC), the MRTN rates decrease by only 4 lb N/acre. While these “entire-region database” N rates may seem reasonable, they are likely not most appropriate for individual states. Climate, soils, and production practices are different across the Corn Belt, so it is reasonable that needed N fertilization rates would vary. Separate analyses of the datasets from each state shows that MRTN rates are indeed different across the four states (Fig. 3). Some states have quite similar MRTN rates (Minnesota and Wisconsin being good examples), others are different. It appears that the more northern region (Minnesota and Wisconsin) has lower N fertilization requirement, which could easily be due to higher organic matter soils and climatic differences. Guidelines developed from the MRTN analysis would therefore be different between some states. Consistency comes from the similar analysis process, not from having the same N rate guidelines across the whole region.

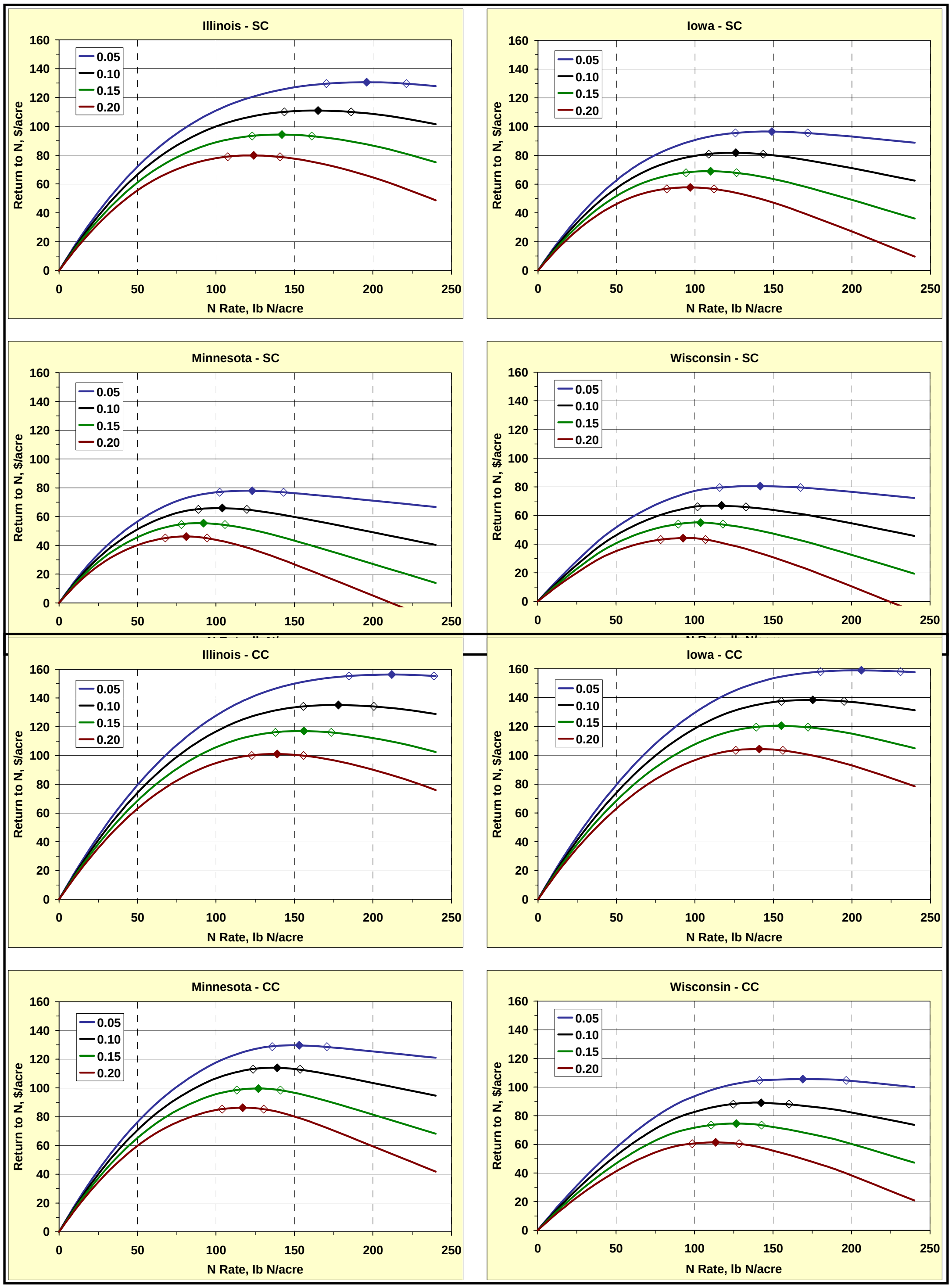

Figure 3. Net return to N, MRTN, and profitable N rate ranges for SC and CC datasets from the four states. Corn grain price was held constant at $2.20/bu and N prices at $0.11, $0.22, $0.33, and $0.44/lb N give price ratios of 0.05, 0.10, 0.15, and 0.20, respectively.

The prices of N and corn affect the net return to N, as well as the point of MRTN and width of the profitable N rate range around the MRTN (Fig. 3). As N becomes more expensive relative to corn price (that is, as the price ratio $/lb:$/bu increases), net return is reduced, MRTN is reduced, the width of the profitable N rate range decreases, and economic penalty with high N rates (above optimum) becomes more severe.

Across the four states, the MRTN rate is higher for CC than SC. This follows the expected trend, and what has been measured in research studies for many years. The difference in MRTN rate is not consistent between states. For SC, at a 0.10 price ratio ($0.22/lb N:$2.20/bu corn), the MRTN rate is 163, 123, 101, and 107 lb N/acre respectively for Illinois, Iowa, Minnesota, and Wisconsin datasets. For CC, the MRTN rate is 176, 174, 136, and 139 lb N/acre respectively for Illinois, Iowa, Minnesota, and Wisconsin datasets. The largest difference between rotations is for Iowa data, the smallest for Illinois data, with Minnesota and Wisconsin intermediate. The MRTN rate difference between the Iowa SC and CC datasets (51 lb N/acre) is consistent with what has been suggested for the SC rotation effect for many years in Iowa (Voss and Shrader, 1979). In Illinois, this difference averages about 40 lb N/acre when the two rotations are evaluated next to one another in the same field. Some of the reason the difference is less than the “soybean N credit” of 40 lb in Illinois is because the Illinois SC and CC datasets have results from different sites. It is possible that some corn following corn is on more-productive soil. If so, then more of the N requirements may be provided by the soil. Although data were not accumulated for rotations other than SC and CC, the same MRTN approach can be applied when corn follows other crops. First- and second-year corn after forage legumes are good examples. All that is required is an adequate N response trial dataset.

While the analysis presented used each entire state database, subsets can be created to determine if site conditions, management history, or regions within or across states should have the same or different rate guidelines. Here are a few examples. For the Illinois SC dataset, the MRTN is slightly lower for SC in the northern portion of Illinois (163 lb N/acre) versus southern Illinois (179 lb N/acre). Although the difference is not large, rate guidelines could be adjusted for these two regions. As mentioned earlier, this difference in N fertilization need could be due to different soils and climatic conditions. For the Iowa SC dataset, the MRTN rate is similar when grouped into various yield ranges (128 lb N/acre for 0-150 bu/acre; 126 lb N/acre for 150-200 bu/acre; and 127 lb N/acre for 200+ bu/acre). This indicates that different N rate guidelines are not needed based on yield level in Iowa. For the entire multi-state database, the MRTN rate is 4 lb N/acre higher for no-till versus tilled soils; not a large enough difference to suggest N rate adjustment based on tillage. Other subsets can be analyzed in the same manner. Most such analyses conducted to date suggest that grouping data by site characteristics does little to improve N rate guidelines.

What This Means for Corn N Rate Guidelines

An example of how N rate guidelines based on the MRTN approach might look is given in Table 1 for the Iowa SC and CC datasets. Choice of a N rate can be adjusted by using current prices (price ratio); moving between MRTN rates as price ratios change; moving toward the low or high end of the profitable range based on price ratios, availability of enterprise capital, soil productivity potential, yield-limiting factors, external perception, or production risk tolerance/aversion. This guideline approach gives producers, and their advisers, opportunity to adjust choice of N rate.

The impact of using the regional approach for making corn N rate decisions will likely be different across states. How much the guidelines will change from those currently used in an individual state will depend on the recommendation system currently in use as well as the results of the MRTN analysis using that state's N response data. More important will be the overall benefits from having a common approach used in each state. As new data are generated, they can be added to the database to improve the basis for the calculations. Not only will the analysis of recent response data provide up-to-date information, but the economic focus will help producers choose N application rates that have potential for maximizing return. With the current issues of high price and uncertain supply, having current information will provide needed help with tough N fertilization decisions.

Table 1. Example N rate fertilization guidelines for SC and CC in Iowa based on N:corn price ratios and economic return calculated by the MRTN approach.

	SC			CC		
Price Ratio	LOW†	MRTN	HIGH†	LOW†	MRTN	HIGH†
$/lb:$/bu	- - - - - - - - - - - - - - - -	- - - - - - - -	lb N/acre	- - - - - - - -	- - - - - - - -	- - - - - - - -
0.05	125	145	170	180	200	230
0.10	105	125	145	155	175	195
0.15	90	110	125	140	155	170
0.20	80	95	110	125	140	155

† LOW and HIGH rates approximate the profitable range for $1.00/acre below and above the MRTN for each price ratio.

The actual impact of applying the MRTN approach will likely be smaller in Iowa and Wisconsin than in some other states. The currently suggested N rates in those two states appear close to that derived from the MRTN analysis. Also, both states had previously moved away from yield-based recommendations. Wisconsin recommendations had already become more directly based on results of N rate trials. In Iowa, current MRTN analysis is providing N rates that are strikingly similar to fertilizer N rate ranges suggested for many years. In other states, especially those utilizing yield-based rate systems, the potential impact will be large. Even if rates don't change much, introducing a new system will be a significant conceptual challenge. For producers that use a yield-based approach, and have been producing exceptionally high corn yields, the rate guidelines developed from the MRTN approach will likely be lower than those used now. This will be a concern to producers, but it is a change that research indicates should happen. That is, N rates driven by yield-based recommendations are substantially higher than the EONR found N response trials, especially for corn following soybean.

Some uncertainty always exists in regard to having sufficient N to meet crop needs. This occurs because of variation in optimum N among sites and among years at a site. Producer concerns usually focus on the potential for severe yield and economic loss if N is deficient, as shown with low rates in Fig. 3. With inexpensive N, this can easily lead to high N application rates as a way to alleviate such uncertainty. The MRTN results shown in Fig. 3 indicate that when N is inexpensive compared to corn price, rates well above the MRTN result in only minor decline in net return. However, as N becomes more expensive relative to corn price, high application rates will result in significant economic losses. Therefore, using high N rates to "ensure" high yield should be reconsidered with today's N prices. The flat net return surrounding the N rate at

MRTN reflects the small yield change that occurs near optimum N. This indicates that choosing an "exact" N rate is not critical for optimal yield, and this should give producers confidence that N applications based on MRTN will be adequate.

To help understand uncertainty with choice of a particular N rate, percent chance of N sufficiency (outlined in Nafziger et al., 2004) can be calculated for each rate guideline and price ratio (example for the Iowa datasets given in Fig. 4). The chance of a chosen N rate being a sufficient rate (conversely, a "not deficient" rate) can be determined. While it may seem desirable to have N rate sufficiency near 100 %, that is, have little to no N deficiency risk, it is not economical to apply N at rates providing that level of sufficiency. This can be seen by comparing the N rates at high level of sufficiency in Fig. 4 for the Iowa datasets with the net return at the same N rates in Fig. 3 for the same datasets. In general, N rates at the MRTN tend to be at or above the EONR in some 60 to 80 percent of the trials in a database. While 20 to 40 percent chance of "insufficiency" may seem high, the nature of the response curves is such that the economic penalties for over-application and under-application tend to be at a minimum at the MRTN. Therefore, while producers bear some level of risk in order to maximize economic return from N fertilization, the MRTN provides the best estimate, based on actual data, of the N rate at which such risk is minimized.

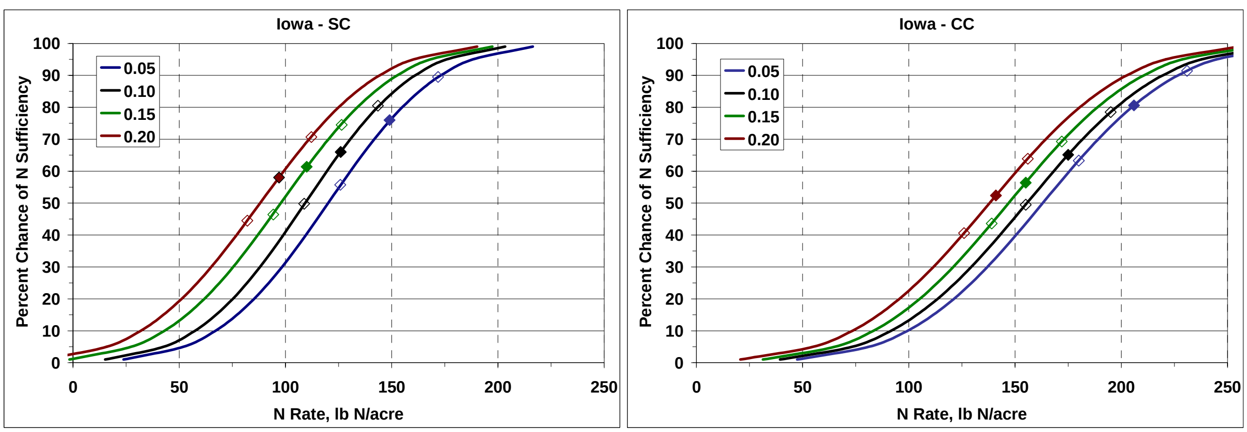

Figure 4. Chance of N rate sufficiency from the Iowa SC and CC datasets. The MRTN rate is indicated by the closed symbols and the N rates (HIGH and LOW) defining the range of similar profitability (within $1.00/acre of the MRTN) indicated by the open symbols.

Summary Comments Regarding the MRTN Approach

Nitrogen rate guidelines should provide producers the opportunity to maximize economic return from applied N. Yield responses measured in N rate trials conducted across many sites provides the database needed for economic analysis. The MRTN approach provides a flexible method to develop N rate guidelines directly from response databases, either on a local or regional basis. Of most importance, the MRTN approach incorporates economic analysis, is based on maximizing return to N fertilization, and uses up-to-date N research data. With the ease of calculation, guidelines can be adjusted for various factors affecting corn N fertilization need such as rotation, geographic location, etc. and economic factors like N fertilizer and corn prices. Additional features such as environmental penalties for over-application or grain quality effects of N nutrition can be incorporated into the calculations as well. For example, excess N could be assigned a cost per lb of N, or a decrease in protein content as a consequence of under-application could be assigned as a penalty to the corn price.

Because the MRTN approach relies on current N rate response data, there must be an adequate number of trials available in order to develop or update guidelines. This requires an aggressive and on-going research program, especially if N guidelines are desired for specific geographic locations, soils, rotations, or other situations. The more data that are available and the more robust the N response database, the better N rate guidelines will be and the more specific they can become.

Summary Observations from Application of the MRTN Approach

- The MRTN approach, through direct analysis of N response trial datasets, provides a straightforward development of N rate guidelines.
- The MRTN approach is useful not only for providing N rate guidance, but also for increasing understanding of corn response to N application and economic profitability.
- The MRTN rate and profitable range of N rates surrounding the MRTN provides guidelines for rate selection and flexibility for producers in addressing risk and price fluctuation.
- Higher N prices relative to corn grain prices (larger price ratio, $/lb:$/bu) results in reduced net return, lower MRTN rate, reduced width of the profitable N rate range around the MRTN, and greater economic penalty with N rates above optimum.
- Nitrogen rates well below optimum result in severe reduction in net return, especially with more N-responsive crop sequences such as CC.
- If adequate data exist, subsets can be created to determine if production practices, management history, prior crop, or regions within or across states could have similar or different rate guidelines.

Additional Information

A regional publication called "Concepts and Rationale for Regional N Rate Guidelines for Corn" will be available in the near future. Check with the Extension program in your state for availability of printed copies or on-line web access. The publication covers the regional guideline approach outlined here and provides detailed results from applying the MRTN approach to the four-state N response databases.

Also, a web tool was developed, the "Corn Nitrogen Rate Calculator," that is based on the MRTN approach. It calculates the MRTN, profitable N rate range, net return, chance of N sufficiency, and other information directly from the N response trial databases for Illinois, Iowa, Minnesota, and Wisconsin. Calculations can be computed for CC or SC, and can be compared with up to four sets of N fertilizer and corn prices. This calculator is located at http://extension.agron.iastate.edu/soilfertility/nrate.aspx.

Acknowledgments

Other individuals involved in development of the regional approach to N rate guidelines and compiling state corn N response trial databases include: Sylvie Brouder, Purdue University; Larry Bundy, University of Wisconsin; Brad Joern, Purdue University; Robert Hoeft, University of Illinois; Randy Killorn, Iowa State University; Carrie Laboski, University of Wisconsin; Robert Mullen, The Ohio State University; Gyles Randall, University of Minnesota; and George

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Thanks are extended to the many individuals and researchers who have worked tirelessly to conduct the N response trials and to the producers who donated land and time for these trials.

References

Nafziger, E.D., J.E. Sawyer, and R.G. Hoeft. 2004. Formulating N recommendations for corn in the corn belt using recent data. In Proc. N. C. Ext.-Ind. Soil Fertility Conf., Des Moines, IA. 17-18 Nov., 2004. Potash and Phosphate Inst., Brookings SD.

Voss, R.D., and W.D. Shrader. 1979. Crop rotations-effect on yields and response to nitrogen. Publication pm-905 (out of print). Iowa State University Extension, Ames, IA.

IMPLEMENTATION OF REGIONAL NITROGEN FERTILIZATION GUIDELINES FOR CORN IN WISCONSIN

Carrie Laboski[1]

Introduction

Recently soil fertility specialists in Wisconsin, Minnesota, Iowa, and Illinois have agreed to use the same philosophy to develop N rate guidelines for corn (grain). This new philosophy will reduce some of the differences in N rate recommendations between states and more importantly will provide for producer flexibility in setting a N rate that maximizes profitability. The approach used is data intensive (both research farm and grower fields) and is based on maximizing return to N fertilizer.

The new N rate guidelines for Wisconsin are provided in Table 1. In order to determine the N application rate using this table, one must first know:

- ✓ Soil yield potential. All soils in Wisconsin have been classified into yield potential categories based on the soil's rooting depth, water holding capacity, drainage, and length of growing season. Soil yield potentials can be found in bulletin UWEX A2809 "Soil test recommendations for field, vegetable, and fruit crops".
- ✓ Previous crop.
- ✓ N:corn price ratio. This is the price of N per pound divided by the price of corn per bushel.

Using these three pieces of information, a N rate can be identified that will, on average, maximize economic return to N (MRTN). A range of N rates that will produce economic profitability within one dollar per acre of the maximum can also be identified.

Example: *If corn will be grown on a high yield potential soil, N costs $0.36/ lb N and the outlook for corn is $2.40/bu (a price ratio of 0.15), and the previous crop was corn, then the N application rate that would be most likely to produce the greatest economic return is 120 lb N/a. A range in profitable N rates for this situation is 100 to 135 lb N/a. If the situation were the same except that the previous crop was soybean, then the N rate would be 100 lb N/a with a profitable range of 85-115 lb N/a.*

Within this system there is no longer a soybean N credit. Instead, a separate analysis of sites where corn followed soybean was used to develop the recommendations. It is important to continue to take N credits for forage legumes, leguminous vegetables (snap beans, peas, lentils, etc), green manures, and animal manures. These N credits are not changing. With regard to soil nitrate tests, the preplant nitrate test (PPNT) will remain the same; while the presidedress nitrate test (PSNT) will be used as an N credit to subtract from a previously determined N application rate.

These N rate guidelines are based on research where N losses were minimal or non-existent. Thus, time of application and form of N used does not affect the profitable N rates, because no loss of N is assumed.

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Table 1. Suggested N application rates for corn (grain) at different N:corn price ratios.

Soil and Previous Crop	N:Corn Price Ratio ($/lb N:$/bu)							
	0.05		0.10		0.15		0.20	
	Rate[1]	Range[2]	Rate[1]	Range[2]	Rate[1]	Range[2]	Rate[1]	Range[2]
	lb N/a (Total to Apply)[3]							
HIGH/V. HIGH YIELD POTENTIAL SOILS								
Corn, Forage legumes, Leguminous vegetables, Green manures[4]	165	135-190	135	120-155	120	100-135	105	90-120
Soybean, Small grains[5]	140	110-160	115	100-130	100	85-115	90	70-100
MEDIUM/LOW YIELD POTENTIAL SOILS								
Corn, Forage legumes, Leguminous vegetables, Green manures[4]	110	90-135	100	80-110	85	70-100	75	60-90
Soybean, Small grains[5]	90	75-110	60	45-70	50	40-60	45	35-55
IRRIGATED SANDS AND LOAMY SANDS								
All crops[4]	215	200-230	205	190-220	195	180-210	190	175-200
NON-IRRIGATED SANDS AND LOAMY SANDS								
All crops[4]	110	90-135	100	80-110	85	70-100	75	60-90

[1] Rate is the N rate that provides the maximum return to N (MRTN).
[2] Range is the range of profitable N rates that provide an economic return to N within $1/a of the MRTN.
[3] These rates are for total N applied including N in starter fertilizer and N used in herbicide applications.
[4] Subtract N credits for forage legumes, leguminous vegetables, green manures, and animal manures. This includes 1st, 2nd, and 3rd year credits where applicable. Do not subtract N credits for leguminous vegetables on sand and loamy sand soils.
[5] Subtract N credits for animal manures and 2nd year forage legumes.

Guidelines for Choosing an Appropriate N Application Rate for Corn (Grain)

1. If there is >50% residue cover at planting, use the upper end of the range.
2. When corn follows small grains, the mid-to-low end of the profitable range is most appropriate.
3. If 100% of the N will come from organic sources, use the top end of the range. In addition, up to 20 lb N/a in starter fertilizer may be applied in this situation.
4. For medium and fine textured soils with >10% organic matter, use the low end of the range.
5. For course textured soils with <2% organic matter, use the high end of the range.
6. For course textured soils with >2 % organic matter, use the mid to low end of the range.
7. If there is a likelihood of residual N (carry over N), then use the low end of the range or use the high end of the range and subtract preplant nitrate test (PPNT) credits.

Examination of the range of profitable N rates for the various price ratios reveals that there generally is significant overlap between ranges. This suggests that a N application rate may be chosen that will come close to maximizing profitability for many economic scenarios. Figure 1 provides a graphical depiction of this. At favorable price ratios (smaller numbers; e.g. 0.05), the range in profitability is larger than at less favorable price ratios. This is largely because the penalty for over application of N at favorable price ratios is not as severe when the price of N is low and the price of corn is high. As the price ratio becomes less favorable (gets larger; e.g. 0.20), the range of profitability becomes smaller because the penalty for over application of more expensive N is much greater than at favorable price ratios.

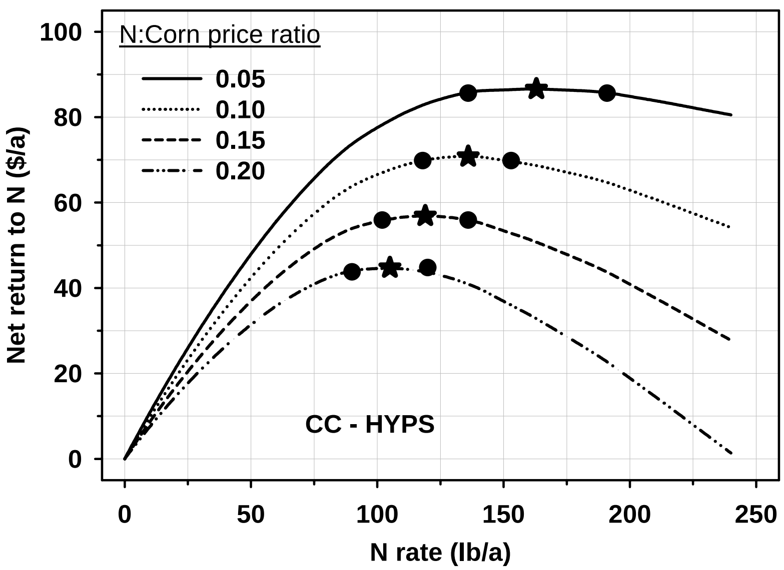

Figure 1. Profitable N rates for corn following corn (CC) on high/very high yield potential soils (HYPS) for N:corn price ratios of 0.05, 0.10, 0.15, and 0.20. Stars represent the maximum return to N (MRTN) and circles the low and high ends of the range of profitability (within $1/a of MRTN) at each N:corn price ratio.

Determining Price Ratios

One question many producers may have is related to determining the appropriate price ratio for their situation. The first thing to do is determine how much N costs on a $/lb basis. The next thing to do is to determine the price or value of the corn in $/bu. Then the price ratio can be calculated as the price of N divided by the price of corn. Table 2 was developed to help producers with this. In Table 2 the price of N ranges from $0.20 to $0.50/lb and the price of corn ranges from $1.80 to $3.60/bu. This provides a fairly large range of N and corn prices at which to look. However, attention should be focused on the price ratios in the box outlined in black. This box highlights the price ratios when N is $0.30 to $0.40/lb and corn is $2.00 to $2.60/bu. These are likely reasonable price ranges that producers will be working with in 2006. It can be seen that the price ratio varies from 0.12 (top right) to 0.20 (bottom left). These ratios are no where near the very favorable price ratio of 0.05 that appears on the left side of Table 1 nor are they close to the 0.06 price ratio that was used to develop our previous recommendations.

Table 2. Price ratio of N:corn (ie. \$/lb N ÷ \$/bu corn).

Price of N[†] \$/lb N	Price of Corn (\$/bu corn) 1.80	2.00	2.20	2.40	2.60	2.80	3.00	3.20	3.40	3.60
0.20	0.11	0.10	0.09	0.08	0.08	0.07	0.07	0.06	0.06	0.06
0.22	0.12	0.11	0.10	0.09	0.08	0.08	0.07	0.07	0.06	0.06
0.24	0.13	0.12	0.11	0.10	0.09	0.09	0.08	0.08	0.07	0.07
0.26	0.14	0.13	0.12	0.11	0.10	0.09	0.09	0.08	0.08	0.07
0.28	0.16	0.14	0.13	0.12	0.11	0.10	0.09	0.09	0.08	0.08
0.30	0.17	0.15	0.14	0.13	0.12	0.11	0.10	0.09	0.09	0.08
0.32	0.18	0.16	0.15	0.13	0.12	0.11	0.11	0.10	0.09	0.09
0.34	0.19	0.17	0.15	0.14	0.13	0.12	0.11	0.11	0.10	0.09
0.36	0.20	0.18	0.16	0.15	0.14	0.13	0.12	0.11	0.11	0.10
0.38	0.21	0.19	0.17	0.16	0.15	0.14	0.13	0.12	0.11	0.11
0.40	0.22	0.20	0.18	0.17	0.15	0.14	0.13	0.13	0.12	0.11
0.42	0.23	0.21	0.19	0.18	0.16	0.15	0.14	0.13	0.12	0.12
0.44	0.24	0.22	0.20	0.18	0.17	0.16	0.15	0.14	0.13	0.12
0.46	0.26	0.23	0.21	0.19	0.18	0.16	0.15	0.14	0.14	0.13
0.48	0.27	0.24	0.22	0.20	0.18	0.17	0.16	0.15	0.14	0.13
0.50	0.28	0.25	0.23	0.21	0.19	0.18	0.17	0.16	0.15	0.14

[†] Price of N (\$/lb N) = \$/ton fertilizer x (100 / % N in fertilizer) ÷ 2000

Valuing Grain and Manure N

Placing a value on fertilizer N is relatively easy in that the price of N is known at the time of purchase and application. The realistic value of grain will vary depending on where the grain is sold and how savvy a producer is in marketing the grain. Grain that will be used on farm as livestock feed should be valued at the price it would cost to purchase grain if feedstocks run short. The value of N in manure may vary between farms and between fields on farms depending upon the availability of land on which to spread manure. If a large enough land base is available to spread all manure, then the value of the N in manure could be considered to be equivalent to fertilizer N. This would mean that it would be more useful to spread the manure on as many acres as possible and reduce purchased N fertilizer, assuming poor or less than desirable N:corn price ratios. If the land base is limited, then spreading manure at a rate not to exceed the amount needed to maximize yield (top end of the profitability range for a N:corn price ratio of 0.05) would be appropriate. On some farms, there may be some fields that cannot receive manure and others that can. Thus, N application rates may be higher for fields receiving manure and lower for fields receiving fertilizer N.

Profitability and Potential Yield Loss

The price ratios in Table 2 show that current economics are not similar to the price ratio that was used to develop the old guidelines. Thus, using a price ratio of 0.05 to determine N application rates in 2006 is likely not appropriate for most producers. To maintain profitability, producers should reduce N rates to a level determined by current economics. One concern that many producers have is that reducing N rates will greatly reduce yield. Figure 2 shows the percent of maximum yield obtained for corn following corn and corn following soybean on high/very high yield potential soils, along with irrigated sands. It can be seen that for corn following corn on high yield potential soils, reducing N rates to 120 lb N/a will result in yield being about 97 % of maximum yield. Or stated another way, will result on average in a 3% yield reduction. At a 200 bu/a yield level, this is a loss of approximately 6 bu/a from maximum yield. It must be remembered that producing maximum yield is not economical because the cost of the additional N is more than the value of the yield gain. So reducing N rates will reduce yield, but improve overall profitability. In this example, when N rates are reduced to 120 lb N/a, it is likely that some firing of the lower leaves on the stalk will be seen. It is acknowledged that most producers generally consider late season firing to be undesirable. However, it must be noted that supplying enough N to keep plants dark green through physiological maturity (black layer) means that N fertilizer has been over supplied from a profitability standpoint. For all soil types, the N rate at the MRTN for the 0.20 N:corn price ratio produces, on average, 94-95 % of maximum yield.

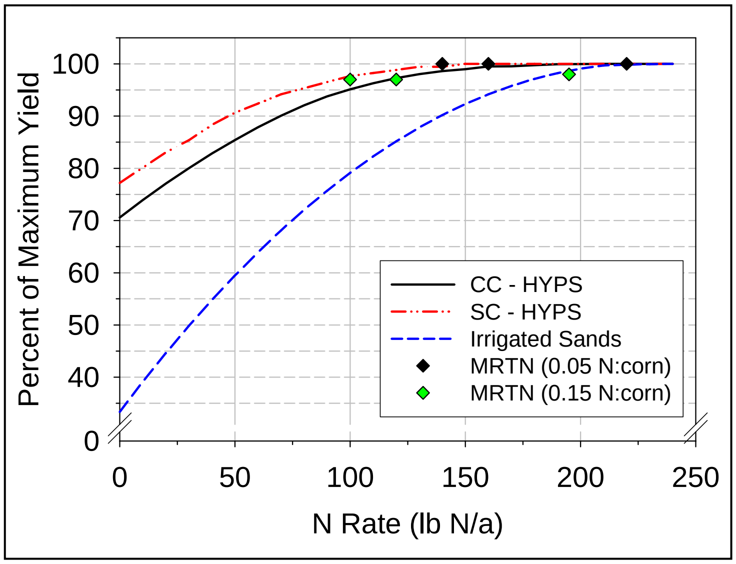

Figure 2. Percent of maximum yield obtained on average at each N rate for corn after corn (CC) and corn after soybean (SC) on high/very high yield potential soils (HYPS) and for all previous crops on irrigated sands with the exception of forage legumes and green manures. Diamonds represent the maximum return to N (MRTN) for each situation at price ratios of 0.05 and 0.15.

Nutrient Management Standards

These new N application rate guidelines can work well with nutrient management standards. Currently, the nutrient management standards reference the 1998 version of UWEX bulletin A2809 (Soil test recommendations for field, vegetable, and fruit crops). That document contains our old recommendations. A comparison of the old recommendations, which were developed at a price ratio of 0.06, to the new guidelines at a price ratio of 0.05 shows a minimal difference in N rates, particularly when starter fertilizer N is considered. The new N rate guidelines will rarely provide a N rate that is greater than the old recommendations that are referenced in the standards. Thus, these guidelines can be used and still meet the criteria outlined in the nutrient management standards.

What About Corn Silage?

The relationship between silage yield and N application rate is similar to that for grain yield and N rate. Silage quality is not greatly influenced by N application rate over the range of N rates provided in Table 1. Thus, these new N application rate guidelines can also be used for corn silage. If a producer would like to reduce N rates on silage, then they can do so by choosing a N:corn price ratio that reflects typical prices for N and grain.

Percent of maximum silage yield at various N application rates is similar to the percent of maximum grain yield provided in Figure 2. Thus, a producer can use Figure 2 to determine the amount of silage yield that will likely be lost when N rates are reduced. In a situation where all of the silage is being feed to livestock on the farm, producers my want to maximize yield, in order to minimize purchased feed, and therefore would use the 0.05 price ratio. However, if a producer is selling silage, then they would likely want to maximize the profitability of silage production and would reduce N rates according to the N:corn price ratio using relevant N and grain prices.

Summary

- The new N rate guidelines provide producers flexibility in setting N application rates that reflect economic conditions on their individual farm operations.
- These guidelines were developed using a regional philosophy that confirms our previous recommendations and are consistent with current nutrient management regulations.

BULK STORAGE RULE

Matt Laak [1/]

{This page provided for note taking}

[1/] Wis. Department of Agriculture, Trade and Consumer Protection, Madison, WI.

IMPACT OF LAND PRICES ON THE RURAL ECONOMY

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MARKETING TO A DEALERSHIP'S CHANGING CLIENTELE

Robert Cropp[1]

Introduction

Urban sprawl and home developments in the countryside have placed many farm supply businesses, both cooperatives and non-cooperatives in a market environment characterized with having the traditional farmer along with part-time (hobby) farmers and non-farm home owners. This situation offers farm supply businesses both a business challenge and opportunity. This paper focuses on this challenge and opportunity primarily in serving the urban non-farm customer.

The Different Customers

Even traditional farmers have different needs and expectations. Some have rather small operations and others very large operations. A farm supply business needs to differentiate in how they do business with these two types of farmer customers. The large farmer is in a position to negotiate for price and services and may not be as loyal to a given supplier as is the smaller farmer. Price is important for the traditional farmer, but so is service and product quality. Competition and demands of the large farm operations challenge management of farm supply businesses in maintaining a favorable net profit margin.

The demands and needs of part-time or hobby farmers are quite different from the traditional farmer. Price may not be as big of an issue. Service may be more important. Service may include custom application on relatively small plots of land, weekend and late hour service and customized products such as horse feed. But, this type of customer may offer the potential for higher profit margins, especially if the potential business volume justifies the personal and equipment to serve this type of customer.

The non-farm or urban home owner is a much different type of potential customer. They take pride in their lawns. They may have interest not only in lawn and garden fertilizer, chemicals and pesticides, but also lawn and garden tools and equipment. They may be so-called environmentalist interested in organic lawn and garden products. They often have pets and may be a horse or two. Weekend and evening hours for shopping are important. Price is important but, technical advice and information may also be very important.

Serving the Non-farm or Urban Home Owner

Non-farm or urban home owners may be located where there are more than one option for obtaining lawn and garden fertilizer, chemicals and pesticides. Some are primarily interested in price and not service. They are attracted to no or limited service suppliers such as Farm and Fleet, ShopKo, Wal-Mart, Home Depot and Menards. These outlets also normally have lawn and garden tools and equipment and may carry bedding plants and shrubbery. Their prices are normally quite competitive.

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Other potential customers are looking for a more full–service supplier. They go to garden shops and some hire full-service lawn care. Some hardware stores also come close to providing full-service lawn and garden care and tools and equipment.

Many farm supply businesses do try to serve the non-farm or urban customer to some extent. One challenge is letting this customer know that they can serve them. The potential customer may view the business as only a business to serve farmers. For some the distribution center doesn't look inviting to the non-farm or urban customer. But, surveys show that consumers have a rather favorable image of "cooperatives". They view them as being honest, trustworthy, concern for the environment and community and the like. Some cooperatives have tried to capitalize on this. For example, the electric cooperatives have a national advertisement called Touchtone Energy. CHS Inc. has used ads stating "We are owned by our customers."

Offering just fertilizer and perhaps some chemicals and pesticides to these non-farm and urban customers may not offer the farm supply business a significant profit center. For one thing, price will need to be competitive with Farm and Fleets and discount outlets. But, in order to be a significant part of the business and a profit center, the farm supply business needs to seriously consider the non-farm or urban consumer as a potential customer. This may require investing in an attractive and customer friendly looking store. In addition to offering fertilizer, chemicals, and pesticides (including organic products), garden seeds, bedding plants, shrubbery, lawn and garden tools and equipment should be considered, and may be hardware, home appliances, gasoline and home heating fuels as well. But, to attract these potential customers and to compete with other full-service suppliers high quality service provided by friendly, knowledgeable employees who understand and have the patience to serve these customers is highly important. This is important because once again the farm supply business may not be able to compete on price alone.

The bottom line is that farm supply businesses interested in serving the non-farm or urban customer needs to convey a message that their business is different in some way from other business options. Why should or what is the advantage for one of these potential customers for doing business with your business? As mentioned, price needs to be competitive, but more is probably needed. This could be product quality or a complete line of products to satisfy the variety of uses by this customer. But, probably the greatest opportunity to distinguish your business from the other business option is service. That is having the employees who have the time, interest and patience to understand and to work with the customer. The employees need to be friendly and have sufficient technical knowledge of the products and services to give advice, recommendations and to answer customer questions. And of course the store must be attractive and conveniently located.

Option for Farm Supply Cooperatives

Farm supply cooperatives have the option of treating their non-farm customers as non-member business or member business. If non-member business, any net profits earned from non-members can be placed in the un-allocated equity (net worth) of the business. The co-op pays the normal corporate income tax on the net profits. If this non-member business is significant enough, it may allow the co-op to build its equity capital requirements while returning a greater share of profits from its farmer-member business to members as an end of the year cash patronage refund. This could help to maintain and to grow its farmer-member business.

The farm supply business could treat these non-farm customers as member business. This means the non-farmer customers are members of the cooperative and they share in the patronage pool. The cooperative could have a separate pool for farmer-member business and non-farm member business or one single pool, which is the common practice. The non-farm member now shares in the net profits of the cooperative. At the close of the business year, they will receive a cash patronage refund and may build up investment in the cooperative as allocated equity just as the farmer-member does. The cooperative pays no corporate income on the net profits paid out as a cash patronage refund or the proportion retained as allocated equity. This cash patronage refund, and perhaps the opportunity to build equity in the cooperative, even if relatively small, may be significant in distinguishing the cooperative from other businesses. The non-farm customer may appreciate the patronage refund which they would not receive from other types of businesses.

The cooperative can give these non-farm members voting rights or no voting rights. If voting rights are granted, this means they would have a one-member-one vote right to elect a board of directors and perhaps be elected to the board. Some cooperatives feel that the major purpose of the cooperative was and still is to serve the farmer-customer. Allowing non-farm members a vote and to the possibility of being elected to the board could change the business priorities of the cooperative. Other cooperatives see no problem with allowing the non-farmer member a vote and the possibility of serving on the board.

Summary

For farm supply businesses located in or near a major metropolitan area or experiencing a growth in non-farm home owners, targeting these non-farm consumers as customers may offer a solid business opportunity. This may be particularly the situation if no other businesses are targeting and adequately serving these same non-farm consumers. But, if this is to be a significant segment of the company's business, it must be seriously considered with a commitment of adequate capital and human resources to give an advantage over other options in serving this potential customer. There needs to be sufficient business volume generated to profitably support the commitment of capital and human resources. Most likely a significant business volume cannot be generated by competing on price alone.

THE WORKING LANDS INITIATIVE: WHAT IS IT AND WHY DO YOU CARE

Linda H. Bochert [1/]

- The Working Lands Initiative is about finding common ground on new strategies for preserving Wisconsin working lands (agriculture, forestry, tourism & recreation use). Wisconsin can be green and growing.
- The Working Lands Initiative is about boosting Wisconsin's economic development, especially in rural communities, in order to strategically protect the land for the bio-economy (biomass of forestry and agriculture materials) and protect all our natural resources for future generations. Wisconsin must be planning for prosperity.
- The Working Lands Initiative goals include creating a policy tool kit for state and local government to protect these critical lands. These policy tools will include a natural resource portfolio that recognizes the "other" values of working lands such as water recharge areas, critical habitat for wildlife and carbon sequestration.
- The Working Lands Initiative will seek innovative partnerships between public and private entities to maximize efforts in preserving our natural resources through Community Collaboration Networks and a shared vision.

Why Now?

DATCP is pursuing the Working Lands Initiative with a diverse group of stakeholders as our steering committee. The timing is critical because:

- We still have much to preserve and sustain in Wisconsin's working lands.
- We have many diverse and rapidly urbanizing areas of Wisconsin. Critical working lands are being lost or fragmented.
- Wisconsin is well positioned to be a leader in the bio-based economy.
- The next Federal Farm Bill presents opportunities for transitioning away from a commodity payment system to a conservation credit system. Wisconsin could be a pilot state for new models.

Benefits and Potential Outcomes of Working Lands Initiative

- Preparing Wisconsin for the bioeconomy of the future by determining the critical mass of lands needed for sustainable biomass crops.
- Creating broad business community and citizen support for shaping the Wisconsin landscape in ways that grow the economy, preserve its natural beauty and keep agriculture on the economic roadmap.
- Policy recommendations to the Governor and Legislature.
- Providing a policy tool kit for local government and private entities to determine what are the best ways to preserve working lands.
- Targeting private investments and state resources to areas where agriculture and rural growth can be sustained without being overcome by other development uses.

[1/] Michael Best & Friedrich, Madison, WI.

- Identifying key lands and waters for long-term environmental stewardship protection. These lands can often best be surrounded by working agriculture lands.
- Formulating a natural resource portfolio available to farmers and financial investors looking to expand agriculture business in Wisconsin. This portfolio could include carbon sequestration credits, financial payments or credits for conservation easements and financial credits for water quality improvements. This portfolio can be a part of strategy to assist farmers in building equity besides the sole answer of selling the farm to fund their retirement.
- Coordinating state programs in tourism, transportation, commerce, and agriculture so that they work together, not against each other, in promoting economic vitality and environmental sustainability of working lands.
- Positioning Wisconsin for the next Farm Bill with innovative programs that complement the policy of these major federal appropriations.
- Leveraging more federal and private dollars to protect working lands.

Context for Policy Discussion:

The Department of Agriculture, Trade and Consumer Protection (DATCP) is focusing on three key strategies for Wisconsin in the coming months:

1. We want Wisconsin to continue to be Green and Growing. That means we can diversify the agriculture economy, seek more value-added opportunities for agriculture, expand operations and still protect the Wisconsin environment.

2. The Working Lands Initiative - This is about preserving a critical mass of land in Wisconsin for agriculture, forestry, recreation, tourism and achieve this with strategic planning for business and housing growth in an environmentally friendly way.

3. The Governor's BioConsortium - a catalyst for necessary actions to advance the emerging bioeconomy and potential energy conservation opportunities.

The premise of the Working Lands Initiative is that Wisconsin's land base, along with its natural resources of clean waters, rich forests and ample habitat areas, are critical to the state's economic sustainability and need to be maintained in an environmentally friendly way.

WORKING LANDS INITIATIVE

Steering Committee Members

Richard Barrows: Associate Dean and Director, College of Agricultural and Life Sciences, University of Wisconsin-Madison.

Sue Beitlich: President of the Wisconsin Farmers Union.

Linda H. Bochert: Partner in the Land and Resources practice area of the law firm Michael Best & Friedrich LLP.

Jerry Bradley: Past president of the Dane County Farm Bureau; past member of the Dane County Drainage Board. Mr. Bradley is a 5th generation farmer in the Town of Sun Prairie.

Ed Brooks: Dairy farmer since 1971. In 1979, he was elected as a director to the Wisconsin Dairies Cooperative, now Foremost Farms, and has served as Chairman of the Board for the past 15 years

Denny Caneff: Executive Director of the River Alliance of Wisconsin.

Richard Cates: Faculty member in the Department of Soil Science, UW-Madison; DATCP Board member.

Vicki Elkin: Executive Director of Gathering Waters Conservancy.

Rob Gottschalk: A principal at Vandewalle & Associates, an economic development, planning and design consulting firm in Madison.

Steve Guthrie: A professional forester who has lived and practiced forest management in Northern Wisconsin since 1977. Currently, he manages an 80,000-acre industrial forest property for Tomahawk Timberlands L.L.C., a private company which purchased the property from Packaging Corp. of America in 1999.

David Helbach: Director of Corporate Affairs for Alliant Energy Corporation in Madison.

Steve Hilger: Partner in Hilgers Farms, Inc. of Bloomer, Wisconsin.

Mark O'Connell: Executive Director of the Wisconsin Counties Association.

Jim Holperin: Secretary of the Wisconsin Department of Tourism.

Edward Huck: Executive Director of the Wisconsin Alliance of Cities.

Margaret Krome: Policy Program Director for the Michael Fields Agricultural Institute in East Troy, Wisconsin; DATCP Board member.

Thomas D. Larson: Director of Regulatory & Legislative Affairs for the Wisconsin Realtors Association.

Bill Oemichen: President and CEO of the Wisconsin Federation of Cooperatives and the Minnesota Association of Cooperatives.

Gary Rohde: Former Dean of the College of Agriculture, Food and Environmental Sciences, UW-River Falls, and Secretary of DATCP.

Sharon L. Schmeling: Chairman of the Jefferson County Board of Supervisors.

Rick Stadelman: Executive Director of the Wisconsin Towns Association.

John B. Torinus Jr.: Chairman and CEO of Serigraph Inc. since 1987; previously served as Business Editor and columnist for the Milwaukee Sentinel.

Curtis Witynski: Assistant Director of the League of Wisconsin Municipalities.

Dan Poulson: Co-Chair, DNR Board Member and former Director of the Wisconsin Farm Bureau.

Jerry Deschane: Wisconsin Builders Association.

Steve Hiniker: Executive Director of 1000 Friends of Wisconsin.

Pat Cornelius: Oneida Tribe.

MANURE MANAGEMENT ON THE URBAN/SUBURBAN FRINGE

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COMMUNICATING WITH NON-FARM NEIGHBORS

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WISCONSIN'S LIVESTOCK FACILITY SITING LAW AND PROPOSED RULE

Richard Castelnuovo[1], Jennifer Heaton-Amrhein[2], and Coreen Fallat[3]

Abstract

In 2004, Wisconsin enacted the Livestock Facility Siting Law (2003 Act 235) designed to reform local regulation affecting livestock facilities. The law is intended to ensure a more predictable and fairer system of local regulation. While the new law retains local authority to control rural land use through planning and zoning, it mandates that local governments follow state standards and procedures if they require individual approval for new and expanding livestock facilities. Central to the siting law are standards that local governments must apply whenever they make decisions to approve or deny applications for livestock facilities. These state siting standards are being developed through rule making, in accordance with specific requirements set forth in the law. As proposed in the final draft rule, the standards will protect air and water quality, while providing the livestock industry a predictable regulatory framework within which to grow and modernize.

Introduction

The livestock facility siting law is part of a trend among states to standardize and streamline the approval process for new and expanding livestock facilities. Approaches vary among states, but officials share a common concern about improving the business climate for animal agriculture in their states. While it may not be the most critical factor in making a state more competitive, improvements in local regulation can create a more attractive business climate. There is research to suggest that the nature and extent of local regulation can impact business decisions to site or expand livestock facilities (Lazarus, 1999). Furthermore, there is a perception in the farm community that regulation in Midwestern states such as Wisconsin is onerous, inhibiting farmers from building new or expanded livestock facilities (Sands, 2001). In his "Grow Wisconsin" plan, Governor Doyle recognized the connection between growth in the livestock industry and local regulation by writing, "Currently, one of the greatest impediments to the location and expansion of agricultural businesses in our state is uncertainty in local government permitting processes and a myriad of standards that vary by jurisdiction." Since local governments can currently enact their own, distinct regulations, there is the potential for over 1,000 different regulatory schemes throughout the state.

Ensuring the competitiveness of Wisconsin's dairy industry has significant implications for the state's economic well being. Wisconsin's farms and agricultural businesses generate more than $51.5 billion in economic activity and provide jobs for 420,000 people, according to a March 2004 study (Deller, 2004). To maintain its competitiveness, Wisconsin needs to produce more milk to retain processors. The state is likely to meet its need for more milk primarily through the growth of larger dairies.

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> The fact that large dairy operations will be the source of the milk production gains needed to maintain the state's dairy industry is noteworthy because it suggests that efforts to restrict the expansion of larger scale dairy farms may be ill-advised. These actions would most likely curb growth in total milk production in the state and make it difficult for dairy plants to get the supplies of milk they need to stay in business. If this happens, dairy plants could very well shut down their Wisconsin operations. This loss of dairy plants will hurt small and moderate sized dairy operations–just as it does large dairies–because the pay prices for all milk will decline as fewer dairy plants are left in the state to compete for milk. Thus all Wisconsin dairy producers could lose if milk supplies do not increase at the rates needed to keep existing dairy plants operating in the state (Jones, 2002).

The state's agricultural agency, the Department of Agriculture, Trade and Consumer Protection (DATCP) took the initiative to address this important issue. In 2003, DATCP's Secretary convened an advisory committee made up of government representatives, farmers and farm groups, and environmentalists to consider issues related to local livestock regulation. The advisory committee unanimously recognized the need to secure the future of our livestock industry, and developed a series of recommendations that formed the basis of the livestock facility siting law.

Codified at s. 93.90, Stats., the livestock facility siting law provides a more predictable and fairer framework for local decisions to approve or deny the siting of the livestock facility. The law addresses both the reality and perception that local decision-making is not timely, is often based on standards not grounded in sound science, and imposes unpredictable and changing conditions. The law superimposes the following requirements on conditional use permits and other forms of approval used by local governments to regulate the siting of livestock facilities:

a. Precludes regulation of new and expanding livestock facilities under 500 animal units, unless the local government has an ordinance that meets the law's grandfathering provision for use of a lower regulatory threshold.
b. Applies science-based standards in deciding all applications for local approval, and only allows the use of other standards if they are justified based on public health and safety and are specified in an ordinance in advance of the application submittal.
c. Follows clear deadlines for processing applications to reduce delay.
d. Recognizes that a complete application creates a presumption of compliance with the state standards.

Siting Standards

State standards for the siting of new and expanding livestock facilities are at the core of this new regulatory framework. DATCP was required to adopt these standards by rule, making use of current runoff control standards and other laws related to farms. In specifying standards, DATCP had to consider whether the standards were (1) protective of public health or safety, (2) practical and workable, (3) cost-effective, (4) objective, (5) based on scientific information, (6) designed to promote the growth and viability of animal agriculture, (7) designed to balance the economic viability of farm operations with natural resource protection and other community interests, and (8) and usable by local officials. See 93.90(2)(b), Stats.

As required by the law, DATCP convened a technical panel to provide recommendations concerning the state siting standards. The panel included university researchers, government experts, conservation officials, and private consultants. Experts were recruited from DATCP, the Department of Natural Resources, and the Natural Resource Conservation Service (NRCS). The panel had expertise in barnyard runoff control, feed storage, manure storage, nutrient management, and odor management. The work of the panel was enhanced by the participation of an expert from Minnesota who provided information on state-of-the-art methods for odor management. The panel met from June to October 2004 to prepare its recommendations, which were presented to the department in the form of a preliminary draft rule including an application for local approval and worksheets. The panel's work product was reviewed by the advisory committee that originally developed recommendations for the legislation. The proposed standards were revised by the advisory committee before being approved for public hearings. The department held twelve public hearings—attended by over 800 people—and received almost 550 oral and written comments. The draft rule was revised based on these public hearing comments.

The proposed siting standards will protect water quality from the impacts of livestock facilities that are not properly designed, constructed and operated. Unregulated facilities may pose risks to surface water from improperly applied manure, runoff from animal lots and feed storage, and overflowing waste storage facilities. They also may create groundwater risks as a result of leaking waste storage facilities, and runoff that finds its way to sinkholes and other groundwater conduits. Potential water pollutants include nutrients (phosphorus and nitrogen), bacteria, sediment and organic matter. The biological environment of a waterbody can be impaired by organic matter. This organic matter can drastically reduce dissolved oxygen levels, increase nutrient loading which can result in eutrophication, and increase ammonia concentrations to levels that can be lethal to aquatic species.

Applicants for local approval must meet siting standards by demonstrating compliance with the following requirements designed to protect water quality. Applicants are required to meet existing water quality setbacks, including those established through local shoreland, wetland and floodplain ordinances and state well protection codes. They must document that they have adequate land to apply the manure they generate. Facilities with 500 or more animal units or those without an adequate land base for manure application must complete a checklist that demonstrates that they can manage nutrients according to technical standards. As part of this checklist, applicants must use soil test results or other values to determine manure applications.

Applicants must show that all waste storage structures can operate without risk of failure or discharges. For new and substantially altered waste storage structures, applicants must design and construct these structures according to NRCS technical standards 313 and 634. Applicants must evaluate existing facilities to establish that these facilities can operate without risk of failure or discharges. Where appropriate, they also must close storage structures according to NRCS standards 360. Applicants are required to show that they have storage capacity adequate to meet their needs based on the facility's anticipated waste generation.

Applicants must control runoff from animal lots by meeting NRCS technical standard 635 for new and substantially altered lots. They must evaluate existing facilities using the BARNY model to show acceptable phosphorous runoff. A higher level of control is required if a lot is near surface water. No lot can have discharges to sinkholes or other conduits to groundwater. For buildings, bunkers and paved areas used to store high moisture feed, applicants must divert clean water from the structure, and collect and treat leachate. New and substantially altered structures must be built at least 3 feet above groundwater and bedrock. In addition, if a structure covers more than 10,000 square feet, it must have a system to collect leachate that may leak through the structure's floor (if the floor cracks, for example).

The siting standards require livestock operators to follow certain practices near waterways that are consistent with the agricultural performance standards in NR 151, Wis. Admin. Code. These practices require the diversion of clean water from animal lots and other structures, prevent the unconfined stacking of manure near waterways, prevent overflow from waste storage, and restrict grazing on streambanks to ensure adequate vegetative cover.

The proposed siting rule also contains a standard to address the generation of chronic odor by livestock housing, waste storage areas including lagoons, and animal lots. If not properly controlled, odors may become offensive and a source of concern for others within the community. Disputes over odor have, in fact, been a major source of contention in local communities and an issue that has directly effected the approval or denial of the siting or expansion of livestock facilities. Offensive odors are distinct from air pollutants such as ammonia and hydrogen, which are not the direct focus of the siting standards at this time.

Instead, the siting standards as currently proposed require that applicants manage odor from facilities. If an applicant proposes a new facility with 500 or more animal units or an expansion with 1000 or more animal units, the applicant must demonstrate that the proposed production facilities (animal housing, animal lots and waste storage) will have acceptable odor levels. Applicants more than 2500 feet from their neighbors or under the established size thresholds do not have to meet the odor standard. Odors levels are predicted using a model. As the first step in modeling odor, an applicant must calculate the facility's odor generation based on the size of proposed structures. Facilities that generate odor beyond a maximum score must install odor control practices. Depending on the separation distance of the operation from neighbors, an applicant may also need to implement odor control practices to protect neighbors. A local government has additional latitude to award discretionary points to assist an applicant in passing the odor standard, if it wishes to award these points. The final draft rule no longer includes an odor management standard for manure applied to fields.

Although the standard for managing odor included in the proposed rule is not designed to address air pollution, it is worth noting that the control of odors may be effective in controlling pollutants such as ammonia and hydrogen sulfide. For example, impermeable covers can reduce odor generation, and reduce ammonia emissions from manure storage structures. Likewise biofilters installed to reduce odors from housing can significantly reduce hydrogen sulfide and ammonia emissions.[1] However, in other cases, practices such as composting may increase volatilization of ammonia. DATCP has committed to working with the Department of Natural Resources and others to further research in the area of odor and air emission management, and has received a $1.3 million Conservation Innovation Grant from NRCS for this purpose.

In addition to the proposed standards, applicants must also comply with all existing laws that apply to the proposed facility, meet local setbacks (with state maximums) and develop employee training and incident response management plans.

Local Implementation

The state siting law and proposed rule will effect local governments wishing to regulate the siting of livestock facilities through the use of a local conditional use or other siting permits. Livestock operators wishing to site or expand in jurisdictions that do not require local approval will not need to complete a state application. Local governments that require local approval through conditional use or other siting permits must use the state standards, state application form, and state procedures. If a local government currently has an ordinance that regulates livestock siting, it has six months after the effective date of the siting rule to update its ordinance. In the interim, the local government must use the state standards, application, and procedures if it wishes to continue to regulate livestock siting. The revised ordinance must include the state standards, thresholds, and timelines, and also include any application fee and enforcement provisions. Local governments are able to adopt standards into local ordinance that are more stringent than state standards. To do so, they must adopt written and scientific findings of fact to demonstrate why the more stringent standards are needed to protect public health or safety. After the siting rule is effective, local governments may adopt an ordinance that regulates the siting of livestock facilities at any time, but must use the state threshold, standards, and procedures.

Conclusion

By creating uniform standards for the local regulation of livestock facility siting, the livestock facility siting law and the implementing rule should provide a more conducive environment for modernization of existing facilities and construction of new facilities. Livestock operators will know in advance the requirements they must meet to receive local approval, and will have assurances of approval if they submit a completed application showing that the proposed facility meets the siting standards. Local determinations will be simplified by use of a standard application and worksheets that demonstrate compliance with the siting standards. Because the siting standards are objective and science-based, the participants and the public will have greater confidence in the local approval process. The standards incorporate water quality protections related to manure storage and management, and provide a mechanism to address odor management and feed storage concerns. In their present form, the siting standards address the requirements enumerated in the siting law. These requirements will continue to be touchstones as the standards in the proposed rule are subject to additional review. In the final draft rule, the department has committed to a systematic annual review of standards implementation and local regulatory activity. However the siting standards may change, they will remain central to the implementation of the new legal framework created by the livestock facility siting law.

References

Deller, S. 2004. *Wisconsin and the Agricultural Economy*, Staff Paper No. 471, available at www.uwex.edu/ces/ag/wisag/documents/wisconsin%20and%20the%20ag%20economy%20-%20deller.pdf

Jacobson, L. et al. 1998. Odor Control For Animal Agriculture, BAEU-17, available at http://www.bae.umn.edu/extens/aeu/baeu17.html

Jones, B. 2002. The Changing Dairy Industry: A Comparison of Recent Trends In Wisconsin Milk Production To Those In the US and Selected Dairy States.

Lazarus W. et al. 1999. Summary of literature related to industry structure and competitiveness and profitability and economic viability: *Generic Environmental Impact Statement on Animal Agriculture in Minnesota*, available at www.eqb.state.mn.us/geis/LS_Economic.pdf, citing Mo Y, Abdalla CW. 1998. *Analysis of Swine Industry Expansion in the US: The Effect of*

Environmental Regulation, Staff Paper 316. University Park, PA: Department of Agricultural Economics and Rural Sociology, Pennsylvania State University. (A seven year study (1988-95) of trends in swine production in 13 states evaluated economic and other factors affecting industry growth. While the study found that economic factors were very significant to industry growth, it also found that growth was more pronounced in states with state required agricultural exemptions to zoning.)

Sands, Laura. 2001. Run for the Border: Onerous Permits Chase Livestock Across State Lines. *Top Producer*. A Farm Journal Publication, [article focuses on the high cost of obtaining a feedlot permit (said to be $50,000 in one in Minnesota case and $70,000 in another), threats of legal action, and negative local attitudes which are causing livestock producers to consider relocating to locations outside the Upper Midwest]

University of Iowa Environmental Health Sciences Research Center (UIEHSRC). 2002. *Iowa Concentrated Animal Feeding Operation Air Quality Study*, available at http://www.public-health.uiowa.edu/ehsrc/CAFOstudy.htm

MONITORING THE VARIANT WESTERN CORN ROOTWORM IN WISCONSIN[1/]

Southeast Wisconsin Variant Western Corn Rootworm Trapping Network

The 'eastern variant' of the western corn rootworm (WCR), *Diabrotica virgifera virgifera*, has developed a behavioral adaptation to the corn-soybean rotation in some parts of the Midwest. The variant western corn rootworm (VWCR), first documented in east central Illinois, then in Michigan, Indiana and Ohio, is known to circumvent the corn-soybean crop rotation by laying eggs in soybean. Like normal corn rootworm beetle populations, the Vwcr moves readily between corn and other crops between late July and early September. Unlike normal rootworm beetles, the VWCR can lay heavy populations of eggs in soybean fields, resulting in risk of economic injury to corn planted the next year.

Reports of lodged corn that followed soybean in various parts of southeast Wisconsin have prompted concern that northern migration of the VWCR had reached the state. In 2003, *UWEX* County Agricultural Agents, Extension Specialists and corn-soybean producers from **Racine, Kenosha, Rock, Walworth, Green, Waukesha, Jefferson, Dane and Columbia counties** coalesced to form the *Southeast Wisconsin Variant Western Corn Rootworm Trapping Network*. **Dodge and Grant Counties** were added to the network in 2005. The group's primary objectives have been to determine whether and the extent to which the VWCR is active in Wisconsin and provide education to farmers and crop advisors relative to monitoring and managing this pest. See the Proceedings of the 2005 Wisconsin Fertilizer, Aglime and Pest Management Conference for a complete project description and 2003 and 2004 results.

Published IPM research recommends a trap-based scouting protocol for VWCR in soybean to estimate egg-laying activity and provide information to guide treatment decisions for corn planted the next spring (O'Neal et al., 2001). The UW Extension Network follows the soybean scouting protocol developed by the University of Illinois using 12 Pherocon AM yellow sticky traps evenly spaced throughout the soybean field to be rotated to corn (Cook et al., 2005). Trapping begins the last week of July and continues for 4 weeks. Each week, total WCR beetle counts are recorded from each trap and traps are replaced. At the end of the sampling period, the average number of adults caught/trap/day is calculated. An average of 5 beetles/trap/day (B/T/D) over the August sampling period has been documented to result in economic root injury for corn planted in the field the next season. Visually, regular WCR and VWCR adults look the same. Currently, there are no genetic screening methods available to distinguish between the two strains. Trap-based scouting and use of the IPM threshold for adult beetles in soybean is the most reliable method available to determine treatment needs for first-year corn.

In 2005, the Network monitored 71 soybean fields in southern Wisconsin to notify farmers of changes in the distribution of VWCR in Wisconsin (Figure 1). Of these, 13 exceeded the economic threshold of 5 B/T/D. As in 2003 and 2004, these **higher levels of VWCR activity were restricted to Kenosha, Racine, Walworth and Rock counties, with one exception–in Dodge County**. One of the five fields trapped in Dodge County also exceeded the threshold and two of the five were just under the threshold. This indicates a northward movement in Wisconsin of the VWCR from the far southeastern counties into Dodge County. While none of the ten fields trapped in Jefferson County (next county south of Dodge) exceeded the threshold, two of the ten approached it.

[1/] Funding provided by the Wisconsin Soybean Marketing Board; see list of Network participants at the end of this paper.

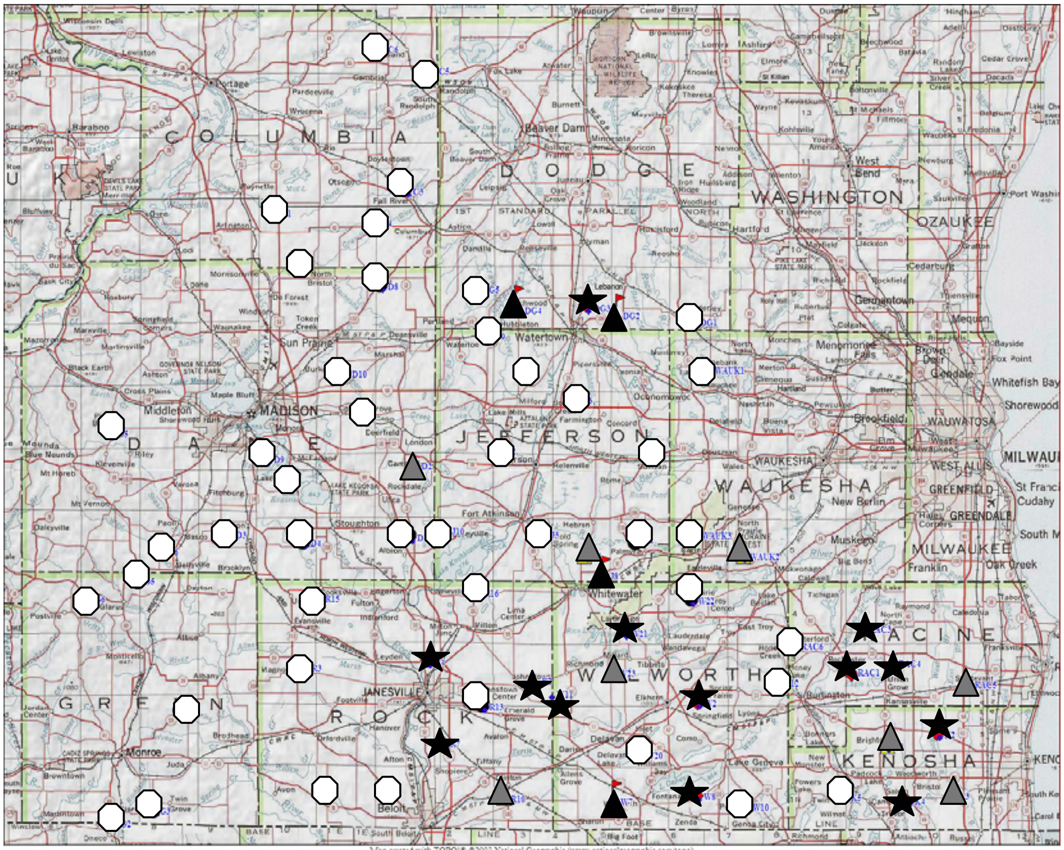

Figure 1. Western corn rootworm beetle abundance in 69 soybean fields trapped for 4 to 5 weeks during August-September 2005 in Southeastern Wisconsin. <u>Open white circles</u> well below threshold (0.00 to 2.99 B/T/D); <u>Grey triangles</u> below threshold (3.00 to 3.99 B/T/D); <u>Black triangles</u> near threshold (4.00-4.99 B/T/D; <u>Black stars</u> above threshold (5.00 B/T/D and greater). [2/]

Data from this project show the need for producers of corn and soybean in these affected counties (Kenosha, Racine, Walworth, Rock, and Dodge) to be aware that corn planted after soybean is now at an increased risk for economic damage from VWCR feeding. The degree of risk for an individual field, however, is difficult to determine due to the variation with which thresholds are exceeded. For example, in the affected counties in 2005, 22 of the 35 fields trapped were below the economic threshold. Trapping soybean fields for WCR activity is currently the most reliable way for assessing the risk to a following corn crop and can be used as part of an IPM-based approach to determine the need for a corn rootworm insecticide or Bt rootworm corn hybrid at planting. As of now, farmers outside the affected counties appear to face low risk for economic damage from VWCR in corn following soybean.

Whether farmers will choose to trap or automatically use an insecticide treatment will depend on the costs and returns of each approach. Preliminary economic analyses favor trapping, but additional evaluation is needed, which is one of the next steps for this project. Other next-steps include evaluation of lower intensity trapping/monitoring methods and monitoring adult <u>VWCR activity</u> in additional crop rotations.

[2/] In addition to the 69 soybean fields monitored in 10 contiguous counties (Fig. 1), 2 fields were monitored in Grant Co.. Both Grant Co. fields trapped well below threshold at 0.24 and 0.56 B/T/D, respectively.

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References

Cook, K.A, S.T. Ratcliffe, M.E. Gray, and K.L. Steffey. 2005. Western corn rootworm variant: scouting information sheet. Integrated Pest Management Program, University of Illinois Extension, http://ipm.uiuc.edu/fieldcrops/insects/western_corn_rootworm/wcr.pdf

O'Neal, M.E., M.E. Gray, S. Ratcliffe, and K.L. Steffey. 2001. Predicting western corn rootworm (Coleoptera: Chrysomelidae) larval injury to rotated corn with Pherocon AM traps in soybeans. J. Econ. Entomol. 94: 98-105.

Southeast Wisconsin Variant Trapping Network. 2005. Mapping the corn rootworm variant. Proc. 2005 Wis. Fert., Aglime and Pest Mgmt. Conf. 44:174-179.

ARMYWORM TROUBLES IN 2005

Ryan Tichich, Jerry Clark, and Eileen Cullen [1/]

Introduction

The true armyworm *(Pseudaletia unipuncta*) causes some damage in parts of the state almost every year. True armyworm should not be confused with "fall armyworm," another corn insect pest that occurs later in the season, usually only on very late planted corn.

The true armyworm is an early season pest that attacks grass crops like small grains and corn. Armyworms climb into corn whorls and "rag" the leaves from the outer edges of the leaves in towards the midrib. When infestations are severe, only the midribs will be left behind.

Armyworm Biology

True armyworms have three generations per season. Armyworm moths lay eggs on grass in cornfields and on small grains in May and June; thus grassy weed control in corn is important in preventing armyworm infestations.

The eggs hatch in approximately 10 days, depending on temperature. This first generation of caterpillars is usually the most troublesome. They feed for 3 to 4 weeks and then pupate in the soil, emerging as adult moths in about 2 to 3 weeks. This process is repeated again producing a third generation. In September, this third generation of nearly full-grown caterpillars spends the winter in the soil. In the spring, the caterpillars finish growing and pupate in mid-April to early May. In two to three weeks the moths emerge and the eggs for the first generation are laid. One female moth can lay several hundred eggs.

Usually two scenarios can occur can unfold with armyworm infestations: 1) infestations occur throughout the corn field in July if grass weeds (foxtail, quackgrass) or sedges are present in the field when during armyworm moth flight and oviposition. As a result, the plants in scattered areas of the field will have ragged leaves from larval feeding. In the second scenario, armyworms migrate from pastures, oats, or grassy alfalfa fields and damage corn plants along the border rows of the field.

Armyworms in 2005

In 2005, several severe infestations were reported. Reports first came in from Polk County on July 22. Infestations seemed to be in pockets within the county and often seemed linked to later than normal weed control. Reports from Sauk County four days told a similar story. With in the next few days, several reports came in from St. Croix, Jackson, Pepin, Chippewa, Dunn, Burnett, Washburn, Sawyer, and Rusk Counties. In many cases, these infestations were quite severe – often only the midribs of corn plants were left behind. Producers in these areas also reported caterpillar migration to adjacent fields.

[1/] Polk and Chippewa County Agricultural Agents and Extension Entomologist, respectively, Univ. of Wisconsin-Extension.

Armyworm Management

The first step in management is to assess the population and age of the caterpillars. Check five sets of 20 plants at random. Record the number of damaged plants and the number of worms per plant. Spot treat, if possible, when you find two or more armyworms (3/4 inch or smaller) per plant on 25% of the plants or one per plant on 75% of the plants. Finding the worms while plants are still small before severe damage occurs increases the value of control. Younger worms are easier to control than those approaching maturity.

Controlling weeds early is also a key factor in preventing infestations. Delayed post emergence herbicide applications can also cause problems because by the time the herbicide has been applied, armyworms populations have become established. When the grass is finally dies off, caterpillars are forced to the corn plants. However, keep in mind that "weed-free" fields do not guarantee immunity from armyworm attack as they can migrate into corn fields from adjacent grassy fields.

References

Boerboom, C.M., E.M. Cullen, J.D. Doll, R.A. Flashinski, and C.R. Grau. 2005. Pest management in Wisconsin field crops: A guide to managing weeds, insects, and diseases in corn, soybeans, forages and small grains. UWEX Pub. no. A3646. Univ. of Wisconsin-Extension, Madison, WI.

Cullen, E.M. 2005. Advanced armyworm and outbreak pockets in western Wisconsin. Wis. Crop Manager 12(21):3-4.

POTENTIAL FOR SOYBEAN STEM CANKER RESURGENCE IN WISCONSIN

Craig R. Grau and Nancy C. Koval[1]

In the 1950s and early 1960s, stem canker was the most important soybean disease and slowed the expansion of soybean acres in the Midwest. Highly susceptible soybean varieties were discontinued and replaced by varieties less susceptible or moderately resistant to stem canker. Stem canker is regarded as a warm temperature disease and thus the climate of Wisconsin has been regarded as less conducive for stem canker. However, symptoms typical or suggestive of stem canker have increased in frequency since the late 1990's. Stem canker was observed commonly in 2003 and 2005 in Wisconsin, but was less prevalent in 2004. Stem canker is regarded as part of a stem disease complex that also includes white mold (Sclerotinia stem rot) and brown stem rot. While white mold is often very obvious, brown stem rot and stem canker are often overlooked or confused with stress related to climatic conditions or with seasonal changes in soybean growth and development. If considered as a complex, brown stem rot, white mold and stem canker occur across a range of climatic conditions that essentially ensure a high probability that one of them will be yield-limiting in a given year. Thus, the ideal soybean variety would have resistance to each disease.

Stem canker has increased in incidence and severity throughout the north central U.S. and Ontario, Canada. The recent resurgence of stem canker in the north central region has not been explained. However, likely factors are associated with reduced tillage, shortened rotation systems and changes in soybean germplasm. Additionally, the stem canker pathogen may have undergone genetic changes or related fungi may have emerged and are capable of causing similar symptoms.

Stem canker has been divided into northern stem canker and southern stem canker based on two causal agents. Northern stem canker was first reported in the late 1940s in Iowa, and by the 1950s, the disease had spread into the upper Midwest and Canada. Southern stem canker was reported in the south in 1973, and by 1984, had been detected in all southern states. Northern stem canker and southern stem canker are caused by *Diaporthe phaseolorum* var. *caulivora* and *Diaporthe phaseolorum* var. *meridionalis*, respectively. The host range of both pathogens has not been study extensively, however, over 16 weed species are known to harbor *D. phaseolorum*. Alfalfa and possibly other forage legumes are hosts to the cause of northern stem canker *Diaporthe phaseolorum* var. *caulivora*.

Symptoms

Initial expression of symptoms occurs during the early reproductive stages, with the development of a small, reddish-brown superficial lesion at the base of branches or petioles. The lesion is first observable in the leaf scar after the petiole has fallen. The lesion elongates and becomes dark brown or black, sunken in appearance and often girdles the stem. As a result of an

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uncharacterized phytotoxin produced by the fungus, interveinal chlorosis and necrosis are expressed in the leaves and is soon followed by plant death. Above and below the canker, green tissue is present and the leaves on the dead plant wither but remain attached. A top dieback can occur and results in a characteristic shepherd's crook curling of the terminal bud.

Epidemiology

The stem canker pathogen over winters in colonized stems and infected seed. Long distance dissemination of the pathogen is made possible by the movement of infested soybean residue and to a lesser extent by infected seed. Seed infection by northern stem canker can be as high as 10 to 20%. Short distance dissemination occurs in soybean fields in the spring as pycnidia (fruiting bodies) begin to develop on soybean residue from previous soybean crops. Conidia (spores) are released beginning in late April continuing into June and serve as the primary inoculum. Splashing and wind driven rain disperse spores up to 6 feet from the point inoculum source to petioles, petiole bases, stems, and leaves. The growth stage of the plant at the time of exposure to the inoculum greatly influences the incidence and severity of stem canker. Exposure to inoculum at V3 corresponds to the highest severity of disease. Disease severity is progressively reduced when first contact is delayed from V3 to V10 growth stages. Secondary inoculum is released from pycnidia present in stem cankers, but plants infected by secondary inoculum express minimal yield loss due to delayed infection. Conidia produced at this time however, contribute to the inoculum potential for future soybean plantings.

Environmental conditions during the vegetative stages govern disease development. Temperature greatly influences infection, with the highest levels of infection occurring when the air temperature is between 82 and 93°F, with and optimal temperature of 83.5°F. Temperature and period of wetness are significantly related. Rainfall during plant vegetative growth is critical for the development of stem canker epidemics. Cumulative rainfall, not the number of rainy days, is related to higher disease severity. Severe stem canker has also been observed in irrigated fields. Although rain is needed to disperse spores and is required for infection of plants, stem lesions and plant mortality have been greater in years with a dry period during later reproductive growth stages. It is this relationship with dry weather that may lead to stem canker being misdiagnosed as stress caused by a deficit of soil moisture. Frequently stem canker is most severe in low areas of fields, much like white mold, which would make less sense if plant mortality has occurred because of low soil moisture.

Yield losses have been reported to be as high as 50 to 80% in naturally infested fields. The incidence of stem canker in 2003 and 2005 was highest observed in decades and likely resulted in significant yield loss. It is difficult to assess yield loss precisely, but observations in 2005 suggest a significant inverse relationship between retention of dead leaves at harvest maturity and soybean yield (Fig. 1). Caution is advised not to attribute all retention of dead leaves at harvest to stem canker. This symptom is also associated with Phytophthora root rot, brown stem rot and white mold. Differences in stem symptoms and signs are characteristic and can aid in accurate diagnosis. Accurate diagnosis of the cause of leaf retention at harvest maturity is important because management of each of the previous diseases can be different.

Management

Stem canker is effectively managed by the combination of planting resistant cultivars and reducing infested residue on the soil surface. Deep plowing can reduce crop residue prior to planting a soybean crop. Seed for planting should not be harvested from fields with a history of stem canker. The benefits of crop rotation to reduce stem canker have not been demonstrated in production fields. Delayed planting can reduce the incidence and severity of stem canker; however, loss of yield potential that accompanies delayed planting makes this a questionable control strategy.

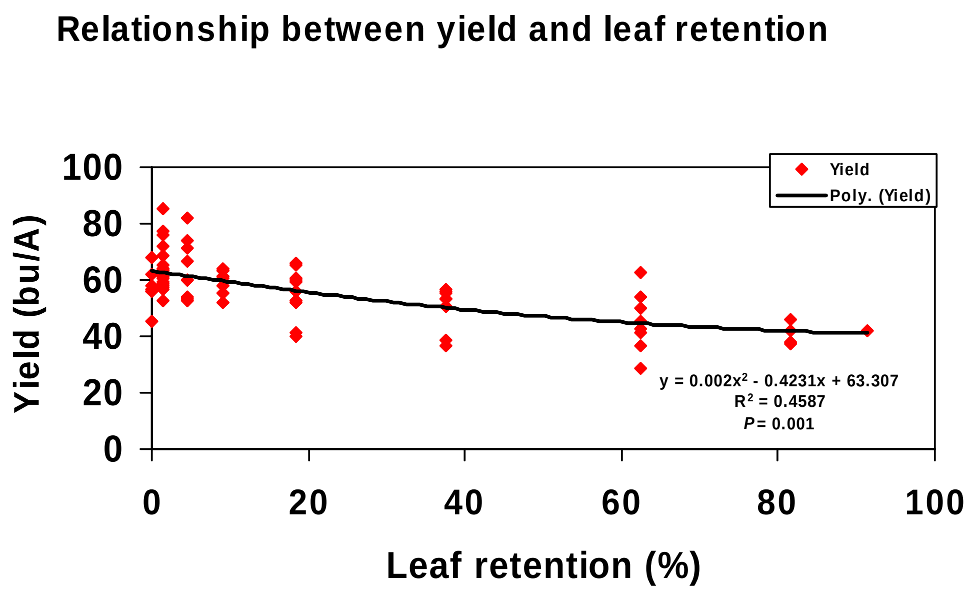

Figure 1. The incidence of retention of dead leaves at harvest maturity predicted a decline in yield in research plots located at the West Madison Agricultural Research Station in 2005. Stem canker is believed to be the cause of leaf retention.

Studies at the West Madison Agricultural Research Station in 2005 provide evidence that soybean varieties differ in reaction to stem canker. The incidence of plants with classic stem canker stem lesions was low, but leaf retention at harvest maturity was used to differentiate among a set of commercial varieties and experimental breeding lines. Less leaf retention was associated with higher yields among the soybean varieties and breeding lines (Table 1). Leaf retention at harvest maturity generally indicates that the plant dyed prematurely and suddenly at a previous growth stage. However, many companies report a reaction to southern stem canker but not northern stem canker. Northern stem canker is believed to be the predominate form of stem canker in Wisconsin. Studies are planned for 2006 to further study stem canker and how to evaluate soybean varieties for stem canker resistance in field trials.

Table 1. Performance of soybean varieties for yield and leaf retention at harvest in the presence of stem canker at the West Madison Agricultural Research Station in 2005.

Variety	Yield	Leaf Retention
	bu/a	%
Dwight	54.0	31
IA2021	60.4	8
O'SOY 211RR	56.5	18
IA 2068	54.1	21
W01-1164	57.4	10
W01-1167	58.5	6
AG2403	62.2	11
H2494	67.2	30
W02 586	51.3	16
W02 589	45.1	56
LSD p = 0.10	6.0	

Fungicides applied to seed are reported to reduce stem canker but will not completely eliminate the incidence of this disease. Foliar fungicides can be effective when applied during vegetative stages, however, results are inconsistent. The current interest in fungicides to improve soybean health and yield has focused on leaf diseases. However, there are indications that fungicides may have direct and indirect effects on stem infecting pathogens. Stem canker is a candidate for experimentation on the role of fungicides to improve soybean stem health. Although not specifically labeled for stem canker, most fungicide products registered for soybean rust and other leaf diseases would be active against stem canker. Stem canker control may be a non-target benefit from fungicides applied with the intent of improving soybean leaf health.

References

Koval, N.C., and C.R. Grau. 2005. Soybean stem health. Proc. 2005 Wis. Fert., Aglime, and Pest Management Conf. 44:86-94.

Grau, C.R., A.E. Dorrance, J. Bond, and J.R. Russin. 2004. Fungal diseases. p. 679-763. In R. Borema and J. Specht (ed.) Soybean monograph. 2nd ed. ASA. Madison, WI.

Soybean Plant Health website- http://www.plantpath.wisc.edu/soyhealth/stemcanker.pdf

SOYBEAN APHID SUCTION TRAPPING [1/]

Eileen Cullen [2/]

An entry point for understanding soybean aphid as a pest during the soybean growing season is to be familiar with how this insect alternates between asexual and sexual phases on two different plant hosts, buckthorn and soybeans, over the calendar year.

Soybean aphid overwinters in the egg stage on common buckthorn, an exotic, weedy, shrub common in much of the Midwest north of I-80. Eggs hatch on buckthorn in spring (late March, early April). From each overwintered egg on buckthorn in early spring, a wingless female soybean aphid known as the fundatrix, or "stem mother" hatches. These stem mothers are asexual and give live birth to wingless female aphid nymphs, producing several generations on buckthorn. By late spring/early summer, winged soybean aphid females are produced that leave buckthorn in search of soybean.

Migrant soybean aphid females arrive in soybean fields in mid- to late June and begin to form colonies, leading to multiple generations. Soybean aphids during the growing season are all female and reproduce without mating, giving birth to live female nymphs. Winged aphids that occur during the summer months are females capable of dispersing between fields to colonize new soybean host plants. In fall, soybean aphid females produce winged males and winged females (gynoperae). These winged migrants take flight back to buckthorn. Once they arrive on buckthorn, winged females give birth to a non-winged egg-laying female (oviparae). She mates with the winged males on buckthorn and lays the overwintering eggs to start the process again.

Aphid expert Dr. David Voegtlin *Illinois Natural History Survey* has been successful at monitoring the September & October flights of soybean aphid from soybeans back to buckthorn. For the past four years, Voegtlin has operated a suction trap network in Illinois (currently 9 traps). In 2001 and 2003, Illinois had low fall flights and the next growing seasons (2002 and 2004, respectively) the soybean aphid was not an economic problem. In fall 2002 the Illinois suction traps had a large fall flight and growers experienced a major and widespread regional soybean aphid outbreak during the 2003 soybean growing season. The Illinois fall flight in 2004 was the highest yet, and 2005 proved to be another "soybean aphid year" in the region, although not as uniformly as during the 2003 outbreak.

In 2005, Wisconsin joined a new Midwest soybean aphid suction trap network. Wisconsin (5 traps) joins Iowa (4 traps), Indiana (6), Kansas (1), Kentucky (1), Michigan (3), Minnesota (4), Missouri (1), Nebraska (1) and Virginia (1) in this expanded soybean aphid suction trap network.

Wisconsin soybean aphid suction traps are in operation June through October in Walworth County, near Sharon, Wisconsin; Columbia County at the Arlington Agricultural Research Station; Waushara County at the Hancock Agricultural Research Station; Grant County at the Lancaster Agricultural Research Station; and in Eau Claire County at the Pioneer Hi-Bred Int'l. Research Station.

1/ Funding provided by the Wisconsin Soybean Marketing Board

2/ Assistant Professor and Extension Entomologist, Dept. of Entomology, Univ. of Wisconsin-Madison, 1630 Linden Dr., Madison, WI, 53706.

Objectives of the UW Extension Soybean Aphid Suction Trapping project are to:

1. Establish a statewide soybean aphid suction trap grid in Wisconsin.

2. Determine when soybean aphids leave their overwintering host (buckthorn) to colonize Wisconsin soybean fields. Use this information to alert Wisconsin producers of aphid dispersal to new fields throughout the growing season as well as threat incidence of soybean viruses vectored within season by winged soybean aphids.

3. Estimate overwintering soybean aphid populations moving back to buckthorn in the fall as a means to predict soybean aphid population pressure (low, moderate, high) in soybeans the next growing season.

Soybean aphid suction trap captures in June indicate that winged female aphids have left buckthorn, and the potential for soybean infestation has begun for the season. Likewise, trap captures during July and August indicate the level of dispersal flight between soybean fields as soybeans undergo reproductive growth. While suction trapping is not a replacement for field monitoring, it does provide a regional alert system. The most important objective of the project is to record fall trap captures of winged soybean aphid females and males migrating back to the overwintering host, buckthorn. Fall trap captures appear to have predictive value as to the size and success of the overwintering soybean aphid population and its impact during the subsequent growing season. Will this pattern hold throughout the region, and from year to year?

To answer this question, text excerpts are provided below from an excellent recent article by David Voegtlin and Robert O'Neil in Vol. 2, No. 2, May 12, 2005 of *The New Agriculture Network*. You can access the entire article online at the *Wisconsin Crop Manager* Vol. 12, No. 12, May 26, 2005 http://ipcm.wisc.edu/wcm/pdfs/2005/05-12insect2.html

> "Many factors can influence the size of the following year's aphid population in soybeans. To start with, large numbers of multi-colored Asian lady beetles can be found on shrubs and trees in the latter part of September and into October. An abundance of these predators on buckthorn can effectively prevent the deposition of over-wintering eggs, and the subsequent production of spring migrants that fly into soybeans. Those eggs that are successfully deposited must survive the winter and after successfully hatching, they need to survive the spring weather. Heavy rains and sub-freezing temperature in early spring can eliminate young colonies on buckthorn. In the spring, lady beetles (and other predators) become active and will feed on soybean aphid colonies on buckthorn. So while the aphid can outbreak, factors that lead to an outbreak are many, and all along the way lay pitfalls that can help prevent or ameliorate aphid outbreaks in any given year."

Based on low fall 2005 trap captures in Wisconsin and neighboring states, the pattern would suggest a relatively low soybean aphid pest status level during the 2006 growing season. This is the first test of the hypothesis at a regional scale.

Reference

Allison, D., and K.S. Pike. 1988. An inexpensive suction trap and its use in an aphid monitoring network. J. Agric. Entomol. 5:103-107.

Soybean Aphid Suction Traps in Wisconsin

North Central IPM Center — Regional Soybean Aphid Suction Trap Network

Wisconsin Soybean Marketing Board

Eileen M. Cullen

Suction Traps started in Illinois Fall 2001.

Predictive potential based on fall trap captures of winged soybean aphid males and females flying back to buckthorn to overwinter.

Eileen M. Cullen

Illinois Experience …

Fall 2001 Trap Catches Very Low
2002 Growing Season low soybean aphid year

Fall 2002 Traps caught 700+ migrants
2003 Growing Season outbreak soybean aphid year

Fall 2003 Trap Catches again Very Low
2004 Growing Season very low soybean aphid year

Fall 2004 Traps caught 1,765 migrants
2005 Growing Season moderate to high aphid year

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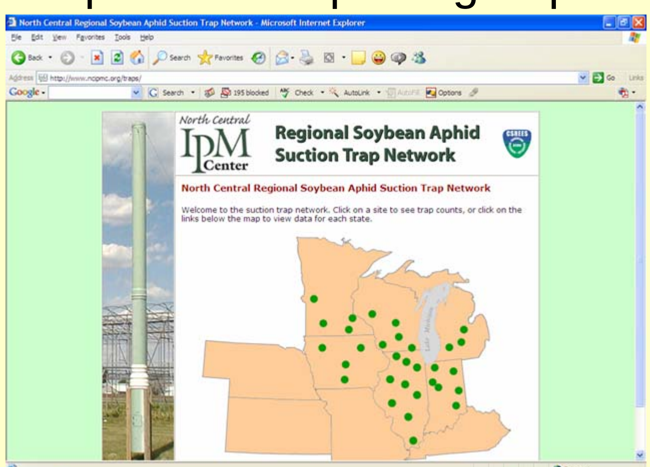
Bookmark this page!

http://www.ncipm.org/traps/



Eileen M. Cullen

Fall 2005 to
2006 Growing Season

6 states now testing suction trap predictive value

Collection Jars sent weekly June – October to *Illinois Natural History Survey* for expert aphid identification.

Counts posted to Website

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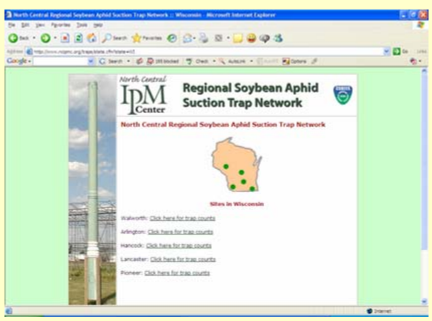

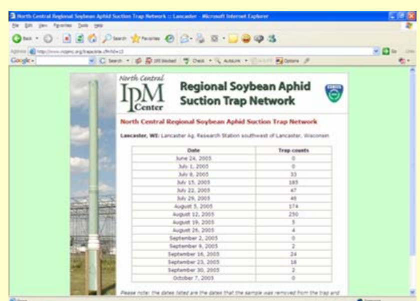

Walworth Co. (near Sharon, WI)
Arlington Agric. Res. Station
Lancaster Agric. Res. Station
Hancock Agric. Res. Station
Pioneer Research Station (near **Eau Claire, WI**)

Eileen M. Cullen

WI Soybean Aphid Suction Trap Catch, 2005

Date	Walworth	Arlington	Hancock	Lancaster	Eau Claire
Jul 15	75	316	46	185	17
Jul 22	147	---	81	47	38
Jul 29	30	42	11	46	33
Aug 5	180	83	51	174	226
Aug 12	75	78	120	250	278
Aug 19	4	19	35	5	222
Aug 26	5	8	0	4	8
Sept 2	3	0	1	0	7
Sept 9	0	1	1	2	3
Sept 16	0	1	3	24	1
Sept 23	5	0	0	18	3
Sept 30	0	0	---	2	1
Oct 7	0	0	0	0	---
Oct 14	0	0	0	0	0

Eileen M. Cullen

Key Points ...

- Summer suction trap catch is not predictive, these catches represent all-female population. Dispersal flight between fields in growing season.
- Watch September-October flights for predictive potential! These are winged males & females migrating to buckthorn, the host plant where overwintering eggs are laid.

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Preliminary conclusions …

- Fall 2005 Trap captures low in WI (see previous slide) other states similar.
- Based on history of traps in Illinois, low 2005 fall captures we are seeing now indicate low soybean aphid year potential for 2006.

Eileen M. Cullen

UNDERSTANDING VIRUS POTENTIAL IN COMMERCIAL SOYBEAN FIELDS[4]

Nancy Koval[1], Craig Grau[2] and Eileen Cullen[3]

Bean pod mottle virus (BPMV), *Soybean mosaic virus* (SMV), and A*lfalfa mosaic virus* (AMV) are frequently associated with soybean in Wisconsin (Table 1). The incidence of each virus has corresponded to activity of its primary insect vector. The bean leaf beetle, *Ceratoma trifurcata,* vector of BPMV, was most active between 2000 and 2002, with a noticeable decline since (Cullen et al., 2005). Although several aphid species transmit SMV and AMV, incidence of SMV and AMV relates strongly to the occurrence of the soybean aphid, *Aphis glycines*. Data and field observations suggest that BPMV is the virus most capable of causing yield loss in commercial soybean fields in Wisconsin. However, the threat of BPMV is greatly diminished because of sporadic occurrence of bean leaf beetle populations needed for epidemics to occur. In contrast to the bean leaf beetle, soybean aphid population densities required for transmission of SMV and AMV have occurred more frequently since the soybean aphid was first detected in Wisconsin in 2000.

Soybean aphid has emerged as an important pest of soybeans, and direct effects of feeding can result in significant yield reduction (Fujan, 2004). Insecticides are effective for soybean aphid control and are justified when aphid densities have reached economic threshold. The direct effects of the soybean aphid are documented (Fujan, 2004), but its economic impact as a virus transmitting agent is less clear. Transmission of SMV and AMV has been documented to increase proportionally to increasing soybean aphid population densities during the growing season. Although SMV is common in research plots, it has been difficult to detect SMV in commercial soybean fields.

Soybean viruses such as SMV and AMV are controlled most effectively by avoidance of insect vectors through planting of virus resistant soybean varieties. Although two public soybean varieties have been identified as resistant to SMV, this resistance trait is not common among commercial Roundup Ready varieties, and seldom is this trait mentioned in seed company information. Insecticides are an important tactic to control soybean aphids, but research to date suggests that insecticides do not consistently control transmission of SMV. Thus, foliar insecticide application is not a likely explanation for the low incidence of SMV in commercial soybean fields.

Research has been directed towards exploring traits among soybean varieties that could have an impact on SMV incidence. The primary source of SMV is SMV-infected seed. Seed transmission of 1 to 5% has been documented (Grau, 2005). Aphids acquire SMV from infected seedlings and transmission can occur throughout the growing season, with yield and seed quality being the most affected if transmission occurs prior to the R2 growth stage.

A research project was initiated in 2004 and continued in 2005 to determine why SMV has not become epidemic in commercial soybean fields despite high soybean aphid activity in recent years. Experiments were designed to answer the following questions: 1) Do commercial soybean varieties respond differently (yield and virus incidence) to insecticide applied for soybean aphid control? 2) Are commercial soybean varieties available that are resistant to soybean aphids and SMV? 3) Is seed transmission of SMV low among commercial soybean varieties? Answers to these questions can help identify factors that result in low occurrence of SMV, and provide guidance to the soybean seed industry for breeding varieties and producing seed.

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[4] Funding provided by the Wisconsin Soybean Marketing Board.

Table 1. Assessment of viruses detected in Wisconsin soybeans.

Virus	Risk level	Symptoms	Transmission
Bean pod mottle virus (BPMV)	High yield loss can be expected when high populations of bean leaf beetle are active during early vegetative growth stages	Young leaves in the upper canopy exhibit light green to yellow mottling; some puckering and distortion; stems remain green with mature pods; retain petioles after leaf drop. Seed discolored by pigments that bleed from hilum.	Bean leaf beetle is Common vector; seed transmission is less than 1%.
Soybean mosaic virus (SMV)	Low at present time for reasons unknown SMV is readily transmitted by the soybean aphid.	Leaves develop a mosaic of light and dark green areas; surface of leaves become raised or blistered; chlorosis may develop between dark green areas; wavy leaf margins or downward curling; maturity delayed and infected plants and remain green at harvest. Seed discolored by pigments that bleed from hilum.	32 aphid species transmit SMV; common seed transmission rates are 1-5%; Reaction of soybean varieties is not well documented.
Alfalfa mosaic virus (AMV)	Low at present time. Incidence is greater than SMV in commercial fields.	Bright yellow mosaic of leaves; leaf veins are yellow but leaf is a normal green color.	Transmitted by aphids; seed transmission 1-35%.

Experimental Protocol

The primary goal of the project is to investigate the potential role of soybean varieties in development and implementation of integrated pest management practices directed at the control of soybean aphids and associated viruses. The first step is to determine whether current commercial soybean varieties react differently to the soybean aphid, and whether soybean varieties modify the efficacy of insecticides to control the soybean aphid and associated viruses. The second step is to determine whether control of the soybean aphid can result in reduced virus transmission as well as improved yield and seed quality. Results from this project will increase our understanding of soybean aphid behavior and virus transmission patterns across a selected group of soybean varieties.

Twenty-eight soybean varieties were selected for this study. Nineteen commercial varieties were selected based on high yield performance in variety trials conducted by the Department of Agronomy in 2003 (Table 2). Five varieties (Vinton 81, IA 1008, IA 2017, IA 2065 and IA 2068) were selected for their identity preserved food grade status and/or suitability to USDA certified organic production systems, and four were selected as SMV susceptible varieties (Dwight, IA 2021) and SMV resistant check varieties (NE 3001, Colfax).

Soybean aphid population densities were monitored weekly for all 28 varieties in a completely randomized block split plot design (insecticide vs. no insecticide) replicated four times. The organophosphate insecticide Lorsban 4E was applied (1 pt./acre) to all 28 varieties in the insecticide plots at the R1 growth stage (July 8th, 2005) after soybean aphids had reached the economic threshold of 250 aphids per plant in several of the plots throughout the experiment. Lorsban 4E was applied due to the presence of twospotted spider mite in the experimental plots at the West Madison Agricultural

Research Station. Severity of virus symptoms and incidence of SMV infected plants were recorded for all plots. Plots were harvested for yield and incidence of seedcoat mottling recorded on a subsample of seeds from each plot following mechanical harvest.

Results

Soybean varieties differed in ability to support populations of the soybean aphid. DKB 25-51 had the fewest soybean aphids and IA 2017 supported the highest aphid populations. Yield improved 1.7 bu/a with one application of Lorsban insecticide when data were combined for all soybean varieties. Soybean aphid populations were reduced for all varieties after treatment with Lorsban, but the percentage of control was greater for some varieties. Statistically, all varieties responded equally to insecticide treatment for yield. However, differences of 8 to 11 bu/a were obtained for seven of the 28 varieties in the trial. Yield was improved by the Lorsban treatment for O'Soy 211RR and NE 3001, but reduced for AG2403, DKB 23-51, NK S24-K4, Colfax, and Vinton 81 (Table 3).

As expected, the incidence of SMV was low for NE3001 and Colfax, the resistant check varieties, and high for Dwight, a susceptible check variety. Five varieties, NK S20-F8, NK S24-K4, O'Soy 163RR, IA 2021, and IA 2065, expressed incidence of SMV similar to the resistant check varieties. Yield of the SMV resistant varieties was 8 to 9 bu/a higher than Dwight, the susceptible check variety. The incidence of SMV ranged from 0 to 50% in unsprayed plots and from 1 to 58% in treated plots. Soybean varieties differed in response to insecticide application and SMV incidence (Table 3). One application of Lorsban resulted in lowered SMV for DSR 234RR, H2627RR, RT2440, and Spansoy 253RR while increasing SMV for Dwight. Ten soybean varieties expressed 10% or less seedcoat mottling, a tolerance level acceptable for utilization by food grade markets (Table 2). Incidence of mottled seed was not affected by Lorsban.

Summary of Results for 2005

- Soybean aphid populations at R2 growth stage were correlated with SMV incidence and incidence of mottled seed, but not yield (Table 4).
- SMV reduced yield based on higher yield for SMV resistant check varieties compared to susceptible check varieties, and significant correlation between disease variables and yield (Table 4).
- Lorsban insecticide reduced the population density of the soybean aphid, however yield, averaged for 28 soybean varieties, was not increased by this treatment.
- Overall soybean aphid was controlled by Lorsban, but the percentage of control was greater for some varieties.
- Some soybean varieties supported lower populations of the soybean aphid in the untreated plots.
- Five commercial varieties were identified that expressed resistance to SMV comparable to the resistant check varieties.
- SMV incidence increased for three, and decreased for three varieties after treatment with Lorsban. This is the first observation of increased incidence of SMV following the application of an insecticide.
- Ten soybean varieties expressed 10% or less seedcoat mottling, generally acceptable for food grade markets.
- Experiments will be conducted during winter months to determine whether soybean varieties differ in seed transmission of SMV.

- Results in 2005 suggest that insecticides will remain the most effect control option for the soybean aphid until soybean aphid resistant varieties enter the market.
- BPMV and AMV were incidence levels were low for all soybean varieties.

Conclusion

Two variables were investigated in this study to explain the low incidence of SMV in commercial soybean fields, 1) potential SMV resistance among commercial soybean varieties and 2) insecticidal control of soybean aphid. Based on our results from 2005, neither of these variables identified the mechanism responsible for low SMV incidence in commercial soybean fields. Ten of the 19 commercial varieties screened in this experiment had an SMV incidence greater than 20%, indicating that many commercial varieties in fact do not currently provide acceptable SMV resistance. An application of Lorsban insecticide for soybean aphid suppression resulted in lower SMV incidence for only three of the 28 varieties in the experiment.

These results indicate that seed transmission of SMV may be higher in our experimental plots than is commonly the case in commercial soybean fields. Seed from the 2005 plots at West Madison are currently being assayed for SMV transmission. 2006 field experiments will be designed to further quantify the rate of seed transmitted SMV among soybean varieties and test the hypothesis that SMV transmission is significantly limited to seed borne inoculum.

References

Cullen, E., K. Lambrecht and A. Phibbs. 2005. Bean leaf beetle and bean pod mottle virus in Wisconsin – where do we stand? Proc. 2005 Wis. Fert., Aglime, and Pest Mgmt. Conf. 44:83-85.

Fujan, G. 2004. Soybean aphid research update. North Central Soybean Research Progr WWW document. URL http://www.planthealth.info/aphids_researchupdate.htm

Grau, C. 2005. Soybean viruses and soybean seed. WWW document. URL http://www.plantpath.wisc.edu/soyhealth/viruscomplex/virusseed.htm

Plant Health Initiative; North Central Soybean Research Program. http://www.planthealth.info/

Soybean Plant Health website, Univ. of Wisconsin-Madison. http://www.plantpath.wisc.edu/soyhealth/

Table 2. Evaluation of commercial cultivars for reaction to aphid virus complex at West Madison Agricultural Research Station, 2005.

Entry	Yield	Seed mottling	R6 24-Aug virus rating	R5 15-Aug SMV incidence	R3 15-Jul soybean aphid population
	bu/a	% incidence	% severity	%	per plant
Commercial cultivars					
A2247	66.2	4	35	31	87
AG2403	67.6	5	20	17	87
AG2703	58.2	43	53	13	71
AG2203	61.8	5	32	19	70
DSR218	65.2	7	30	18	84
DSR234RR	62.4	14	22	21	87
DKB 25-51	62.7	10	77	24	60
DKB 23-51	56.1	7	71	33	112
H2627RR	63.9	38	35	28	130
NKS20F8	70.5	13	13	11	99
NK S24-K4	69.3	31	32	11	107
O'SOY 163RR	65.5	2	27	8	94
O'SOY 211RR	63.4	16	35	21	118
PIONEER 92M72	55.7	53	29	19	83
PIONEER 92B38	67.5	38	12	26	71
RT 2092	62.2	22	37	28	65
RT 2440	63.8	24	42	26	83
SPANSOY 250	66.0	36	21	54	94
SPANSOY 253RR	64.6	19	37	18	69
Public cultivars					
Colfax	68.0	1	13	1	92
Dwight	60.2	40	16	28	160
IA1008	61.1	32	16	12	97
IA2017	57.1	50	32	23	171
IA2021	68.3	32	19	6	104
IA2065	72.9	4	30	8	68
IA2068	62.7	26	54	13	100
NE3001	69.3	2	9	6	95
Vinton 81	56.7	38	14	27	75
Mean	63.9	22	31	20	94
P-value (variety)	<0.1	<0.1	<0.1	<0.1	9.1
LSD(10%)	6	12.8	17	6.9	52
CV%	11	71	67	193	66

Table 3. Evaluation of commercial cultivars for reaction to insecticide treatment at West Madison Agricultural Research Station, 2005.

Entry	Yield NT[1]	Yield Lorsban	R5 8/15/2005 SMV incidence NT	R5 8/15/2005 SMV incidence Lorsban	R3 7/14/2005 Soybean aphid population NT	R3 7/14/2005 Soybean aphid population Lorsban
	bu/a		%		per plant	
Commercial cultivars						
A2247	67.9	64.5	28	34	132	42
AG2403	72.3	62.9	13	21	152	22
AG2703	56.6	59.7	16	9	111	31
AG2203	60.9	62.8	14	24	108	32
DSR218	66.1	64.4	13	24	128	40
DSR234RR	62.8	62.1	29	14	143	30
DKB 25-51	63.9	61.6	26	21	89	30
DKB 23-51	60.5	51.6	29	38	158	65
H2627RR	66.6	61.3	25	31	234	27
NKS20F8	71.5	69.5	16	5	150	48
NK S24-K4	73.8	64.8	15	8	197	17
O'SOY 163RR	66.1	64.9	6	9	136	51
O'SOY 211RR	59.5	67.3	19	24	201	36
PIONEER 92M72	56.7	54.7	16	21	146	20
PIONEER 92B38	67.4	67.6	24	28	116	27
RT 2092	59.4	65.0	26	29	104	26
RT 2440	66.7	61.0	35	16	136	31
SPANSOY 250	68.6	63.3	50	58	148	40
SPANSOY 253RR	63.4	65.8	33	6	112	27
Public cultivars						
Colfax	73.5	62.6	0	1	146	38
Dwight	57.8	62.7	15	41	283	37
IA1008	60.9	61.2	13	12	144	49
IA2017	56.5	57.6	28	18	310	31
IA2021	67.0	69.7	8	3	178	29
IA2065	75.1	70.6	3	14	110	26
IA2068	64.6	60.9	15	11	144	56
NE3001	64.1	74.5	0	11	159	32
Vinton 81	62.4	51.0	31	23	117	33
Mean	64.7	63.1	19	20	153	35
P-value (Variety x Lorsban)	27.8		<0.1		8.2	
LSD (10%)	NS		11.5		20	
CV%	11		193		66	

[1]- NT=No insecticide treatment

Table 4. Correlation coefficients among variables for yield, seed mottling, virus incidence and severity, aphid populations and plant stand at West Madison Agricultural Research Station, 2005.

		Yield	Seed mottling	Virus rating	Aphid population 1-Jul	Aphid population 14-Jul	Plant stand	SMV incidence	
Yield	R	1.00	-0.29	-0.18	-0.09	-0.08	0.25	-0.22	R
	p-value		<.0001	0.01	0.18	0.24	0.00	0.00	p-value
Seed Mottling		R	1.00	0.13	-0.11	0.18	-0.10	0.29	R
		p-value		0.05	0.11	0.01	0.12	<.0001	p-value
Virus rating			R	1.00	-0.13	0.09	-0.02	0.20	R
			p-value		0.05	0.16	0.82	0.00	p-value
Aphid population 1-Jul				R	1.00	-0.10	0.10	0.07	R
				p-value		0.13	0.15	0.30	p-value
Aphid population 14-Jul					R	1.00	-0.16	0.12	R
					p-value		0.02	0.07	p-value
Plant stand						R	1.00	-0.03	R
						p-value		0.63	p-value
SMV Incidence								1.00	

WISCONSIN INSECT SURVEY RESULTS 2005 AND OUTLOOK FOR 2006

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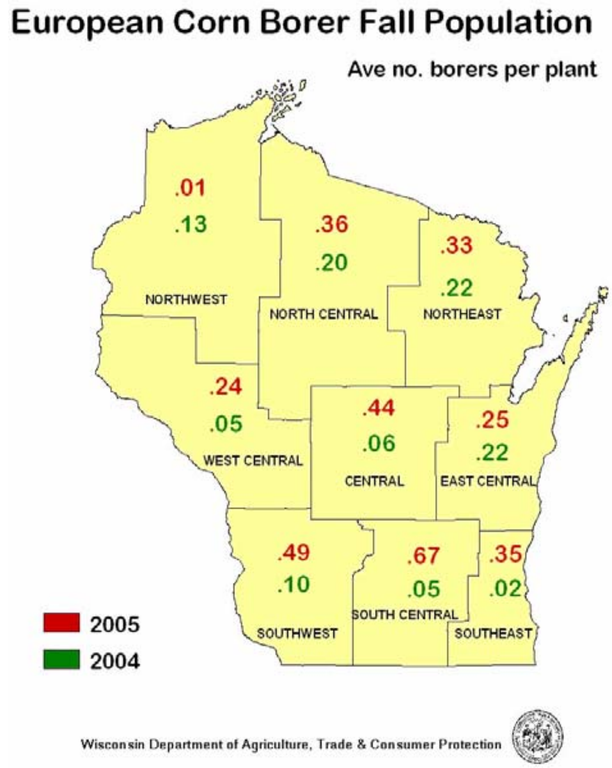
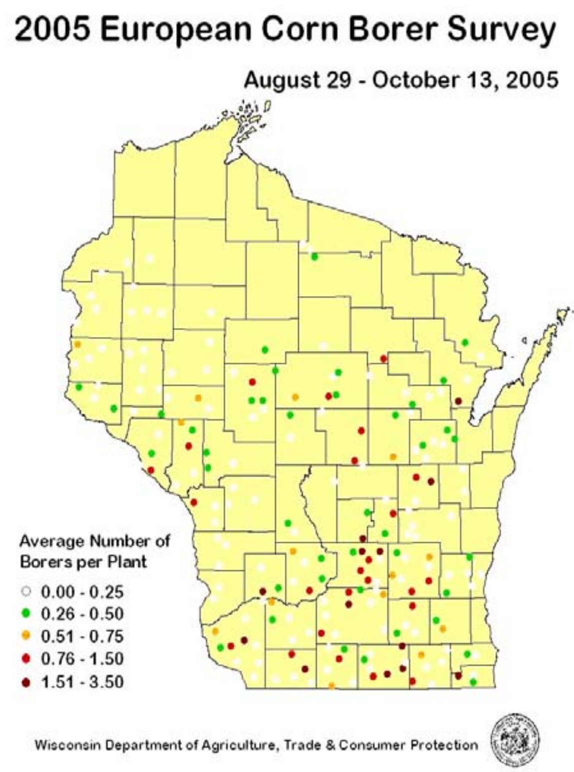
European Corn Borer

The annual fall survey showed the average European corn borer population in the state to be 0.40 borer per plant (40 borers per 100 plants). This compares to 0.10 in 2004 and a 50-year average of 0.49. Increases occurred in every district except the northwest, a probable outcome given last fall's record-low population. The most substantial increases were noted in the southwest, south central and southeast districts where populations rose from 0.10 in 2004 to 0.49, 0.05 in 2004 to 0.67, and 0.02 in 2004 to 0.35, respectively. Approximately 87% of the corn fields surveyed had larval populations below 1.0 borer per plant (182 of 210 fields), while 13% of the corn fields had high larval populations, ranging from 1.0-3.5 borers per plant (28 of 210). As a reminder, a corn borer population of 1.0 borer per plant is economically important, having been shown to reduce yield by as much as 5% during the first generation, and 2.5% by the second generation.



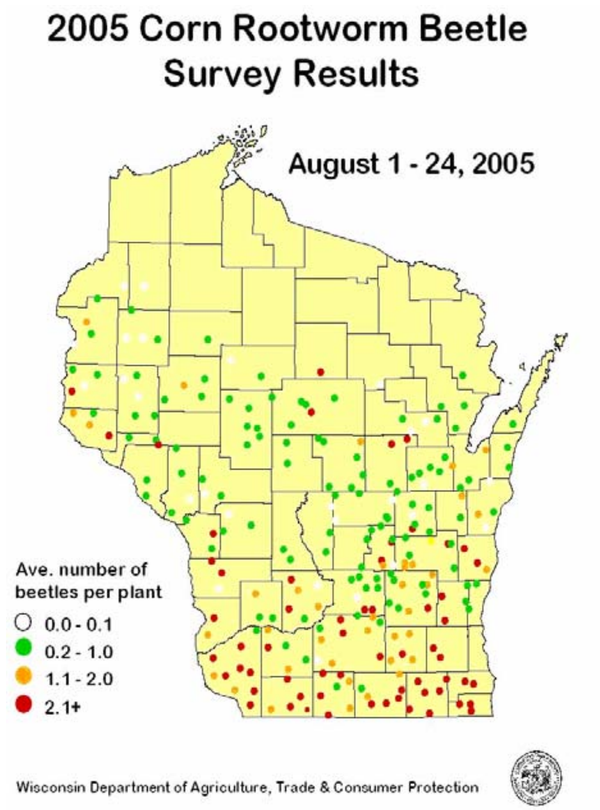
A statewide average of 0.40 borer per plant suggests a light to moderate first flight of corn borer moths should be anticipated next spring. What follows the first flight, an increase or decrease in corn borer densities, depends on factors such as activity of natural enemies and weather conditions during May and June.



Corn Rootworm

The first adults of the season were observed during the week of July 8 in Walworth and Dane County corn fields, and by July 22, both beetles and silk feeding in drought-stressed fields were common. Damage in the form of lodged plants first became evident about July 25 following severe thunderstorms, and might have been evident earlier, if not for the insufficient rainfall and absence of storm activity throughout July of 2005.

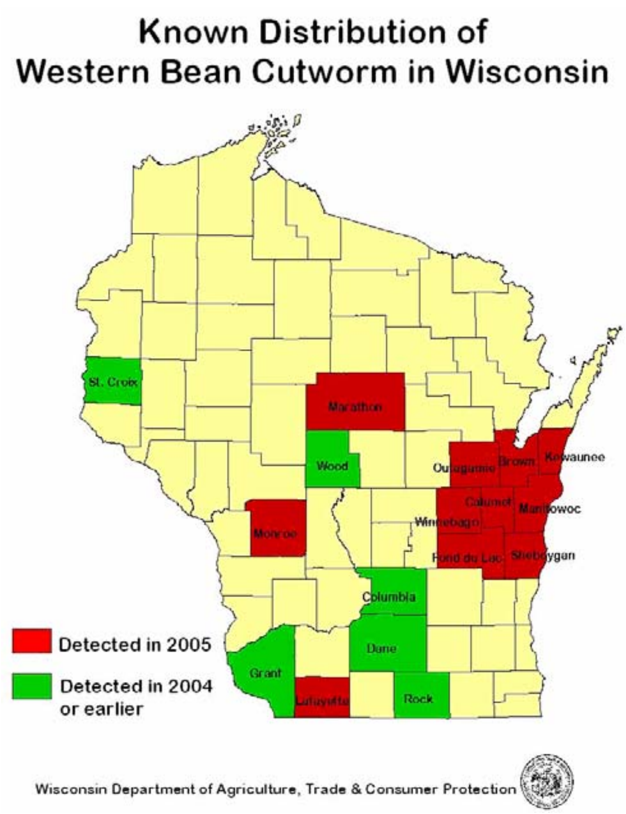
The annual corn rootworm beetle survey began during the first week of August, with preliminary findings indicating heavy beetle populations in the southern half of the state. The survey, which was timed to correspond with peak adult emergence during the first two weeks of August, found high adult rootworm populations across much of the state, with the exception of the north central and northeast districts. The statewide average of 1.6 beetles per plant more than doubled the 0.75 beetle per plant threshold widely considered to indicate a potential for corn rootworm problems in continuous corn the following year. Corn rootworm beetle populations were particularly high in the southwest and southeast districts, where averages of 3.2 and 3.8 beetles per plant were recorded, respectively.

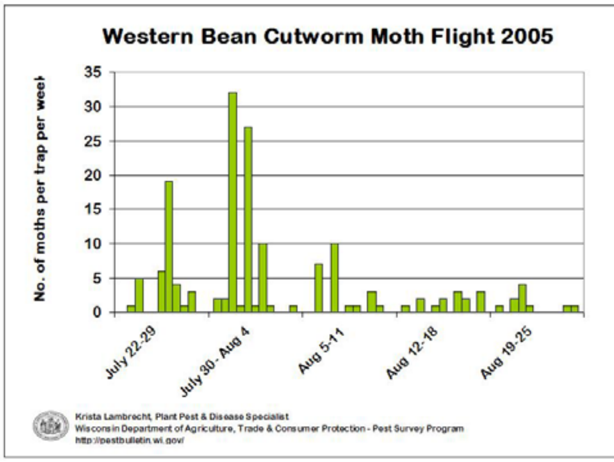


In addition, the beetle survey showed the western species, *Diabrotica virgifera* LeConte, to be the dominant species statewide, comprising 58% of all rootworms present. Emergence of rootworm adults was essentially complete by August 19, although weather conditions continued to favor rootworm activity into early October.

Western Bean Cutworm (WBCW)

In 2005, Wisconsin's first coordinated WBCW trapping network was established to track the emergence of moths and to monitor flight activity. WBCW is a new pest of corn to the Midwest that has a reputation of causing 30-40% yield loss in its native western cornbelt states. Pheromone traps were placed at 14 southern and east central sites during the week of July 15, and within a week's time captures began to escalate. Egg laying in corn began by mid-July, either the week or July 15 or July 22, although DATCP specialists found no evidence of WBCW in corn fields during general surveys. Moth flight peaked by August 4. The following week, fewer and fewer moths were registered at trapping sites, and no WBCW moths were trapped after August 25. The highest WBCW moth captures of 2005 were recorded between July 30 and August 4.





In 2005, WBCW was recorded for the first time in Calumet, Kewaunee, Manitowoc, Outagamie and Shawano counties. Interestingly, the WBCW moth counts registered in Wisconsin pheromone traps were not comparable to those recorded in neighboring states. The highest cumulative capture of WBCW this season was 38 moths at the McFarland site in southern Dane County; treatment guidelines for WBCW are based on a cumulative capture of 700-1000 moths. Although WBCW now appears to have a widespread distribution in Wisconsin, low localized populations indicate the risk of significant western bean cutworm damage is low, for now.

True Armyworm

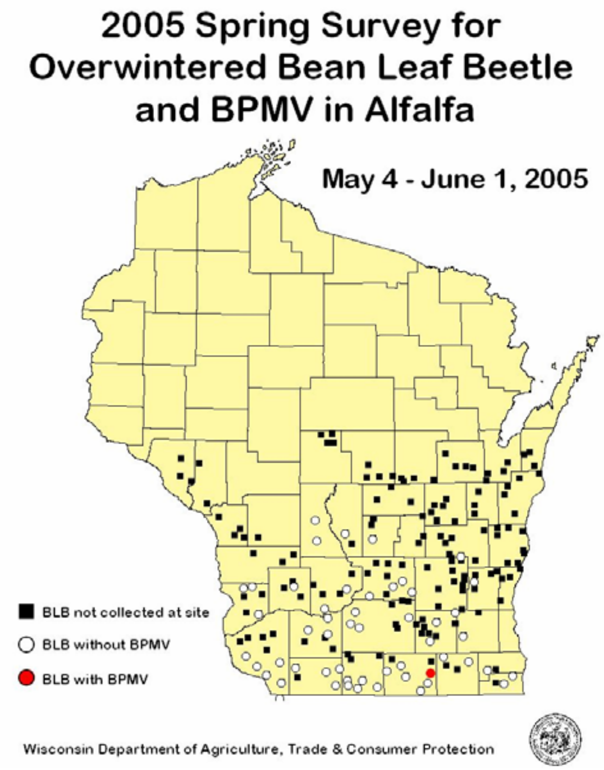
The earliest news of armyworm troubles came during the week of July 29 from Monroe County UW-Extension agent Bill Halfman, who reported armyworms had decimated a 48-acre corn field on the Monroe/Vernon County line. The same week, scattered problem areas were detected in Burnett, Polk, Rusk, Sawyer and Washburn counties, signaling that outbreaks were not limited to the west central district. The march of armyworm caterpillars continued during the week of August 5, as more ravaged corn fields were detected in more counties. Alarming levels of defoliation were spotted in Crawford, Chippewa, Pierce and Marathon County fields where corn leaves were stripped to the midrib on 50-100% of the stalks. In many cases, the armyworm larvae were nearly mature by the time the infestation was noticed, thus, there was little for farmers to do. Moderate moth captures continued at during the last week of August at Northwest black light trapping sites, suggesting armyworm activity did not fully subside until early September. After armyworms had run their course last season, it appeared corn fields in the west central, northwest and central districts were hardest hit.

Several variables contributed the outbreaks of 2005, including widespread weed problems and late herbicide applications that prompted the migration of armyworms from grassy fields to corn plants following weed control. Fortunately, only one of the generations of armyworm was destructive last summer.

Bean Leaf Beetle

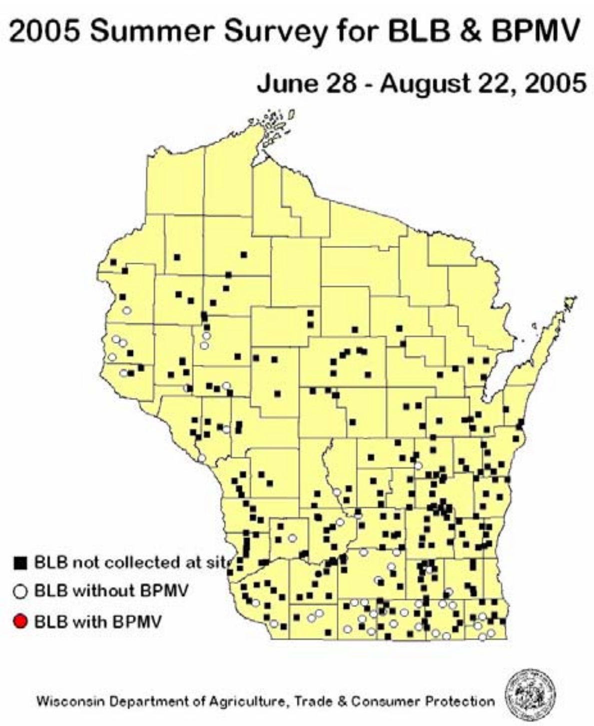
The spring survey for overwintered bean leaf beetles began in Green County on May 4, and advanced as far as Adams, Juneau and Marquette counties by June 1. The survey found overwintered beetles in 51 of 204 (25%) southern and central alfalfa fields visited. Laboratory analyses of the beetles collected from the 51 sites found bean pod mottle virus (BPMV) in one beetle from a Rock County field, while bean leaf beetles from the other 50 fields tested negative for BPMV. Testing of beetles was conducted using DAS ELISA kits from Agdia Inc., Elkhart, Indiana.

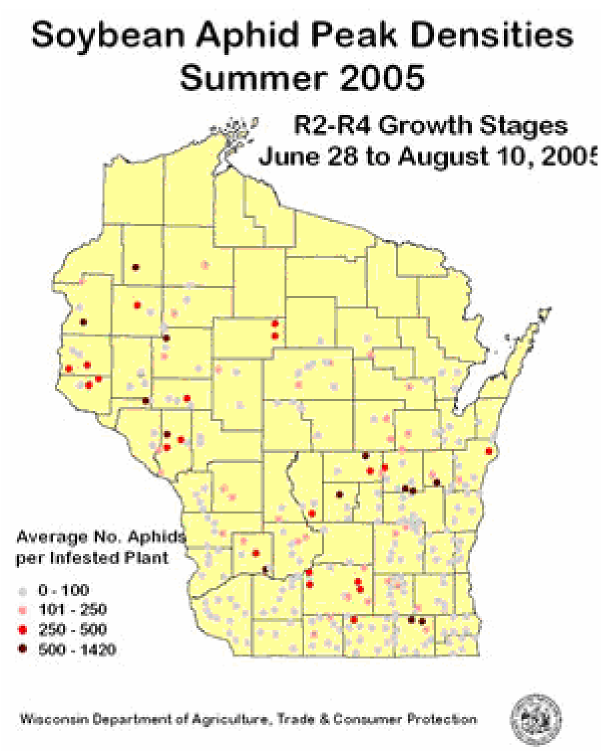
A summer follow-up survey of first generation bean leaf beetles, conducted between June 28 and August 22, found bean leaf beetles at 47 of 276 survey sites (17%). Individual beetles were tested for BPMV using the same DAS ELISA method used to test beetles from the spring survey. No summer bean leaf beetles tested positive for BPMV. In addition, soybean leaflets from each of the 276 fields were collected tested for BPMV. No BPMV was found in any of the 276 soybean fields sampled. Survey findings suggest early-season BPMV transmission by bean leaf beetles should not be an issue in 2006.



Soybean Aphid

The soybean aphid season began early in 2005, with the first detection of aphids on June 1 in western Dane Co. The annual soybean aphid survey, conducted from June 28 to August 22, found the statewide average number of aphids per infested plant increased to 120 in 2005, up from 14 in 2004, and down from the average of 770 aphids per infested plant in 2003. Soybean aphids were detected in all but five of the 274 fields surveyed this season (98%), an increase from 73% in 2004, and a slight decrease from 100% in 2003. A total of 88% of the survey sites had noneconomic aphid levels, while 34 of the 274 (12%) sites had peak aphid densities above the 250 aphid per plant threshold. In comparison to previous years, the peak aphid densities recorded in 2005 were moderate. Peak densities were considerably higher than in 2004, but significantly lower on average than those encountered in 2003 and in preceding years. High temperatures through the months of July and early August (>90°F) helped to limit aphid population growth in 2005.





THE CONCEPT OF SOYBEAN PLANT HEALTH

Martin A. Draper [1/]

One of the greatest challenges producers and researchers alike have had to address is protecting the yield potential of the soybean crop. Soybeans abort a large percentage of their blossoms, giving up yield. Why does this happen and how can that loss be reduced? Perhaps what needs to be addressed is the overall health of the plant. Plant health is a wholesome concept. Who could be opposed to such an idea? Perhaps the more important questions are, "What is plant health and who can define what is?"

Without a doubt, most people would agree that a healthy plant is likely to be more productive. What we don't understand is, what plant health is! What affects the health of a biological organism? Certainly the absence of infectious disease is a component in this definition. However, infectious disease is not the only cause of yield loss. Nutritional disorders and deficient macro- and micronutrients are significant causes of plant stress that can limit productivity as well. Environmental factors such as timeliness of rainfall and the temperatures range relative to the optimum for plant growth can also effect production. On a smaller scale, each of the factors above can influence physiological processes that relate to yield. Most of us don't want to look inside the molecular processes of the plant, but that is really where yield is being built. What if something as simple as high temperature stress at the wrong stage of crop development shut down a physiological process that diverted energy to be stored in seed, limiting yield? How can these stresses that limit yield be managed?

In recent years, claims have been made that fungicides can increase yield in the absence of disease. Some fungicide chemistries appear to provide this response with greater frequency. This response appears to be difficult to predict, but likely is a response to a number of factors, including suppression of apparent and unapparent diseases and the alteration of the crop plant's physiology. Various plant growth conditions and environmental stresses are likely associated with this phenomenon of enhanced yield.

In a recent comparison of fungicide trials across the northern soybean production region, responses of zero to nearly 19 bushels per acre have been achieved, a yield increase of more than 40% in that instance. Strobilurin and strobilurin-triazole premixes appear to provide the most frequent favorable responses. Economically favorable yield responses, statistically valid increases of 4 bushels per acre or greater, occur about 30-35% of the time with strobilurin fungicides. Triazole products only result in economically favorable yield responses in 10-12% of the instances in which they are used. Data are not available from all sites, but it appears that when measurable reductions in leaf disease are documented, there is a greater likelihood of seeing a response.

Efforts are being made to identify risk factors that may increase the frequency of observing a favorable response to fungicide applications, but at this point most soybean pathologists hesitate to recommend a prophylactic treatment in the absence of a disease risk. As soybean rust becomes a more established disease concern, fungicide applications will be come more commonplace. What we learn about the response to application of these fungicides now will improve our chances of seeing favorable responses in future years.

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FIELD TESTS ON IMPROVING SOYBEAN HEALTH

Craig R. Grau[1/] and Bryan Jensen[2/]

Disease resistant varieties, cultural practices and fungicide/insecticide seed treatments have been the primary means to improve soybean health compromised by soybean diseases. The threat of Asian soybean rust in North America has triggered a renewed interest in the use of fungicides to manage soybean diseases. Soybean rust has generated an unprecedented number of Section 3 and Section 18 registrations for fungicides efficacious to soybean rust. Several Section 3 fungicide products have been applied to soybean for several years. Most activity has been in the Southern USA. Septoria brown spot, downy mildew and powdery mildew are diseases that conceivably are additional diseases controlled by Section 3 products. Frogeye and Cercospora leaf spot would be additional diseases that would be targeted for control in Southern states. Septoria brown spot and downy mildew are regarded as "cosmetic diseases" of minimal effect on yield by many plant northern plant pathologists. Powdery mildew is believed to be an exception, but a recent study at the Univ. of Wisconsin-Madison found that 80% of commercial soybean varieties are resistant to powdery mildew and thus, fungicides are unnecessary. Nevertheless, many ag professionals and farmers have been experimenting with foliar applied fungicides and in some cases, report economic improvement in yield.

Besides direct fungicidal activity against leaf pathogens, several fungicide products are reported to slow the maturation process of the soybean plant resulting in a perceived longer period of grain fill. This secondary effect of a fungicide is hypothesized to allow treated soybeans to better tolerance stress. We hypothesize that stem and possibly root pathogens are affected by the secondary effect of fungicides on plant maturation. Brown stem rot and stem canker are diseases being targeted for research.

Fungicides have had an inconsistent effect on soybean yield. The majority of studies have resulted in 1 to 3 bu/a improvements, but not the 4 bushel or more yield enhancement needed for economic feasibility. However, enough studies have resulted in yield increases of 5 to 10 bu/a to continue investigations on where and when foliar applied fungicides can be applied to soybean management systems. When yield is not improved by fungicides, a common conclusion is that disease pressure was inadequate to result in higher yields for fungicide treated soybean.

Use of Headline Fungicide for Improving Soybean Health-2005

Purpose: Determine whether Headline fungicide can improve health and yield of soybean.

Procedure

Headline foliar fungicide was applied at the rate of 6 oz./A (plus 1 pt. NIS /100 gallons of water) to soybean on large scale side-by-side strip trials and compared to an untreated check at nine locations throughout Wisconsin. Headline was applied at a minimum of 20 gallon of water per acre, a droplet size of 250 to 300 microns, and at growth stages R2 to R3. The number of replications was to be determined by the grower and cooperator. Yields were taken using the growers combine in conjunction with yield monitors, weigh pads or weigh wagons.

[1/] Professor, Dept. of Plant Pathology and [2/] Outreach Program Manager, Dept. of Entomology, Univ. of Wisconsin-Madison

Table 1. Cooperators and locations of Headline strip trials in 2005

Cooperator	County	No. of replications
Mike Bertram,	Wood	5
Bill Halfman	Monroe	3
Paul Kivlin	Polk	3
Paul Kivlin	St. Criox	3
Richard Proost	Dane	2
Richard Proost	Kenosha	2
Richard Proost	Washington	2
Karen Talarczyk	Green	1
Karen Talarczyk	Green	1

Results

There was a statistical yield advantage (P=0.05, Duncan's NMRT) of 1.4 bu/a using Headline (6 oz/a) when compared to the untreated check. The difference in yield ranged form -2.5 bu/a to 6.5 bu/a. The greatest negative response occurred at the Kenosha County location and may have been related to stress caused by low soil moisture. Headline-treated areas were observed to retain a darker green color at several locations.

Table 2. Yield results summarized by location.

Location	Treatment	Avg. yield bu/a	Yield advantage (+) or disadvantage (-) to Headline
Wood County	Headline	47.4	+ 0.6
	Untreated	46.75	
Washington	Headline	44.5	+ 2.0
	Untreated	42.5	
St. Croix	Headline	50.5	+ 1.5
	Untreated	49.0	
Polk	Headline	47.7	+ 3.4
	Untreated	44.3	
Monroe	Headline	65.7	+ 0.6
	Untreated	65.1	
Kenosha	Headline	33.5	- 2.5
	Untreated	36.0	
Green	Headline	67.5	0
	Untreated	67.5	
Green	Headline	72.7	- 1.1
	Untreated	73.8	
Dane	Headline	66.5	+ 6.5
	Untreated	60.0	

Conclusions

The value of foliar applied fungicides, in the absence of soybean rust, has not been resolved.

Current data suggest that there is a 10% probability of an economic return for fungicides applied to soybean at the R1 to R3 growth stages.

The dry climate of 2005 may have lowered the potential for leaf diseases resulting in fewer economic responses to foliar applied fungicides.

Research is needed to determine which diseases are controlled directly, which diseases may be controlled by indirectly by altered growth and development by foliar applied fungicides.

It is critical that soil-borne diseases and insects be controlled in fields targeted for foliar applied fungicides. Soybean cyst nematode and soybean aphids are candidates for compounding causes of stress that could negate the benefits of foliar applied fungicides.

SPIDER MITES: A TO Z

Eileen Cullen [1/]

Populations of the Twospotted spider mite, *Tetranychus urticae* Koch, increase during periods of hot, dry weather and may cause severe soybean crop damage. Major twospotted spider mite outbreaks in the Midwest occurred in 1983 and 1988. The 2005 growing season, with abnormally dry to drought conditions, led to a third outbreak particularly in parts of Illinois, Michigan, and Wisconsin.

Spider mites feed with long, needle-like mouthparts that are inserted into leaf cells. Contents of the individual, living cells are extracted by mites, in contrast to most piercing-sucking insects such as the soybean aphid, which feed on plant sap in the plant vascular tissues. Spider mite feeding results in reduced chlorophyll content of leaves with many small white or yellow spots, called “stippling”. Severe spider mite injury results from a combination of cell and tissue disruption, along with yield reducing water loss and heat stress typical of drought conditions. Data vary from state to state, but yield reductions of 40 to 60% in fields infested with twospotted spider mites during late vegetative and early reproductive soybean growth have been documented (Klubertanz, 1994).

Twospotted spider mite adults are tiny (less then two-tenths of an inch), yellow-green, with eight legs. Adults are named for the dark pigmented spots on either side of their oval bodies. Eggs are round and white to light yellow and are found on soybean leaves along with adults and webbing that may be noticeable on infested leaves. Symptoms of twospotted spider mite feeding are often recognized before pest presence is confirmed. This is attributable to the minute mite size, feeding that occurs primarily on undersides of leaves, and sporadic nature of infestations.

Infestations are commonly first noted at field edges near dirt and gravel roads that kick up dust, desiccating plants further. However, apparently healthy plants within the field can also be affected. Spider mites disperse within and between fields by climbing to the top of a plant and spinning tiny strands of silk that, when caught on breezes, allow the mites to drift to new host plants. Females lay eggs on the underside of leaves. Immatures include one six-legged larval stage and two eight-legged nymphal stages. Twospotted spider mites in northern states such as Wisconsin overwinter as adult females in sheltered field margin areas. Spider mites are known for their ability to reproduce quickly, with several overlapping generations within one growing season. Females can lay hundreds of eggs in a lifetime. Eggs hatch in 2 to 4 days; nymphs develop in 2 to 4 days; and adults can live up to 21 days with better survival in hot, dry environments (Minn. Dept. of Agric., 2005). Depending on temperatures, twospotted spider mite generations are completed in 4 to 14 days with the fastest developmental rates above 91°F (Klubertanz, 1994).

Field monitoring should begin along field margins where infestations are likely to start. Upper, middle and lower canopy leaves should be examined for stippling. Turn soybean leaves over to confirm presence of spider mites with a 10X hand lens. Adults can also be detected by tapping soybean plants over a clipboard onto a white sheet of paper. Dislodged spider mites will be apparent by the dark abdominal spots and can be seen as tiny specks moving on the paper. Before spot treatments are applied, thorough monitoring of the entire field is recommended.

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No specific economic threshold has been developed for twospotted spider mites in soybeans. For soybeans, estimate the percentage of leaf surface damaged by mites (stippling, discoloration). General treatment guidelines (based on percent leaf discoloration) recommend treatment at 10 to 15% leaf discoloration and presence of live mites between bloom (R1) and pod fill (R5) (Gray, 2005; DiFonzo, 2005). Based on experience and data obtained during the 1988 twospotted spider mite outbreak, treatment decision guidelines for the upper Midwest soybean growing region have been well summarized by entomologists at Ohio State University (Table 1).

Table 1**.** Evaluation scheme for twospotted spider mites in soybean**.**
(Based on an article from the late Dr. Hal Willson, originally printed in June 14, 1999, C.O.R.N. Newsletter, and in 2005 OSU C.O.R.N. Newsletter and MSU Field Crop Advisory Team Alert Newletter.)

Presence of mites	Damage	Assessment
Barely detected on undersides of leaves in dry locations or on edges of fields.	Barely detected.	1 - ***Non-economic***
Easily detected on undersides of leaves in dry locations or on edges of fields. Difficult to find on leaves within the field.	Foliage green, but stippling injury detectable on undersides of leaves, although not on every plant.	2 - ***Non-economic,*** but keep monitoring
All plants are infested when examined closely.	All plants in field exhibit varying levels of stippling, even on healthy leaves. Some speckling and discoloration of lower leaves. Field margins and dry areas exhibit severe damage.	3 - ***Rescue treatment*** is warranted, especially if many immatures/ eggs are present.
All plants heavily infested when examined closely.	Discolored and wilted leaves easily found throughout the field. Severe damage evident.	4 - Effective ***rescue treatment*** will save field.
Extremely high numbers.	Field discolored, leaves drying down. Significant foliage and stand loss.	5 - Rescue treatment may not save field. However, new growth may resume if treated.

Treatment may be delayed if cooler temperatures and high humidity are expected. Although rainfall reduces the risk of damaging spider mite populations, thunderstorms alone cannot be relied upon to eliminate spider mite infestations, particularly when rains arrive after establishment of large mite populations and are followed by hot, dry conditions.

In a scouting-based integrated pest management (IPM) program utilizing chemical control for twospotted spider mite and/or soybean aphid, it is important to know which pests are present (one or both) and at what densities. Some products registered for soybean aphid are not expected to control twospotted spider mite. For example, the organophosphates Lorsban 4E (0.5 to 1 pint/acre) and Dimethoate (1 pint/acre) are labeled for spider mite control in soybeans. Therefore, these are the two registered products most often recommended for twospotted spider mite control in the Midwest soybean growing region. The pyrethroid active ingredients lambda-cyhalothrin (Warrior or Silencer at 3.84 oz./acre) and gamma-cyhalothrin (Proaxis at 3.84 oz./acre) are also labeled for spider mites on soybeans, but for suppression only, not control.

Among the synthetic pyrethroids, studies conducted with twospotted spider mites in corn indicate that applications of the active ingredient Permethrin (e.g., Ambush, Pounce) were associated with a significant increase in the population of twospotted spider mites (Ayyappath et al., 1996). Reproductive stimulation (increased egg laying) of pests by sublethal doses of insecticide is known as 'hormoligosis'. This phenomenon has been suggested as one of the factors causing insecticide-induced twospotted spider mite outbreaks associated with Permethrin on corn. The association is related more to residues of these products on corn plants, rather than direct exposure of spider mites to the insecticide (Ayyappath et al., 1997).

If detected early, and drought conditions are not severe, edge or spot treatments may be sufficient to stop the spread of spider mites. Under very dry conditions, mites will usually occur throughout the field and spot treatments are unlikely to prevent the infestation from spreading. Yield expectations in spider-mite treated fields may require adjustment because of droughty conditions associated with outbreaks. In 1988, and again in 2005, some fields in southern and east central Wisconsin required repeat treatments for spider mite control. The rapid recovery of mites after treatment, even with organophosphates labeled for control, significantly adds to the cost and difficulty of controlling this pest (Klubertanz, 1994).

The most effective natural enemy of twospotted spider mites is a fungal pathogen, *Neozygites floridana*, that attacks all stages of mites and is host-specific to spider mites. Infected mites have a waxy or cloudy appearance and mite death occurs within 1 to 3 days of infection. Production of infective spores depends on environmental conditions which must be cooler than 85°F and with at least 90% relative humidity. At least 12 to 24 hours of such conditions are believed necessary for extensive spread of the disease, and spider mite populations may decline rapidly in response to fungal disease activity (Klubertanz, 1994).

Favorable conditions for spider mite outbreaks are infrequent in the upper Midwest soybean growing region. However, familiarity with spider mite identification, injury symptoms, sampling methods, treatment guidelines, chemical control options and expectations, and natural control factors is important when monitoring soybean fields during periods of hot, dry weather.

References

Ayyappath, R., J.F. Witkowski, and L.G. Higley. 1996. Population changes of spider mites (Acari, Tetranychidae) following insecticide applications in corn. Environ. Entomol. 25:933-937.

Ayyappath, R., J.F. Witkowski, and L.G. Higley. 1997. Ovipositional responses of two species of spider mites (Acari, Tetranychidae) to sublethal concentrations of permethrin and methyl parathion on corn. Environ. Entomol. 26: 489-496.

DiFonzo, C. 2005. You might have mites. Field Crop Advisory Team Alert, 20(14): July 28, 2005. Michigan State University, WWW document. URL http://www.ipm.msu.edu/CAT05_fld/FC07-28-05.htm#4

Gray, M. 2005. Twospotted spider mite infestations in soybeans intensify as drought conditions persist. Pest Management and Crop Development Bulletin, 15(4): July 1, 2005. WWW document. URL http://www.ipm.uiuc.edu/bulletin/article.php?issueNumber=15&issueYear=2005&articleNumber=4

Hammond, R., and B. Eisley. 2005. Twospotted spider mites. Crop Observation and Recommendation Network (C.O.R.N.) Newsletter. July 18, 2005 - July 26. WWW document. URL http://corn.osu.edu/index.php?setissueID=93

Klubertanz, T.H. 1994. Twospotted spider mite. p. 92-95. In L.G. Higley and D.J. Boethel (ed.) Handbook of soybean insect pests. Entomol. Soc. Am., Lanham, MD.

Minnesota Department of Agriculture. 2005. Two-spotted spider mite. WWW document. URL http://www.mda.state.mn.us/biocon/plantscape/twospottedspidermite.htm

WISCONSIN BUFFER INITIATIVE: A NEW MODEL FOR NATURAL RESOURCE PROGRAMS

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DEVELOPMENT AND VALIDATION OF THE WISCONSIN PHOSPHORUS INDEX

Laura Ward Good and Larry G. Bundy [1/]

In their national policy guidelines on nutrient management, the USDA-Natural Resources Conservation Service (NRCS, 1999), identified three strategies for managing phosphorus (P) applications to cropland on a field-by-field basis to reduce the risk of resulting surface water contamination. Two of the strategies – limiting applications to agronomic recommendations and limiting applications above specified soil test P threshold levels – rely on soil test P as the sole indicator for guiding manure management decisions. The third NRCS strategy is the use of a comprehensive P loss risk assessment, or P Index.

Development

Phosphorus indices are being developed on a state-by-state basis throughout the United States. The Wisconsin P Index assesses risk by calculating a gross estimate of the P that would be delivered annually in runoff from a field to the closest water body. Separate estimates are made for annual edge-of field loads of dissolved and particulate (sediment-bound) P, as well as for acute (single-runoff-event) P losses from unincorporated manure and fertilizer P applications. The dissolved and sediment-bound P load equations take the form:

Annual runoff/sediment amount x average runoff/sediment P concentration = P load

RUSLE2, the NRCS most current tool for estimating soil erosion, is used to estimate sediment loss and also is part of the procedure for estimating annual non-winter rainfall runoff volumes. Runoff volumes for the winter period (frozen and thawing soil) are estimated using a different procedure, as soil and management factors influence runoff volumes differently during this period. The equations estimating runoff and sediment P concentrations were developed using Wisconsin small plot and simulated rainfall runoff research, as were the single-event factors for unincorporated P applications. Based on research, the proportion of surface-applied manure P at risk of loss in runoff varies by season, with the highest risks of loss in the winter.

To arrive at a total P Index value, the three types of annual edge-of-field P loads are added together, and then multiplied by a factor that represents the proportion of the total annual P load leaving the field that is expected to be delivered to the nearest stream or lake. This delivery factor is based on the average slope and distance of the field-to-stream runoff flow path. More information on the P Index equations and the research base for each can be found at http://wpindex.soils.wisc.edu/.

The information needed to run the P Index is information that is available to producers and crop consultants. For the most part, it is information that is already used routinely in nutrient management or conservation planning:

- Routine soil test reports
- Fertilizer P rate, method, and timing of application.
- Manure type, P rate, method, and timing of application
- Soil series or mapping unit, field slope, slope length, crop and tillage method •Distance and average slope to water from the edge-of-field

A nutrient management planning software program that calculates field-by-field P Index values, SNAP-Plus, can be downloaded for free from http://www.snapplus.net.

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Validation

Currently, 18 cropped fields in Wisconsin have had at least one crop-year of continuous year-round runoff monitoring. These fields are on both private and research farms. The in-field monitoring systems are of two types: automated samplers on H flumes installed by United States Geological Survey (USGS) staff and passive samplers with flow splitters used by University of Wisconsin researchers. Both types are designed to operate during the freezing and thawing conditions of snowmelt events as well as during non-winter runoff events. Runoff volumes, sediment, and dissolved and total P concentrations were measured year-round at every site. The monitored fields vary by crop, tillage, soil test P, soil type, topography, and P applications – all of which are taken into account in the Wisconsin P Index. The monitoring has allowed us to calculate annual P loads for each monitored crop year for each site and compare them to the annual edge-of-field P Index value. The purpose of this comparison is to determine if the P Index is effectively assessing the relative effects of field characteristics and management practices on agricultural P losses.

Annual P Loads (Crop Years 2003 and 2004)

Total P loads ranged from 0.2 to 26.8 lb/acre/year, and were well correlated with P Index values, as shown in the graph below (Figure 1). Annual P loads were not at all related to field soil test P (Figure 2). This is because some of the fields with the highest soil test P had very little runoff and sediment loss and vice versa.

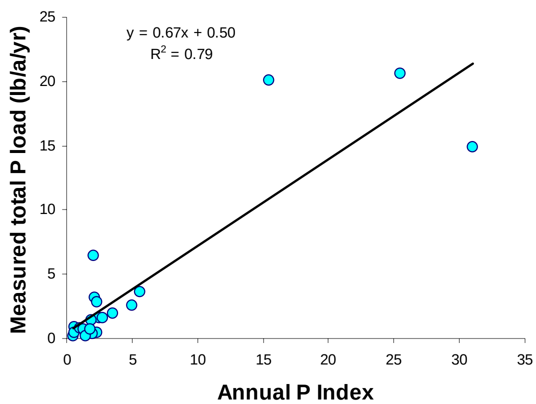

Figure 1. Measured annual total P loads compared to annual edge-of-field P Index values for 18 Wisconsin fields in 2004 and 3 fields in 2003.

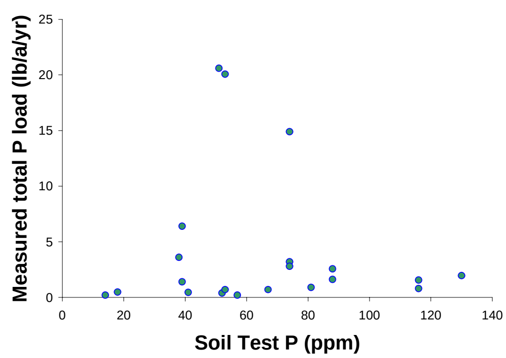

Figure 2. Measured annual total P loads compared to field soil test P values for 18 Wisconsin fields in 2004 and 3 fields in 2003.

A close examination of the monitoring data revealed that the good relationship between P Index values and monitored loads was primarily a result of the P Indexes ability to estimate management effects on sediment-bound P losses. Most of the results (18 fields) shown are from crop year 2004, which was characterized by unusually heavy spring and summer rainfall throughout most of Wisconsin. Sediment loss ranged from 0.03 to 26.8 tons/acre/year, with the highest losses from fields in consecutive years of corn silage. These silage fields also had the highest annual sediment-bound P loads, as shown in Figure 3.

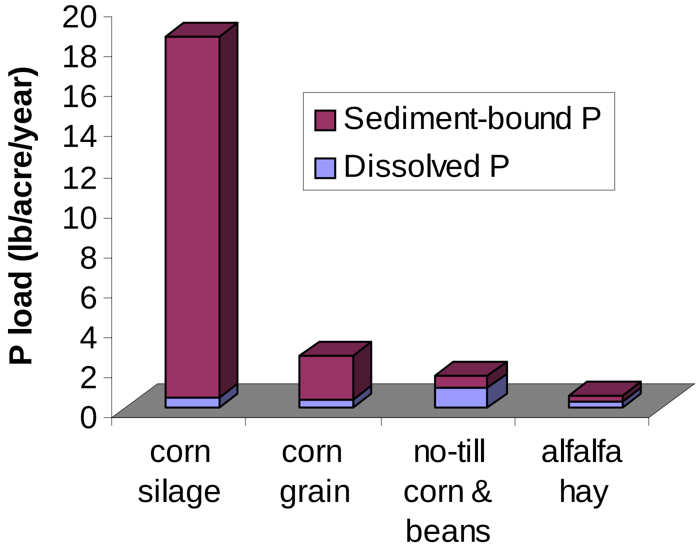

Figure 3. Annual sediment-bound and dissolved P loads by crop and tillage category for 18 Wisconsin fields in 2004 and 3 fields in 2003. Corn silage (tilled), 3 fields; corn grain (tilled) is 1st and second year, 7 fields; no-till corn or soybeans; 5 fields; established alfalfa or alfalfa/grass hay; 6 fields.

Winter Losses (Crop Year 2005)

Crop year 2005 was characterized by an unusually high number of winter-time runoff events and little-to-no spring and summer runoff state-wide. While the lack of non-winter rainfall runoff makes it impossible to use the 2005 crop year data to assess the P Index's ability to evaluate the relative effects of management practices on non-winter P loads, we can compare the winter-time (frozen and thawing soil) P loads to winter P Index values calculated from the P Index components related to runoff from frozen and thawing soil. These are:

- Winter-time runoff dissolved P
- Acute P losses from manure applications to frozen/snow-covered soil.

Adding these two components together produces a winter-time P Index value that is well-correlated with the 2005 winter-time runoff ($r^2 = 0.70$, preliminary data).

Summary

The Wisconsin P Index is a nutrient management planning tool for assessing the risk of P delivery from a given field to the nearest surface water body. On-field runoff monitoring data collected to date indicate that the P Index adequately assesses the relative effects of field conditions and management on P losses in rainfall and snowmelt runoff from crop land. Soil test

P by itself, however, is not a good predictor of field P runoff loads because it does not take into account a field's potential for runoff and erosion.

Acknowledgments

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Reference

Natural Resources Conservation Service (NRCS). 1999. General Manual, 190-GM, Issue 9, Part 402.

THE ABILITY OF WISCONSIN DAIRY FARMERS TO CONFORM TO 590 NUTRIENT MANAGEMENT STANDARDS [1]

J. Mark Powell[2] and Douglas Jackson-Smith[3]

Introduction

Most (approximately two-thirds) of Wisconsin's dairy farms are self-sufficient in grain and forage production, and therefore have more than adequate cropland area for manure spreading (Powell et al., 2002; Saam et al., 2005). Recent studies revealed, however, that many dairy farmers use only a portion (25 to 45%) of their total cropland area for manure spreading (Saam et al., 2005). Manure spreading on Wisconsin dairy farms can be linked to the amount of manure actually collected, and therefore that needs to be land-spread [for example, less manure is collected in the southwest (56% of total annual herd production) than in the south central (72%) or the northeast (68%) regions; Powell et al., 2005]; the presence of manure storage; labor availability and machinery capacity for manure spreading; variations in the manure "spreading window", or days that manure can be spread given regional differences in weather and soil conditions; and distances between where manure is produced and fields where manure can be applied. Although Wisconsin dairy farmers face these and other challenges in manure management, most farmers appear to be adhering already to the 2005 Code 590 Nutrient Management Standard. Information in this Research Brief was gleaned from the "On-Farmers' Ground" project that studied nutrient management practices on 54 representative dairy farms across Wisconsin during the period 2002-2005. Detailed records were kept on the types and amounts of feed, fertilizer and manure used, and legume nitrogen credits available during the period October 2003 to September 2004.

Farm Selection and Characteristics

"On Farmers' Ground" (OFG) farms were selected from a pool of 804 respondents to the 1999 Wisconsin Dairy Farm Survey (Jackson-Smith et al., 2000). "Stratified random sampling" procedures were used to provide an OFG study population of 54 farms that represent the range of farm sizes, livestock densities (cow:cropland ratios) and manure recycling capacities typical of the Wisconsin dairy industry (Saam et al., 2005; Powell et al., 2005). The farms are distributed across the 12 principal dairy counties, major soil types, and watersheds of impaired waterbodies in Wisconsin (Figure 1). The hilly, southwest (SW) is characterized by well-drained silt loam soils; the relatively flat, northeast (NE) region has less permeable clay loam and loam soils; and the undulating south-central (SC) region has landscapes and soils somewhat intermediate to those of the SW and NE. The dairy herd and cropping system characteristics of the OFG farms (Table 1) are similar to the general dairy farm population in these regions (Jackson-Smith et al., 2000). Farmer attrition, incomplete data and other factors provided verifiably reliable nutrient management information on 33 of the original 54 farms.

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Figure 1. Regional, county and watershed location of "On-Farmers' Ground" dairy farms in Wisconsin.

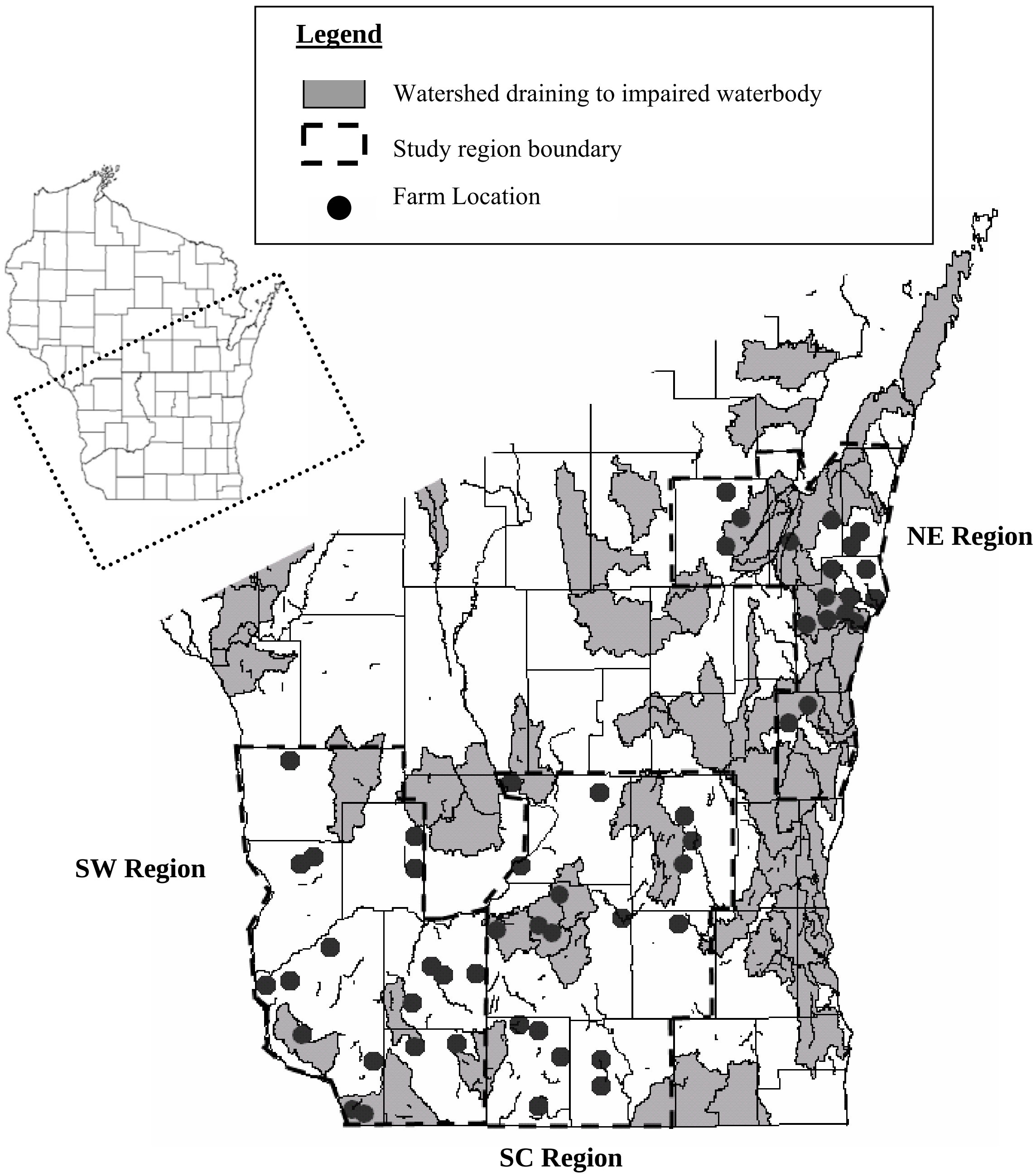

Table 1. Regional dairy herd and cropping characteristics of 54 representative dairy farms in Wisconsin.

	Regions			
Production components	SW (n=18 farms)	SC (n=18 farms)	NE (n=18 farms)	All (n=54 farms)
Herd size	% of n farms			
1 to 49 cows	31	26	16	25
50 to 99 cows	56	53	68	59
100 to 199 cows	0	10	5	6
200+ cows	13	11	11	10
Animal type	number of animals per farm			
Lactating cows	49 (11-270)†	53 (23-480)	52 (32-387)	52 (11-480)
Dry cows	9 (2-50)	10 (0-75)	8 (3-46)	9 (0-75)
Young heifers	14 (0-30)	20 (5-173)	15 (5-145)	15 (0-173)
Mature heifers	20 (0-55)	28 (5-247)	35 (0-245)	28 (0-247)
Land use	acres per farm			
Total operated cropland	161 (37-636) †	223 (94-1094)	203 (74-839)	198 (37-1094)
Corn grain	35 (0-171)	74 (0-342)	30 (0-134)	37 (0-342)
Corn silage	12 (0-267)	27 (0-322)	37 (17-327)	27 (0-327)
Soybeans	0 (0-64)	0 (0-743)	0 (0-131)	0 (0-743)
Alfalfa	54 (10-245)	62 (20-277)	64 (32-270)	62 (10-277)
Small grain	0 (0-32)	0 (0-40)	0 (0-151)	0 (0-151)
Pasture	42 (0-129)	10 (0-186)	3 (0-15)	10 (0-186)

† Median (minimum-maximum). For data sets (e.g., dairy herd size and land use distribution) that do not have a normal distribution, a median is a better measure of central tendency than a mean.

Manure Phosphorus (P) and Nitrogen (N) Application Rates to Cropland

Wisconsin's NRCS 590 Nutrient Management Standard (http://www.datcp.state.wi.us/arm/agriculture/land-water/conservation/nutrient-mngmt/planning.jsp, accessed September 6, 2005) provides the following general guidelines:

- V.A.1.d. Annual P recommendations may be combined into a single application that does not exceed the total P recommendation for the rotation (this high single application not permitted on frozen ground).

- V.A.1.f. Available N from all sources shall not exceed the annual N requirement of non-legume crops….

Phosphorus Applications to Cropland

The amount and source of P applications were tracked on 8,880 cropland acres in 1,070 fields (Table 2). On average, annual available P_2O_5 applications were similar, a rate range of 32 to 37 lb/acre, across all three regions. There was, however, considerable variation in available P_2O_5 application rates. Approximately 80 to 90% of the total surveyed cropland area received available P_2O_5 applications below 50 lb/acre, the annual P_2O_5 replacement level for most field crops, and 95 to 98% of the total cropland received available P_2O_5 application rates below the 2-year replacement level of 100 lb/acre. Of all surveyed cropland acres (8,880), application in excess of 3-year P crop removal

(150 lb/acre) occurred only on approximately 35 acres situated on 2 of the 12 surveyed farms in the NE, on 30 acres on 4 of 12 farms in the SC, and on 50 acres on 5 of 9 farms in the SW. In all regions, approximately 70% of total P_2O_5 applications came from manure and 30% from fertilizer.

Table 2. Available phosphorus applications to cropland on 33 dairy farms in the northeast (NE), south-central (SC) and southwest (SW) regions of Wisconsin (Oct. 03 to Sept. 04).

Parameter	Measurement	Region		
		NE	SC	SW
Operational	Farms (n)	12	12	9
	Fields (n)	293	289	488
	Cropland area that received manure (acres)	3420	3090	2370
Rates of available P_2O_5 applied to cropland (lb/acre)†	Field average (range)	32 (0-310)	34 (0-415)	37 (0-460)
	Application category	% of total cropland area		
	0	30 (12)‡	23 (12)	41 (9)
	1-50	50 (12)	54 (12)	48 (7)
	51-100	15 (12)	17 (11)	8 (8)
	101-150	4 (5)	5 (7)	1 (6)
	>150	1 (2)	1 (4)	2 (5)
Source of total P_2O_5 applications (%)	Manure	70¶ (40-100)	70 (35-100)	70 (27-100)
	Fertilizer	30 (0-58)	30 (0-64)	30 (0-73)

† Assumed manure availability of 60% and fertilizer availability of 100%.
‡ Mean, (number of farms having cropland within application category) in parentheses.
¶ Mean, (minimum – maximum) in parentheses.

Nitrogen Applications to Corn

On the 33 farms, manure was applied to corn (3,345 acres), established alfalfa/hay (3,130 acres), newly established alfalfa/hay (810 acres), soybeans (705 acres), small grains (435 acres), and a few miscellaneous crops. Available N applications to corn varied from 0 to 600 lb/acre across the state and averaged 105 lb/acre in the SC, 165 lb/acre in the NE, and 180 lb/acre in the SW (Table 3). From 55 to 60% of the total corn acreage received between 75 and 225 lb available N/acre. Application in excess of 225 lb available N /acre occurred on 6 of 12 farms comprising 19% of the total corn acreage in the NE; on 3 of 12 farms comprising 5% of the corn acreage in the SC; and on 6 of 9 farms comprising 10% of the total corn acreage in the SW region. In all regions, 28 to 36% of available N applications came from previous legumes, 26 to33% from manure and approximately 40% from fertilizer. Given that total available N applications rates to corn corresponded closely to recommended levels, most dairy farmers appear to be crediting the amount of N provided by previous legumes and manure applications.

Table 3. Available nitrogen applications to corn on 33 dairy farms in the northeast (NE), south-central (SC) and southwest (SW) regions of Wisconsin (Oct. 03 to Sept. 04).

Parameter	Measurement	Region		
		NE	SC	SW
Operational	Farms (n)	12	12	9
	Fields (n)	108	116	132
	Corn area (Acres)	1200	1330	815
Rates of available N applied to cropland (lb/acre)	Field average (range)	165 (0-600)	105 (0-340)	180 (15-600)
	Application category	% total corn acerage		
	0	<1 (1)†	<1 (1)	0 (0)
	1-75	26 (8)	39 (6)	31 (5)
	76-150	33 (10)	41 (12)	45 (7)
	151-225	21 (8)	14 (10)	14 (7)
	>225	19 (6)	5 (3)	10 (6)
Source of available N (%)	Legume credits‡	30¶ (0-90)	28 (0-100)	36 (0-100)
	Manure	28 (0-100)	33 (0-100)	26 (0-100)
	Fertilizer	42 (0-100)	39 (0-100)	38 (0-100)

† Mean, (number of farms having cropland within application category) in parentheses.
‡ Assumed (1) 1st year alfalfa N credits of 120 and 70 lb/acre for medium/fine and sandy textured soils, respectively and 40 lb N/acre for soybeans except no credit on sandy soils ; (2) 1st year manure N availability of 60%; (3) fertilizer N availability of 100%.
¶ Mean, (range) in parentheses.

Timing of Manure N and P Applications

The 590 Standard provides the following general guidelines:

> V.A.2.b.(3). When frozen or snow-covered soils prevent effective incorporation at the time of application and the nutrient application is allowed…..
>
> - …do not apply nutrients within the Surface Water Quality Management Area (SWQMA - The area within 300' and draining to perennial streams and within 1,000' of lakes or ponds), and
> - …do not exceed the P removal of the following growing season's crop when applying manure.

Winter Manure Applications in SWQMA.

On average, most (80 to 90%) of the cropland area operated by Wisconsin dairy farmers is not situated in the SWQMA (Table 4). Some farms in each zone, however, have one-third to one-half of their total operated cropland areas within SWQMA. Of total annual manure applications, only 10 to 25% occurred during winter, most (75 to 95%) applications were outside the SWQMA. Data variability suggests that relatively few farms would have to change current practices to adhere to the 2005 Code 590 Standard. The last OFG interviews (March, 2005) revealed that many farmers who winter-spread manure in SWQMA would be willing and able to change the timing and location of manure application to adhere to 590 Standard. Some, however, would require assistance in managing manure runoff from feedlots and unrestricted livestock access in SWQMA to reduce the risk of impairing water quality.

Table 4. Mean (minimum-maximum) cropland and SWQMA buffer areas, and farmer manure spreading behavior on 33 dairy farms in northeast (NE), south-central (SC) and southwest (SW) Wisconsin.

Parameter	Measurement	Region		
		NE	SC	SW
Operational	Farms (n)	12	12	9
	Total cropland area (acres/farm)	274† (74-670)	245 (91-673)	161 (37-283)
Cropland not within SWQMA	% of total operated cropland	88 (66-100)	80 (52-94)	91 (62-100)
Cropland within SWQMA	% of total operated cropland area	12 (0-34)	20 (6-48)	9 (0-38)
	% of total cropland area in 300' stream buffer	1 (0-5)	7 (0-28)	7 (0-35)
	% of total cropland area in 1000' pond buffer	11 (0-34)	13 (0-48)	2 (0-14)
Winter-spread manure	% of annual manure spreader trips in winter	10 (0-100)	27 (0-100)	25 (0-100)
Winter-spread manure in code 590 buffers	% of total winter-spread cropland not in buffers	93 (69-100)	75 (38-100)	82 (40-100)
	% of total winter-spread cropland within buffers	7 (0-31)	25 (0-62)	18 (0-58)

† Mean, (minimum – maximum) in parentheses

Winter Application of Manure P

Manure applications during the winter (Dec.-Feb) were limited to relatively small cropland areas (Table 5). In the SW, only 8% of total manured area (annual basis) received the manure during winter months, followed by the NE (12%) and the SC (22%) regions. In areas where manure was winter-spread, most application levels did not exceed 50 lb P_2O_5/acre, the approximate P removal of a following growing season's crop. Of the 8,880 acres surveyed, approximately 2.5% (155 acres in the SC region, and 70 acres in the SW) received manure during winter that would have been in excess of annual crop P removal.

Table 5. Manure P_2O_5 applications during winter on 33 dairy farms in the northeast (NE), south-central (SC) and southwest (SW) regions of Wisconsin (Oct. 03 to Sept. 04).

Season	Measurement	Region		
		NE	SC	SW
Operational	Farms (n)	12	12	9
	Cropland area that received manure over year (acres)	3420	3090	2370
	Winter-spread cropland area (acres)	410	675	190
Available manure P_2O_5 applied to cropland during winter (lb/acre)	Application category	% total crop area		
	0	88 (12) †	78 (12)	92 (9)
	1-50	12 (8)	17 (10)	5 (6)
	51-100	0	4 (9)	1 (5)
	101-150	0	0.5 (1)	1 (3)
	>150	0	0.5 (1)	1 (2)

† Mean, (number of farms having cropland within application category) in parentheses.

References

Bundy, L.G., K.A. Kelling, E.E. Schulte, S. Combs, R.P. Wolkowski, and S.J. Sturgul. 1994. Nutrient management practices for Wisconsin corn production and water quality protection. UWEX Pub. A3557. Univ. of Wisconsin-Extension, Madison. WI

Buttel, F.H., D. Jackson-Smith, and S. Moon. 1999. A profile of Wisconsin's dairy industry. Program on Agricultural Technology Studies (PATS), Univ. of Wisconsin-Madison.

Jackson-Smith, D.B., S. Moon, M. Ostrom, and B. Barham. 2000. Farming in Wisconsin at the end of the century: Results of the 1999 Wisconsin farm poll. Research Summary No. 4. Program on Agricultural Technology Studies (PATS). Univ. of Wisconsin-Madison.

Powell, J.M., D.B. Jackson-Smith, and L.D. Satter. 2002. Phosphorus feeding and manure recycling on Wisconsin dairy farms. Nutr. Cycl. in Agroecosyst. 62:277-286.

Powell, J.M., D.F. McCrory, D. B. Jackson-Smith, and H. Saam. 2005. Manure collection and distribution on Wisconsin dairy farms. J. Environ. Qual. 34:2036-2044.

Saam, H., J.M. Powell, D.B. Jackson-Smith, W.L. Bland, and J.L. Posner. 2005. Exploring the use of animal density standards for nutrient management policy on Wisconsin dairy farms. Agric. Syst. 84:343-357.

NUTRIENT MANAGEMENT FOR CROP PRODUCTION AND WATER PROTECTION

Sue Porter [1/]

Hopefully before the end of 2006, the Wisconsin Department of Agriculture, Trade and Consumer Protection's (DATCP) Board will approve a rule related to nutrient management on farms. Current rules are mostly based on nitrogen and can be inconsistently implemented from county to county. This rule would incorporate the September 2005 Natural Resources Conservation Service's 590 nutrient management standard based on nitrogen and phosphorus. DATCP adopted the current rules in 2002 as part of a redesign of state nonpoint pollution abatement programs mandated by the Legislature. DATCP proposes to incorporate the updated federal standard in state nutrient management rules to help prevent manure and phosphorus runoff and improve water quality. This will also to help ensure that manure is applied in a cost-effective and environmentally sound manner. It will also reduce fish kill and well contamination risks. Adopting this rule amendment will fulfill DATCP's nonpoint-rules commitment to keep Wisconsin rules consistent with federal standards.

Cost Sharing

Updating ATCP 50 Wis. Admin. Code will allow state cost sharing to be provided to county land conservation departments, and then to farmers, for implementing the September 2005, 590 nutrient management standard. Under this existing DATCP rule, all farmers who apply manure or commercial fertilizer to cropland (not just livestock operators) must implement a nutrient management plan. This requirement took effect on January 1, 2005 in certain watersheds, and will take effect on January 1, 2008 elsewhere. However, state law makes enforcement contingent on cost sharing for farms not regulated by other means. Enforcement is therefore limited by the availability of cost-share funds and state and local authorities. Farms that must comply regardless of cost-sharing include those holding a pollution discharge elimination system permits from the Department of Natural Resources, farms that claim farmland preservation tax credits, and farms that are required by local ordinances to have permits for manure storage facilities or livestock facilities expansions. Current DATCP cost-share funding levels make it possible to target about 20,000 acres per year starting in late 2006 (less than 1% of Wisconsin's crop acreage). These cost-share funds will be mainly targeted where runoff has caused fish kills or well contamination or at priority farms noted in the county's *Land and Water Resource Management Plan*.

Counties have *Land and Water Resource Management Plan* to promote compliance with farm conservation requirements (see s. ATCP 50.12). Counties will seek voluntary compliance and will offer information, cost-sharing and technical assistance to help landowners comply. As a last resort, a county may seek enforcement action against a landowner who refuses to implement required conservation practices. A county may not seek enforcement action until it complies with applicable cost-sharing requirements under s. ATCP 50.08. A county may pursue any of the following enforcement options, as appropriate:

- The county may suspend a violator's eligibility for farmland preservation tax credits (see s. ATCP 50.16(6)).
- DNR may issue a notice of discharge, requiring a violator to obtain a pollution discharge permit from DNR (see ch. NR 243).
- The department of justice or a district attorney may file a civil forfeiture action against the violator (see s. 281.98, Stats. that authorizes penalties not less than $10 nor more than $5,000 for each violation).

[1/] Nutrient Management Specialist; Wis. Department of Agriculture, Trade and Consumer Protection, PO Box 8911, Madison, WI, 53708-8911.

- The county, town, city, or village may take action to enforce its own ordinance, if any.
- County compliance procedures should be consistent with ss. ATCP 50 and ss. NR 151.09 and 151.095. A county should spell out compliance procedures in its land and water resource management plan, as provided in s. ATCP 50.12(2). The DATCP and DNR will work with counties to develop suggested guidelines for county compliance programs.

Nutrient Management Planning Requirements

A nutrient management plan must be prepared or approved by a qualified nutrient management planner. A farmer may prepare his or her own plan if the farmer has completed a DATCP-approved training course within the preceding 4 years, or is otherwise qualified under current rules. A nutrient management plan must identify the lands on which the operator will apply manure and other nutrients. It must be based on soil tests that determine the nutrient needs of the affected cropland. A soil test laboratory, certified by DATCP, must conduct the soil tests. A nutrient management plan must comply with the NRCS 590 nutrient management standard. The draft rule also incorporates requirements for manure nutrient values in a nutrient management plan to be based on either standard "book values" in WI Conservation Planning Tech Note WI-1, or manure analysis conducted at a laboratory that participates in the Manure Analysis Proficiency (MAP) program.

Changes to 590 - DATCP and NRCS held joint public hearings on the NRCS nutrient management standard that is incorporated in this rule. Some of the changes to the standard are:

- Allowed phosphorus calculations over a maximum 8-year, rather than 4-year, crop rotation to better reflects the length of a typical dairy rotation when manure is applied during the rotation. The federal requirements to assess P using the PI or soil test P levels are incorporated into the Wisconsin 590 standard to allow producers more flexibility than either single method. The Wisconsin P Index is based on results from P research and is a tool to rank fields on their potential to deliver phosphorus to surface water bodies. The PI is available on the web as part of the SNAP-Plus nutrient management, get this software from ***http://www.snapplus.net*** .
- The conservation plan must address cropping practices that control sheet and rill erosion to tolerable levels (T) and provides treatment of ephemeral soil erosion. Sheet and rill soil erosion calculations shall be based on current NRCS erosion prediction technology or the soil loss assessment calculated using the Wisconsin Phosphorus Index model. If you do not use the Wisconsin Phosphorus Index model to determine sheet and rill soil erosion rates, contact your local conservation department for assistance in developing a current conservation plan.
- Manure applications to frozen or snow-covered land must comply with supplementary local restrictions, if any, spelled out in an individual farm conservation plan agreed upon between the farmer and the county land conservation committee.
- Clarified provisions related to wells and winter manure applications near lakes and streams. Exempted manure deposited by grazing animals.
- Restrictions on liquid manure applications near lakes and streams.

References

USDA Natural Resources Conservation Service. 2005. Nutrient Management Code 590 Conservation Practice Standard, NRCS, WI September 2005.

Wis. Department of Agriculture, Trade and Consumer Protection. ATCP 50 Wis. Admin. Code 2002 and Proposed Final Draft ATCP 50 Wis. Admin. Code, October 24, 2005.

NMP vs. CNMP and Third Party Vendors

Fertilizer, Aglime and Pest Management Conference

January 18, 2006

NMP vs. CNMP

- NMP (Nutrient Management Plan): A conservation practice developed based on the NRCS 590 Nutrient Management Practice Standard.
  - Managing the amount, source, placement, form and timing of the application of nutrients and soil amendments.
  - NRCS requires a professional agronomy certification or completion of NRCS recognized training and education or experience as the minimum qualifications to develop a 590 plan.

NMP vs. CNMP

- CNMP (Comprehensive Nutrient Management Plan): A conservation plan that is unique to livestock operations which identifies resource concerns and conservation planning alternatives.
  - Developed based on the policy guidance located in the NRCS National Planning Procedures Handbook (NPPH) Part 600.5

NMP vs. CNMP

- A CNMP Must Address
  - Manure and Wastewater Handling and Storage
  - Land Treatment Practices
  - Nutrient Management
  - Record Keeping
- A CNMP May Also Address
  - Feed Management
  - Other Utilization Activities

NMP vs. CNMP

- CNMP Certification - To certify a CNMP for cost sharing purposes an individual must possess **ONE** of the following:
  - CNMP Plan Approval: possess NRCS recognized certification as a conservation planner and completion of approved training in the development of a CNMP.
  - CNMP Plan Development – Total Plan: possess a Professional Engineering License and completion of approved training in the development of a CNMP.

CNMP Component Certifications

- Manure and Wastewater Handling and Storage
  - Requires a Professional Engineering License or Engineering Job Approval for public sector employees
  - CNMP Plan Development Training/Proficiency
- Land Treatment
  - CNMP Plan Development Training/Proficiency
- Feed Management
  - Credentials as a Livestock Feed Management Professional
  - CNMP Plan Development Training/Proficiency

CNMP Certification

UWEX has submitted the WI training for TechReg certification. Approval would allow participants to certify for:

- CNMP Plan Development – Land Treatment
- CNMP Plan Development – Manure and Waste Water Handling and Storage (engineering license required)
- CNMP Plan Development – Nutrient Management
- CNMP Total Plan Development (engineering license required)

CNMP Certification

UWEX has submitted the WI training for TechReg certification. Approval would **NOT** allow participants to certify for:

- CNMP Plan Approval (requires completion of Conservation Planning NRCS Training Modules 1-9 (WI UWEX Conservation Planning training will be submitted for separate TechReg approval by 02/06).
- CNMP Plan Development – Feed Management (a separate training will likely be developed in cooperation with WI UWEX).

CNMP Certification

- A listing of "Recognized" Private Sector CNMP Planners has been posted on the Wisconsin NRCS website (http://www.wi.nrcs.usda.gov/technical/private_cnmp.html)
  - Listed planners are eligible to complete CNMP's for EQIP cost sharing
  - Planners that have completed the training but are not listed need to follow up with me to verify training records

CNMP, NMP Third Party Vendors

- NRCS has been challenged to implement a "voluntary" CNMP process to assist livestock producers to comply with environmental regulations.
  - Must carry out without additional staff
  - Most effective to include professionals already utilized by the livestock producer
  - Use financial incentives to producer or Technical Service Provider funding to implement

FY-05 CNMP Accomplishments

- Wisconsin NRCS reported a total of 163 CNMP's written in FY-05
  - 74 required for EQIP funded manure storage
  - 16 written by Discovery Farms on members farms
  - 30 completed by private contractor
  - 46 other local planning activities

CNMP Cost Sharing

- FY-2006 Local Work Group (Field Office) based CNMP-CLFP sign up is underway through 12/30/05.
  - Highest ranked applications will be selected for contract development.
  - DC's are being encouraged to share the list of TechReg and WI NRCS "Recognized" CNMP planners with potential CNMP-CLFP applicants.

FY-06 CNMP Cost Sharing

- Development of CNMP-CLFP: 70% of actual cost not to exceed $10,000
  – Cost to develop 590 nutrient management plan portion of the plan is not eligible for calculating the 70% cost sharing payment.
- $2000 flat rate payment to participant upon completion of the CNMP-CLFP to cover record keeping and time spent to develop the plan.
  – CNMP-CLFP not eligible for TSP TA payment

Private Sector Role

- NRCS' goal is to stimulate private sector participation in the CNMP planning process.
  – NRCS employees cannot participate in the development of CNMP's that are funded through the EQIP incentive payment.
  – NRCS is relying on private sector planners to help explain the benefits of a CNMP to livestock producers.

Contact Information

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Technical Service Provider Update

Fertilizer, Aglime and Pest Management Conference

January 18, 2006

TSP Funding Issues

- TSP funds are annually allocated to the NRCS state offices.
- Cost sharing contracts include a "place holder" to document participants selection of a TSP.
- TSP funds are not available for payment until they are released to the NRCS state office and the individual contract has been modified to add the annual TSP funds.

TSP Funding Issues

- Wisconsin NRCS' initial FY-06 budget allocation has a 70% reduction in TSP TA funds.
- Priority for use of limited TSP TA funds will be existing contracts where TSP funds were requested at the time the contract was written.
- May not be enough TSP TA dollars to fund all existing contract items.

TSP Funding Issues

- Current proposal is to assign highest priority to contracts that have not received a TSP payment in prior years.
- FY-06 TSP TA calculations will be based on the NTE rate in effect at the time that payment is requested.
- Revised FY-06 TSP NTE rates are anticipated by January 2006.

TSP Funding Issues

- WI NRCS has moved to raise EQIP FA cost sharing rates to include TSP costs.
  - EQIP FA funds are locked into the contract at the time the contract is approved.
  - TSP TA funds are annually appropriated and are not guaranteed.
  - **Need to discuss payment arrangements with EQIP participants prior to completing work.**

CNMP Cost Sharing

- For EQIP purposes the Comprehensive Nutrient Management Plan (CNMP) practice name has been changed to CNMP – Comprehensive Livestock Farm Plan (CNMP-CLFP).
  - Name changed to de-emphasize "nutrient management" (more than just 590)
  - NRCS national CNMP policy still controls plan content and planner certification requirements

FY-06 EQIP Cost Sharing

- 590 Nutrient Management Plan Development
  - Livestock producers are only eligible for 590 if done as a part of a CNMP-CLFP. 590 must be included as a separate cost sharing contract item to earn a cost sharing FA payment for 590 plan development and updates.
  - 590 Nutrient Management is not eligible for an additional TSP payment in FY-06. The flat rate cost sharing payment was raised.

FY-06 Cost Sharing

- 592 Feed Management
  - Livestock producers are only eligible for 592 if done as a part of a CNMP-CLFP. 592 must be included as a separate cost sharing contract item to earn a FA cost sharing payment for 592 plan updates.
  - 592 Feed Management is **NOT** eligible for an additional TSP payment in FY-06.
  - Cost to develop a 592 plan can be included in the calculation of the CNMP-CLFP 70% cost sharing payment.
  - 590 Nutrient Management is required as a supporting practice.

FY-05 Cost Sharing

- TSP TA funding is not authorized to pay for the development of a CNMP-CLFP, a 590 Nutrient Management Plan or a 592 Feed Management Plan in EQIP contracts written in FY-2005.
  - The cost to develop the 590 and 592 plans are an eligible expense for calculating the 70% cost sharing payment.
  - Costs for updating the 590 and 592 plans are only cost sharable using FA if these practices were included in the contact as individual cost sharable items.

TA Payments

- 590 and 592 practices that were contained in FY-05 and earlier contract and **NOT** associated with a CNMP-CLFP are eligible to continue to earn both TA and FA payments where the EQIP participant requested TSP TA funds at the time the contact was developed.

TA Payments

- FY-05 and prior year contracts will be modified as funds allow to add TSP TA to contracts where the EQIP participant requested TSP TA funds at the time the contact was developed.
  - FY-06 TSP TA contract modifications for 590 and 592 will be based on the 911 practice design TSP component ONLY (CNMP-CLFP is not eligible for TSP TA).
  - FY-06 TSP TA contract modifications for practices other than 590 and 592 the use of 911, (design) 912 (layout) and 913 (checkout) will continue to be entered.

CNMP-CLFP Issues

- Review EQIP contract with participant to determine cost sharing funds available for CNMP-CLFP development.
  - Not all contracts have additional 590/592 funds as a separate contract item.
  - Discuss estimated cost for development of the CNMP-CLFP.
  - Discuss payment arrangements prior to beginning work on the plan.

Contact Information

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United States Department of Agriculture
Natural Resources Conservation Service

Conservation Security Program

A new way to think of conservation

United States Department of Agriculture
Natural Resources Conservation Service

Conservation Security Program

A new way to think of conservation

- Rewards farmers practicing good conservation
  – Other programs used to fix problems
- Incentives to improve further
- Concentrates on working lands
- Voluntary program authorized in 2002 Farm Bill

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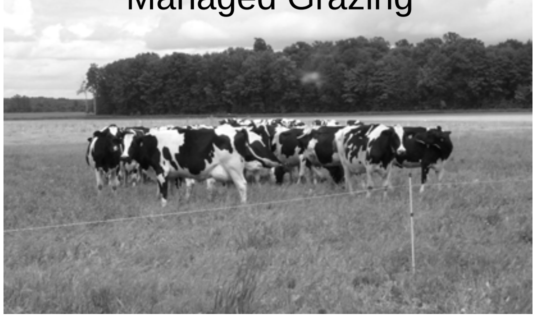
Managed Grazing



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Residue Management: No-till

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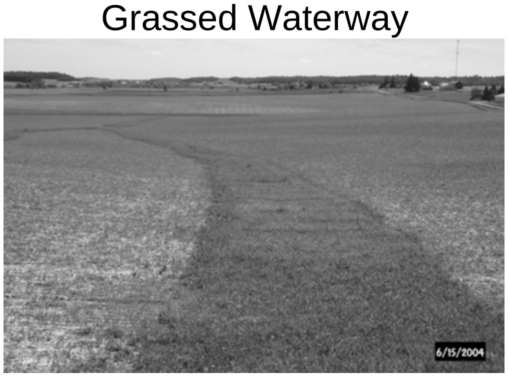
Grassed Waterway



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2004 Summary

- 18 pilot watersheds in 22 states
  – $41.4 M in funding (TA=15%)
- Lower Chippewa and Kishwaukee in WI
  – 219 contracts
  – Over $2 M in payments
- Fast-tracked
  – Sign-up in July, payments in September

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Natural Resources Conservation Service

Lower Chippewa River

United States Department of Agriculture
Natural Resources Conservation Service

Nationwide in 2005

- No longer a pilot program
  - In all 50 states, $202 M
- 202 new watersheds plus 18 prior year
- More time to prepare, sign-up, and process
- Program tweaks and improvements

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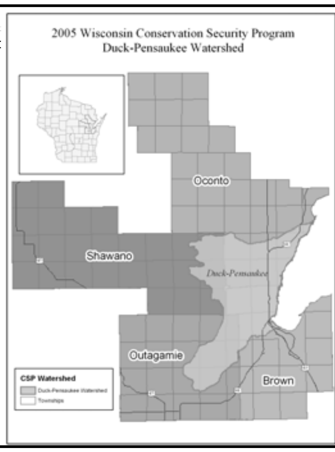

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2005 WI CSP Outcomes

- 273 Contracts
  - 179 Tier I, 62 Tier II, 32 Tier III
- 84,800 acres
  - 11% to 17% of watershed ag. land
- $7233 average payment in 2005
- $1.94 M statewide (plus payments on 2004 contracts)

United States Department of Agriculture
Natural Resources Conservation Service

CSP: Application Process

Eligibility Requirements

- Privately owned or Tribal lands
- Majority of operation within CSP watershed
- In compliance with HEL/wetland provisions
- Own or rent land
- Applicant shares risk and is entitled to share of crops/livestock

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Defining the CSP Operation

- Applicant defines the operation
  - – Can be owned or rented but applicant needs to control for length of contract
  - – Only one contract per applicant
- Change in ownership or loss of rented land
  - – Request a modification, a transfer or withdraw
  - – Only refund NRCS when practices paid for but not yet in place

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CSP: Application Process

Eligibility Requirements, cont'd

- – Eligible lands include
  - Cropland, orchards, vineyards, pasture
- – Lands that are not eligible include
  - Land in the Conservation Reserve Program, Wetlands Reserve Program, or Grasslands Reserve Program cannot receive stewardship payments
  - Recently converted cropland
  - Forest land

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CSP: Application Process

- Key practices for eligibility (already in place)
  - – **Nutrient management and pest management**
  - – **Maintaining or improving soil condition**
    - **Residue management, cover crops, etc.**
  - – **Minimum requirements for pasture condition**
  - - **Requirements vary with soil, slope, crop, etc.**

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Conservation Security Program

- **Tier Structure**
- **Payment Components**

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Conservation Security Program

Tier Structure

Tier	Resources Treated	Scope	Contract
Tier 1	Water & soil quality	Part of operation	5 years
Tier 2	Water & soil quality	Entire operation	5 to 10 years
Plus: Agree to address one add'l resource concern			
Tier 3	All resources	Entire operation	5 to 10 years
Plus: Agree to additional activities			

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CSP: Four Payment Components

• An annual stewardship payment for the benchmark (existing) conservation treatment.

• An annual existing practice payment for maintaining conservation practices.

• An enhancement component for exceptional and innovative conservation effort.

•One-time new practice component for additional practices

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CSP: Enhancement Components

Enhancement examples:

- Wildlife Habitat (general or declining species)
- Soil Conditioning Index (from RUSLE2)
- Energy audit, renewable energy
- Irrigation efficiency
- Organic pest management

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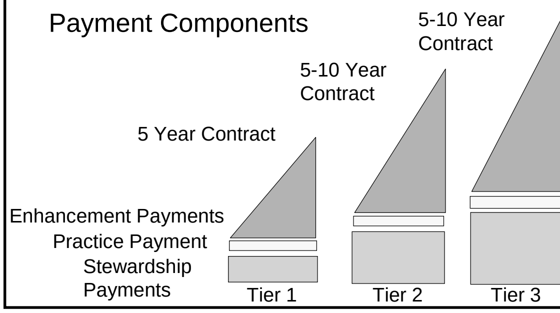
Conservation Security Program

Payment Components



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"We've always been conservation minded because the soil is so important to us. The soil is our strength, as our sign says."

Nancy Kavazanjian, Dodge County CSP Participant

Greg and Judie Sage Farm

U.S. Department of Agriculture
NRCS Natural Resources Conservation Service

"Conservation has been the premise of our farm. With CSP, we're happy to be rewarded for our practices."

Greg Sage, Buffalo County CSP Participant

Prissel Valley Farm

U.S. Department of Agriculture
NRCS Natural Resources Conservation Service

"I guess that's really what I like about CSP because I'm just doing things the way I've done them and it happens to fit CSP. So like I say it is a good reward for conservation things we've had in place on the farm."

Brian Prissel, Pepin County CSP Participant

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CSP in 2006

- Wisconsin Watersheds
  - Grant-Little Maquoketa
    - Shared with Iowa
    - 714,000 acres, 80% in farms
  - Lake Dubay
    - 1.2 M acres, 39% in farms
- Expect a winter sign-up period

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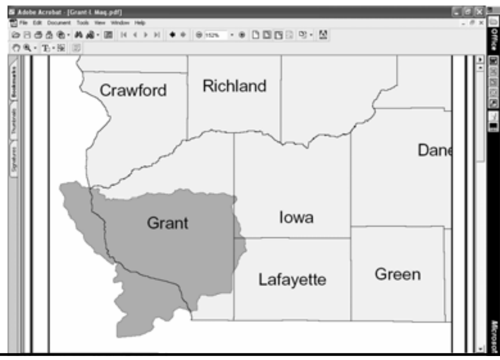
Grant-Little Maquoketa River



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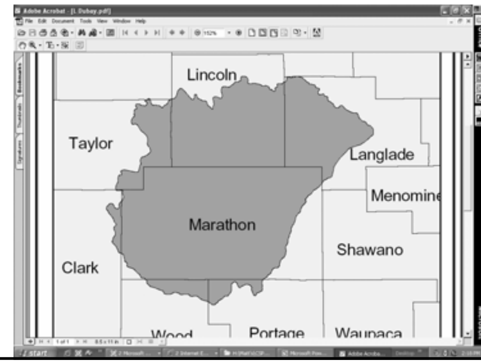
Lake Dubay



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Getting Farmers Ready for CSP

- What can farmers do to prepare?
  - Implement or update nutrient and pest management plans
    - Keep good records
  - Update conservation plans
    - Waterways in place
    - Riparian areas treated
    - Positive Soil Conditioning Index (SCI)

United States Department of Agriculture
Natural Resources Conservation Service

Thank you!

- Questions or comments?
- For more information, visit the WI NRCS website:
  - http://www.wi.nrcs.usda.gov/programs/csp.html

FERTILIZER RULE UPDATE: ATCP 40

Lorett Jellings [1/]

{This page provided for note taking}

[1/] Wis. Department of Agriculture, Trade and Consumer Protection, Madison, WI.

MANAGING YOUR ENERGY USAGE

Bill Johnson [1/]

The price of natural gas, electricity and crude oil have undergone a period of volatility since 2000 with the expectation that increased energy costs will remain in our near term future. While it is difficult to accurately predict prices and price ceilings, there are strong indicators that domestic and worldwide demand will continue to increase in 2006. During 2005 the supply side of the energy equation experienced hurricane induced infrastructure disruptions, substantially limiting domestic natural gas and crude oil supplies, while rail disruptions limited coal delivery from the Wyoming Powder River Basin to electrical generation facilities.

While there is little individuals can do to significantly effect energy supply, collectively, consumers can reduce energy consumption thereby reducing demand on energy resources and help manage energy costs. While some businesses have seen significant reductions in energy use through utilization of energy conservation and energy efficient technologies, many of have still experienced energy costs above previous year levels. Beyond the reduction in use of energy, consumers have additional options that can assist them manage energy costs. Utilities have electric and natural gas rate structures designed to encourage customers to use energy during periods of higher energy supply and reduced energy production costs. Understanding the advantages and limitations of utility rate structures is important in managing any business.

Selection of appropriate energy efficient technologies, use of alternative energy resources, equipment maintenance, energy management systems and application of utility rate structures should all be considered when trying to reduce the impact of energy costs on a business enterprise. There are utility, state and USDA programs available to assist in the selection and financing of alternative energy and energy efficient equipment for agricultural businesses. The location, quantity and nature of a businesses energy usage will determine which utility rates are available to the business and whether the business is eligible for utility, state or USDA financing.

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NPK WORLD DEMAND AND MARKET OUTLOOK

Mike Rahm [1/]

{This page provided for note taking}

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CORN AND SOYBEAN SITUATION

T. Randall Fortenbery [1/]

Corn and soybean markets experienced significant volatility in the 2004/2005 marketing year. The combinations of drought, low river levels, export disruptions from hurricane Katrina, and better than expected yields all contributed to the volatility. As one might expect, the most attractive prices for both old crop and new crop occurred in the summer months when producers were most concerned with poor yields, and then fell quickly as the export pace was disrupted and actual yields came in well above initial expectations. Thus, while prices were quite attractive early in the production season, most producers were reluctant to market new crop grain, and ended up facing low prices and abnormally weak basis levels at harvest. Problems were compounded by a large carryover from 2004, resulting in significant strains on storage facilities and forced use of non-conventional storage strategies.

On the positive side, current USDA projections suggest another year of record corn demand. Feed usage for 2005/2006 is projected to be below year ago levels, but this is offset by a substantial increase in seed and industrial use. Ethanol use is expected to continue to increase, exceeding last year's corn contribution to ethanol production by 19 percent. With passage of the US Energy Bill in summer 2005, annual increases in corn used for ethanol will likely be sustained for at least the next 5 years.

Corn exports are also projected to exceed last year's level, and total 1.9 billion bushels. As of late December 2005 exports were on pace to match or exceed that level. In addition, USDA is expecting reduced export activity from South Africa, Argentina, and China this marketing year.

Wisconsin producers who were able to store their 2005 crop and collect the Loan Deficiency Payment (LDP) at harvest (harvest LDP's averaged about 40 cents per bushel in Wisconsin) have already enjoyed some significant price improvement. However, there are large challenges ahead. Current USDA projections for the 2006 carry-over are in excess of 2.4 billion bushels, several hundred million more than 2005 carryover. If this is realized, significant improvement in new crop corn prices for fall 2006 will be difficult to sustain without another significant weather scare during the production season. As of late December 2005, December 2006 corn futures were trading at about $2.45 per bushel. With anything close to a 2006 10 billion bushel crop and the current 2006 carryout projection, this price will not hold through the 2006 harvest season. USDA is projecting the average US farm price for corn in 2005/06 to be about $1.80 per bushel. This compares to an average US price of $2.06 last marketing year.

Domestic demand for soybeans is expected to also be robust this year, but slightly less than 2005/2004. Crush is expected to consume about 1.7 billion bushels, an increase of almost 1.5 percent. However, both exports and seed and residual are expected to be below year ago levels.

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The USDA (December 2005 estimate) is projecting an average US soybean price for 2005/2006 about $5.35 per bushel. This is a reduction of almost 40 cents per bushel over 2004/2005, and slightly below Wisconsin average cash prices that existed in late December 2005. One key to price activity in early 2006 months will be crop progress in Brazil and Argentina. While current projections are for increased production relative to year ago levels, actual production in each of the last two years has fallen well short of early projections. Both basis levels and futures prices suggest profitable soybean storage for Wisconsin producers in 2005/2006, but, as is usually the case, the risks associated with soybean storage are much higher than corn storage. If South American weather is favorable in the January/February period, soybean prices will have little upside. However, if, as has happened the last couple of years, early South American soybean projections prove overly optimistic, significant price improvement is possible.

ENERGY CONSERVATION FOR FARM COOPERATIVES

Scott Sanford [1]

There are many things that can be done to reduce electrical and gas costs at farm cooperatives. They can be as simple and low cost as changing a light bulb or may require upgrading or replacing a grain dryer to reduce energy costs by thousands of dollars per year. The annual operating cost needs to be calculated for each energy-saving option under consideration because a lower initial cost is seldom an indication of annual cost of ownership and operation. The paper briefly looks at lighting technologies, space heating, grain drying, grain handling and electric motors in terms of energy efficiency.

Lighting

There have been many new advances in lighting technologies in recent years. Compact fluorescent lamps (CFL), T-8 linear Fluorescent lamps and Pulse-Start Metal Halide lamps are a few of those technologies.

Compact fluorescent lamps have existed for many years but recent advances have solved many of the issues of earlier versions. They are design to be a direct replacement for incandescent bulbs, providing the same illumination while using only 25% of the electricity. The expected life of a CFL is also considerably longer, lasting 6,000 to 10,000 hours versus an average of 750 to 1000 hours for the typical 100 watt incandescent bulb. This results in lower maintenance costs. Fluorescent lamps are know for not working well in cold temperatures but CFL have been engineered to work down as low as - 20°F. They do require a few minute to warm up in cold weather but once warm will provide almost full rated output. If used in moist, corrosive or dusty environments, the lamps should be housed in a protective sealed fixture. When purchasing compact fluorescent lamps for use in enclosed fixtures, look for a rating on the packaging that the lamps are design for use in enclosed fixtures or purchase lamps with 10,000 hour life ratings for best results. If a CFL in an enclosed fixture starts to flicker, that's an indication the ballasted has overheated.

T-12 linear fluorescent lamps (1-1/2" in diameter) have been used widely for many years because of their higher efficiency than incandescent lamps but are now being replaced by the newer T-8 linear fluorescent lamps (1" diameter). T-8 lamps are 20% more energy efficiency than T-12 lamps and last 65% longer, lowering operating and maintenance costs. They use electronic ballasts (versus electromagnetic ballast) which allow the lamps to work at temperatures down to 0°F with no flickering which is a fault of T-12 lamps. There is a high output (HO) T-8 version that will work down to -20°F which makes them suitable for cold areas where an instant on light is needed. The T-12 and T-8 lamps are the same length and use the same sockets so an existing fixture (provided it is in good condition) can be retrofitted by replacing the ballast and lamps. Manufacturers have introduced 48-inch 6-lamp sealed fixtures that can be used in damp, dusty condition that are intended to replace metal halide lamps. T-8 fluorescent lamps are about 35% more energy efficient than metal halide lamps and provide about the same lamp life.

Mercury vapor, metal halide and high pressure sodium lamps are all in a class of lamps called high intensity discharge (HID) lamps. Mercury vapor lamps are the least energy efficiency of the three types and have high lumen depreciation, losing half of their light output every 5 years. They never really burn out, just fade away. For outdoor or indoor lighting with high ceiling

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heights (greater than 12 feet) high pressure sodium (HPS) lamps are recommended. These high efficiency lamps emit a yellow / orange light and are 150% more efficient than a mercury vapor lamp. A mercury vapor would require 2.5 watts to produce the same amount of light as 1 watt would produce in a HPS lamp. If color recognition is require, then pulse-start metal halide lamps would be recommended as it emits a white light and has a high color rendering index (the ability of humans to perceive colors under different lights compared to sun light – 100% equals sunlight). Pulse-start metal halide lamps are a newer version of a metal halide lamp that starts faster, is about 10% more efficient, has 50% longer life and less lamp depreciation (loss of light output as the lamp ages). Lamp types and ballasts can not be mixed therefore changing a lamp type will require changing the entire fixture.

Table 1 lists the lamp types use in agricultural in order of energy efficiency as determined by the light output, measured in lumens, divided by the energy input, measured in watts (lumens/watt). Other information in the table includes average lamp life, color of light emitted, Color Rendering Index (CRI) which is a measure of how well humans can perceive colors illuminated by a particular lamp type, Correlated Color Temperature index (CCT) which is a description of the color appearance in degrees Kelvin, minimum starting temperature, and whether the lamp proves light instantly or requires a warm-up period. The table should be helpful in selecting new or replacement lamps.

Table 1: Comparison of lamp types (Data adapted from manufacturer's literature)

Lamp type	Lumens/watt @mean lumens	Average life (hr)	Color	CRI	CCT (K)	Starting temp. (F)	Instant on
Incandescent	7-20	1000	White	100	2800	> -40°F	Yes
Halogen	12-21	2-6000	White	100	3000	> -40°F	Yes
Mercury Vapor	26-39	24,000	Blue-Green	15-50	3800-5700	-22°F	No
Compact Fluorescent	45-55	6000 to 10,000	White	82	2700	32°F or 0°F	Yes *
Metal Halide	41-79	10,000 - 20,000	White	65-70	3000-4300	-22°F	No
Pulse Start Metal Halide	60-74	15,000 - 30,000	White	62-75	3200-4000	-40°F	No
T-12 Fluorescent	62-80	9000 to 12,000	White	52-90	3000-5000	50°F	Yes
T-12 High Output Fluorescent	30-70	9000 to 12,000	White	52-90	3000-5000	-20°F	Yes
T-8 High Output Fluorescent	81	18,000	white	75	3000-5000	-20°F	Yes
High Pressure Sodium	66-97	24,000	Yellow-orange	22 - 70	1900-2100	-40°F	No
T-8 Fluorescent	76-100	15,000 - 20,000	white	60-86	3000-5000	50°F or 0°F	Yes

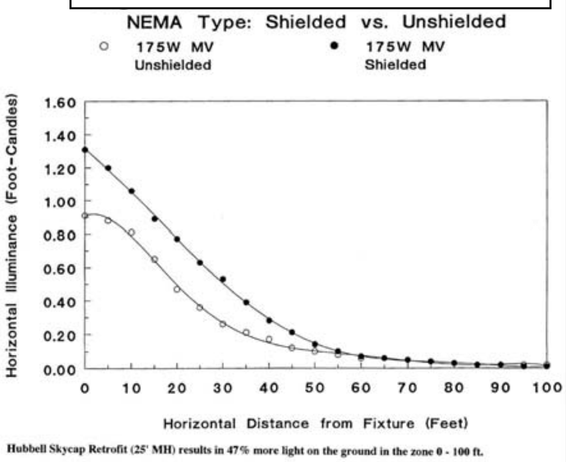
* Requires warm-up to reach full output

Outdoor Lighting

The old standby lamp for outdoor lighting is a 175-watt mercury vapor lamp in a fixture that is designed to be mounted on a pole and is often called a pole or yard light. It has a diffuser/refractor that allows the light to be emitted in almost all directions. About 30% of the will travel above horizontal and is lost to the sky. A full cut-off reflector can be fitted to most yard light fixture to reflect the light to the ground were it is desired. Figure 1 is a graph of the light levels at the ground for a 175 watt mercury vapor lamp. The difference in light level between the curves represents 47% more light at the ground. If the 175 watt lamp provided adequate light without the full cut-off reflector, then a 70 watt or 100 watt high pressure sodium light with a full cut-off reflector will provide more light at about half the cost. The full cut-off reflectors can be retrofitted to most existing fixture for $30 to $45 depending on brand. There are three manufacturers of the full cut-off reflectors to fit yard lights, General Electric – Sky Guard, Hubbell – SkyCap and RAB Manufacturing – Down Blaster.

Photo 1 – Full Cut-off Reflector

Figure 1 – Shielded light distribution



Is Lighting Needed All Night?

If not, lights can be controlled with clock timers or for yard lights there is a "Half-Night" photo sensor available that measures the night length daily and turns the light off the second half of the night saving half the electrical cost. Half-night photo sensor is manufactured by Thomas and Betts Corp (DPN124 2.6) and can be ordered through electrical equipment suppliers.

Outdoor lighting is often installed for "security" reasons but if ***no one is watching the hen house*** is there really security? However, if a photo/motion sensor is used to control lighting and the light turns on, it is more likely to be noticed or to discourage intruders than if the light is on continuously. Multiple motion sensors and lights can be installed to cover large areas if needed.

Lamp Disposal

All of the lighting technologies available today contain some amount of mercury vapor except for incandescent and halogen bulbs. This includes compact fluorescent lamps (CFL), linear fluorescent lamps (all types), mercury vapor, metal halide, high pressure sodium lamps and low pressure sodium lamps. Wisconsin state law requires all businesses to recycle mercury containing lamps or to dispose of them as hazardous waste. Companies that do not recycle their waste lamps may be considered hazardous waste generators and subject to hazardous waste rules. Recycling is much cheaper and helps in protecting our environment. Companies that recycle lamps recover the mercury, smelt the metals and recycle the glass resulting in a win-win situation. Some lamps are TCLP (toxicity characteristic leaching procedure) compliant which means they contain lower amounts of mercury but they still contain mercury and should be recycled.

Space Heating

Since 1992, manufacturers of furnaces have had to manufacture furnaces with minimum Annual Fuel Utilization Efficiency (AFUE) ratings of 78% or higher. Today there are two classes of furnaces: high efficiency and mid-efficiency. The high efficiency in a gas furnace are 90% or higher efficiency while oil fueled furnaces are 80% or higher. High efficiency furnaces are available for forced air heating or hot water / hydronic systems. These types of heating systems are best for office or retail space. These new furnaces are generally low maintenance but that doesn't mean maintenance is not needed. Annual maintenance is highly recommended to replace filters, tighten belts, and check burners.

For large retail spaces, warehouses, or areas with high ceilings, low intensity radiant heating systems can reduce energy costs while still providing a comfortable environment. Radiant heating heats the objects under the heaters and not the air directly. They offer quick warm up and the ability to heat localized areas and not the entire space which saves energy.

Grain Drying

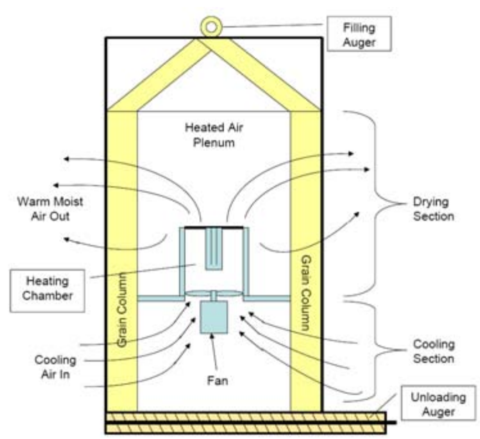
The energy efficiency rating of grain dryers is measured as BTU per pound of water removed. Efficiency ratings will vary by grain type (corn, wheat, soybeans). There are not any unified test standards for rating grain dryers in North America so manufacturer's ratings may not always be comparable. There is some limited independent test data for dryers and limited research data to use for comparisons. A general rule of thumb for energy usage in a high temperature dryer is 0.02 gallons of LP gas or 0.018 Therms of natural gas per bushel per % point moisture removed and 0.01 kWh of electricity per bushel per % point moisture removed.

The first step to reducing energy costs is to only dry clean grain. It is recommended that grain be screened before and after drying to remove chaff, weed seeds, bees wings, and broken kernels. This will increase air flow in dryer, reduce plugging of screens and aeration floors and dry only salable product.

Cross-Flow Dryers

Cross-flow dryers are very popular but are not an efficient dryer unless heat recovery is included. Heat can be scavenged from the grain being cooled in the dryer or from the lower drying section to reduce energy costs by 10 to 20%. Existing dryers can be retrofitted with ductwork to capture and recycle scavenged heat for intake air to the heating section. Many new dryers use reverse flow or suction cooling where all or a portion of the air for the heated section is drawn through the cooling section. The air enters the dryer by passing through the column of corn in the cooling section, picking up heat from the corn as it cools and then passes through the fan and burner into the heating section plenum, see Figure 2. Reverse flow cooling is available on horizontal or tower dryers.

Figure 2:
Reverse Flow Cooling



Mixed Flow Dryers

Mixed flow dryers are a high efficiency column type dryer that does not have screens and can therefore dry grains from rape seed to corn. They are 20 to 40% more efficient than the typical cross-flow dryer, using a con-current and counter flow air pattern to dry the grain. The retention time for mixed flow dryers is typically twice as much as a cross-flow dryer and is sited for less variation of kernel moisture and higher starch utilization (up to 10%). These dryers are available with multiple heating zones if needed. The mixed-flow dryers may cost a little more than a cross-flow dryer but have lower energy costs. The analysis of a 900 bushel/hour cross-flow dryer compared to a mixed flow dryer indicated a 1 to 2 year payback on the additional investment based on energy savings only. Mixed-flow dryers are available in capacities from 250 to 4600 bushels per hour for 10 points of moisture reduction in corn. The one disadvantage of mixed-flow dryers is a larger footprint requirement as compared to a tower type cross-flow dryer. There are four companies that sell mixed-flow type dryers in North America, see Table 2.

Table 2 – Mixed flow dryer manufacturers.

Grain Handler USA, Inc,	Minneapolis, MN;	612-722-1085
NECO (Nebraska Engineering Co.),	Omaha, NE;	1-800-367-6208
Phoenix Rotary Equipment, Ltd.,	Nisku, Alberta;	1-888-891-9929
Cimbria Bratney Co.,	Des Moines, IA:	1-800-247-6755

Continuous In-Bin Dryer

Continuous in-bin dryers are basically automated bin dryers that have control systems to automatically sense the grain moisture and divert the grain to a storage bin as it dries. This dryer type is 25 to 40% more efficient than cross-flow dryers. The continuous in-bin dryer system can be installed in an existing grain bin with a full aeration floor or in a new bin. The control system sensors monitor the grain moisture at the bottom of the bin and when the grain is dry, a sweep auger takes a sweep around the bin floor to remove the dried grain. Grain is transferred to a storage or dryeration bin hot where it is cooled. With this system the wet grain is piled on top of the drying grain which eliminates the need for a wet bin and the associated grain handling to transfer wet grain. The drying capacity of continuous in-bin drying systems ranges from 8000 to 17,000 bushels per day (330 to 700 bu/hr) which limits their feasible to small cooperatives. Aside from size limitations, continuous in-bin dryers will accumulate fines on the aeration floor and typically will require shutting down and emptying out every 3 to 5 days to remove the fines. An advantage of this type of dryer is that it can be used for storage at the end of the drying season by running the dryer as a re-circulating dryer for the last batch. Several companies can install the automated systems to convert a batch bin dryer to a continuous dryer.

In-Bin Cooling

The procedure for in-bin cooling is to transfer the grain hot at a moisture level 1 to 1.5% points above the desired storage moisture level to the storage bin. Cooling fans are turned on as soon as filling starts and run until the grain is within 5 to 10°F of ambient air temperature. Typically 0.2% points of moisture can be removed from corn per 10°F of temperature reduction during cooling. A 10 to 15% savings in fuel costs can be expected along with an increase in dryer capacity of up to 33%.

Dryeration

Dryeration offers three advantages: energy savings, an increase in dryer capacity of up to 70% and an increase in grain quality. The dryeration process involves transferring the corn hot to a bin with aeration at 2 to 3% points of moisture above storage moisture level, allows the corn to steep without aeration for 4 to 12 hours and then cooled before transferring it to storage. Grain should not be stored in the dryeration bin because moisture will condense on the bin walls causing pockets of wet grain that will spoil if not moved. The steeping process allows the moisture remaining in the kernel to equalize before cooling. This reduces seed coat stress cracks by 36% and kernel breakage by 5% according to one university study compared to rapid cooling. For continuous operations, multiple steeping bins will be needed so while one bin is steeping, another bin is being filled. The energy savings from this process can be up to 25%.

Dryer Maintenance

Maintenance before and during the drying season is very important for optimal efficiency of a dryer. Before the fall drying season, belts should be checked and tightened, check burner for proper operation (blue flame), clean fan housings, tighten and lubricate bearings, make sure all guards are in place, check electrical controls and switches, and calibrate thermostats and sensors. During drying operations, screens need to be check and cleaned daily, spot check plenum temperatures and check grain handling equipment.

Grain Handling

Although grain handling is not as expensive as drying, anytime we can use gravity to move a product, costs are reduced. For tall bins using a Side Discharge chute will reduce handling costs and may increase handling capacity, see Photo 2. A side discharge is a pipe that extends into a bin through the side wall to the center of the bin. It is important that the pipe extend to the center of the bin so that the forces the grain exerts on the bin walls remain uniform as the grain is removed. If the grain is unloaded from the side instead of the center, the forces on the bin side walls will not be uniform and could lead to structural failure. A gate on the side discharge is used to control the grain flow.

Photo 2 – Side Discharge Chute

Motors

There are many motors used in the grain handling process: fans, augers, grain legs, etc. The Department of Energy estimates that motors consume 50% of all electricity in the U.S. and accounts for 84% of electricity used in agricultural production or electric motors consume $84 of every $100 of a cooperatives electric bill. Over the lifetime of a motor, the cost of energy to operate the motor is approximately 95% of its original cost. Choosing an energy efficient motor will pay dividends especially on high horsepower motors and motors that run many hours per year. Too often motor decisions are made at the time of a failure when the clock is ticking and downtime costs are escalating. Motor Matters is a program developed by Washington State University for the US Department of Energy, recommends inventorying your motors and running a cost analysis to determine what the best option is when and if a motor fails. Those options may include re-winding the motor, replacing it with a standard motor or replacing it with a high efficiency motor. It is also recommended that sources for re-winding services or new motors be researched ahead of time so when a motor needs to be replaced or re-wound, the planned decision can be implemented. This many require negotiations with your motor supplier to stock motors and motor parts required for critical operations or having motors on inventory at the cooperative. There is software available to aid in setting up a planned motor replacement program from the U.S. Department of Energy. Refer to the reference list for information on where to find the MotorMaster+ software.

There are three classes of 3-phase motors available. A "standard motor" is a three-phase motor made prior to 1997 and they may or may not meet the minimum efficiency standard specified in the Energy Policy Act (EPAct) which took effect January 1, 1997. EPAct motors are motors manufactured since 1997 that meet the minimum efficiency standard. "NEMA Premium Efficiency" motors are the most energy-efficient 3-phase motors available with efficiencies 1 to 3% higher than an EPAct 3-phase motor for the size range of 1 HP to 200 HP. The difference between a standard motor and a NEMA Premium Efficiency motor could range from 1 % for a 500 HP motor up to 16% for a 1 HP motor. Some of the efficiency increases may seem small but for large motors and/or motors that operate 40 hours or more per week even small increases in efficiency can result in substantial savings.

High-efficiency single-phase motors are also available from several manufacturers despite there not being an industry standard. Both Baldor and Leeson manufacture motors that are 4 to 19% more efficient than standard single-phase motors. (There may be other manufacturers with high efficiency single-phase motors but the author was not aware of any at the time of writing.) The horsepower sizes available in high-efficiency versions range from 1/4 HP to 5 HP. Table 3 lists the high efficiency motor sizes available and a comparison of their efficiency with standard single-phase motors.

Power Transmission

It is important to keep motor power transmission components well maintained to keep energy costs low. This includes belt drives, chain drives, drive couplers, and gear boxes. Belt drives require the most maintenance because the belt material will elongate with age and the sides of the belt can wear, cracked or be contaminated with lubricants causing them to slip and not transfer all power. Other issues that can affect belt life include mis-alignment of pulleys and incorrect belt tension. Loose belts on a fan can affect air flow by up to 30%. Roller chain drives have the advantage of no slippage but require lubricant to maintain a long productive life. A chain running in an oil bath or having an oil drip will help maintain lubrication of the chain. The alignment of sprockets should be checked to see that they are in-line with each other to prevent premature failure. Drive couplings are designed to accommodate some misalignment between the motor and the driven component. Too much misalignment can cause the coupling to wear and fail. If the drive coupling allows for movement via a splined shaft, then lubrication will be required so the splined can move freely on the shaft. Gear box lubrication is the most important factor in maintaining long life. Gearbox lubricants may either be oil or grease and should be changed based on manufacturer's recommendations.

Table 3 – High-efficiency single phase motor efficiencies.

Motor horsepower HP	Std efficiency motor % efficiency	High efficiency motor % efficiency
1/4	55	74
1/3	60	76.5
1/2	62 – 68	78
3/4	74	83
1	67	83
1-1/2	75.5	84
2	75.5	82.5
3	78	85.5
5	80 – 82.5	86.5

Energy Efficiency Grants

Focus on Energy

Wisconsin has a state energy conservation program called Focus on Energy that offers grants for energy conserving equipment including, lighting, motors, furnaces, and grain dryers. Focus on Energy services are available to 85 percent of the homes and businesses in Wisconsin. The remaining 15 percent are customers of certain municipal or cooperative utilities that have chosen not to participate in Focus on Energy but have their own energy conservation programs. To determine if you are eligible, visit www.focusonenergy.com or call 800.762.7077 and ask for the agricultural program office. The agricultural program offers free energy audits and analysis to agricultural businesses.

USDA 9006 Energy Efficiency and Renewable Energy Grants

The 2002 Farm Bill contains funding for grants for encourage rural small businesses to invest in energy efficient equipment and renewable energy. It is a competitive grant cycle that is usually accepts applications from mid-March to mid-June. The purchase of a high-efficiency grain dryer to replace an aging dryer would qualify under past grant rules. More information can be found at www.rurdev.usda.gov/rbs/farmbill/.

References

Safe Lamp and Bulb Management, DNR Publication: WA 195-03, Wisconsin Department of Natural Resources, Madison, WI, 2003.

"Energy Costs for Corn Drying and Cooling", Bill Wilcke, Minnesota/Wisconsin Engineering Notes, University of Minnesota, 2004. Available at www.bae.umn.edu/ennotes/P/P102-2004-09.htm.

Motor Planning Kit – 2.0, Consortium for Energy Efficiency, Inc., 2005. Available at www.motorsmatter.org.

Grain Drying Systems, D.E. Maier, F.W. Bakker-Arkema, 2002 Facility Design Conference, Grain Elevators & Processing Society, 2002.

Grain Drying, Handling and Storage Handbook, MWPS-13, Midwest Plan Service, Iowa State University, Ames, Iowa, 1987. Can be purchased from www.mwpshq.org.

Design and Testing of a Mixed Flow Grain Dryer, J.E. Montross, Q. Liu, K.E. Weidmayer, F.W. Bakker-Arkema, American Society of Agricultural Engineers, 1999.

"How to buy a Premium Energy-Efficient Electric Motor", Federal Energy Management Program, U.S. Department of Energy, 2001.
Available at www.eere.energy.gov/femp/pdfs/emotors.pdf.

Induction Motor Efficiency Standards, Johnny Douglass, Washington State University Cooperative Extension Energy Program, 2005. Available at www.energy.wsu.edu/ftp-ep/pubs/engineering/motors/EfficiencyStandards.pdf.

MotorMaster+ 4.0 software, U.S. Department of Energy, Industrial Technologies Program. Available at http://eereweb.ee.doe.gov/industry/bestpractices/software.html.

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VIRULENCE PROFILES OF SOYBEAN CYST NEMATODE

Ann MacGuidwin [1/]

Soybean Cyst Nematode

The soybean cyst nematode, *Heterodera glycines*, is a common pest of soybean in Wisconsin and the U.S. The SCN is undetected in many fields and may be one of the most widespread diseases affecting soybean. Yield losses of up to 30% can occur with no apparent symptoms on soybean stand or plant vigor. Population densities build slowly over time, usually in a very patchy pattern. Declining or stagnant yields or delayed canopy closure are subtle clues that should raise suspicion of SCN. Confirmation during July of the soybean year can be made by visual inspection of soybean roots for the presence of white females. Diagnosis at other times or during the rotation year must be made from soil tests conducted in a laboratory.

Damage thresholds for initiating management of SCN vary with soil type and location, but a general guideline for action is 150 eggs per 100 cc soil. The most effective and economical means of reducing yield loss due to SCN is to plant a resistant variety. Studies in Wisconsin and other states in the north central region showed that resistant varieties yielded more than susceptible varieties in almost every field infested with SCN. There are a wide range of varieties to choose from and most combine SCN resistance with traits of herbicide or disease resistance.

Extensive screening of soybean from China and Russia revealed seven lines with resistance to SCN. Of these, three lines are ancestors of the varieties in maturity groups suitable for Wisconsin conditions: P.I. 548402 ("Peking"), P.I. 88788, and P. I. 437654. Resistance to SCN, conferred by several different genes, is manifested after nematodes enter roots. Juveniles are lured into resistant plants and begin to feed, but are trapped inside roots as host resistance reactions begin. Rapid death of the cells chosen as the feeding site leaves nematodes stranded without food. These plant defense responses are triggered by chemical signals given off by SCN. Not all nematodes produce signals that are recognized by the plant and these individuals go on to feed, reproduce, and pass their "lucky" genes to their offspring. Almost all populations of SCN have some individuals capable of evading resistance reactions.

Virulence Profiling of SCN Populations

There are two schemes for characterizing ability of a SCN population to develop in resistant plants – the SCN race and the Hg (*Heterodera glycines*) type schemes. The objective of both schemes is to determine if a population is virulent (able to evade resistance reactions) against the SCN resistance genes used in modern breeding programs. The methods to determine race or Hg type are similar. Nematode eggs are added to pots of the soybean lines used in the test (4 lines for the race test or 7 lines for the Hg type test plus a standard susceptible line) and allowed to grow for 30 days. The plants are then harvested, the nematodes removed from the roots, and counted. The number of nematodes recovered from each line is divided by the number recovered from the standard susceptible line and multiplied by 100. This percentage is called the female index, or FI. Populations that have an FI less than 10% are considered to lack virulence for the resistance genes carried in that line. Populations that have an FI greater than 10% are considered to be virulent for those resistance genes.

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Profiling the virulence of SCN populations is accomplished by simultaneously testing the population against multiple soybean lines, each carrying a unique set of resistance genes. For the race scheme, the population earns pluses and minuses determined by the 10% rule (less than 10% = not virulent, > 10% = virulent) on four soybean lines, for a total of 16 possible races (Table 1).

Table 1. SCN race scheme.

Race	"Pickett"	"Peking"	P.I.88788	P.I.90763
1	-	-	+	-
2	+	+	+	-
3	-	-	-	-
4	+	+	+	+
5	+	-	+	-
6	+	-	-	-
7	-	-	+	+
8	-	-	-	+
9	+	+	-	-
10	+	-	-	+
11	-	+	+	-
12	-	+	-	+
13	-	+	-	-
14	+	+	-	+
15	+	-	+	+
16	-	+	+	+

The Hg type scheme is similar except that seven soybean lines are used (Table 2). The standard susceptible line used for comparison in both schemes is "Lee 74". The naming convention for populations in the Hg type scheme is the number of all lines with an FI greater than 10% (e.g., an Hg type 1.2.3 is virulent against resistance genes in P.I. 548402 ("Peking"), PI 88788, and PI 90763.

Table 2. Soybean lines used in the Hg type test.

Hg Type	Soybean Line
1	P.I. 548402 ("Peking")
2	P.I. 88788
3	P.I. 90764
4	P.I. 437654
5	P.I. 209332
6	P.I. 89772
7	P.I. 548316

Methods

Fifteen SCN populations from 13 counties were evaluated using Hg type testing. None of the populations had ever been exposed to a SCN resistant variety in the field. Nematodes were cultured in the growth chamber on a SCN susceptible variety to increase population densities. Three replications of the seven differential soybean lines were compared to "Lee 74" for nematode development expressed as the Female Index (FI). All tests were conducted in a growth chamber with a 12/12 hour photoperiod and air temperature of 28^{o}C for 30 to 32 days. The tests were repeated at least once for most populations.

Results

Thirteen of the fifteen populations tested to date were virulent on P.I. 88788 (Table 3). These populations were be classified as either race 3 or 6 ("Pickett" is not included in the Hg type test, so it is not possible to identify races distinguished by their reaction to "Pickett"). Four of fifteen populations were virulent on "Peking" (P.I. 548402). No population was virulent on P.I. 437654.

The Hg type test and the race test use development of adults as evidence of virulence. We conducted one experiment to compare, for P.I. 88788, egg production versus development of adults (Table 4). Egg production was a more conservative indicator than female development for one population, less conservative for one population, and about the same for two populations.

Implications

Most populations of SCN are composed of some individuals that are not affected by the resistance genes carried in P.I. 88788, the most common source of SCN resistance in varieties bred for Wisconsin conditions. These findings are very similar to a study conducted in Missouri in 2005, but researchers there attributed the result to the fact that P.I. 88788 has been used extensively. Our data represent variation inherent in the populations because the SCN came from farms that had never grown SCN resistant varieties. These data warrant caution about overuse of varieties with P.I. 88788 resistance and suggest that rotating P.I. 88788 resistance with either "Peking" or "Hartwig" (P.I. 437654) is advisable for some populations.

There are two reasons that the data should not be interpreted as a call to abandon P.I. 88788 resistance all together. First, virulence profiles are based on success of the nematode rather than success of the crop to withstand nematode parasitism. Commercial varieties derived from the P.I.s carry many other traits that can confer the ability to tolerate SCN feeding, so yield data should be examined before deciding on the best soybean genetics to use. Evaluations of commercial varieties with P.I. 88788 resistance show that they perform well and are important tactics for managing SCN in Wisconsin. Second, there is concern that overuse of "Hartwig" resitance (CystX) could select for the very small proportion of the population that is already able overcome that source of SCN resistance. Data from laboratory studies have shown that SCN populations virulent on P.I. 437654 were also virulent on other resistance genes.

Table 3. Results of Hg type tests for Wisconsin populations of SCN

SCN population	Trial	# females on Lee	FI on P.I. 88788	Hg type	Race
Waushara-1	1	107	1	0	3
Columbia-1	1	289	7	7	2 or 11
	2	234	30	1.2.5.7	
Shawano-1	1	98	8	7	4 or 16
	2	79	3	6	
	3	74	8	7	
	4	284	40	1.2.3.5.7	
Dunn -1	1	76	6	5.7	3
Dunn-2	1	69	12	2.5.7	1 or 5
Walworth-1	1	134	55	1.2.3.5.6.7	4 or 16
	2	249	62	1.2.3.5.6.7	
Waupaca-1	1	131	10	1.2.5.6	2 or 11
	2	98	36	1.2.5.6.7	
	3	96	32	1.2.3.5.6.7	
Dane-1	1	278	24	2.7	1 or 5
Sauk-1	1	131	35	2.5.7	1 or 5
	2	124	63	2.5.7	
Juneau-1	1	85	81	2.5.7	1 or 5
	2	298	79	2.5.7	
Racine-1	1	122	7	0	1 or 5
	2	176	17	2.5.7	
Racine-2	1	94	19	2.5.7	1 or 5
Buffalo-1	1	95	54	2.5.7	1 or 5
	2	78	52	2.5.7	
	3	169	73	2.5.7	
Grant-1	1	154	47	2.5.7	1 or 5
	2	62	16	2.7	
Washington-1	1	89	11	2.5.7	1 or 5
	2	64	28	2.5.7	

Table 4. Comparison of FI based on cysts versus egg counts.

Population	FI cysts	FI eggs
Sauk	26	41
Buffalo	105	108
Grant	41	22
Dane	29	15

Future Work

We are continuing virulence profiling using populations from additional counties. We are also simulating the overuse of resistant varieties with these populations in growth chamber studies to see how quickly (if at all) virulence profiles shift. Other studies are identifying the range of yield responses represented in commercial varieties with P.I. 88788 resistance when challenged with SCN populations from different counties in Wisconsin.

THE AMERICAN EXPERIENCE WITH SOYBEAN RUST

Martin A. Draper [1/]

The Asian species of the Soybean rust pathogen (*Phakopsora pachyrhizi*) was introduced to South America in 2001. In that time it spread rapidly. Following its initial appearance in Paraguay, rust was identified in Brazil and Argentina in 2002, Bolivia in 2003, and an as yet unconfirmed report from Columbia in 2004, leading to the introduction and initial identification in the US in November of 2004 associated with Hurricane Ivan.

The winter of 2004-2005 held great interest as soybean pathologists and the industry watched for the extent of the range of the survival of the soybean rust pathogen. As the winter freeze penetrated deep into the south in December 2004, it became clear that the overwintering inoculum needed to feed a disease epidemic in 2005 had been severely reduced. From a single know site in Pasco Co., Florida, the disease gradually spread northward to 138 counties in nine states (AL, FL, GA, KY, LA, MS, NC, SC, and TX) between February 23 and December 6, 2005. Of the first detections in each county, 109 were in soybean and 38 were in kudzu. Nonetheless, kudzu is tremendously important in the overwintering process and the spread and distribution of pathogen. Georgia wound up being the crossroads, the site where the battle was pitched. In much of the south, midsummer drought prevented infection and disease development, despite the fact that several forecasting systems were indicating that inoculum was being introduced. In Georgia, research plot yields were reduced by 40-60% in some locations while producers reported losses of 20 bushels per acre. Georgia statewide average yields in 2005 were 28 bushels per acre, so a loss of 20 bushels per acre represents a significant reduction in production. In many cases, rust was recognized late in crop development or after the disease was well established. From 2004 to 2005, planted soybean acres in Georgia dropped by greater than one third. Had soybeans been more densely planted in 2005, rust inoculum may have increased more rapidly and losses may have been greater.

As the season progressed, rust continued up the Atlantic coastal plain, to near the North Carolina border with Virginia. The westernmost (TX) and northernmost (KY) penetrations of the disease were identified on kudzu very late in the growing season. The Kentucky site was killed back by frost within days of being recognized. As of the end of December, the TX site was reported to have died back by 90%, but the remaining kudzu leaves were rust infected. Cold weather in the southeastern US has killed back most of the infected kudzu, reducing the inoculum and risk for 2006, but the freeze has not been as far south as in December 2004. As such, the 2006 growing season will likely have a greater risk of rust from more widespread inoculum sources. However if that risk is to develop into disease, local environmental conditions will be crucial. As in 2005, scouting and monitoring sentinel plots will offer the best information on early detection and quick response with fungicide applications to prevent extensive disease development.

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TRACKING SOYBEAN RUST: SENTINEL PLOTS AND SPORE TRAPPING

Bryan Jensen[1] and Craig R. Grau[2]

Introduction

Tracking soybean rust's movement throughout the United States is an essential Integrated Pest Management technique. Crop advisors need to know where soybean rust is currently detected and if rust is moving northward so they can recommend appropriate management practices. During the 2005 growing season, soybean rust sentinel plots were coordinated in a 32 state area. Furthermore, spore movement was monitored through the use of two different style of traps.

Soybean Sentinel Plots

The 2005 soybean rust sentinel plot network was established in 32 states. These plots were intended to provide the means of first detection within a state or region. In Wisconsin, 22 sentinel plots were monitored in 19 counties by UW Extension, Agricultural Research Station and UW-Madison research personnel. Nationwide, an average of 25.75 plots were monitored/state. The Wisconsin, plots were monitored on a weekly basis from emergence to the end of August when the threat of soybean rust had ended. A national protocol was established to detect soybean rust at the 5% level of incidence. As a result 150 leaves were examined each week/plot for signs and symptoms of soybean rust. All questionable samples were sent to the UW Plant Disease Diagnostic Clinic. Although no positive samples were found, USDA protocol for handling the first potential soybean rust positive sample/state consist of sending a duplicate sample to the USDA laboratory in Beltsville, Maryland for official confirmation. Dissemination of this information was through the USDA's Soybean Rust Website, http://www.usda.gov/soybeanrust/ Additionally, the Plant Disease Diagnostic Clinic operated a toll free (866-787-8411) telephone recorded message which was funded by the Wis. Soybean Marketing Board. Plans are underway to identify a minimum of 15 soybean sentinel plots in Wisconsin for the 2006 growing season.

Spore Trapping

Two different spore trapping systems were studied in Wisconsin to determine if an early warning system was reliable and useful. These traps are considered experimental at this time. One of these trap styles was an active system which used a trap designed to collect and filter rainwater. Filter papers were changed after a rain event and were analyzed by the UW Plant Pathogen Diagnostic Clinic using Polymerase Chain Reaction analysis to determine if DNA from Asian soybean rust is present. Six of these traps were used at each of three locations, the Arlington, West Madison and Lancaster Agricultural Research Stations. The Wis. Association of Professional Agricultural Consultants also sponsored a network of rainfall traps during the 2005 field season. Soybean rust spores were not detected in either trapping network.

A passive spore trapping system was also studied using traps supplied by Syngenta. These traps were styled after a wind vane and a petroleum covered microscope slide was mounted inside the trap and replaced on a weekly schedule. Two traps were monitored in Wisconsin as part of a nationwide effort. Slides were sent by overnight express to Dr. John Rupe, Univ. of Arkansas, for visual analysis to determine if rust spores were present. One "rust-like spore" was detected in a trap located at the West Madison Agricultural Research Station.

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SORTING THROUGH THE SOYBEAN LEAF DISEASE COMPLEX[1]

Brian Hudelson[2]

Although soybean rust was not detected in Wisconsin n 2005, Plant Disease Diagnostics Clinic (PDDC) staff spent a substantial portion of their time this past growing season examining soybean samples for evidence of soybean rust. The basic strategy for monitoring samples for soybean rust at the PDDC uses an initial visual and microscopic examination of putative rust samples, with a follow-up where appropriate with a more sensitive technique called polymerase chain reaction (PCR).

Visual examination of rust samples is relatively straightforward. Soybean leaves [and leaves of other potential hosts of *Phakopsora pachyrhizi* (the soybean rust pathogen) such as snap bean, pea, bird's-foot trefoil, white clover, purple crownvetch, lupine, and yellow sweetclover] are initially scanned with the naked eye for brown or yellow spots. Suspect areas are then viewed under a dissecting microscope at magnifications that range from roughly 10 to 60 times normal size. In particular, one looks for rust pustules, the pimple or volcano-like reproductive structures of the soybean rust fungus that form on the undersurface of leaves. If pustules are not present, leaves are placed in a moist chamber [i.e., a plastic bag or other container (e.g., a petri-plate) lined with moistened paper toweling] for 24 hours, then reexamined. All soybean samples submitted to the PDDC in 2005 tested negative for soybean rust, showing no signs of *P. pachyrhizi* sporulation.

Confusion regarding the presence of soybean rust arises because several common soybean diseases mimic soybean rust. The most common of these diseases is brown spot, caused by the fungal pathogen *Septoria glycines*. This disease leads to the formation of numerous small brown spots on soybean leaves, particularly those from plants that are under stress. Brown spot can be distinguished from soybean rust as *S. glycines* does not produce pustules, but does produce urn-shaped reproductive structures filled with spaghetti-like spores that are readily visible under a compound microscope. Another common soybean rust look-a-like is bacterial blight. This disease is caused by the bacterium *Pseudomonas savastanoi* pv. *glycinea*, which causes small, angular leaf spots with yellow haloes. *P. savastanoi* pv. *glycinea* does not produce pustules or other reproductive structures, but under the compound microscope, one can often observe large numbers of bacterial cells streaming from bacterial blight leaf spots. Probably the most problematic soybean rust look-a-like is downy mildew, which causes yellow to brown spots on soybean leaves. To make matters even more confusing, the downy mildew pathogen (*Peronospora manshurica*) sporulates on the undersurface of leaves forming masses of spores that look very similar to the spore masses produced by *P. pachyrhizi*. Microscopically however, *P. manshurica* produces oblong "spore" (technically called

[1] Funding for soybean rust diagnostics at the Plant Disease Diagnostics Clinic is provided by the Wisconsin Soybean Marketing Board and the North Central Plant Diagnostic Network.

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sporangia) that are borne on antler-like structures, rather than spores borne in pimple-like pustules.

If soybean rust-like spores are observed on soybean (or other) leaves, definitive confirmation of *P. pachyrhizi* requires use of polymerase chain reaction (PCR). PCR is a techniques that allows one to look for a sequence of DNA (i.e., genetic material) that is unique to a particular organism (in this case *P. pachyrhizi*), even when this sequence may be present in very low numbers. PCR technology uses enzymes that naturally replicate DNA in cells to make copies of the unique DNA sequence of interest in a test tube, thus making the DNA more readily visible using light-sensitive dyes. In the case of soybean rust, first reports of the disease on soybean and other hosts in Wisconsin must be confirmed with PCR by USDA APHIS. All subsequent finds on a particular host need not be confirmed by PCR, but can be made using microscopic examination. However the PDDC's current policy is to confirm at least first reports (on soybean or any other host) in each Wisconsin county using PCR.

In 2006, the PDDC will continue to offer free soybean rust testing for soybeans and other soybean rusts hosts. Submission forms are available by mail from the PDDC or online at www.plantpath.wisc.edu/pddc. For additional information on soybean rust and other soybean diseases, feel free to contact the PDDC at (608) 262-2863 or bdh@plantpath.wisc.edu.

LABELS AND LEGAL USE OF RUST FUNGICIDES

Pat Kandziora [1/]

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[1/] Wis. Department of Agriculture, Trade and Consumer Protection, Madison, WI.

WISCONSIN DISEASE SURVEY 2005 AND NEAR MISSES

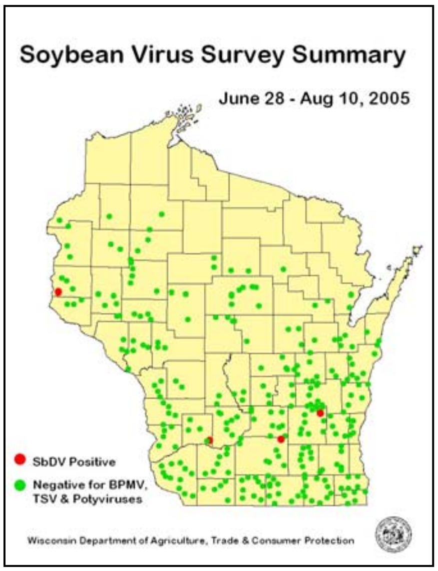
Adrian Barta[1] and Anette Phibbs[2]

Highlights of 2005 Survey

Soybean viruses scarce.
Soybean dwarf virus found again.
Frogeye leaf spot (*Cercospora sojina*) reappears.
Viruses on snap beans were minimal.
Four counties added to soybean cyst nematode map.
No wheat streak mosaic virus or High Plains virus found in corn or wheat; only one incident of maize dwarf mosaic virus in surveyed corn.
Twenty-one corn seed production fields found to have Stewart's wilt (*Pantoea stewartii*).

Soybean Virus Survey

A statewide survey for viruses and soybean aphid prevalence was conducted from June 28th to August 10th, 2005. Observations and samples were collected from 276 R2-R5 soybean fields across Wisconsin. At four points in each field, the uppermost fully-unfurled trifoliate was picked from 10 plants and stored on ice until delivered to the Plant Industry Laboratory. Soybean aphid populations were counted, an estimation of defoliation percent made, and plants were examined for soybean rust.



In the laboratory, samples were ground and tested by ELISA for bean pod mottle virus (BPMV), soybean dwarf virus (SbDV), tobacco streak virus (TSV) and a broad potyvirus test (includes bean common mosaic virus, bean yellow mosaic virus, soybean mosaic virus and others). Tests were conducted using DAS ELISA kits from Agdia Inc., Elkhart, IN, in accord with manufacturer's protocols.

In the samples tested, no BPMV, no TSV and no potyviruses were detected, and only four of the 276 fields were positive for soybean dwarf virus. No soybean rust was detected in any surveyed Wisconsin field in 2005.

Soybean Dwarf Virus

Soybean dwarf virus was first detected in soybeans in Wisconsin in 2003. In 2004, the virus was detected in five of 293 soybean fields sampled. In 2005, SbDV was detected in four of 276 fields sampled. Companion surveys of clover (also reported to be a host) found the virus in 33 of 77 samples in 2004, and in 61 of 92 samples collected in 2005. (One note regarding the clover results: ELISA is notoriously difficult with clover, due to "noise" in the system. The actual incidence of SbDV in clover may be less than indicated.)

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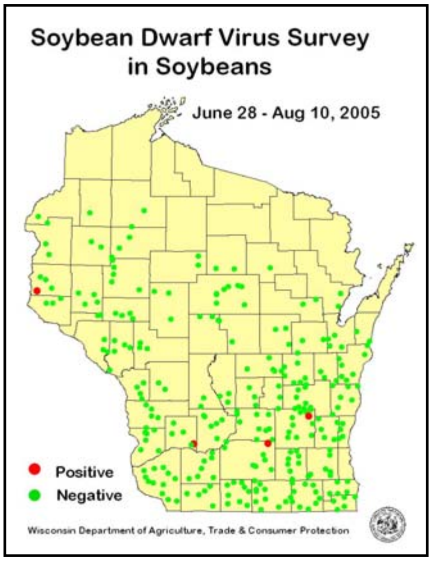
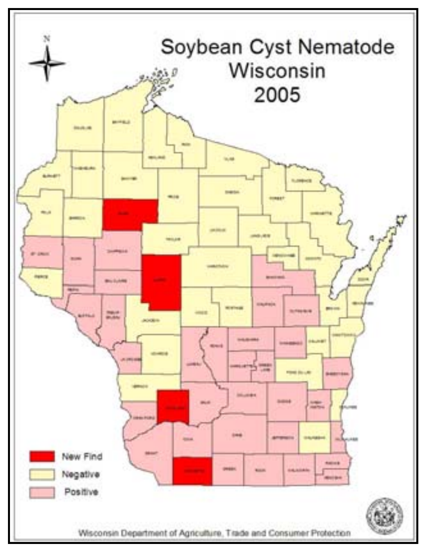
Several strains of SbDV are known to exist, with different aphid vector relations. Work is underway to classify the strain or strains in Wisconsin soybeans and clover. Certain strains of SbDV have been shown to be vectored by *Aphis glycines* under greenhouse conditions, but the apparent large reservoir of virus present in clover and the relative low rate of infection in the soybean crop suggest that the soybean aphid is an inefficient vector of the disease, or that as-yet-unrecognized differences in strains exist in the state. *A. glycines* will feed on red clover under greenhouse conditions, but is rarely reported to do so in the field, and does not overwinter on clover.



The apparent widespread prevalence of the virus in clover does raise concerns about the potential threat from a mutation in either insect or virus, or from a new vector entering the system in the future.

<u>Viruses on Snap Bean</u>
A survey of 33 commercial snap bean fields detected cucumber mosaic virus in three fields, and one field (Portage County) tested positive for the potyvirus group. All samples were negative for BPMV and TSV.

<u>Frogeye Leaf Spot</u>
A soybean field in Richland County was found to have frogeye leaf spot, caused by *Cercospora sojina*. This disease is common in the Mississippi delta region, and is reportedly increasing in incidence in Iowa. *C. sojina* overwinters on soybean residue. The first reported DATCP detection was made in 2000 in Iowa County; one detection was made in 2001 in Richland County. Frogeye leaf spot may be a growing concern for WI soybean growers in the future.



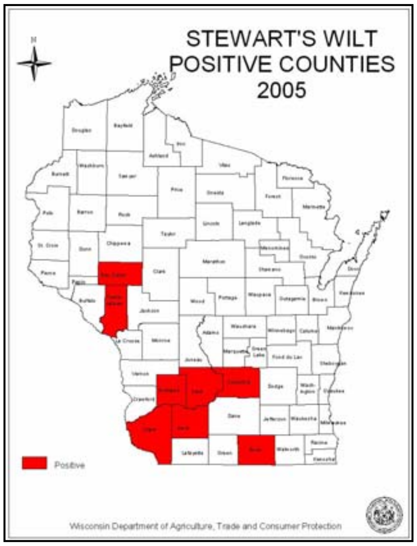
<u>Soybean Cyst Nematode</u>
In 2005, four counties (Lafayette, Richland, Clark and Rusk) were added to the list of Wisconsin counties known to be infested by soybean cyst nematode, *Heterodera glycines*. This brings the total number of counties infested in Wisconsin to 37, comprising the great majority of the soybean acreage in the state. Growers in counties where SCN has been identified should test for the organism. Guidance in management of the nematode is available at http://www.plantpath.wisc.edu/soyhealth/scn.htm.

<u>Wheat Streak Mosaic Virus, Maize Dwarf Mosaic Virus and High Plains Virus</u>
A survey of the state's wheat crop for wheat streak mosaic virus (WSMV), the High Plains virus (HPV) and maize dwarf mosaic virus (MDMV) was conducted from June 6 to June 20, 2005. High Plains virus is not known to occur in Wisconsin, nor is the vector of both HPV and WSMV, the wheat leaf curl mite (*Aceria tosichella*), known to occur here. Samples were collected at 82 wheat fields across the eastern half of the state and tested in the laboratory. No WSMV, MDMV or HPV was detected in wheat.

Between August 28th and September 9th, samples were collected from 44 fields of corn seed production inbreds. These samples were also tested for the three viruses. All samples were negative for all three viruses, except one field in Dane County, which tested positive for MDMV.

<u>Stewart's Wilt</u>

Since appearing in 1999 after a 56 year absence, Stewart's wilt (caused by the bacteria *Pantoea stewartii*) has been found in inbred and sweet corn fields almost every year. In 2000, the disease was found in 10 counties of the state; in 2001, no disease was detected. In the years 2002-2004, only one or two infected fields were detected each year. The 2005 seed field inspections found the disease in 21 of 44 fields surveyed, or 48% of the fields visited. The disease occurred in eight counties, as far north as Eau Claire County.



Stewart's wilt is of regulatory concern, and importation of seed from *Pantoea*-infected fields is prohibited by at least 23 countries worldwide. The bacteria is vectored by the corn flea beetle (*Chaetocnema pulicaria*), which is also the overwintering reservoir. Winter temperatures are likely the primary factor regulating the incidence of this disease in Wisconsin, by influencing flea beetle winter mortality.

DAIRY FEED: A NEW CASH CROP

Mike Rankin[1/]

Introduction

Cash grain producers generally sell their grown commodities through traditional marketing outlets that set a price for delivery or allow the grower to take advantage of various price risk marketing tools (forward contracts, options, etc.). Occasionally, a neighboring dairy producer may be in need of additional feed because of a less than optimum growing season. This has often resulted in a transaction between farms for high moisture corn or corn silage. It's the classic example of neighbor helping neighbor and has been a long tradition among Wisconsin farmers. So in one sense the thought of selling crops to provide feed for a nearby dairy farm is nothing new. What is relatively new, and becoming more commonplace, is a **long-term** arrangement between farms to supply feed (generally forage as corn silage and/or alfalfa).

So what has brought about this increase in contractual arrangements between the "grain" farmer and "dairy" farmer? A number of factors contribute, but the overriding one is the fact that many dairy farmers only want to concentrate on the dairy enterprise. This is often the case when farms expand cow numbers and when there are smaller new start-up operations. These dairy farms need both feed and acres to spread manure. Further, they know that they will need to make it economically attractive for their feed grower because that individual has other options whereas the independent dairy unit does not. This is generally not difficult because "feed" value is often higher than "grain" value. In the ideal situation, both farm units stand to make more money than if the diary grows its own feed and the grain farmer sells the crop through traditional marketing channels.

Advantages and Disadvantages

Let's first look at the advantages and disadvantages of feed contract arrangements. Of course this becomes a matter of perspective depending on whether you're the "giver" or "receiver." Here, our attention is on the feed grower:

Grower Advantages:

- Unlike a land rental arrangement, the grower maintains an economic "stake" in the crop and is offered a competitive return for their labor and management.
- If growing corn silage:
    - Lower risk to grow when compared to grain or vegetable crops in terms of planting date, cool growing seasons, or an early fall frost.
    - Offers growers the opportunity to spread fall tillage operations over a longer period because the corn silage crop is harvested earlier.
    - Growing corn for silage is not much different than growing corn for grain.
- If growing alfalfa:
    - High value crop compared to grains.
    - Tremendous crop rotation benefits in terms of nitrogen credits, soil erosion control, and yield enhancement of the subsequent crop.
- Opportunity to utilize manure for both nutrient and soil quality characteristics.

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Grower Disadvantages:

- Often, payment arrangements are based on a set price for quantity. This can result in losing any upside market swings but also takes out risk from downside movement.
    - This concern can be overcome with a floating price contract, which is based on grain markets over a designated period of time. Either local markets prices or Chicago Board of Trade nearby futures can be used.
- The grower becomes an unsecured creditor. It's important to build good relationships and know who you're dealing with.
- Corn silage and alfalfa have higher nutrient removal rates than corn for grain or soybeans. For example, corn for silage will remove 80 to 90 lb/acre more potassium (K) than corn for grain. This additional removal needs to be figured into the value of the crop or replaced with a subsequent manure application by the dairy enterprise.
- Corn residue is removed as silage. This may have ramifications in terms of soil conservation plans. The impact may be negated if alfalfa is also grown in the rotation.
- Growing alfalfa is very different than growing grain crops and there may be an initial learning curve.

Contract and Pricing Considerations

There have been numerous approaches to setting-up feed supply contracts. There is simply no right or wrong way to formulate a contract and pricing options as long as both parties are content with the arrangement and understand their obligations. It's always a good idea to examine some existing contracts and talk to growers who have experience with these arrangements. Just as corn silage and alfalfa differ in the way they are grown and managed, they too differ in the way they are priced. Here are some considerations:

Corn Silage

To begin, it's always good to figure your expected gross return on dry grain. This helps to set "floor" price on the return you need to have when shifting to a silage enterprise. Include in this analysis your costs for harvesting, drying, storing and transporting the grain. Silage pricing is often based from some measure of dry corn price. For example, 7.5 bu grain/wet ton silage times the grain price, adjusted for harvesting cost. The system can be the same from one year to the next; however, the corn price used may be different depending on market movement. In the case of short-term, contractual arrangements (not permanent from year to year), forage "market" factors may be taken into account. When forage is short because of alfalfa winterkill, drought, etc., corn silage value increases beyond that based solely on the dry corn price. In permanent contractual arrangements, these types of market forces are less of an issue. There will be years when the price paid or received is higher or lower than the prevailing market price in that year. Before negotiating a contractual arrangement, have a floor and ceiling price set from which to work.

Harvested corn silage can vary in moisture from year to year and from field to field. It's important to set prices based on a specific moisture in the same way that dry grain is priced based on a standard of 15.5% moisture. The standard moisture for corn silage is often set at either 65% or 0% (100% dry matter). As with dry grain, moisture really matters. For example, silage priced at $18.00 per ton @ 65% moisture equates to $15.43 per ton @ 70% moisture and $20.57 per ton @ 60% moisture. A corn silage moisture conversion chart is available on the UW-Extension Team Forage web site at www.uwex.edu/ces/crops/uwforage/uwforage.htm.

Another consideration that is becoming more important for dairy producers feeding silage is hybrid selection. Often, the dairy producer either selects the hybrid to be grown or offers the grower a list of hybrids to choose from. This is usually not a big deterrent to the grower because the dairy is as interested in getting high yields of high quality feed as the grower. Forage quality of corn silage is primarily dictated by harvest time whole plant moisture and the hybrid selected. For this reason, quality is rarely used as a factor in adjusting base price. It's much easier to set parameters on an acceptable whole plant moisture (if the grower is also responsible for harvesting) and make appropriate hybrid selections.

The question of "Who is responsible for harvesting?" is another consideration in feed arrangements. Typically, it is the dairy producer who takes responsibility by contracting with a custom harvester. This is also the preferred arrangement by the grower as well because they often do not have the harvesting equipment and it puts the burden of a timely harvest on the feed buyer. In some cases, the forage grower has the equipment and facilities to harvest and/or store the feed. Generally this occurs because the grower has an existing dairy operation but desires to spread fixed costs over more acres by providing feed to other operations. Some provide a full total mixed ration on a daily basis. The contractual considerations are similar except that the purchasing dairy generally sets quality parameters. Further, because the feed is purchased coming out of storage, there is often a premium paid for the feed because shrink losses have already been incurred by the grower. Shrink losses in a well managed bunker silo are generally between 10-15%.

Alfalfa

To state the obvious, growing alfalfa is much different than growing a grain crop. It will require a bigger "leap" for a traditional grain crop producer to devote acreage to a perennial crop like alfalfa. That said, growing alfalfa holds some inherent advantages in terms of crop rotation effects, N credits for a subsequent crop, and soil erosion/soil quality benefits. Higher initial establishment costs, pest control, and higher P and K demands are all things that must be considered. Alfalfa is also subject to winterkill or injury and there is year to year yield variation. Again, the burden of harvest is generally placed on the purchasing dairy operation.

Unlike corn silage purchase arrangements, alfalfa is often priced based on yield and forage quality. In many cases, a base price is set for one ton of dry matter at a specific forage quality (e.g. $100 per ton for forage that has 18% CP and 150 RFQ). The price is then adjusted up or down based on the quality of the delivered feed. Usually an acceptable range is set around quality parameters. An example of a hay pricing structure in a computer spreadsheet format and used by several farms in Fond du Lac County can be viewed at:
www.uwex.edu/ces/crops/HayPricing.htm

Measuring Yield and Quality

In the rush of harvest, shortcuts are sometimes taken in an effort to quantify yield and/or quality. Suffice to say that it is extremely important to be accurate when weighing loads for yield or taking samples for quality. Small errors with large volumes of feed quickly translate into large errors and great sums of money. Many large dairies have invested in on farm scales for trucks and wagons. In permanent contractual arrangements, using estimates based on silo or wagon size simply isn't good enough. Make sure that all contractual parties are clear on how both yield and quality will be determined.

Summary

Cash cropping milk provides traditional grain crop growers a viable alternative enterprise that has both a nearby market where feasible and profit potential beyond that of traditional grain crops. Business relationships are built long-term instead of “as needed” on an annual basis. It’s important to build these relationships on trust, while at the same time putting agreements in writing. There are many examples in the state of successful feed grower-dairy arrangements. They vary in scope, the type of crops grown, and how prices are determined. What often isn’t different is the fact that each partner benefits.

LINKING FARMS: A FINANCIAL SOLUTION

Josh Betcher [1/]

In the process of linking dairy farms with cash grain farms to utilize the benefits of manure, questions arose on how to determine if manure should be exchanged between farms. Is it feasible to ship manure from farm-to-farm? How far can we ship manure and still have some economic value left? Can we charge for manure as a commodity? If we ship the manure this far who will pay for the hauling?

The goals of my research were to determine if, and how far, it is feasible to haul manure and to develop a working model that business consultants and farmers can use to judge how far manure can be hauled and what it is worth to each party involved. My hypothesis was that it is feasible to haul manure to the neighboring farms with an economic benefit to both parties. The distance that the manure could be hauled will vary from operation to operation.

With the help of my advisors, peers, extension agents, and individuals in the industry, I have developed an excel sheet that determines the break-even distance for hauling manure. To give the sheet a more user friendly feel, a whole enterprise budget is the framework of the sheet. The distance is based off of manure application rate, nutrient value, fertilizer price, diesel price, and hauling charges. Being that the manure is an input that is replacing fertilizer in the budget, changes in the rest of the budget only effect the bottom line not the break-even distance. For distances less than the break-even, the remainder value can be used between the two farms as their leverage. For distances greater than the break-even, the negative balance is what the dairy farm would have to subsidize to the grain farmer to take the manure.

The scenario that we set up is one where the dairy farm has reached a limit on hauling manure on the property near the farm. Under this implication, the farm must ship their manure greater than one mile so the hauling fees that are incurred for the first mile are being charged to the dairy farm. I have formed a scenario budget using average dairy slurry nutrient values and current fertilizer prices from the Marshfield, WI testing labs, hauling information from the Wisconsin Waste Haulers Association, and an enterprise budget for a corn grain farmer derived from five years of historical data from the PEPS contest. The scenario budget shows that average dairy manure can be hauled a distance of over 5 miles and still has economic value.

Overall, the model shows that it is feasible to ship manure to the neighboring farms, but the distance that it can be shipped depends mainly on the commercial fertilizer price and the value of the manure being applied.

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BUSINESS OPPORTUNITIES: LINKING CASH GRAIN AND DAIRY FARMS

Kevin Erb [1/]

In the early 1990s, manure management was seen by some ag service providers as a significant threat to the financial health of their businesses (Reduced fertilizer sales as farmers took credit for manure's nutrients). And while fertilizer sales have fallen, newer opportunities (soil sampling, nutrient management plan services) have arisen to soften or even offset some of the financial impact.

The advent of phosphorus based nutrient management plans means that the typical livestock farm will need access to more acreage to deal with their farm's manure. Since land is not cheap, more and more farmers are beginning to look into agreements with neighboring farmers to take manure. This can provide a business opportunity if you position your business properly.

These agreements usually take one of two forms: exchanges between cash grain and livestock producers (exchange of feed/cash for manure), and agreements between two livestock producers (you haul on my rented land near your barn, and I'll do the same).

A unique aspect of the cash grain/livestock relationships as they've developed in northeast Wisconsin is that one of the parties generally switches to a different consultant or agronomy service after a few years (usually to the service provider of the livestock farmer). It appears that the cash grain producers feel they are getting more services from the livestock producer's agronomist than from their own (these include advice on when to chop silage for highest feed value, soil testing, fertilizer recommendations, etc).

The main question for you to ask as you begin to think about these agreements is: **How can we generate revenue**? A second question is just as important: **How can we keep (and expand) our client base?** The key is to provide both parties with a service that they feel is worth paying for.

Case Study #1: Outagamie County. Two farmers (dairyman with 70 head, 300 acre cash grain farmer) located in an urbanizing area near Appleton, both served by the same independent crop consultant. Their location (along a major highway) was limiting their ability to access fields due to heavy traffic. Their crop consultant negotiated an agreement to provide take manure (keeping it on the same side of Hwy 10), and to exchange high potassium feed for lower potassium feed. The cash grain farmer was no longer hauling grain across Hwy 10 to his on-farm storage. The contract negotiation was provided as a part of existing service agreements between the agronomists and the farmers.

Case Study #2: Oconto County. A dairy on limited acreage needed land for manure application (to meet the requirements of local ordinances). He was served by one agronomist, and the three participating cash grain farmers were split between the same agronomist and a competitor. The dairyman's agronomist and nutritionist sat down with the cash grain farmers and their agronomists to help put together a basic agreement, including who paid for the soil testing, nutrient management planning, value of feed and manure and feed harvest timing advice. Prior to

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the agreement, only one of the cash grain farmers soil sampled. Now all three are on full scouting and soil testing programs. Neither agronomist received compensation for working on the agreement, but both have increased service sales to participating farmers. If you decide to become involved, it helps to ask a few questions and put together a list of potential benefits to your clients. These might include:

How can we provide a service to livestock producers?

- Ability to meet nutrient management plan or other regulations
- Allow for expansion without land costs
- Improve animal health (lower soil K = less high potassium feeds)
- More flexibility for future manure applications
- Recordkeeping
- Ability to act as a go-between in negotiating the agreements (easier if both parties are currently your clients)

How can we provide a service to cash grain producers?

- Increase soil tilth (water, nutrient holding capability)
- Cross-linked sales with crop scouting (weed concerns)
- Potential revenue source guidance (taking manure)
- Increase per-bushel price with a local market (lower hauling/drying costs)

Of course, having sample agreements available makes this type of arrangement much easier. Any agreement should be run by both producers' attorneys before the final signature.

MANURE SPREADING AND ITS EFFECTS ON SOIL COMPACTION AND CROP YIELD

Gregg Sanford[1], Josh Posner[2], and Ron Schuler[3]

Abstract

With the increasing size of farm equipment, the potential for soil compaction has become a real problem. According to some grain farmers, compaction from manure spreading equipment is a factor limiting their acceptance of slurry as a soil building and soil fertility resource. To address the issue of compaction caused by manure spreaders, eight on-farm sites were set up in the fall of 2004 and spring of 2005. At each site three treatments were applied (manure, farmer's check, and tanker compaction only), and replicated three times. In addition to the on-farm trials, an on-station site was set up in Arlington. The on-station site examined the impact of multiple passes of heavy slurry equipment as might occur on field roads or headlands. After one year of field trials, it appears that compaction from manure spreaders does not adversely affect corn yields when it is applied in reasonably dry conditions. There was no significant difference between the three treatments in seven of the eight on-farm sites. Despite non-significant differences at the plot scale, hand harvests of the on-station trial showed a 10 to 15% reduction in corn yield for rows that were directly within the tire track when there were multiple passes.

Introduction

Despite the nutrient content of manure many grain farmers have indicated that they are hesitant to bring slurry onto their land due to concerns regarding soil compaction (pers. comm. Columbia County Crop Production Club, 2003). Their concerns are not unfounded as manure tankers commonly carry volumes ranging from 3,000 to 7,500 gallons and can weigh from 20,000 to 35,000 pounds per axle. These weights exceed the 20,000 lb/axle benchmark that has been shown to contribute to subsoil compaction, which is generally not alleviated by freeze/thaw cycles or tillage (Lowery and Schuler, 1991, 1994, Håkansson et al., 1987). However, slurry tankers are not that much heavier than some of the equipment already used by grain farmers. For example a single axle, 500 bu. grain cart has an axle weight of approximately 31,000 lbs full, and a combine with a hopper capacity of 250 bu can weigh over 27,000 lbs/axle when loaded with corn at 20% moisture.

Heavy equipment, especially on wet soils, can cause soil deformation, compaction, and destruction of soil structure resulting in anaerobic microbial buildup, denitrification, and reduced water use efficiency and nutrient uptake by the crop (Abu-Hamdeh, 2003, Håkansson et al., 1987, Lowery and Schuler, 1991, Wolkowski, 1990). Approximately 80% of potential soil compaction occurs during the first traffic pass, and subsequent passes lead to additional but progressively less compaction that is almost negligible by the fourth pass (Daum, 1996). Under certain conditions, these changes can result in yield reductions. For example, Lal and Ahmadi (2000), working in Ohio, found that compaction (16,500 pounds/axle) reduced corn yields (approximately 14%) in 2 out of 11 years on a fragic silt loam soil but in a six year companion study, axle weights up to 44,000 pounds had no effect on yield. In a similar type of study Lowery and Schuler (1991) found

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that axle weights of 17,600 lbs and 27,500 lbs reduced corn yields, in the first year of a four-year study, by 4 and 14% respectively on a Rozetta silt loam (fine-silty) and 14 and 43% respectively on a slightly heavier Kewaunee silt loam (fine). Much of the current research addressing compaction however, is focused on potential yield loss, and was conducted under extreme conditions (multiple passes with entire plot coverage). This probably does not represent actual yield losses since most of a production field is not directly under the tire tracks. When looking at some common manure spreading equipment, the percent of tire track to spreader width ranges from 10 to 40 % (Table 1). In addition, although there has been extensive research on machinery induced compaction (Alakukku et al., 1995, Evans et al. 1996, Håkansson et al., 1987, Lal and Ahmadi, 2000, Lal, 1996, Lowery and Schuler, 1991, 1994, Stewart et al., 1994, Wolkowski, 1990, 1991), very little has been done to address this issue in conjunction with the application of manure, which can positively effect soil structure and yield.

Two questions are posed in this study:

1. Does the compaction caused by the application of manure result in lower corn yields; and,
2. Does the manure itself, help to mitigate the effect of compaction due to the general benefits associated with manure (plant nutrients, increased porosity, water infiltration, nutrient uptake, increased organic matter and soil biological activity)

It was decided to address these issues as on-farm trials. The trial included three treatments:

1. **F**-farmer's check with fertilizer and no manure
2. **M**- where manure replaced some of the fertilizer requirement
3. **C**-compacted plot where loaded spreader traversed the plot without adding manure

Table 1. Spreader width and % field traffic.

Spreader	Tire specs	Application width	% of application width under the tire
Broadcast Truck[1]	11R-22.5	~30 ft.	13.3%
Broadcast Tank[2]	28L-26	~50 ft.	9.2%
Injection Tank[3]	30.5L-32	12 ft.	41.6%

[1]Husky 4,000 gallon truck mounted tank
[2]Waste Handlers by J-Star 4,600 gallon tractor-pulled slurry tank
[3]Balzer 5,700 gallon tractor-pulled slurry tank

On-farm Trials

Site Characterization and Trial Layout

Eight on-farm research sites were established in the fall of 2004 and spring of 2005 in Dane, Jefferson, Columbia and Walworth Counties. A characterization of these sites and the application of the treatments are outlined in Table 2. At each site fields were selected that had not received manure or bio-solids in the past 10 years. The experiment was set up as a randomized complete block design with three replications at each site. Plot sizes were determined based on manure spreading, corn planting and harvesting equipment and ranged from 30 to 45 feet wide and 300 to 480 feet long (0.2 to 0.5 acres/plot).

Table 2. Characterization of on-farm sites.

Site	Previous crop	Soil texture	% OM	Drainage[1]	Type of tanker	Axle wt. of tanker lbs.[2]	Manure incorporated Yes/No	Date of app.	Post-application tillage
1	Soybean	clay loam	2.8	PD	Tractor Pulled (Broadcast)	24,000	No	11/3/04	None
2	Wheat	Silt loam	3.5	WD	Tractor Pulled (Broadcast)	24,000	No	11/3/04	Field Cultivator
3	Soybean	Silt loam	3.7	WD	Truck Mounted (Broadcast)	19,880	Aerway	11/14/04	Zone till
4	Wheat	Silt loam	4.0	WD	Truck Mounted (Broadcast)	19,880	Aerway	11/14/04	Field Cultivator
5	Corn	Silt loam	1.3	MWD	Tractor Pulled (Injected)	26,400	Yes	5/4/05	Field cultivator
6	Alf.	Loam	2.6	WD	Tractor Pulled (Injected)	30,955	Yes	4/27/05	Field finisher
7	Wheat	Silt loam	2.2	WD	Tractor Pulled (Injected)	30,955	Yes	10/9/04	Field finisher
8	Wheat/ Clover/ Alfalfa	Silt loam	2.5	MWD	Tractor Pulled (Injected)	26,400	Yes	9/20/04	Field cultivator

[1] Drainage class: PD = poorly drained, MWD – moderately well drained, WD = well drained

[2] Axle weights are based on weights of loaded slurry tankers.

Manure Spreading and Compaction

Based on informal surveys with nutrient spreaders and extension personnel, the target spreading rate was 12,000 gal/a. Plots were designed to be long enough to empty the spreader in one pass in order to insure that all manured plots got an equal amount of manure. This resulted in the manured plots (M) having a changing axle weight across the plot, while the compacted plots (C) (without manure) had a constant full weight applied to the plot. As can be seen in Table 2, in four cases, the manure was applied using a tractor-pulled tank with an injection toolbar and at the remaining sites manure was broadcast. The former system required 3 passes across the plot and in the latter-- just one. The compaction treatment was applied by driving over the plot with a loaded slurry tanker using the same traffic pattern that was used for spreading. Conditions were generally good for field operations at all sites on the day of manure application. Rainfall ranged from 0.1 to 0.8 inches and fell from two to seven days prior to manure spreading.

Corn Phase

Corn was planted in the spring of 2005 at all sites. Selection of corn variety, seeding rate, herbicide program and other cultural practices were left up to the farmer-participant. Crop nutrient needs were met with fertilizer in the farmer check (F) and compaction only (C) treatments, and manure plus sidedressed nitrogen (according to the Pre-Sidedress Nitrate Test (Bundy and Andraski, 1995)) in the manured treatment (M). All the plots received starter fertilizer. At each site corn was harvested from the middle six rows of each plot using the farmer-participants' combine.

Headlands Project

Although most of the field is only trafficked once when manure is being spread, parts of the field (headlands, field entrance) receive multiple passes. In order to study the impact of this more extreme compaction due to manure spreading, a factorial experiment plus check plot was established using broadcast manure. The treatments include:

M1-Manured plot with one pass
M6-Manured plot, trafficked 5 times and the manure applied on the 6th pass
C1-Trafficked once but no manure added
C6 -Trafficked six times but no manure added.
F-farmer's check without manure added

The Headlands Project was established at the UW Madison Agricultural Research Station in Arlington. The field was a Plano silt loam (3.4% OM), had been in a no-till corn / soy rotation for the previous 5 years, and had no history of manure application. The experiment was set up as a randomized complete block design with four replications. Plots were 45 feet wide by 125 feet long. Manure was spread on April 15, 2005 at a rate of 12,000 gallons per acre using a 4,600-gallon Waste Handlers slurry tanker (24,000 lbs /axle) pulled by a Case IH 8920 tractor. Soil moisture (0 to 6 inches) at the time of spreading was 26 to 31% and tire tracks were clearly visible following application of treatments. Manure was incorporated within three days of application using a chisel plow.

Spring Practices

Selection of corn variety, seeding rate, herbicide program and other cultural practices at the research station were handled by the research station staff. Side-dressing with 28% UAN (Urea Ammonium Nitrate) was done according to UWEX PSNT recommendation on all plots.

Fall Harvest

Prior to whole plot harvest, hand harvested areas were taken in each plot to evaluate the impact of compaction on crop yield at varying distances from the tire tracks. Three sampling stations were randomly assigned to each plot. At each station a five-foot length of corn row was harvested from the row in the tire track, the row 30 inches from the tire track, and the row 60 inches from the tire track. Samples were shelled and analyzed for % moisture, test weight, and then weighed. Following hand harvests the middle six rows of each plot were harvested using a JD 9500 combine to determine plot yields.

Results and Discussion

On-Farm Trials

Combined analysis of corn yield at the 8 on-farm trials is shown in Table 3. Treatment was not significant (p = 0.17) (Manure=193 bu/a; Farmer check= 187 bu/a; Compaction only=189 bu/a). When linear contrasts were used to address our two research questions we found that compaction (C) did not significantly decrease corn yield when compared to our farmers' check (F) ($p = 0.67$), and manure did not "ameliorate" any negative effect of compaction ($p = 0.17$). Site was highly significant ($p<0.0001$) with much (>60%) of the site effect accounted for by location within the state (Table 3). There is a trend of reduction in yield from the sites in south-central Wisconsin (sites 1-4) to the sites in southeastern Wisconsin (5-8) (Fig 1). This difference in yields with location is likely the result of soil type and available water during the growing season. The 2005 growing season was dry with total rainfalls from May 1 to Sept 15 of 10.78, 12.14, and 7.31 inches for Columbia, Jefferson, and Walworth counties respectively[4]. In addition to site, there was a significant site by treatment interaction ($p = 0.0437$). At seven of our eight sites the manured treatment (M) yielded as well if not better than compaction only (C) and farmers' check (F) but at one site, it gave the lowest yield. It is important to note that farmers, based on the PSNT results, applied on average 50# less sidedressed N to the manured (M) vs. non-manured (C and F) plots.

Table 3. ANOVA table of combined on-farm analysis.

Source	d.f.	Sum of Squares	Mean Square	F value	p > F
Site	7	45,172.48	6,453.21	53.18	<0.0001
SC v. SE	*1*	*28,541.43*	*28,541.43*	*235.22*	*<0.0001*
Trt	2	412.17	206.10	1.87	0.1713
Site*Trt	14	3,215.92	229.71	2.08	0.0437
Block(Site)	16	1,941.97	121.34	1.10	0.3955
Error	31	3,418.31	110.27	--	--
Total	70	54,794.49	--	--	--

Note: contrast within site is for south central (SC) sites vs. south eastern (SE) sites.

Headlands Study

Whole plot yields

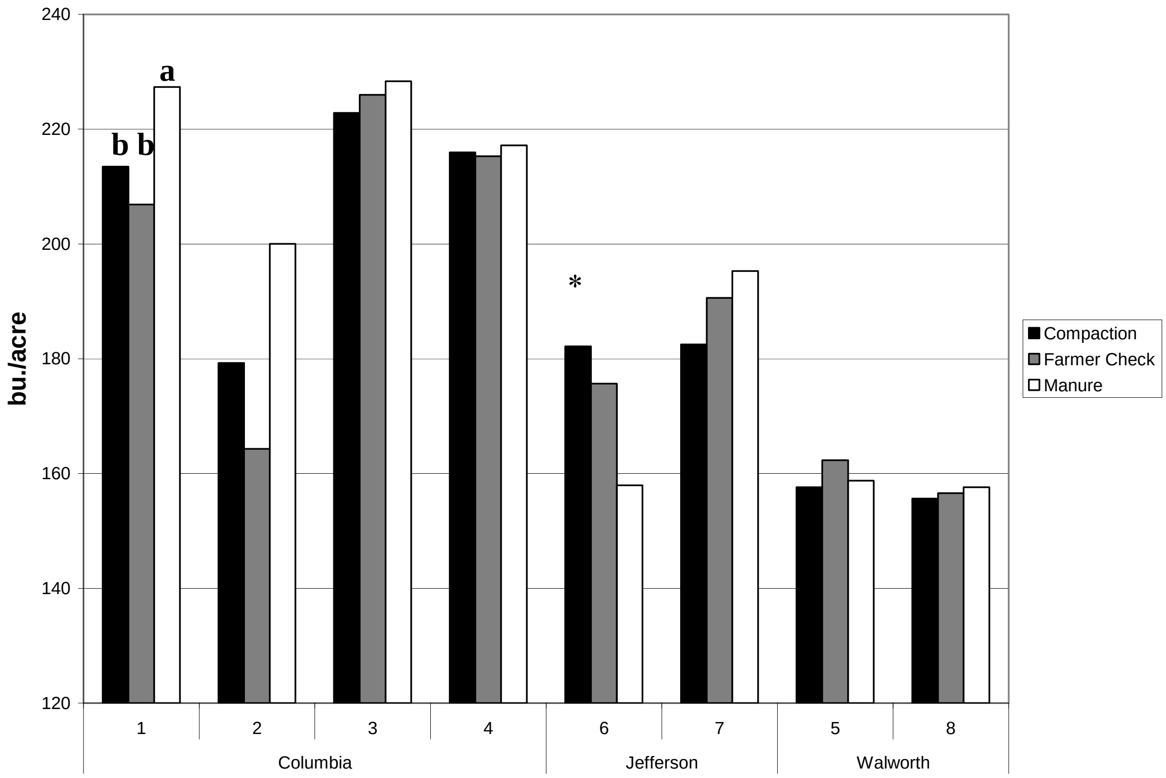
As with the on-farm trials, there was no effect due to treatment in the on-station trial. Looking specifically at our hypotheses: 1) the single compaction pass resulted in similar yields to the farmer check and 2) the manured plot did not ameliorate yields above the compacted plot. Surprisingly, even the heavily trafficked C6 had yields nearly equivalent to the farmer's check.

Hand harvests

A trend begins to appear with the hand harvests (Table 4). While distance from the tire track was not important with one pass, both M6 and C6 (six pass treatments) yields increased significantly from within the tire track to 60 inches from the tire track.

[4] Midwest Regional Climate Center http://mcc.sws.uiuc.edu/

Fig 1. Site by site on-farm yield summary.



Note: bars with different letters are significant at α = 0.05,
* mean value based on two data points rather than three

Table 4. Summary of 5-foot long hand harvest yields—estimated corn yield in bu/a.

	1 Pass		6 Pass	
Treatment	Manure	Compaction	Manure	Compaction
Within tire track	185	181	168[a]	146[a]
30 in. from tire track	187	188	166[a]	171[b]
60 in. from tire track	179	176	184[b]	176[b]

Note: Columns with differing letters are significantly different at α=0.10.

Conclusions

In this study we are asking two questions: 1) Does the compaction caused by the application of manure result in lower corn yields; and, 2) If lower yields do result, does manure itself, help to mitigate the effect of compaction. In our on-farm and on-station trials, although loaded axle weights were high (19,880 to 30,995 lb), plots that were driven across with a slurry tanker, but received no manure gave equivalent yields as non-trafficked farmer check plots. Furthermore, yields were not significantly improved from the addition of manure suggesting that there was no amelioration effect of manure. However, when rows were harvested individually, it appeared that rows within/ directly next to the tire tracks did produce less corn than those at 60" from the track. Within-track yields of multiple trafficked areas were reduced by 10% to 16% compared to rows 60" away from the tire tracks. These preliminary results suggest that, when driving on relatively dry soils, the compaction caused by manure spreaders does not significantly reduce corn yields on the majority of the field but headlands or field entrances will yield slightly less.

References

Abu-Hamdeh, N.H., 2003. Compaction and sub soiling effects on corn growth and soil bulk density. Soil Sci. Soc. Am. J. 67:1213-1219.

Alakukku, L., and P. Elonen. 1995. Long-term effects of a single compaction by heavy field traffic on yield and nitrogen uptake of annual crops. Soil Tillage Res. 36:141-152.

Bundy, L.G., and T.W. Andraski. 1995. Soil yield potential effects on performance of soil nitrate test. J. Prod. Agric. 8:561-568.

Daum, D.R. 1996. Soil compaction and conservation tillage. Penn State Coop. Extension, Conservation Tillage Series (3).

Evans, S.D., M.J. Lindstrom, W.B. Voorhees, J.F. Moncrief, and G.A. Nelson. 1996. Effect of subsoiling and subsequent tillage on soil bulk density, soil moisture, and corn yield. Soil Tillage Res. 38:35-46.

Håkansson, I., W.B. Voorhees, and H. Riley. 1987. Vehicle and wheel factors influencing soil compaction and crop response in different traffic regimes. Soil Tillage Res. 11:239-282.

Lal, R., and M. Ahmadi. 2000. Axle load and tillage effects on crop yield for two soils in central Ohio. Soil Tillage Res. 54:111-119.

Lowery, B., and R.T. Schuler. 1991. Temporal effects of subsoil compaction on soil strength and plant growth. Soil Sci. Soc. Am. J. 55:216-223.

Lowery, B., and R.T. Schuler. 1994. Duration and effects of compaction on soil and plant growth in Wisconsin. Soil Tillage Res. 29:205-210.

Stewart, G.A., and T.J. Vyn. 1994. Influence of high axle loads and tillage systems on soil properties and grain corn yield. Soil Tillage Res. 29:229-235.

Wolkowski, R.P. 1990. Relationship between wheel-traffic-induced soil compaction, nutrient availability, and crop growth: a review. J. Prod. Agric. 3:460-469.

Wolkowski, R.P. 1991. Corn growth response to K fertilization on three compacted soils. Soil Tillage Res. 21:287-298.

STRUVITE: A RECOVERED AND RECYCLED PHOSPHORUS FERTILIZER

Phillip Barak and Alysa Stafford [1/]

Struvite, magnesium ammonium phosphate hexahydrate—is a biogenic mineral of low solubility. For 150 yrs, it has been proposed as a fertilizer but its use has been limited to high-value crops because of the additional cost of manufacture. With the advent of new interest in removing phosphorus from wastestreams before land application, recovery of phosphorus as struvite has gained new interest. Pot studies show that struvite outperforms diammonium phosphate on a unit-for-unit basis in terms of dry matter production, P uptake, and extractable residual P. Various local wastestreams are candidates for struvite removal with little or no chemical additions using molecular templates as nucleating surfaces.

Struvite is a biogenic mineral of the composition magnesium ammonium phosphate hexahydrate ($MgNH_4PO_4{\bullet}6H_2O$), with a solubility of 0.2 g/L in water. Humans most often encounter struvite as either urinary sediments or kidney stones, both usually associated with infections of the urinary tract that hydrolyze urea into ammonia and raise urine pH. Struvite is also occasionally encountered in canned seafood, such as lobster, crab, salmon, or tuna, in which (harmless) glass-like slivers form over time, sometimes 5 to 8 mm in length, when ammonia and phosphate released from tissue during processing reacts with magnesium-rich seawater. Struvite is also known as a nuisance in sewage treatment plants (Rawn et al., 1939) when it forms blockages in pipes following anaerobic digestion of solids, a process releasing considerable ammonium and phosphate into the digester liquor. Struvite is also known to form in animal manure, hence its synonym 'guanite', although it is often difficult to determine whether it is present upon excretion or whether it forms upon microbial decomposition of the manure. Presumptive evidence exists for the presence of struvite in poultry manure (Cooperband and Good, 2002) and clear evidence from quantitative x-ray diffraction indicates that struvite and brushite are found in fresh sheep manure in roughly equal proportions and together account for 63% of P in the feces (Shand et al., 2005.) Clearly the presence of so much sparingly-soluble mineral P in the manure will affect the transfer of manure phosphorus to water and runoff.

Struvite contains 5.7% N and 12.6% P by weight; the phosphate is entirely citrate-soluble (Bridger et al., 1962) and the fertilizer analysis in oxide form is 5.7-28.8-0, with 9.9% Mg. As long ago as 1858, struvite has been proposed as potential phosphorus source for agriculture, and repeatedly since then. In fact, struvite appears to form in soil upon fertilization with other ammonium phosphate fertilizers, particularly when neutral or alkaline conditions prevail. Diammonium phosphate (DAP), itself highly water soluble, forms struvite using soil magnesium as the third constituent (Lindsay and Taylor, 1960; Lindsay et al., 1962); struvite formation in soil upon addition of ammonium polyphosphate has also been reported (Ghosh et al., 1996). When struvite is added to soil, phosphorus release appears to be largely the result of microbial nitrification of the ammonium constituent rather than simple dissolution (Bridger et al., 1962). In the 1960s, WR Grace & Co. secured patent rights for manufacture of an ammonium/potassium magnesium phosphate fertilizer, marketed under the tradename of MagAmp as a slow-release fertilizer, made by adding magnesium oxide or magnesium hydroxide to monoammonium phosphate (Peng et al., 1979); cost of production kept this for use in high value-added applications, such as floriculture, only. Alternative methods of producing struvite by the addition of sulfuric acid to rock phosphate and olivine, followed by ammoniation (MacIntire and Marshall, 1959), have not been economically feasible.

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Over the last decade, interest has grown in extracting phosphorus from wastewater and agricultural manure, and struvite has emerged as a strong candidate. The primary motivation for phosphorus recovery is reduction of the phosphorus load when landspreading biosolids and manure on already phosphorus-rich fields, and only secondarily to economically produce high analysis phosphorus fertilizer by recycling instead of manufacture from virgin materials. In most cases, it has been determined that the anaerobic digest liquors and manures are deficient in magnesium and the pH is too low for optimal struvite removal. The addition of magnesium chloride, sodium hydroxide, or magnesium oxide has been frequently proposed, along with carbon-dioxide stripping by sparging to raise the pH. A small number of wastewater treatment plants around the world have built struvite-recovery facilities; the cost of adding magnesium salts and base clearly outweigh the economic value of the struvite as a bulk fertilizer material, but additional savings in prevent struvite obstructions of pipes are convincing (Ueno and Fujii, 2001; Jaffar et al., 2002). A number of struvite-recovery operations have been tested or built for agricultural manure handling operations. Notable are struvite production from veal manure in the Netherlands and pig manure in Japan (CEEP, 2003) and Australia (v. Münch and Barr, 2001). Work in the U.S. at an advanced state are those in Tennessee (Burns et al., 2001; CEEP, 2003) and North Carolina (CEEP, 2004) in piggery manure lagoons. At least in some cases, the precipitate formed upon addition of chemicals is 1:2:0.2 N:P:Mg instead of 1:1:1, indicating that the majority of the phosphate removed was not struvite, but perhaps calcium phosphates along with mixtures of other precipitates. As modern manure handling procedures becomes more similar to wastewater treatment, removal of struvite from agricultural manure becomes more feasible; in fact, the addition of sodium phosphate, as well as magnesium, to dairy manure anaerobic digester effluent has been proposed to remove dissolved ammonium as struvite (Uludag-Dmirer et al., 2005).

Although struvite forms relatively readily from supersaturated solutions, removing struvite crystals from a mixture of suspended solids is problematic since the specific gravity of struvite, 1.6, only slightly exceeds that of common suspended organic solids. The nucleation and crystallization can be localized by use of a molecular template consisting of a densely negatively-charged surface that matches the spacing of the magnesium hexahydrate crystallographic plane of struvite (Barak et al., 2005.) Such templates, whether floating compressed Langmuir monolayers or self-assembling monolayers on a solid substrate, can direct formation of relatively large (0.2 to 2 mm), symmetrical struvite crystals on the treated surface, which can be particularly advantageous in removing struvite products from digester liquors and liquid manure. Additional research has shown that magnesium can be dosed by compulsive ion exchange using cation exchange membranes with magnesium salts separated from the digester liquors and liquid manure.

With the renewed interest in producing struvite—not from virgin fertilizer materials but as a recovered resource from waste streams—examination of struvite as a phosphate fertilizer and comparison against the favored fertilizers of the day becomes an interesting subject. Previous studies have shown struvite to be approximately equal to or surpass monocalcium phosphate and dicalcium phosphate in efficiency (Lindsay and Taylor, 1960; Richards and Johnston, 2001; Johnston and Richards, 2003). However, ammonium phosphates are currently the predominant phosphate fertilizers in the United States, particularly diammonium phosphate (DAP) and a straightforward comparison between ammonium phosphate and struvite seems particularly relevant. The purpose of this study was to analyze the efficiency of struvite as a phosphorus fertilizer in comparison to the synthetic fertilizer DAP using dry matter yield, P concentration in plant dry matter, P uptake in above ground dry matter, and residual Bray P in the soil as measures of comparison.

We conducted a greenhouse experiment in which corn was grown for six weeks in 1.5-kg pots of P-deficient Plano silt loam from Arlington Research Station. Treatments were a control and two rates of DAP (50 and 100 mg DAP-P/kg) and one rate of struvite (36 mg struvite-P/kg): all treatments were brought to a uniform N rate of mg N per kg soil with urea. Pots were brought to field capacity and regularly watered by weight, with no drainage from the pots. Struvite for this experiment was produced in our lab by crystallization from a supersaturated solution of magnesium sulfate and ammonium phosphate, dried, and lightly ground to match the particle size of the DAP.

During the 6-week growth period in the greenhouse, the corn plants grew vigorously and appeared healthy and free of visible pathogens, with healthy and dense roots upon disassembly at harvest. Corn plants grown in the no-phosphorus-added pots were, as intended, visibly phosphorus deficient, with reddish purple tips and leaf margins. Those plants grown in pots that received DAP and struvite were visibly taller than the no-phosphorus controls and phosphorus deficiency symptoms were absent. Statistical analysis showed that the dry matter production of the 36 mg struvite-P/kg was identical to that of the 100 mg DAP-P/kg treatment, and both outperformed the 50 mg DAP-P/kg treatment and the control.

Examination of the amount of phosphorus offtake in the aboveground plant showed (Fig. 1) that the 36 mg struvite-P/kg treatment was equivalent to 42 mg DAP-P/kg, and struvite therefore had a relative efficiency of 117% compared to DAP. Similar analysis for average residual Bray P found that the 36.4 mg struvite-P/kg soil treatment was equivalent to that expected of 64.9 (+/-12.3) mg DAP-P/kg soil, or 178% equivalency.

We have conducted some chemical analyses of potential local wastewater sources from which struvite recovery could be considered (Table 1). All five samples reflect anaerobic conditions, as evidenced by the very low concentrations of nitrate compared to ammonium. At the Nine Springs Water Treatment Plant (Madison Metropolitan Sewerage District, Madison, WI) we have found that the gravity belt thickener (GBT) feed and filtrate (not shown) are supersaturated with regard to struvite, which is consistent with the tendency of these waters to form pipe obstructions as they leave the anaerobic digesters; the magnesium supply of these waters is relatively small compared to the ammonium and phosphate concentrations and will therefore be limit the amount of struvite formed. In contrast, the supernatant by gravity settling at another part of the plant has a high level of dissolved phosphorus but is not close to struvite saturation. Several working manure lagoons sampled at the Arlington Research Station gave varying results. Those that were slightly acidic were supersaturated with respect to brushite, a dicalcium phosphate dihydrate mineral. On the other hand, the sample that was slightly alkaline (#2) was undersaturated with regard to brushite but very nearly saturated with struvite, which may account for its lower dissolved P concentration. We do not have sufficient information or controlled experimental conditions to allow us to speculate as to the differences between #2 and samples #1 and #3, but clearly struvite formation in the manure samples is favored by an abundant supply of magnesium from the plant diet that is nearly absent in the municipal wastewater. The significance of finding that some wastestreams are struvite-saturated is that the expense of additional chemicals may be avoided, particularly if nucleation of struvite in recoverable forms can be coaxed. Using the self-assembling membrane and compulsive ion exchange technologies of Barak et al. (2005), well-shaped struvite has been formed from GBT filtrate in the laboratory; with self-assembling membranes, crystallites of yet-undetermined composition were formed from the dialyzate from manure lagoon #2.

Taken as a whole, the future looks bright that the phosphorus of various organic waste streams, both municipal and agricultural, may be reduced by recovering a desirable, high-analysis phosphorus fertilizer, struvite.

References

Barak, P. 1990. SPECIES: A spreadsheet program for modeling speciation of soil solution. J. Agron. Educ. 19:44-46. [http://www.soils.wisc.edu/~barak/species.htm]

Barak, P., M.E. Tabanpour, M. Avila-Segura, and J.M. Meyer. 2005. Struvite crystallization to remove phosphorus from waste. U.S. Patent Application No. US 2005/0023220 A1. 28 pp. [http://www.warf.org/pubapps/P04039US%20Published%20Application.PDF]

Bridger, G.L., M.L. Salutsky, and R.W. Starostka. 1962. Metal ammonium phosphates as fertilizers. Agric. Food Chem. 10:181-188.

Burns, R.T., L.B. Moody, F.R. Walker, and D.R. Raman. 2001. Laboratory and in-situ reductions of soluble phosphorus in liquid swine waste slurries. Environ. Technol. 22:1273-1278.

CEEP. 2003. Japan: P-recovery from piggery wastewaters; Tennessee: Struvite recovery from swine wastes. SCOPE Newsletter no. 50, p. 5-6.

CEEP. 2004. North Carolina: Struvite recovery from livestock lagoon liquor. SCOPE Newsletter no. 55, p. 14-16.

Cooperband, L.R., and L.W. Good. 2002. Biogenic phosphate minerals in manure: Implications for phosphorus loss to surface waters. Environ. Sci. Technol. 2002:5075-5082.

de-Bashan, L.E., and Y. Bashan. 2004. Recent advances in removing phosphorus from wastewater and its future use as fertilizer (1997-2003). Water Res. 38:4222-4246.

Ghosh, G.K., K.S. Mohan, and A.K. Sarkar. 1996. Characterization of soil-fertilizer P reaction products and their evaluation as sources of P for gram (*Cicer arietinum* L.). Nutrient Cycling Agroecosystems 46:71-79.

Jaffer, Y., T.A. Clark, P. Pearce, and S.A. Parsons. 2002. Potential phosphorus recovery by struvite formation. Water Res. 36:1834–1842.

Johnston, A.E., and I.R. Richards. 2003. Effectiveness of different precipitated phosphates as phosphorus sources for plants. Soil Use Mgmt. 19:45-49.

Lindsay, W.L., A.W. Frazier, and H.F. Stephenson. 1962. Identification of reaction products from phosphate fertilizers in soils. Soil Sci. Soc. Am. Proc. 26:446-452.

Lindsay, W.L., and A.W. Taylor. 1960. Phosphate reaction products in soil and their availability to plants. 7th Intern. Congr. Soil Sci., Madison, WI. IV:580-589.

MacIntire, W.H., and H.L. Marshall. 1959. Magnesium ammonium phosphate from olivine and rock phosphate. Agric. Food Chem. 7:566-568.

v. Münch, E., and K. Barr. 2001. Controlled struvite crystallisation for removing phosphorus from anaerobic digester sidestreams. Water Res. 35:151-159.

Peng, P.H., W.R. Ernst, G.L. Bridger, and E.M. Hartley. 1979. Slow release fertilizer materials based on magnesium ammonium phosphate. Pilot-plant granulation studies. Ind. Engr. Chem. Process Des. Dev. 18:453-458.

Rawn, A.M., A.P. Banta, and R. Pomeroy. 1939. Multiple stage sewage digestion. Am. Soc. Civil Engr. Trans. 105:93–132.

Richards, I.R., and A.E. Johnston. 2001. The effectiveness of different precipitated phosphates as sources of phosphorus for plants. CEEP Report, Dec 2001.

Shand, C.A., G. Coutts, S. Hillier, D.G. Lumsdon, A. Chudek, and J. Eubeler. 2005. Phosphorus composition of sheep feces and changes in the field determined by ^{31}P NMR spectroscopy and XRPD. Environ. Sci. Technol. 2005:9205-9210.

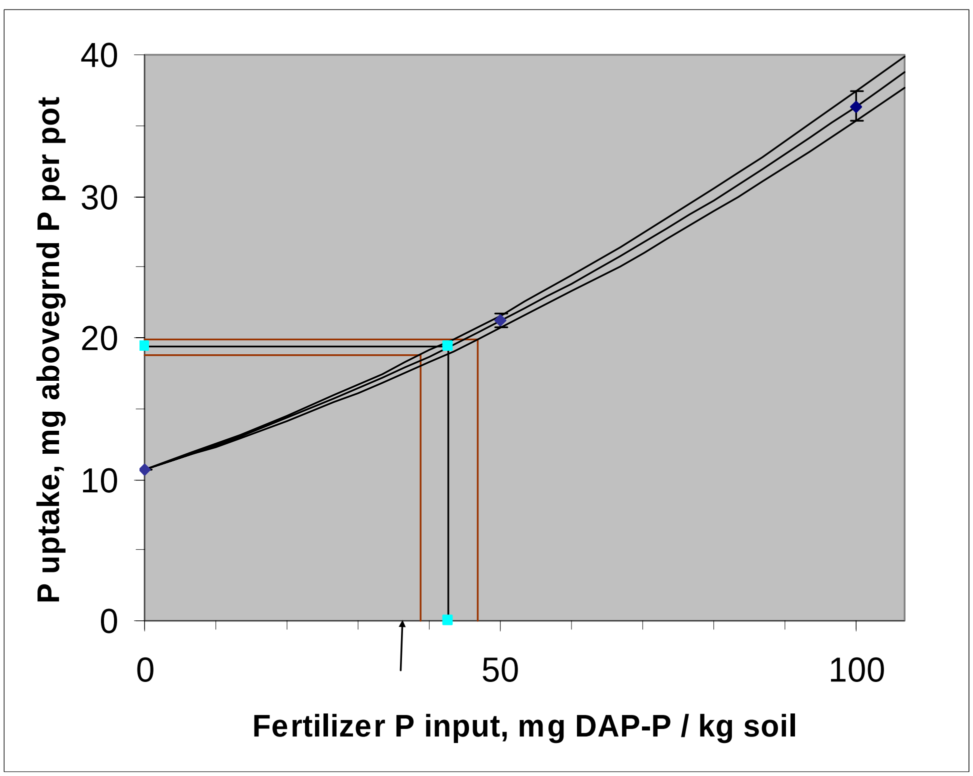
Ueno, Y., and M. Fujii. 2001. Three years experience of operating and selling recovered struvite from full-scale plant. Environ. Technol. 22:1373-1381.

Uludag-Demirer, S., G.N. Demirer, and S. Chen. 2005. Ammonia removal from anaerobically digested dairy manure by struvite precipitation. Process Biochem. 40:3667-3674.

Table 1. Chemical analysis (partial report) of selected wastewaters tested for struvite-forming potential by chemical speciation calculations using SPECIES (Barak, 1990). Where the pIAP (ion activity product) is less than pK_{sp}, the solubility product for a specified mineral, the water sample is supersaturated with respect to that mineral.

		Nine Springs Water Treatment Plant (MMSD)		Arlington Dairy Manure Lagoons		
		Supernatant, gravity	GBT feed	#1	#2	#3
Analysis of water/dialyzate:						
pH		6.67	7.78	6.14	7.35	6.10
NH_4-N	mg/L	35.0	624	823	894	859
NO_3-N	" "	0.03	0.53	0.03	0.06	0.03
Ca	" "	81.1	43.2	375	244	448
Mg	" "	52.9	4.7	282	225	279
Na	" "	265	274	254	370	259
K	" "	20.6	358	2030	2310	2030
PO_4-P	" "	15.7	204	105	20	93
pIAP (pK_{sp}):						
calcite	(8.5)	10.3	8.7	8.8	7.2	8.3
brushite	(18.9)	19.5	18.5	18.7	19.3	18.6
struvite	(13.2)	15.5	12.3	13.6	13.2	13.4

Figure 1. Comparison of P uptake in response to struvite application and DAP-P application at three levels (0, 50, and 100 ppm) with quadratic response line drawn among the means and +/- 1 standard deviation of the means. The average P uptake for the 36.4 mg struvite-P/kg soil treatment was equivalent to that expected of 42.6 (+/-4) mg DAP-P/kg soil.



SOIL SAMPLING FOR NUTRIENT MANAGEMENT PLANS

Ted Bay and Karen Talarczyk [1/]

Farmers develop nutrient management plans to better manage their fertilizer dollars. Increasingly nutrient management plans are required for federal, state, and county government programs. These programs require plans that are written using Wisconsin Nutrient Management Standard 590 guidelines. The Standard requires routine soil testing at least once every four years. Soil testing provides the foundation of sound nutrient management plans.

The Natural Resource Conservation Service Code 590 references UW-Extension A2100, "Sampling Soils for Testing," as the soil sampling guide for Wisconsin. This publication provides guidelines for soil sampling for both conventional fertilizer recommendations and for site-specific management for variable rate fertilizer applications. The method of fertilizer application determines the soil sampling procedure.

Whole field "conventional" soil sampling is used for single uniform fertilizer recommendations for individual fields. These applications are based on the average of the soil test analysis for each field. The basic soil testing guidelines strive for accurate representation of field nutrient needs and include, following a 'W' pattern in the field, pulling 10 or more cores per sample, and no more than five acres per sample. Field areas to avoid are fence lines, field edges, dead furrows, eroded areas and low spots.

Site-specific (grid) sampling results are used to develop an application map with variable lime and fertilizer rates throughout a field. With grid sampling, a systematic approach is used to divide the field into squares of approximately equal size called grid cells. These can be 5 acre, 2.5 acre, or 1 acre in size. With grid point sampling, at least 10 cores are collected from a small area (10 foot radius) around a geo-referenced point. Field areas to avoid are identical to conventional sampling. Grid sampling guidelines in A2100 recommend that fields that in the past have tested in the responsive range (interpretive level of high or below) be sampled on a grid no larger than 200 feet to sufficiently represent the nutrient variability of the field.

Many Southwestern Wisconsin farm fields consist of small, contoured strips. Attempts have been made to develop Nutrient Management Plans on these fields using soil tests derived from grid sampling techniques. Contour strips do not easily lend themselves to the "systematic approach" of dividing a field into grid squares of approximate equal size. Examples of contour fields that were grid sampled show how whole fields are missed or samples are taken on fence lines or field boundaries. As shown in these examples, grid sampling contour strips often results in sampling that does not represent the soil conditions of these fields.

Choosing the appropriate soil sampling procedure is critical to nutrient management planning. Individual fields must be accurately represented in the soil test analysis.

References

Peters, J.B., K.A. Kelling, and L.G. Bundy. Sampling Soils for Testing UWEX A2100. R-05-02-1.9M-50.

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ALLOCATING LIMITED DOLLARS FOR LIME

J.B. Peters and C.A.M. Laboski [1/]

Soil pH affects the activity of soil microorganisms and many of the chemical reactions that occur in the soil. The availability of N, P, K, S, Ca, Mg, and Mo increases as soil pH increases from pH 5.0 to 7.0. The availability of Fe, Mn, B, Cu, and Zn, on the other hand, decreases. Chlorine is relatively unaffected by soil pH. The effect of pH on the availability of N arises mainly from the influence of soil pH on microbial activity. Most of the N and S in soil resides in the organic fraction and is released in available form as crop residues are decomposed microbially. The effect of pH on the availability of the other nutrients is governed by the chemical reactions that take place between these nutrients and soil colloids. One of the principal reasons for liming Wisconsin soils is to reduce the potential for manganese (Mn) toxicity. On the other hand, a deficiency of Mn can occur in high pH soils. For this reason, soil pH has a pronounced influence on the growth and yield of most crops.

The prudent use of aglime is the cornerstone of a good soil fertility program. In Wisconsin, aglime is used to reduce soil acidity and optimize the soil pH for the crops to be grown on a particular field. There are three distinct regions of the state in terms of aglime need and availability. The eastern region of the state is composed of soils which were largely derived from calcareous parent material and normally do not need to be limed. The second region is the north-central part of the state which is made up of soils that are inherently acidic. This area of Wisconsin does not have a source of naturally occurring limestone. As a result, aglime is transported to this north-central region largely from areas in eastern Wisconsin. The third general area is the southern and western counties where limestone is found and "local lime" is produced. This lime is generally not as finely ground as the aglime that is transported from the eastern side of the state to the north-central region. As a result, depending on where you are in the state, aglime can either be a significant cost of crop production or a non-issue (Peters et al., 1996).

Alfalfa

The benefit of achieving and maintaining a nearly neutral soil pH for alfalfa production is well known. Rhizobium species, the bacteria that fix nitrogen in nodules of leguminous plants, do best above a soil pH of 6.5.

Figure 1 shows results of a recent Wisconsin study that confirms that in areas of the state where soil pH is inherently acidic, the pH should be adjusted into the 6.5 to 7.0 range if alfalfa is to be grown. In this study, the average annual dry matter yields when the soil pH was at least 6.5 or higher were approximately 187, 250, and 410% of the yields found at the lowest treatment levels (pH 4.5 to 4.8) for the Hancock, Marshfield, and Spooner locations, respectively. A significant interaction between soil pH and K application rates was observed for dry matter yield at all three locations. This interaction showed that there was little yield response to K at the lower pH levels, but if the soil was limed adequately, substantial response to topdressed K was

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observed (Peters et al., 2003). With rapidly increasing K costs, this interaction is even more important than it has been in the past.

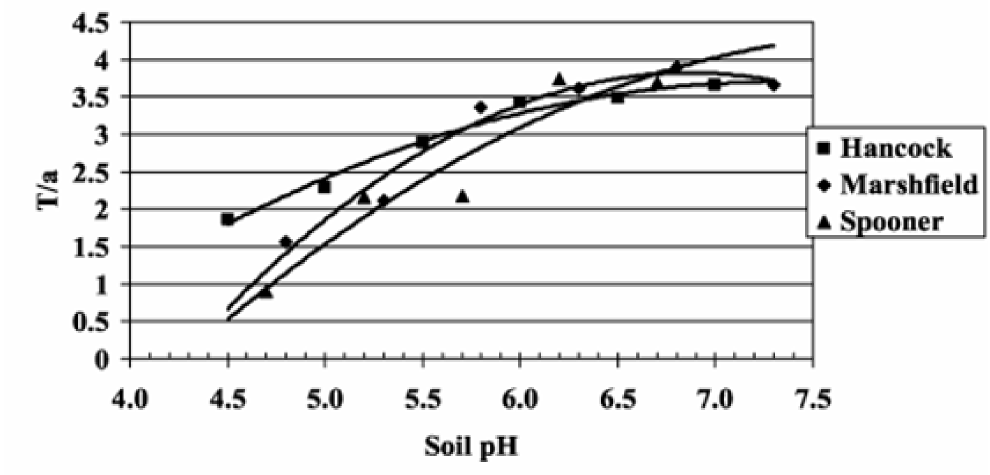


Figure 1. Alfalfa yield response to changes in soil pH at three Wisconsin locations (average 1998 to 2001).

Corn

The benefit of liming for corn production has traditionally been seen as less dramatic. The effect of soil pH on corn grain and silage dry matter yields varies with the growing season and appears to be more pronounced when the crop is under moisture or other stresses.

The impact of changing soil pH levels on corn yield has been studied over the past 30 years at several locations in Wisconsin including the Arlington, Hancock, Marshfield and Spooner Agricultural Research Stations. Additional work was done during this past growing season. The yield of corn silage was maximized as soil pH was increased to pH 6.0 to 6.3 (Table 1). In all of the other long-term data, it appears that our current UW recommendation of maintaining a soil pH of at least 6.0 when corn is to be grown is very appropriate (Figure 2).

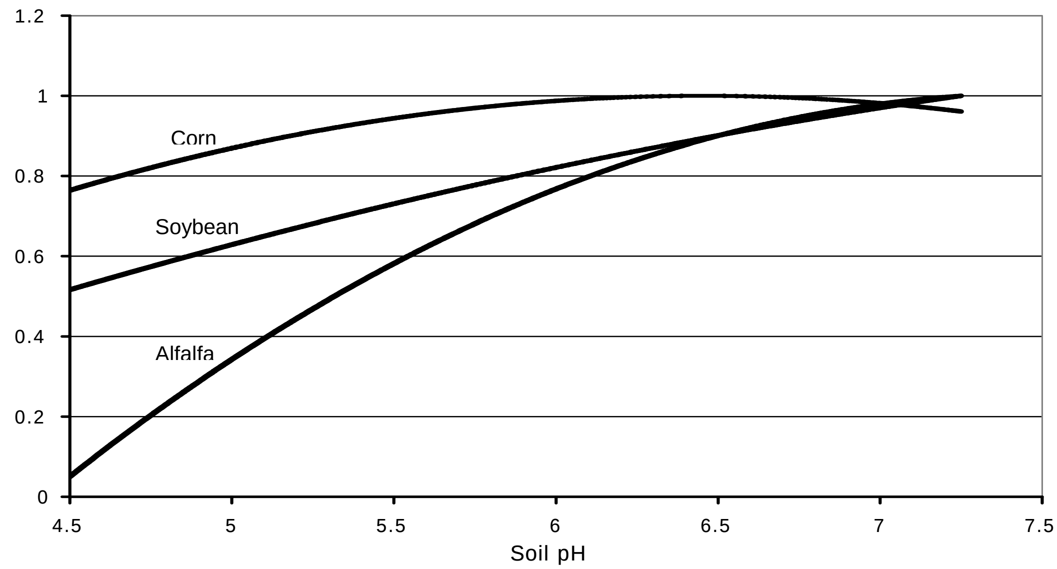
Table 1. 2005 Corn silage yield.

Target	Corn silage	
soil pH	Marshfield	Spooner
	--------- DM yield t/a ---------	
4.7 to 4.8	5.59	5.88
5.2 to 5.3	5.94	6.48
5.7 to 5.8	6.10	6.35
6.2 to 6.3	6.52	7.66
6.7 to 6.8	6.43	7.00
lsd	0.82	0.85

Soybeans

Since many of Wisconsin's soybeans are grown on soils with some degree of acidity, soil pH can have a significant impact on nutrient uptake and yield of soybeans. Recent Wisconsin research (Peters et al., 2005) has confirmed that there can be a significant yield benefit when the soil is limed to a pH of at least 6.3 for soybean production (Figure 2).

Figure 2. Effect of soil pH on crop yield response



Economics of Liming

Aglime, fertilizer, animal waste applications and cultural practices work together to enhance soil productivity and increase profits. With commodity prices not keeping pace with the skyrocketing price of purchased nutrients and other production costs, producers are faced with some very important decisions. When input dollars are limited, as they are in most cases, it is easy to cut back on lime due to the relatively longer payback time when compared to N, P, or K. Ongoing research at three University of Wisconsin Agricultural Research Stations during the past 8 years has included studies involving alfalfa, soybean and corn for grain and silage production. In an effort to document the economic benefit of liming, the potential payback must be allocated over an entire rotation. A typical rotation for much of the dairy producing areas of Wisconsin includes 3 years of alfalfa, 2 years of corn and 1 year of soybeans. The payback from applying various rates of lime to soils at three different research stations was determined in Table 2. Yields achieved during this 6-year rotation on the sandy loam soil at Spooner indicate that when the soil pH is very acidic (<5.0) an application of 3.75 t/a of lime costing approximately $94 resulted in about $441 of additional income. Adding an additional 4.75 tons of lime to increase the soil pH from moderately acidic (pH=5.7) to nearly neutral (pH=6.7) resulted in an additional net return of $487.

Table 2. Economic return from liming for a 6-year rotation.

	Soil pH		
Spooner	4.7	5.7	6.7
Lime needed, t/a	0	3.75	4.75
Lime cost (@ $25/t), $/a	0	93.75	118.75
Avg. annual alfalfa yield 1998-2001, DM t/a	0.90	2.18	3.69
Alfalfa value $/a (@ $100/ton)	90	218	369
Soybean 2004 yield, bu/a	7.5	21.4	27.5
Soybean value $/a @ $5.00/bu	37.50	107.00	137.50
Corn 2005 silage, DM t/a	5.88	6.35	7.00
Corn silage value $/a @ $70/t DM	411.60	444.50	490.00
Corn 2005 grain yield, bu/a	148.1	171.4	163.4
Corn grain value $/a @ $2.10/bu	311.01	359.94	343.14
Gross return for 6-yr rotation, $/a	1030.11	1471.69	1958.89
Return for additional lime, $/a		441.58	487.20

	Soil pH		
Hancock	5.0	6.0	7.0
Lime needed, t/a	0	2.75	3.25
Lime cost (@ $25/t), $/a	0	68.75	81.25
Avg. annual alfalfa yield 1998-2001, DM t/a	1.87	2.89	3.49
Alfalfa value $/a (@ $100/ton)	187	289	349
Soybean 2004 yield, bu/a	48.9	50.0	50.8
Soybean value $/a @ $5.00/bu	244.50	250.00	254.00
Corn 2005 silage, DM t/a	6.86	8.18	8.80
Corn silage value $/a @ $70/t DM	480.20	572.60	616.00
Corn 2005 grain yield, bu/a	181.2	207.5	200.5
Corn grain value $/a @ $2.10/bu	380.52	435.65	421.05
Gross return for 6-yr rotation, $/a	1666.22	2056.50	2256.80
Return for additional lime, $/a		390.28	200.31

	Soil pH		
Marshfield	4.8	5.8	6.8
Lime needed, t/a	0	7.00	9.75
Lime cost (@ $25/t), $/a	0	175.00	243.75
Avg. annual alfalfa yield 1998-2001, DM t/a	1.56	3.37	3.90
Alfalfa value $/a (@ $100/ton)	156	337	390
Soybean 2004 yield, bu/a	26.4	36.1	38.2
Soybean value $/a @ $5.00/bu	132.00	180.50	191.00
Corn 2005 silage, DM t/a	6.23	6.67	6.95
Corn silage value $/a @ $70/t DM	436.10	466.90	486.50
Corn 2005 grain yield, bu/a	149.0	150.0	169.0
Corn grain value $/a @ $2.10/bu	312.90	315.00	354.90
Gross return for 6-yr rotation, $/a	1349.00	1798.40	1958.65
Return for additional lime, $/a		449.40	160.25

NOTE: Marshfield soybean and corn silage yields are average of two sites.
Hancock 1997 yields using optimum N rate.
Marshfield corn grain data from 2002.

At Hancock, the greatest return was found with the first increment of lime for this very sandy soil. Adding 2.75 t/a to increase soil pH from approximately 5.0 to 6.0 resulted in a net return of $390. Applying an additional 3.25 t/a to increase soil pH from 6.0 to 7.0 yielded a net return of another $200.

The imperfectly drained silt loam soils at Marshfield require significantly more lime to reduce acidity than was seen at the other two locations. To increase soil pH from 4.8 (native level) to 5.8 (moderately acidic) requires about 7.0 t/a. This resulted in a net return of nearly $450/acre. Adding another 9.75 t/a to further increase soil pH to the target level for alfalfa production (6.8) resulted in an additional net return of $160/acre.

In all cases net return from liming was calculated by subtracting the cost of the lime from the additional crop yield realized when lime was added. No other adjustments to production costs were made in these calculations.

Summary

It is important that during this period of rising fertilizer prices, that the liming program not be completely neglected. Base your decision to lime on the current soil pH value from a recent soil test, and knowing what crops you plan to grow on a field in the next rotation (4 to 6 years). In general, the three major agronomic crops including alfalfa, corn and soybeans will respond to liming in many situations. In general, the magnitude of the response is alfalfa>soybean> corn (Figure 1). In all cases, crops will be more able to respond to fertilizer inputs if the soil pH is in the recommended range. Please keep in mind that lime should be thoroughly incorporated for maximum effectiveness and allow 2 to 3 years for complete reaction (Peters and Kelling, 1998).

References

Peters, J.B., and K.A. Kelling, 1998. When and how to apply aglime. UWEX Pub. A2458, Univ. of Wisconsin-Extension, Madison, WI.

Peters, J.B., K.A. Kelling, and E.E. Schulte, 1996. Choosing between liming materials. UWEX Pub. A3671, Univ. of Wisconsin-Extension, Madison, WI.

Peters, J.B., K.A. Kelling, P.E. Speth and S.M. Offer. 2003. Alfalfa yield and nutrient uptake as affected by pH and applied K. Commun. Soil Sci. Plant Anal.

Peters, J.B., P.E. Speth, K.A. Kelling, and R. Borges. 2005. Effect of soil pH on soybean yield. Proc. Wis. Fertilizer, Aglime, and Pest Mmgt. Conf. 44:134-138.

REDUCING IN-BARN AMMONIA EMISSIONS TO CONSERVE THE FERTILIZER NITROGEN VALUE OF DAIRY MANURE

J. Mark Powell[1] and Tom H. Misselbrook[2]

Introduction

Dairy farms are thought to emit large amounts of ammonia and therefore contribute to nitrogen (N) fertilization of natural ecosystems and provide precursors for particulates that adversely affect air quality and human health. The 2003 NRC report "Air Emissions from Animal Agriculture" (NRC, 2003) made an urgent call for processed-based research that assists livestock producers and regulatory agencies in developing strategies that reduce the emissions of ammonia and other gasses that impair air quality.

Only approximately 20 to 35% of the N (protein) fed to dairy cows is converted into milk (Figure 1). The remaining N is excreted in urine and feces. Feeding N to dairy cows in excess of their requirements is excreted in urine. About three-fourths of the N in urine is in the form of urea. Urease enzymes, which are present in feces and soil, rapidly convert urea to ammonium. Ammonium can be transformed quickly into ammonia gas. Feces contain little or no urea. For this reason urinary N is much more vulnerable to ammonia volatilization than is fecal N.

Dairy cows produce a lot of urine (approximately 8 gallons/day). Under current feeding and manure handling, storage, and land application techniques, most of the N contained in urine is converted to ammonia gas and lost to the atmosphere. The environmental impacts of ammonia can be broken down into two parts:

(1) How much ammonia-based compounds is actually deposited into different ecosystems, and

(2) Once deposited, how does the N cycle within each ecosystem respond to this input.

Some emitted ammonia is deposited not too far from its source (e.g., barn, lagoon, fields where manure has been applied). In Wisconsin where most dairy farms grow their own crops, approximately 20 to 30% of the emitted ammonia can be deposited on adjacent cropland. Ammonia N deposited in natural ecosystems, however, contributes to ecosystem fertilization, acidification, and the premature "ageing" of the ecosystem. This ammonia N input can cause dramatic shifts in the vegetation, enhancing grass growth and creating fire hazards in some areas. Emitted ammonia also combines with acidic compounds in the upper atmosphere to form particulates. These particulates have been related to haze in urban areas, and also have been attributed to a variety of adverse health effects, including premature mortality, chronic bronchitis, asthma, and hospital admissions.

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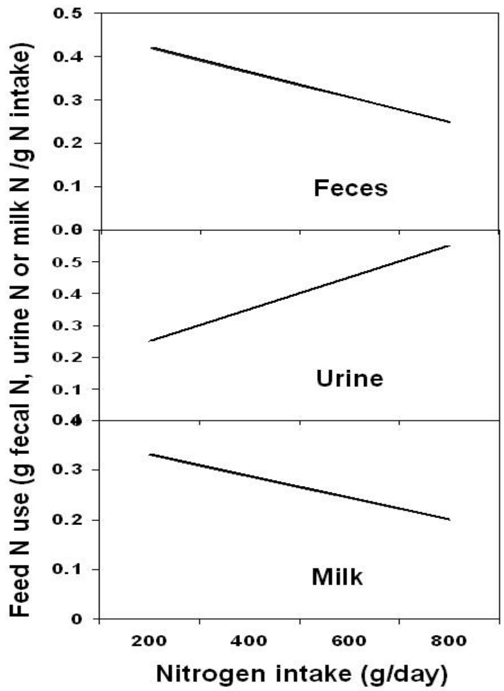
Fig. 1. Relationships between N fed to dairy cows and N secreted in milk and excreted in feces and urine (adapted from Castillo et al., 2000).



Approaches that Reduce Ammonia Losses from Dairy Barns

Ammonia production and loss occur almost immediately in the barn and continue through manure storage and land application. Because ammonia is a gas, losses are inevitable. But ammonia nitrogen loss can be reduced, and the fertilizer value of manure can be maintained through good management.

One of the most reliable approaches to reducing ammonia emissions per unit of milk produced is to increase level of milk production because, to a certain extent, emissions parallel feed intake. On Wisconsin dairy farms, the efficiency by which the crude protein contained in feed is converted into milk (i.e., feed nitrogen use efficiency) varies according to production practices. Milk production and feed N use are highest on farms that use total mixed rations (TMR), that balance rations four times per year, and milk thrice daily (Table 1). These practices put more feed nutrients into product (milk), and less into manure.

Over the long term, continued genetic selection of cows for high milk production potential will be a very effective means of reducing ammonia nitrogen emissions per unit of milk produced. Furthermore, increasing production per animal would decrease the number of cows needed to meet the market demand for milk.

Table 1. Impact of feed management and milking frequency on milk production, and feed N use efficiencies (FNUE) on 54 Wisconsin dairy farms (Powell et al., unpubl.)

Practice	Practice use	Milk Production	FNUE
		lbs/cow/d	%
Use TMR	Yes	74a†	27a†
	No	57b	24b
Balance rations 4 times/year	Yes	67a	26a
	No	54b	21b
Milk thrice daily	Yes	88a	33a
	No	63b	25b
Use Posilac®	Yes	82a	29a
	No	61b	25b

†within a practice, means followed by different letters differ significantly ($P<0.05$).

Protein Fed to Dairy Cows Affects Ammonia Loss

Diet formulation to eliminate excess N usually reduces feed cost, and it is one of the most effective tools for reducing emission into the atmosphere of nitrogen containing compounds from dairy farms. Nitrogen excretion by dairy cows via urine, and therefore the amount of manure N susceptible to loss, is highly influenced by the amount and type of protein fed. As the amount of protein in feed exceeds what is required, relatively less of the N goes into milk and more goes directly into urine production (Figure 1).

Significant reductions in urine production can be obtained by reducing dietary protein levels. For example, if 17.5% dietary protein currently represents an industry average for lactating cows, carefully formulated diets containing 16.0 to 16.2% crude protein, which meets requirements for the lactating cow and still provides a reasonable margin of safety, would reduce N excretion in urine by about 20% (Broderick, 2003).

Various lactation trials have been conducted whereby Holstein cows were fed different levels of crude protein (CP), fiber, corn silage, alfalfa silage, alfalfa haylage, and tannin-containing forages [alfalfa, birdsfoot trefoil low tannin (BF-T-Low) and birdsfoot trefoil high tannin (BF-T-High)]. The principal purpose of these trials was to evaluate diet impacts on milk production and composition. At the end of each trial, diet impacts on ammonia volatilization were evaluated by applying fresh or stored slurries to the surface of soils (Misselbrook et al., 2005).

Thus far, most of the tested diets have had little impact on milk production or quality, but affected the amount and relative N partitioning in urine and feces (similar pattern to what is depicted in Figure 1). Fresh and stored slurry from low CP diet had less than one-half the ammonia loss than slurries from the high CP diet (Table 2). Fresh slurry derived from BF-T-High diets had less ammonia loss than slurry from alfalfa or BF-T-Low diets. Stored slurry from BF-T-High and -Low diets had less ammonia loss than slurry derived from alfalfa.

Table 2. Cumulative ammonia emissions for fresh and stored slurries derived from different dairy diets applied to silt loam soil (Misselbrook et al., 2005).

Trial type	Trial components	Liquid manure type	
		Fresh	Stored
		% applied N volatilized	
CP level	13.6%	31b[#]	12b
	19.4%	68a	29a
Forage tannin type	Alfalfa	31a	30a
	BF-T-Low	33a	23b
	BF-T-High	25b	19b

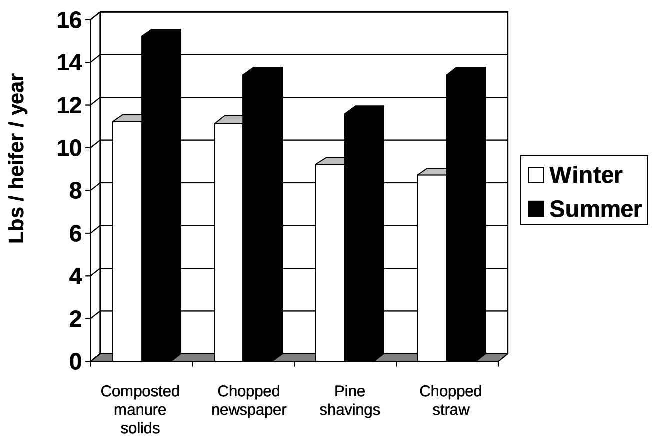
within each trial, values with different letters are significantly different (*P*<0.05)

Bedding Affects Ammonia Nitrogen Loss

Dairy cattle barns are major sources of ammonia emissions to the atmosphere. Our research is showing that the bedding material used can influence the magnitude of these emissions. The physical characteristics (urine absorbance capacity, bulk density) of bedding materials are of more importance than their chemical characteristics (pH, cation exchange capacity, carbon to nitrogen ratio) in determining ammonia emissions from applied urine and feces (Misselbrook and Powell, 2005). For example, of the bedding types commonly used in dairy barns, sand is the least and recycled manure solids the most urine absorbent. When equal volumes of urine were applied to dry bedding, ammonia emissions over 48 h were significantly lower from sand (23% of applied urine N), followed by pine shavings (42% of applied urine N), than from the other bedding types (mean 63% of applied urine N for straw, newspaper, corn stalks and recycled manure solids).

Preliminary results from in-barn trials show a similar pattern of ammonia emissions from beddings to that determined in the lab. Ammonia loss from composted manure solids was greater than from chopped straw and pine shavings (Figure 2). Because of warmer temperatures, ammonia emissions are 20 to 55% greater during the summer than during the winter. These laboratory and in-barn measurements indicate that the selection of bedding may be based not only on cow comfort and health, but also on their ability to reduce ammonia emissions.

Fig. 2. Ammonia N losses from tie-stalls using different beddings.



Impact of Ammonia Loss on Plant Availability of Manure Nitrogen

Ammonia loss from manure is important because it is a direct loss of nitrogen that is available to the farmer. Given the high potential of ammonia nitrogen loss in manure handling, storage, and land application, only a small fraction of the nitrogen excreted by a dairy cow and applied to land may actually be recycled through crops. Furthermore, the loss of ammonia also reduces the nitrogen:phosphorus ratio in manure, which may increase the risk of manure phosphorus applications in excess of crop needs. Many dairy farms have soil test phosphorus levels that exceed agronomic recommendations, and the runoff of phosphorus from these fields and subsequent pollution of lakes, streams, and other surface waters has become a principal concern.

Reducing ammonia losses from dairy farms and making greater use of conserved manure N may quickly make economic sense. Natural gas accounts for 75 to 90% of the cost of making anhydrous ammonia. As the price of natural gas continues to skyrocket, the fertilizer N value of manure, and therefore the conservation of the ammonia N contained in manure will become more important. Reducing volatile N losses would not only conserve manure N available for field applications, but also reduce the amount of carbon dioxide, a greenhouse gas, that is generated in making nitrogen fertilizer.

Conclusions

Substantial reductions in ammonia loss from dairy farms can be achieved by reducing in-barn losses, by covering manure storage, and by incorporation of manure in the field. The following steps can be a guide for action:

1. Remove excess protein from the cow's diet. This normally saves on cost of feed.
2. For new construction, floors that divert urine away from feces can reduce ammonia emissions. Slatted floors facilitate this, but there is still considerable loss of ammonia from the surface of the slatted floor.
3. Select bedding (e.g. sand, straw) that separate feces and urine, which reduce ammonia losses;
4. Cover the manure storage. When organic bedding such as straw is used in free stall, a crust will form on the surface of the slurry pit. This reduces ammonia N losses and odors. Excessive agitation during unloading of the slurry from storage should be avoided.
5. Incorporate manure in the field. However, this strategy needs to consider potential tradeoffs in situations where nitrate leaching may be a concern.

Implementation of 1, 3, 4, and 5 could potentially reduce ammonia N loss from about 115 to 30 to 40 lb/cow/yr, a 65 to 70% reduction. This means additional 70-80 lbs. N per cow would be available annually for application to field crops.

References

Broderick, G.A. 2003. Effects of varying dietary protein and energy levels on the production of lactating dairy cows. J. Dairy Sci. 86:1370-1381.

Castillo, A. R., E. Kebreab, D. E. Beever, and J. France. 2000. A review of efficiency of nitrogen utilisation in lactating dairy cows and its relationship with environmental pollution. J. Anim. Feed Sci. 9:1-32.

Misselbrook, T.H., J. M. Powell, G. A. Broderick and J. H. Grabber. 2005. Dietary manipulation in dairy cattle: Laboratory experiments to assess the influence on ammonia emissions. J. Dairy Sci. 88:1765-1777

Misselbrook, T.H., and J.M. Powell. 2005. Influence of bedding material on ammonia emissions from cattle excreta. J. Dairy Sci. 88:4304-4312.

NRC. 2003. National Research Council. Air emission from animal feeding operations: Current knowledge, future needs. National Research Council. Nat. Acad. Sci. Washington DC.

MANAGING SOYBEAN FATTY ACID COMPOSITION

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SOYBEANS: NEW USES NEW MARKETS

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HOW TO SELECT THE RIGHT MATURITY CORN HYBRID FOR THE CUSTOMER

Joe Lauer [1]

Introduction

Successful corn production requires the selection of the correct hybrids for the production environment. Farmers need to consider yield potential, maturity, pest resistance, and harvestability when selecting hybrids. Proper maturity is important so that the amount of drying necessary after harvest is minimized. High-yielding hybrids whose maturities take full advantage of the available growing season are generally the most energy-efficient choices (Eckert et al., 1987). A hybrid which matures far in advance of anticipated harvest does not make full use of available solar radiation, and therefore does not realize the full yield potential of the growing season and the energy related inputs provided by the farmer. Conversely, a hybrid that is not mature at the time of frost can increase artificial drying costs, in addition to not achieving full yield potential because it was killed before grain filling was complete.

Field drying of corn is a little understood process that greatly influences production costs. Drying corn after harvest is expensive. Assuming LP gas costs $0.70 per gallon and electricity costs $0.05 per kilowatt hour, drying corn from 35 percent harvest moisture to 15 percent requires about 0.472 gallons LP gas per bushel and 0.066 kwh per bushel for a total cost of $0.334 per bushel (Eckert et al., 1987). Harvesting grain at 20 and 25 percent moisture is often cited as a reasonable compromise between drying costs and harvest loss (Olson and Sander, 1988). Drying corn from 20 to 25 percent harvest moisture to 15 percent requires 0.109 to 0.219 gallon of LP gas per bushel and 0.017 to 0.033 kwh per bushel for a total cost of $0.077 to $0.155 per bushel. If 350 million bushels of corn in Wisconsin were harvested between 20 and 25 percent moisture, drying costs would range between $27 to $54 million. A more likely scenario is one-third of the corn at 20 to 25 percent moisture, one-third at 25 to 30 percent moisture, and one-third at 30 to 35 percent moisture. Drying costs for Wisconsin producers under this scenario range between $55 and $85 million.

These costs do not consider yield and quality losses due to hybrids that do not take advantage of the available growing season. In addition, if the moisture content of corn taken to market is more than 15.5 percent (the maximum for No. 2 corn), then the price paid for that corn will be adjusted downward by the prevailing moisture discount, which is usually around 2 percent of market price for each point above 15.5 percent.

Producers need to choose high-yielding hybrids that are dry as practical at harvest. Many shorter-season hybrids approach yields of full-season hybrids and may be several points lower in grain moisture at harvest. Some hybrids dry down more rapidly after maturity (black layer) than others of similar maturity due to loose husks, small cobs and/or thin seed coats.

No standard relative maturity method exists in the corn industry. Since 1929, corn hybrids to be sold in Minnesota were rated for maturity. The law was repealed in 2003 and will be retired in 2006. Little data exists for corn relative maturity recommendations in Wisconsin. The objective of this paper is to describe the optimum relative maturity for corn at various locations in Wisconsin. The paper will also provide guidelines for making corn hybrid maturity recommendations.

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Materials and Methods

Every hybrid tested in the UW hybrid evaluation program is compared against all other hybrids of the same maturity. Relative maturity is determined by comparing grain moisture of hybrids at harvest. Corn is mature when kernels reach maximum dry weight. Optimum relative maturity depends upon the harvest, use and storage methods on each farm. Corn for silage is ready as early as 10 days prior to maximum kernel dry weight, while corn picked for grain is not ready until grain moisture content reaches 23 to 28%.

Beginning in 1995, trials were conducted at Arlington, Chippewa Falls, Fond du Lac, Hancock, Janesville, Lancaster, Marshfield, Seymour and Valders. Each trial consists of two or more hybrids for each 5-day relative maturity increment from 80- to 115-days for a total of 14 to 16 hybrids per trial. The hybrids are top-performing hybrids selected from the UW corn evaluation program. These hybrids change every year as well as the locations of the trial. Yield, moisture and test weight were used to calculate the economics of the relative maturity decision.

Grower return was calculated by multiplying commodity price with yield and subtracting production costs. Corn prices used were $2.00, $2.50, and $3.00 corn. The PEPS corn price is more of a "real world" price annually determined using a marketing strategy where 50% of the crop was sold in November and 25% forward contracted (less basis) to March and July. The November average cash price was derived from Wisconsin Ag Statistics, and the March and July future prices were derived from the Chicago Board of Trade closing price on December 1 every year.

Harvesting costs were estimated for handling ($0.02 per bushel), hauling ($0.04 per bushel), trucking ($0.11 per bushel) and storage ($0.02 per bushel month with 25% of grain shipped in March after 4 months storage and 25% of grain shipped in July after 8 months storage). For the livestock system, no trucking cost is assessed and storage was $0.01 per bushel month. Drying costs were estimated at $0.00, $0.02 and $0.04 per point above 15.5% moisture per bushel for on-farm and commercial corn production systems.

Results and Discussion

Longer-season hybrids have greater potential for higher yields at most locations. In southern Wisconsin, as relative maturity increases, grain yield increases 2.2 bu/A (data not shown). At a corn price of $2.50 and drying cost of $0.02 per point moisture bushel, grower return increases $4.00 /A for each relative maturity unit. For example, at Arlington grain yield increases to a maximum around 106-days relative maturity (Figure 1a). Optimum relative maturity of corn at various locations is shown in (Table 1). At most locations, a significant relationship exists between grain yield and relative maturity. However, at Marshfield and Valders, no relationship between grain yield and relative maturity exists over multiple years of testing (Table 1).

The optimum relative maturity for grower return depends upon the corn drying method and cost (Table 2). The relative maturity that optimizes grower return is different from the relative maturity that optimizes grain yield when drying costs are considered. For example, at Arlington using an on-farm drying method, grower return is greatest with a corn hybrid relative maturity of 101-days relative maturity (Figure 1b and Table 2). At Marshfield, a 93-day hybrid optimizes grower return. Table 2 describes optimum relative maturity for various production system, drying cost, and grain price scenarios.

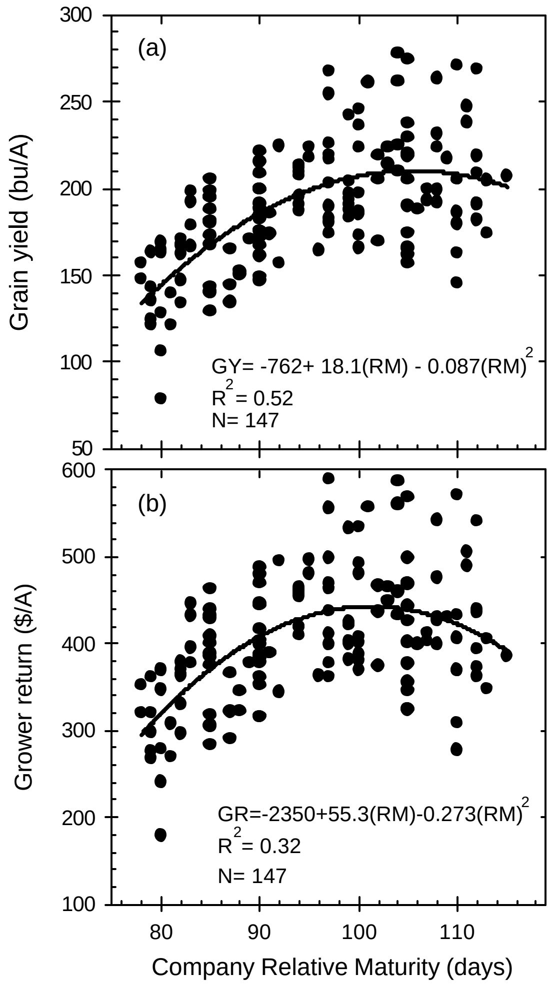

Figure 1. The relationship of relative maturity with a) grain yield and b) grower return ($2.50 corn price, on-farm drying) at Arlington, WI (1995-2004).

Table 1. Optimum relative maturity (days) for grain yield at various locations in WI.

Location	Years tested	Optimum relative maturity
Arlington	1995-2004	106
Janesville	1996-1997	107
Lancaster	1996-1997	112
Fond du Lac	1996-1997	103
Hancock	1995-2004	104
Chippewa Falls	1999-2001	104
Marshfield	1999-2004	---
Seymour	1999-2001	102
Valders	1999-2001	---

Table 2. Optimum relative maturity (days) for three corn production systems.

System:Drying Cost ($ / point bu)	Grain price ($/bu) $2.00	$2.50	$3.00	PEPS
Arlington, WI				
Commercial:$0.04	--	98	99	98
On-Farm:$0.02	100	101	102	101
Livestock:$0.00	106	106	106	107
Janesville, WI				
Commercial:$0.04	104	105	105	105
On-Farm:$0.02	106	106	106	106
Livestock:$0.00	107	107	107	108
Lancaster, WI				
Commercial:$0.04	106	112	112	112
On-Farm:$0.02	112	112	112	112
Livestock:$0.00	112	112	112	112
Fond du Lac, WI				
Commercial:$0.04	--	---	99	99
On-Farm:$0.02	100	101	101	101
Livestock:$0.00	103	103	103	103
Hancock, WI				
Commercial:$0.04	--	--	98	--
On-Farm:$0.02	100	100	101	100
Livestock:$0.00	104	104	104	103
Chippewa Falls, WI				
Commercial:$0.04	--	--	97	--
On-Farm:$0.02	98	99	100	98
Livestock:$0.00	104	104	104	104
Marshfield, WI				
Commercial:$0.04	89	90	91	89
On-Farm:$0.02	92	93	93	92
Livestock:$0.00	--	--	--	--
Seymour, WI				
Commercial:$0.04	--	--	97	--
On-Farm:$0.02	98	99	99	98
Livestock:$0.00	102	102	102	101
Valders, WI				
Commercial:$0.04	--	--	--	--
On-Farm:$0.02	--	--	--	--
Livestock:$0.00	--	--	--	--

Although farmers generally get greatest yields by planting full-season hybrids early, many short-season hybrids produce yields competitive with the best full-season hybrids and are drier at harvest (Figures 1a and 1b).

Farmers need to consider the economic tradeoff between yielding ability and drying costs for hybrid maturity. Full-season hybrids provide the greatest potential for maximizing yield and profitability. Plant several hybrid maturities each year to spread the harvest season and reduce the risk of losses from moisture stress at pollination time or early frost.

Traditionally, the mix of hybrid maturities grown on a farm vary according to the risk one is willing to assume (i.e. 25% of acres grown to full-season, 50% to mid-season, and 25% to short-season maturities). Others recommend mixing hybrid maturities according to the type of environment predicted. The best approach may be to select hybrid maturities based solely on the intended use and drying method in the production system.

To ensure genetic diversity on your farm, select corn hybrids differing for relative maturity. Optimum relative maturity is variable in Wisconsin and depends upon many factors including location, soil, management, corn price, drying method and hybrid traits. Your decision to select hybrid maturity for your farm depends upon:

1. *Desire to accept risk:* Longer season hybrids offer the highest yield potentials, but may also increase drying costs and/or delay harvest.
2. *Potential use:* For dry grain, relative maturities should be shorter-season within the maturity range for the latest acceptable planting date. For high moisture corn and silage, relative maturities should be longer-season within the maturity range for the latest acceptable planting date.
3. *Field conditions:* Shorter season hybrids within the maturity range for the latest acceptable planting date should be selected when field conditions include heavy crop residue, reduced tillage, and heavy soil textures.
4. *Hybrid dry down and grain quality characteristics:* Longer-season hybrids within the latest acceptable planting dates should have fast grain dry-down and high test weight characteristics.

Literature Cited

Eckert, D. J., R. B. Hunter, and H. M. Keener. 1987. Hybrid maturity-energy relationships in corn drying. National Corn Handbook NCH-51:

Olson, R. A. and Sander, D. H. 1988. Corn Production. *In* G.F. Sprague and J.W. Dudley (ed.). Corn and Corn Improvement. Agronomy Monograph 18. p. 639-686. ASA, CSSA, SSSA, Madison, WI.

NEW DECISION-MAKING TOOL TO ESTIMATE
THE NET BENEFIT OF Bt CORN IN WISCONSIN

Paul D. Mitchell [1/]

A new decision-making tool is available for Wisconsin corn farmers and professional consultants to estimate the expected net benefit from Bt corn for controlling European corn borer (ECB). Bt corn provides essentially complete control of the ECB, but corn borer pressure each year is uncertain. The tool uses Wisconsin Department of Agriculture, Trade and Consumer Protection (DATCP) pest survey data to estimate typical ECB populations for each crop reporting district and the associated yield loss. The tool predicts the expected net return from planting Bt corn and the break-even probability. The expected net return is the increase in expected (average) returns net of the additional cost for Bt corn. The break-even probability is the probability that the value of the yield saved by planting Bt corn will equal or exceed the additional cost for Bt corn. Most importantly, the tool uses the farmer's yields and prices, so the expected net benefit and break-even probability are specific to the farmer's operation.

The tool is a bulletin with an accompanying spreadsheet, both available on the internet. The farmer enters his expected price and yield for corn, the added cost for the Bt trait (the "technology fee") for the hybrids he buys, plus the planting density. The tool then uses these responses, plus the farmer's crop reporting district, to predict the expected net return from planting Bt corn and the break-even probability.

"The Expected Net Benefit and Break-Even Probability for Bt Corn in Wisconsin" (http://www.aae.wisc.edu/mitchell/Economics of Bt Corn in WI.pdf) explains the process and how the tool works, plus provides a worksheet and tables that a farmer can use to estimate his expected net benefit for Bt corn and break-even probability. The spreadsheet (http://www.aae.wisc.edu/mitchell/Economics of Bt Corn in WI.xls) accompanying the bulletin does all the calculations once the farmer enters the expected price and yield for corn, the added cost for Bt corn, the planting density, and chooses the crop reporting district.

Overview of Data and Methods

DATCP annually samples numerous fields in each crop reporting district for several pests. ECB population data for the nine crop reporting districts are complete from 1964 to the present. Table 1 reports the estimated mean, standard deviation, and coefficient of variation (CV) of the ECB population for each crop reporting district and the state as a whole. The results in Table 1 follow expectations—average ECB populations increase as one moves south and west, following average summer temperatures. The results in Table 1 also show a relatively high standard deviation and CV for all districts, implying that ECB populations are quite variable from year to year. Economic analysis of yield loss from ECB should take into account this variability in ECB populations. Monte Carlo simulations were conducted to determine yield losses and net returns while accounting for variability in ECB populations, in stalk tunneling by ECB, and in yield losses. Table 2 was constructed using these results. Average yield losses closely follow the average ECB population as reported in Table 1, implying that the net benefit of Bt corn is larger in districts with typically higher ECB populations. Table 2 also shows that the yield loss is quite

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variable, implying that even if on average net benefit is large, the producer will not always obtain this benefit, and can actually loose money with Bt corn in some cases. The break-even probability captures this uncertainty in the net benefit.

TABLE 1. Estimated European corn borer (ECB) population pressure (2nd-generation ECB/plant) for the nine Wisconsin Crop Reporting Districts and the state.

District	Average	Standard deviation	Coefficient of variation
North West	0.31	0.37	120%
North Central	0.17	0.18	105%
North East	0.25	0.29	114%
West Central	0.60	0.89	148%
Central	0.58	0.88	152%
East Central	0.29	0.28	97%
South West	0.79	1.03	130%
South Central	0.70	0.92	131%
South East	0.68	1.24	182%
State	0.49	0.43	87%

TABLE 2. Estimated expected (average) percentage yield loss due to European corn borer and its variability for the nine Wisconsin Crop Reporting Districts and the state.

District	Average	Standard deviation	Coefficient of variation
North West	3.7%	2.7%	73%
North Central	3.0%	2.5%	84%
North East	3.4%	2.6%	76%
West Central	4.7%	3.2%	67%
Central	4.6%	3.2%	68%
East Central	3.7%	2.6%	68%
South West	5.4%	3.3%	61%
South Central	5.1%	3.2%	62%
South East	4.8%	3.4%	72%
State	4.7%	2.7%	57%

Estimating Your Expected Net Benefit

The average yield loss from Table 2 can be used to estimate your expected net benefit from planting Bt corn using a formula carefully described in the bulletin with several examples. The companion spreadsheet can also be used to do all the calculations. This expected net benefit is an estimate of the benefit expected under average conditions, or in other words, the benefit you can expect before you plant. Because your actual yield, actual price, and actual yield loss from ECB damage will likely differ from the averages used for this analysis, your actual net benefit will be different. Different values for expected price, yield, and/or planting density should be tried as part of sensitivity analysis to see how they change your expected net benefit for Bt corn.

Break-Even Probability

The expected net benefit equation can be re-arranged to find the break-even loss—the expected yield loss from ECB needed to justify the cost of buying Bt corn. For example, suppose you pay $20/bag for Bt corn, have an expected yield of 125 bu/ac and an expected corn price of $1.90/bu. What expected yield loss from ECB is needed to make Bt corn worth the extra cost? The bulletin carefully explains how to calculate your break-even yield loss from ECB damage and again provides several examples.

As Table 1 shows, yield loss from ECB damage is quite uncertain. Suppose you know your break even yield loss is 3%. How likely is it that your actual yield loss will be at least 3%, so that you break even? Table 3 (reported in the bulletin) was developed from the Monte Carlo simulations to answer this question. For example, in the north central district, there is a 38.6% of a 3% or greater yield loss. This break-even probability indicates how likely it is that a farmer will at least break even with Bt corn. Table 3 is not reported here, as it is quite long. However, the bulletin reports Table 3 and the steps necessary to calculate your break-even probability with several examples. Alternatively, the companion spreadsheet can be used to perform the calculations automatically.

Summary

The decision aid described here is to help a farmer during the planning phase to decide whether to plant Bt corn. The analysis is based on expected yield, expected price, and expected yield loss from ECB, which are appropriate to use when deciding if and how much Bt corn or conventional corn to plant. Sensitivity analysis (using different expected prices and expected yields) is a simple way to begin examining how your expected benefit and break-even probability change with random yields and prices. This analysis does not include yield losses or added harvest costs from lodging due to ECB damage. Lodging is obviously important, but many factors besides ECB contribute to lodging. Bt corn generally reduces the likelihood and severity of lodging by eliminating ECB damage, so that adding the value of improved lodging control to this analysis would increase the expected net benefit of Bt corn.

Remember that Bt corn has a refuge requirement to slow the development of resistance to the Bt toxin so that farmers can enjoy the benefits of Bt corn for several more years. Currently, these requirements include planting enough non-Bt corn refuge within a half mile so that no more than 80% of your corn acres are Bt corn. Refuge is also an excellent way to evaluate your actual benefit from planting Bt corn. After harvest, use the yields from the Bt and non-Bt portions of your fields to determine if your actual yield loss and actual net benefit were enough to justify the extra cost for Bt corn. You can then compare your results to the expected yield loss and expected net benefit you calculated before planting. If you have yield records for your Bt and non-Bt corn refuge from a long enough time period, you can see how your average losses and the loss probabilities compare to the results in Tables 2 and 3.

If you have questions, comments, or suggestions on the bulletin or spreadsheet, please contact the author: Dr. Paul D. Mitchell, Agricultural and Applied Economics, University of Wisconsin Extension, (608) 265-6514, pdmtichell@wisc.edu.

REFUGE COMPLIANCE

Barb Van Til and Dave Fredrickson [1/]

{This page provided for note taking}

[1/] U.S. Environmental Protection Agency and Wis. Department of Agriculture, Trade and Consumer Protection, respectively.

PLANT BREEDING AND GENETICS: WHERE HAVE WE BEEN, WHERE ARE WE GOING?

William F. Tracy [1/]

{This page provided for note taking}

[1/] Professor, Dept. of Agronomy, Univ. of Wisconsin-Madison.

A New Glyphosate Resistant Soybean

Steven R. Paszkiewicz [1/]

ABSTRACT

Pioneer Hi-Bred International Inc. has plans to introduce hybrids and varieties with an alternative trait for resistance to both glyphosate and sulfonylurea herbicides towards the end of this decade. Scientists at Verdia, a firm which Pioneer's parent company, DuPont, bought in 2004 and integrated into Pioneer's crop genetics research and development division, developed an enzyme exhibiting glyphosate N-acetyltransferase (GAT). This enzyme renders glyphosate ineffective in a different way than current glyphostate-resistance technologies.

Glyphosate operates by inhibiting the enzyme enolpyruvyl-shikimate-3-phosphate synthase (EPSPS) that leads to the biosynthesis of essential aromatic amino acids. The inhibition does not allow plants to survive. Researchers have found some microbial EPSPS enzyme variants that are not inhibited by glyphosate. Plants that contain these enzyme variants can even survive in the presence of high concentrations of the herbicide.

Researchers from Pioneer Hi-Bred, International, Inc. and Verdia Inc. in Redwood City searched for a method to detoxify glyphosate. The advantage of detoxification is that the glyphosate is transformed into a substance that does not harm the plant. They found that an enzyme named glyphosate N-acetyltransferase (GAT) can carry out the process. The GAT enzymes convert glyphosate to N-acetylglyphosate, which is no longer herbicidal or of toxicological relevance (Castle et al., 2004).

Glyphosate is one of the most commonly used herbicides with many food and non-food crops. To develop enzymes useful for conferring glyphosate-tolerant plants, scientists used gene shuffling to improve the efficiency of GAT. Gene shuffling is a process that recombines genetic diversity from parental genes to create libraries of gene variants that are screened to identify those progeny with improved properties. This recombination and selection process can be repeated using improved progeny as parents for the next iteration of shuffling. With the process of gene shuffling, the team obtained an enzyme that had a nearly 10,000-fold improvement over the parental enzymes identified from microbes. The improved enzyme confers glyphosate tolerance to soybean and corn plants when these crops are transformed with the GAT gene. Efficacy trials of lines containing genes from several shuffling iterations are underway in the field and commercial levels of this glyphosate tolerance have been identified in both corn and soybeans.

GAT is the first-ever agricultural trait developed through gene shuffling. The gene shuffling technology should also help Pioneer identify and develop a number of new traits to help plants survive environmental stress, including drought. Pioneer has the exclusive right to use gene shuffling for agricultural purposes. GAT can be inserted in corn, soybeans, cotton, canola and alfalfa and other plants to make them resistant to glyphosate. Since GAT is a transgenic trait, Pioneer will move ahead with the necessary regulatory approvals in the United States and other world markets.

[1/] Pioneer Hi-Bred International Inc.

Furthermore, GAT will be introduced as a stacked trait package with the HRA gene (highly resistance allele) that confers resistance to a number of ALS herbicides (Acetolactate Synthase Inhibitors) to include the SUs (sulfonylureas). This combination will provide growers with increased flexibility and expanded options to customize their weed management strategies with additional herbicide choices. Combined with the GAT trait for glyphosate resistance, the GAT/SU-resistance combination will provide growers with at least two modes of action that will alleviate hard to control weeds and provide producers additional options to practice sound weed resistance management practices. Just as importantly, producers will now have greater capabilities to, fill key weed gaps and/or have herbicide residual options by utilizing combinations of glyphosate and SU herbicides.

These expanded options will also allow companies like Pioneer to offer expanded choices, including additional stacks, to growers in a variety of different seed products.

Reference

Castle, L.A., D.L. Siehl, R. Gorton, P.A. Patten, Y.H. Chen, S. Bertain, H. Cho, N. Duck, J. Wong, D. Liu, and M. W. Lassner. 2004. Discovery and directed evolution of a glyphosate tolerance gene. Science 304:1151-1154.

Division of Ag Resource Management
Plant Industry Bureau

Wisconsin's Seed Law & Rule

Wisconsin Department of Agriculture, Trade & Consumer Protection

Greg Helmbrecht
Plant Pest & Disease Specialist
January 01, 2006

Statutory Authority

DATCP regulates the labeling, sale and distribution of seed under ss. 94.38 to 94.46, Stats., and Ch. ATCP 20 Wis. Adm. Code

- **Why are proposed changes needed?**
- **What are the proposed changes?**

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Why Change Wisconsin's Seed Law?

- **Sections of the current state seed rule refer to the state seed laboratory.**
- **We no longer operate a seed laboratory and have not since about 1990.**
- **Seed testing to ensure compliance is now done through a private lab. All identifiable markings are removed and sent out for testing; only DATCP knows the labeler information.**

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Why Change Wisconsin's Seed Law?

- **Current law cites 1988 Association of Official Seed Analysts (AOSA) Rules for Testing Seed publication. This document is updated regularly.**
- **The prohibited and restricted noxious weed list needs to be updated. Some of the seeds listed are no longer crop management issues and a new set of weed seeds have become problematic.**
- **New germination standards and testing procedures have been developed and adopted by the AOSA for native and nursery seeds.**
- **Native and wildflower seed industries need regulations to protect their industry and Wisconsin's environment.**

Proposed Changes

- **Adopting Recommended Uniform State Seed Law (RUSSL)**

AASCO & RUSSL

The Association of American Seed Control Officials (AASCO) is an organization of seed regulatory officials from the U.S. and Canada. The Association was organized in 1949 from an outgrowth of regional meetings held in various parts of the country. AASCO members meet annually to discuss mutual concerns of seed law enforcement, to receive updates on new seed industry developments, and to update RUSSL, which the organization developed and maintains as a "model" law for states and federal programs.

RUSSL will make labeling requirements uniform from state to state.

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Prohibited Noxious Weed Seeds

DEFINITION

Prohibited noxious weed seeds are those weed seeds which are prohibited from being present in agricultural, vegetable, flower, tree, or shrub seed. They are specific weed seeds that are highly destructive and difficult to control, despite the use of good cultural practices and herbicides.

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Currently Prohibited Noxious Weed Seeds

- **Field Bindweed** (Convolvulus arvensis)
- **Leafy Spurge** (Euphorbia esula)
- **Canada Thistle** (Cirsium arvense)
- **Quackgrass** (Agropyron repens)

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Proposed Prohibited Noxious Weed Seeds

- Field Bindweed (Convolvulus arvensis)
- Leafy Spurge (Euphorbia esula)
- Canada Thistle (Cirsium arvense)
- Wild Proso Millet (Panicum miliaceum)
- Woolly Cupgrass (Eriochloa villosa)
- Kudzu (Pueraria montana var. lobata)
- Mile-a-minute Weed (Polygonum perfoliatum)
- Russian Knapweed (Centaurea picris)

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Other Noxious Weed Seeds to Consider for Prohibited

- Hemp (Cannabis sativa)
- Poison Ivy (Toxicodendron radicans)
- Perennial Sowthistle (Sonchus arvensis)
- Bull Thistle (Cirsium vulgare)
- Musk Thistle (Carduus nutans)
- Plumeless Thistle (Carduus acanthoides)

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Restricted Noxious Weed Seeds

DEFINITION

Restricted noxious weed seeds are those weed seeds are which are objectionable in agricultural crops, lawns, and gardens of this state and which can be controlled by good cultural practices or the use of herbicides.

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Currently Restricted Weed Seeds

- Wild Radish (Raphanus raphanistrum)
- Buckhorn (Plantago lanceolata)
- White Cockle (Silene alba)
- Dodder (Cuscuta spp.)
- Hoary Alyssum (Berteroa incana)
- Wild Oat (Avena fatua)
- Wild Mustard (Sinapis arvensis)
- Downy Brome (Bromus tectorum)
- Oxeye Daisy (Leucanthemum vulgare)
- Giant Foxtail (Setaria faberi)
- Indian Mustard (Brassica juncea)
- Yellow Rocket (Barbarea vulgaris)
- Perennial Sowthistle (Sonchus arvensis)

Proposed Restricted Weed Seeds

- Wild Radish (Raphanus raphanistrum)
- Buckhorn (Plantago lanceolata)
- White Cockle (Silene alba)
- Dodder (Cuscuta spp.)
- Hoary Alyssum (Berteroa incana)
- Wild Oat (Avena fatua)
- Wild Mustard (Sinapis arvensis)
- Quackgrass (Agropyron repens)
- Perennial Sowthistle (Sonchus arvensis)
- Giant Ragweed (Ambrosia trifida)

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Other Noxious Weed Seeds to Consider for Restricted

- Purple Loosetrife
  (Lythrum salicaria)
- Spotted knapweed
  (Centaurea biebersteinii)
- Garlic mustard
  (Alliaria petiolata)
- Dames rocket
  (Hesperis matronalis)
- Teasel
  (Dipsacus sylvestris)
- Goldenrod
  (Solidago canadensis)

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Growing Seed Industry

Wildflower & Nursery Seed

Although native grass seeds are covered by the current seed laws, germination standards have been developed by AOSA which cover many wildflower seed types. This industry is looking for labeling requirements and standards to be met to protect their industry and preserve Wisconsin's environment.

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Seed Law Advisory Committee

- ADAM INGWELL - AGRECOL CORPORATION
- BOB O'DONNELL - FORAGE GENETICS
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- ROBERT DAHL - WDATCP - PLANT INDUSTRY BUREAU
- GREG EDGE – DNR - FOREST GENETICIST TREE IMPROVEMENT AND NURSERIES COORDINATOR
- MARK MARTIN – DNR – NATURAL AREAS PROGRAM AND NATIVE SEED FARM

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More Information?

RUSSL Can be viewed:

http://www.seedcontrol.org/

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POTENTIAL FOR PRODUCTION OF PROCESSING ONION IN WISCONSIN

Alvin J. Bussan and Mike Drilias[1]

Introduction

Onion has been a key crop for Wisconsin's commercial vegetable growers for a number of years, especially on muck soils. Most of the onions produced in Wisconsin are sold on the wholesale fresh market. Competition from other regions of the country has resulted in declining profit margins for onion growers and a slow decline in onion acreage in Wisconsin. Acreage on muck has also been taken out of production as the Wisconsin DNR has purchased property and has implemented permanent wetland restoration on many muck acres.

Onion is a high value vegetable crop with an average annual gross return per acre of approximately $4,000 and farm gate receipt value of $8 million in Wisconsin. Onion requires intensive management and high input levels to minimize the effect of key pests and environmental stress on yield and quality. Development of a processed onion market could provide a steady end market for Wisconsin onion thereby reducing the economic risk of onion production in the state and potentially increase the onion acreage.

Increasing acreage of a vegetable crop such as onion has always been a difficult challenge. Global competition and consolidation within the vegetable processing industry has demanded increasing efficiency within commercial food production and farming systems making this challenge more difficult than ever. However, opportunities such as the geographic location of Wisconsin relative to population centers within the U.S., the capacity of Wisconsin vegetable growers to produce a high quality and yielding crop, and the positive effects of harsh winter climate on pest species still creates positive incentives for vegetable processing within Wisconsin.

The snack food industry has several processing plants in Wisconsin. Snack food processing facilities produce products such as onion rings, breaded mushrooms, zucchini sticks, jalepeno poppers, and breaded cheese curds. Few if any Wisconsin grown onions are used in the onion ring product that is generated by Wisconsin processing facilities. Most of the onions processed into onion rings are purchased from the Treasure Valley in Oregon and shipped to Wisconsin. Wisconsin-produced onion could save $30 or more per ton in overland shipping costs giving locally produced onion a distinct market advantage. Profitability of Wisconsin grown onion could be ensured if savings in transportation costs were shared by the processor with local onion growers. The value of Wisconsin onion production could increase by $30 to 40 million/year if a small portion of the onions processed by the snack food companies were grown locally.

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[1] Vegetable Production Specialist, Association Researcher, Dept. of Horticulture, Univ. of Wisconsin-Madison, 1575 Linden Dr., Madison, WI, 53706

Wisconsin vegetable farmers have demonstrated capacity to successfully produce onions on irrigated sand and muck soils. Yields averaged 300 to 400 cwt/A on sand and 700 to 900 cwt/A on muck in field research trials conducted by Stevenson and Wyman. Wisconsin onion growers produce onions targeted for fresh market consumption and so quality standards are based on those markets. Currently onions are targeted to average 2 to 3" in diameter, for storability, and with flavor characteristics appropriate for fresh market onion. Processing onion quality attributes include size range of 3 to 5" in diameter, single center, ring diameter and thickness, fry characteristics, flavor, and storability. Storage losses would need to be limited to one or two percent with a maximum of 5% in order to meet quality standards of onion processors. To achieve storage goals, optimal onion conditioning practices would need to be developed.

The Wisconsin onion growers and affiliated agricultural service industries need to demonstrate the capability to consistently produce onions with quality attributes that meet the needs of the snack food processing plant in order to secure contracts. In addition, Wisconsin growers must show they can produce yields of onion that would be profitable for the farm and the processing plant. Research is needed to define management systems that would enable growers to consistently produce high quality onion.

Specific management practices that need to be investigated for meeting size, ring, storability and other quality parameters include:

- Identify varieties with high processing quality that are suitable for planting and production in Wisconsin
- Study onion bulking patterns to identify stress factors that lead to interruptions in growth or loss of single centerness and could guide development of appropriate irrigation strategies.
- Evaluation of planting date, rate, pattern, and transplants for yield and quality attributes.
- Companion cropping strategies that will protect seedling onion plants from blowing sand when grown in the Central Wisconsin Vegetable Production region.

Goal: Develop management practices that ensure production of onion with high processing quality and demonstrate the ability of the Wisconsin vegetable industry to consistently produce onions that meet end use value of local processors.

Objectives:

1) Identify optimal management practices for production of onion with superior processing quality.
2) Quantify onion bulking rates over the growing season and measure response to different management practices and stress events.
3) Demonstrate the potential of Wisconsin vegetable growers to produce onions that meet the quality standards of onion processing plants.

Materials and Methods

Field experiments were planned and conducted at two locations during 2005. The first location was in Central Wisconsin on irrigated sand soils. The second location was in Southern Wisconsin on irrigated muck soils. All experiments were repeated at both locations.

Objective 1: Identify optimal management practices for production of onion with superior processing quality. A series of small plot experiments were established on cooperating irrigated sand and muck farms to address specific production issues including variety trials, planting date, crop density, and comparing transplants to seed.

Variety Trials

The purpose of these trials was to identify onions with potential value to the Wisconsin industry. The focus was identifying varieties for their potential processing quality which differs slightly from past trials. Yield was measured as well as growth habit, average bulb diameter, skin texture and storability, shrink in storage, number of rings, ring thickness, single centerness, and other characteristics. Variety trials included over 25 varieties in 2005

Cultural Management Trials

In the future, varieties with the best promise as potential processing varieties will be studied to develop best management practices or production profiles for consistently high quality. Specific studies will identify optimal planting date and seeding rate for onion started from seed or from transplants.

Optimal planting dates were examined for transplanted and onion grown from seed. During 2005, Montero, Vaquero, Ranchero, and Granero were tested in transplant trials. Vaquero was evaluated in different planting date studies. Vaquero was planted at each site as early in the growing season as possible and then at 2-week intervals until the end of May. Similarly, transplanted onions were planted at 2-week intervals from April 15 until June 15. Transplants were purchased from a contract grower in Arizona. Onion were allowed to grow until maturity (when tops lodge) and then harvested. Yield, size, and other quality attributes were assessed for each treatment upon harvest

Optimal planting rates were evaluated for Vaquero only by varying plant spacing within the row, spacing between the rows, and planting in single vs. paired vs. triple rows. A Gasparta vacuum planter was used to precision plant the planting rate trials. Plant spacing within the row will be varied from 2 to 6 per foot. Onion seed rates were varied from 90 to 250 K seed/A. Row configurates were single and paired rows spaced 20” apart.

Objective 2: Quantify onion bulking rates over the growing season and measure response to different management practices and stress events. Onions are sensitive to biotic and abiotic stress like most other crops. Stress effects are often magnified on vegetable crops such as onion when trying to grow high quality end product. Quality factors such as size and single centerness are particularly sensitive to stress events such as drought or heat. Planting date trials were used to quantify the growth and development of onion. Samples of 10 onions were collected from each plot and weight, diameter, ring number, leaf number, and single centerness sampled. Correspondingly, climatic data were also collected to document growth response to potential stresses.

Objective 3: Demonstrate the potential of Wisconsin vegetable growers to produce a crop that meet the quality standards of onion processing plants. Several Wisconsin onion growers grew onion for processing during 2005. Onions were marketed to processors if meeting minimum quality parameters. Onions that failed to meet processing grade were sold on the fresh market.

Results and Discussion

We are currently in the process of collecting quality data and analyzing data from research trials during 2005. Preliminary conclusions are drawn from preliminary analyses and primarily from field scale observations. The 2005 growing season was dry and hot. Early season thrip pressure and pink root limited late season bulking in onion on muck. This limited the size potential and yield of onion on Muck. In contrast, onions grew longer on sand resulting in better size and yield.

Vaquero is a common processing variety and was used because of processor approval. Vaquero grew to good size but was highly variable under WI conditions when planted from seed. Several other varieties had better size and yield potential when planted from seed compared to Vaquero especially under the sand. Growers who planted Vaquero from seed were unable to meet processor quality standards resulting in minimal shipping. Fortunately, the onions that failed to meet process grade were able to be marketed on the fresh market.

Onion transplants performed much better relative to seed. Average onion size was 3.5 to more then 4" in research trials. Planting onion transplants after May 1 greatly reduced yield potential. Wisconsin growers who planted Vaquero transplants had no problem meeting quality standards for processing. However, the cost of transplants could not be justified based on processing price. Growers were able to market large onions to specialty markets at premium prices.

Western onion growers typically grow high quality processing onions from seed at populations of 160,000 plants per acre. Vaquero is typically grown due to its high size potential, peeling characteristics, single centerness and other processing quality attributes. Western growers have little trouble growing onion from seed with average size of 4" in diameter. In contrast, Wisconsin growers face the challenge of growing onions with the same size profile, but with 10 to 30 days shorter growing season. To meet the processing size standards, Wisconsin growers must minimize stress, maximize growing season and use season extension techniques such as transplanting.

Future research will focus on expanding current research. Several varieties showed better production potential relative to Vaquero under Wisconsin conditions. Optimizing cultural practices for varieties with good potential will be focus during 2007.

POAST RESISTANT SWEET CORN AND OTHER HERBICIDE DEVELOPMENTS

Chris Boerboom[1]

Introduction

Postemergence grass weed control options are limited in sweet corn. Accent is labeled to control annual grasses in approved processing sweet corn hybrids. The list of Accent-approved hybrids has been continually updated by DuPont (Table 1). Accent is not recommended for use on other hybrids because the risk of crop injury may not be known. Accent has only been labeled for use on processing sweet corn. However, an Accent label for fresh market sweet corn is expected in 2006. It will be important to know which fresh market hybrids have good tolerance to Accent. A multi-state study was conducted in 2005 to test the tolerance of 114 hybrids, which provides a preliminary indication of Accent tolerance (Table 2).

Table 1. Processing sweet corn hybrids that may be treated with Accent.

ABCO Var. #610	Empire	GG 455*	Lumina
Basin*	Excalibur	GH 0937	Prelude*
Bonus	GG 8	GH 2547	Reward
Challenger	GG 22	GH 2690	Sheba
Chase	GG 43	GH 9589	Sockeye
Climax	GG 57	GH 9597*	Spirit
Cornucopia	GG 63*	GSS 8357	Sprint
Crisp'N Sweet 710	GG 202	GSS 8388	Stetson
Crisp'N Sweet 710A	GG 214	GSS 9299	Suregold
DMC 20-04	GG 246	Harvest Gold	Wht 2801
DMC 20-35	GG 255	HM 701	Zenith
Dynamo	GG 435	Kokanee	781 Ultra
Eliminator	GG 445	Lancaster*	
Excellency	GG 446*	Legacy	

* Hybrids added to the recommended list for 2006.

Poast

A new alternative grass herbicide option in sweet corn is Poast in Poast Protected sweet corn. Poast, which is distributed by Microflo Company, has a supplemental label allowing use on Poast Protected sweet corn. (Poast Plus is a different formulation of sethoxydim and is not registered for use on sweet corn.) Poast Protected is the commercial name for sweet corn that is resistant to sethoxydim and Rogers has a few commercial hybrids available (GH 2042, GH 6333, and GH 6631). This resistance is conferred by a mutation in the ACCase enzyme, which is sethoxydim's site of action. The mutation prevents sethoxydim from binding to ACCase and blocking the enzyme. As a consequence, sweet corn hybrids with this trait are resistant. Sethoxydim resistance in corn was selected as a mutation that occurred during tissue culture. As such, this form of herbicide resistance is not the result of transgenic engineering and should not raise concerns in individuals who are opposed to genetically engineered crops.

Poast can only be applied to Poast Protected sweet corn hybrids. Other hybrids will be severely injured or killed. Poast will control most annual grass weeds and suppress quackgrass.

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However, Poast has no activity on broadleaf weeds and has essentially no residual soil activity. The labeled use rates for Poast are 0.5 to 1.5 pt/a. Crop oil concentrate must be added at 1 qt/a and the addition of 2.5 lb/a ammonium sulfate or 2 to 4 qt/a 28% nitrogen solution may improve control of certain grass weeds. Poast is labeled at 0.5 pt/a to control wild proso millet up to 10 inches tall; at 1 pt/a for crabgrass up to 6 inches tall and foxtails up to 8 inches tall; and at 1.5 pt/a for quackgrass when 8 inches tall. Tank mixtures with atrazine, Basagran, or Laddok S-12 are labeled to control emerged broadleaf weeds. Labeled tank mixtures with Outlook or G-Max Lite would provide residual weed control. Poast applications can be made from emergence until before pollen shed, but tank mixtures with atrazine must be applied before sweet corn exceeds 12 inches. Up to two Poast applications can be made at a minimal interval of 10 days. Rain within 1 hour may reduce the effectiveness of Poast on grass weeds. Sweet corn can be harvested as soon as 30 days after application. Crops on which Poast is labeled can be planted anytime after a Poast application; other crops can be planted 30 days after application.

A logical use for Poast would be to control wild proso millet in sweet corn or other late season grass escapes. However, several factors should be considered. A preemergence grass herbicide would be beneficial for the initial grass weed control. Then, Poast could be applied later in the season to control late emerging wild proso millet. If a preemergence grass herbicide is not applied, Poast would need to be applied early in the season for general grass control, to control early emerging wild proso millet, and to protect the sweet corn from early season weed competition. Because Poast lacks residual control, millet control may be poor by the end of the season without a second Poast application. In previous studies that compared Poast Plus with Accent for wild proso millet control, control was similar between the herbicides, but Poast may have less risk of injuring Poast Protected sweet corn hybrids than Accent's risk of injuring other hybrids. The potential for broadleaf herbicides to antagonize Poast's activity on grass weeds exists. In 2005, giant foxtail control was reduced when Callisto plus atrazine were tank mixed with Poast, but not when Callisto was tank mixed alone with Poast. Antagonism from these tank mixtures was not observed on wild proso millet control in the same trial. At this time, tank mixtures of Poast with Callisto are not being recommended.

Impact

Impact (topramezone) has been registered for use on sweet corn by AMVAC, but the label has not been distributed at the time this article is being written. Therefore, specific details on Impact's application directions cannot be provided. Impact is primarily a postemergence broadleaf herbicide. It has some postemergence grass activity, but consistent grass control should not be expected at the anticipated labeled rates. Therefore, a preemergence grass herbicide should be applied for grass control. Impact's mode of action is a HPPD-inhibitor, which is the same as Callisto and Impact is synergized by atrazine. Options for rotational crops may be limited to corn with higher use rates of Impact. Be sure to review the label for rotational crop restrictions before use.

Mesotrione

For postemergence broadleaf weed control, Callisto (mesotrione) was labeled on all sweet corn types in 2005 and testing of hybrid tolerance is continuing (Table 2). In addition to postemergence applications of Callisto, Camix (premix of Callisto and Dual II Magnum) and Lumax (premix of Callisto, atrazine, and Dual II Magum) are expected to be labeled for preemergence use in sweet corn in 2006.

Table 2. Response of 114 sweet corn hybrids to postemergence applications of Accent, Option (not currently labeled for use on sweet corn), and Callisto at twice labeled rates. A single replication of each hybrid was evaluated at seven locations in Idaho (2), Colorado (1), Wisconsin (3), and Delaware (1). Sweet corn was treated at the V3 growth stage. The adjuvants used with Accent, Option, and Callisto were 1% crop oil concentrate plus 2 lb/a AMS, 1.5 pt/a methylated seed oil plus 2 lb/a AMS, and 1% crop oil concentrate respectively. The average, standard deviation, minimum, and maximum responses are listed. Western sites had no or low injury and Delaware generally had the greatest injury.

Sweet Corn Hybrid Tolerance Evaluation 2005
(7 day after treatment summary)

			Accent (1.33 oz/a) Stunting %				Option (3 oz/a) Stunting %				Callisto (6 oz/a) Chlorosis %			
Company	**Entry Name**	**Genotype**	**Ave**	**Std**	**Min**	**Max**	**Ave**	**Std Dev**	**Min**	**Max**	**Ave**	**Std**	**Min**	**Max**
Crookham	Alexis	Synergistic	1.4	2.4	0	5	7.1	14.7	0	40	7.0	12.8	0	5
Crookham	Ambrosia	Se	2.1	5.7	0	15	8.6	9.9	0	25	2.4	4.6	0	15
Crookham	Argent	Se	13.6	14.4	0	40	8.6	12.5	0	35	22.1	24.3	0	40
Crookham	Bodacious	Se	8.6	10.7	0	30	8.6	14.1	0	40	2.1	5.7	0	30
Crookham	Bojangles	Synergistic	4.3	7.9	0	20	7.1	10.4	0	30	2.4	5.6	0	20
Crookham	Cameo	Synergistic	7.1	14.7	0	40	14.3	14.0	0	40	4.9	9.2	0	40
Crookham	Captivate	Synergistic	6.4	11.1	0	25	7.1	10.7	0	30	6.0	11.2	0	25
Crookham	Celestial	Synergistic	7.1	15.0	0	40	12.1	12.2	0	35	14.6	19.1	0	40
Crookham	Charmed	Synergistic	6.4	9.4	0	20	9.3	13.4	0	35	4.9	11.1	0	20
Crookham	Cinderella	Synergistic	4.3	5.3	0	15	9.3	12.7	0	35	7.1	10.7	0	15
Crookham	CNS710 rust	Sh2	5.7	11.3	0	30	9.3	11.3	0	30	2.9	5.7	0	30
Crookham	CSEYP1-3	Se	5.0	9.1	0	25	5.7	8.9	0	25	2.9	7.6	0	25
Crookham	CSHYP2-57	Sh2	7.1	10.7	0	30	7.1	12.5	0	35	2.1	5.7	0	30
Crookham	CSUWP1-7	Su	13.6	13.5	0	35	17.1	10.4	5	35	9.0	14.4	0	35
Crookham	CSUYP2-28	Su	7.9	12.2	0	30	8.9	12.1	0	35	3.6	7.5	0	30
Crookham	Delectable	Se	6.4	11.1	0	30	13.6	16.0	0	45	4.6	9.2	0	30
Crookham	Eliminator	Su	12.1	15.5	0	40	11.4	13.8	0	35	4.1	9.2	0	40
Crookham	Fleet	Se	7.9	9.9	0	30	12.9	12.2	0	30	1.7	4.5	0	30
Crookham	Holiday	Sh2	5.7	9.3	0	25	11.4	10.7	5	35	3.6	7.5	0	25
Crookham	How Sweet It Is	Sh2	11.4	10.3	0	25	9.3	14.0	0	40	8.3	11.8	0	25
Crookham	Incredible	Se	7.9	14.4	0	40	5.7	11.0	0	30	6.1	12.9	0	40
Crookham	Kristine	Synergistic	5.7	8.4	0	20	7.1	14.7	0	40	6.0	8.7	0	20

			Accent (1.33 oz/a) Stunting %				Option (3 oz/a) Stunting %				Callisto (6 oz/a) Chlorosis %			
Company	**Entry Name**	**Genotype**	**Ave**	**Std**	**Min**	**Max**	**Ave**	**Std Dev**	**Min**	**Max**	**Ave**	**Std**	**Min**	**Max**
Crookham	Maestro	Su	10.0	11.2	0	30	9.3	11.3	0	25	6.4	11.1	0	30
Crookham	Marvel	Sh2	7.9	10.4	0	25	12.1	11.5	5	35	1.7	3.0	0	25
Crookham	Miracle	Se	6.4	9.4	0	25	6.4	12.8	0	35	6.3	9.0	0	25
Crookham	Optimum	Sh2	3.9	6.3	0	17	6.4	12.8	0	35	4.5	5.6	0	17
Crookham	Polka	Synergistic	5.0	6.5	0	15	16.4	16.0	0	35	2.4	3.1	0	15
Crookham	Sugar Buns	Se	2.9	3.9	0	10	4.3	7.3	0	20	3.1	7.5	0	10
Crookham	Venus	Se	5.7	9.3	0	25	7.1	12.9	0	35	3.1	5.6	0	25
Harris Moran	Cavalry	Sh2	11.4	14.4	0	40	18.6	31.1	0	85	1.4	3.8	0	40
Harris Moran	Coho	Su	12.9	11.9	0	35	15.0	10.8	0	30	6.0	9.5	0	35
Harris Moran	Dynamo	Su	20.0	12.6	5	40	15.7	8.4	5	30	20.0	21.8	5	40
Harris Moran	Early Gold	Su	8.6	8.5	0	20	13.6	9.9	5	35	6.9	16.9	0	20
Harris Moran	HM 2390	Su	3.6	6.3	0	15	7.9	9.5	0	25	1.4	3.8	0	15
Harris Moran	HMX 4380BES	Se	3.6	9.4	0	25	16.4	21.0	0	60	2.9	5.7	0	25
Harris Moran	HMX 4383S	Sh2	10.0	14.1	0	35	10.7	10.2	0	30	5.6	9.0	0	35
Harris Moran	HMX 4387WS	Sh2	9.3	14.8	0	40	5.0	5.8	0	15	7.1	14.6	0	40
Harris Moran	HMX 4388S	Sh2	11.4	12.1	0	30	12.9	9.5	0	25	3.9	5.4	0	30
Harris Moran	HMX 4394	Su	7.1	10.7	0	30	9.3	12.1	0	35	4.0	6.1	0	30
Harris Moran	HMX 4396S	Sh2	7.9	10.7	0	30	5.7	6.1	0	15	3.6	7.5	0	30
Harris Moran	Ice Queen	Sh2	3.6	4.8	0	10	10.0	12.2	0	30	4.6	7.2	0	10
Harris Moran	Legacy	Su	2.1	3.9	0	10	4.3	4.5	0	10	1.4	3.8	0	10
Harris Moran	Max	Sh2	14.3	15.9	0	40	10.0	8.2	0	25	4.6	5.9	0	40
Harris Moran	Polaris	Sh2	6.4	7.5	0	20	14.3	12.1	0	35	3.9	5.4	0	20
Harris Moran	Renaissance	Se	2.4	4.6	0	12	10.0	13.8	0	40	2.9	5.7	0	12
Harris Moran	Revelation	Se	5.3	7.1	0	20	12.1	17.3	0	50	1.7	3.0	0	20
Harris Moran	Sentinel	Sh2	7.1	9.9	0	25	5.7	5.3	0	15	6.0	9.1	0	25
Harris Moran	Suregold	Sh2	8.1	12.6	0	35	7.1	6.4	0	15	7.6	14.5	0	35
Harris Moran	Turbo	Su	9.3	14.0	0	40	7.1	4.9	0	15	6.7	10.4	0	40
Mesa Maize	Accord	Se	9.6	13.3	0	35	16.4	11.8	0	35	8.9	10.4	0	35
Mesa Maize	Bon Appetit TSW	Se	2.9	3.9	0	10	6.4	4.8	0	15	1.4	3.8	0	10
Mesa Maize	Bon Jour TSW	Se	7.1	12.9	0	35	7.1	7.6	0	20	2.9	5.7	0	35
Mesa Maize	Breeders Choice	Se	4.3	6.1	0	15	11.4	9.0	5	30	1.0	2.6	0	15

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Company	**Entry Name**	**Genotype**	**Ave**	**Std**	**Min**	**Max**	**Ave**	**Std Dev**	**Min**	**Max**	**Ave**	**Std**	**Min**	**Max**
Mesa Maize	Brocade TSW	Se	5.7	10.2	0	25	8.6	6.3	0	20	2.4	5.6	0	25
Mesa Maize	Chief Ouray	Se	12.9	12.2	0	30	13.6	9.0	5	30	8.9	16.4	0	30
Mesa Maize	Double Gem	Se	14.3	14.0	0	35	18.6	14.1	0	40	4.0	7.3	0	35
Mesa Maize	Lancelot	Se	2.1	5.7	0	15	13.6	9.9	0	25	2.9	5.7	0	15
Mesa Maize	Luscious TSW	Se	6.4	7.5	0	20	7.1	6.4	0	20	5.7	9.8	0	20
Mesa Maize	Merlin	Se	6.4	8.5	0	25	7.1	6.4	0	20	5.1	9.0	0	25
Mesa Maize	Misquamicut	Synergistic	3.6	4.8	0	10	6.4	10.7	0	30	1.4	3.8	0	10
Mesa Maize	Montauk	Synergistic	5.7	7.3	0	20	6.4	2.4	5	10	4.3	9.3	0	20
Mesa Maize	Nantasket	Synergistic	2.1	2.7	0	5	4.3	9.3	0	25	2.9	7.6	0	5
Mesa Maize	Native Gem	Se	5.3	7.9	0	20	7.1	9.5	0	25	1.7	4.5	0	20
Mesa Maize	Precious Gem	Se	7.1	10.4	0	30	10.7	8.9	0	25	6.9	10.8	0	30
Mesa Maize	Spring Treat	Se	2.1	5.7	0	15	6.4	11.1	0	30	2.9	5.7	0	15
Mesa Maize	SugarPearl TSW	Se	1.4	3.8	0	10	5.0	5.8	0	15	2.4	5.6	0	10
Mesa Maize	Tuxedo	Se	2.1	5.7	0	15	7.1	8.6	0	25	2.1	5.7	0	15
Mesa Maize	Welcome TSW	Se	11.4	18.0	0	50	9.3	10.6	0	25	2.0	3.7	0	50
Mesa Maize	Whiteout	Se	3.6	5.6	0	15	7.1	8.6	0	25	3.3	6.1	0	15
Rogers	Bold	Su	8.6	14.4	0	40	10.7	13.7	0	40	6.0	10.8	0	40
Rogers	BSS3495	Sh2	3.6	9.4	0	25	8.6	18.4	0	50	2.9	5.7	0	25
Rogers	Colonial	Se	6.4	6.9	0	20	8.6	12.5	0	35	2.0	4.5	0	20
Rogers	Double Up	Sh2	6.4	8.0	0	20	12.1	15.2	0	40	2.1	3.9	0	20
Rogers	GH 2042	Su	10.7	14.0	0	40	16.4	12.5	5	40	11.9	21.5	0	40
Rogers	GH 2669	Su	11.4	13.8	0	40	10.0	13.5	0	40	8.9	14.0	0	40
Rogers	GH 6631	Su	2.1	5.7	0	15	11.4	15.2	0	45	2.1	2.7	0	15
Rogers	GH 6333	Su	15.3	10.9	5	35	15.7	15.7	5	50	7.0	13.9	5	35
Rogers	GSS 2914	Sh2	10.0	14.1	0	40	14.3	14.0	0	40	9.6	18.1	0	40
Rogers	GSS 3287	Sh2	7.9	10.4	0	30	13.6	9.9	0	30	3.7	5.4	0	30
Rogers	GSS 4165	Sh2	1.4	3.8	0	10	8.6	12.1	0	35	2.1	5.7	0	10
Rogers	GSS1303	Sh2	2.1	3.9	0	10	10.0	12.6	0	35	5.7	5.8	0	10
Rogers	Jubilee	Su	8.6	10.7	0	30	20.7	11.3	5	35	6.7	12.7	0	30
Rogers	Providence	Synergistic	2.9	7.6	0	20	11.4	14.9	5	45	3.6	9.4	0	20
Rogers	SS Jubilee Plus	Sh2	16.4	12.1	0	35	11.4	11.1	0	30	8.3	14.2	0	35

			Accent (1.33 oz/a) Stunting %				Option (3 oz/a) Stunting %				Callisto (6 oz/a) Chlorosis %			
Company	**Entry Name**	**Genotype**	**Ave**	**Std**	**Min**	**Max**	**Ave**	**Std Dev**	**Min**	**Max**	**Ave**	**Std**	**Min**	**Max**
Rogers	Winstar	Sh2	14.3	22.8	0	60	7.1	10.7	0	30	4.6	9.2	0	60
Seminis	Basin R	Sh2	10.0	13.5	0	40	10.0	7.1	0	20	10.3	14.5	0	40
Seminis	Challenger	Sh2	4.3	7.3	0	20	8.6	11.1	0	30	0.7	1.9	0	20
Seminis	Chase	Su	6.4	11.1	0	30	10.0	10.0	0	30	5.3	9.4	0	30
Seminis	Devotion	Sh2	6.4	6.9	0	20	6.4	11.1	0	30	6.1	10.8	0	20
Seminis	EX 08705353	Su	6.4	11.1	0	30	10.0	9.6	0	30	2.6	5.5	0	30
Seminis	EX 08705640	Su	12.1	11.5	0	35	13.6	6.9	5	25	3.9	9.4	0	35
Seminis	EX 08705770	Sh2	47.9	24.3	15	75	42.1	26.3	5	80	26.4	29.8	15	75
Seminis	EX 08705788	Sh2	5.7	13.0	0	35	13.6	12.8	0	40	4.3	9.2	0	35
Seminis	EX 08716636	Sh2	5.0	7.6	0	20	8.6	16.5	0	45	5.0	8.7	0	20
Seminis	EX 9381178	Sh2	1.4	3.8	0	10	9.3	11.7	0	35	0.0	0.0	0	10
Seminis	Harvest Gold	Su	3.6	5.6	0	15	7.1	8.6	0	25	3.9	7.4	0	15
Seminis	Hollywood	Sh2	12.9	14.1	0	35	14.3	15.4	0	40	13.6	22.9	0	35
Seminis	Merit	Su	58.6	25.8	15	85	61.4	35.2	0	100	32.1	32.3	15	85
Seminis	Obsession	Sh2	3.6	5.6	0	15	7.1	8.6	0	25	2.1	5.7	0	15
Seminis	Passion	Sh2	2.9	3.9	0	10	9.3	12.7	0	35	4.1	5.9	0	10
Seminis	Sheba R	Sh2	2.9	3.9	0	10	10.0	10.0	0	30	1.7	4.5	0	10
Seminis	Temptation	Se	1.4	3.8	0	10	10.0	7.6	0	25	2.4	4.2	0	10
Snowy River	Bliss	Su	3.9	4.4	0	12	6.4	8.0	0	20	2.1	3.9	0	12
Snowy River	Colombus	Sh2	12.1	14.1	0	40	10.0	7.6	0	20	6.9	16.9	0	40
Snowy River	Empire	Su	9.3	13.7	0	40	11.4	8.5	0	25	7.0	16.8	0	40
Snowy River	Enterprise	Su	5.0	7.1	0	20	5.0	7.6	0	20	2.9	5.7	0	20
Snowy River	Everest	Sh2	7.1	14.7	0	40	9.3	9.8	0	30	4.3	9.2	0	40
Snowy River	Lancaster	Sh2	6.4	9.0	0	25	10.0	15.8	0	45	2.6	4.5	0	25
Snowy River	Prelude	Su	8.6	11.8	0	30	9.3	11.7	0	35	3.6	6.3	0	30
Snowy River	Punch	Su	13.6	8.0	0	20	10.7	7.3	0	20	7.4	16.8	0	20
Snowy River	Rising Sun	Sh2	2.9	5.7	0	15	9.3	14.0	0	40	2.1	5.7	0	15
Snowy River	UY0607OJ	Su	5.0	6.3	0	15	9.3	10.2	0	30	2.9	5.7	0	15
Snowy River	UY0712OJ	Su	5.0	4.1	0	10	7.9	10.4	0	30	2.9	5.7	0	10
Snowy River	UY1953OK	Su	2.1	3.9	0	10	7.1	10.7	0	30	2.4	4.6	0	10

WEATHER AND INSECT DISPERSAL

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Abstract

Agriculture in the vast majority of the United States has to manage around the winter weather. Winter synchronizes pest populations by creating a common starting point. Insect species unable to overwinter must rely on dispersal to reinfest northern areas or develop methods to exploit the overwintering area. The simple but useful formula: (Population = Birth – Death + /- Dispersal) is a tool to highlight the importance of dispersal. Pest populations are predictable due to the synchronization and common starting point of the crop and pest. Dispersal of adult stages is enhanced via high pressure cells that lift the insects upward and further enchased via wind activity of a surface low level jet stream is created at the boundary of a western counter –clock flow of a low and a clockwise air movement of a high to the east. The cumulative effect of the wind directions around each of these pressure cells creates a strong current northward. An average northward airflow of approximately 15 MPH within the pump can move a pest from northern Texas to central Iowa in 2 days**.** The Spodoptera frugiperda (JE Smith) the fall armyworm, Trichoplusia ni (Huber) the cabbage loopers, Helicoverpa zea (Boddie) the corn earworm and Aphis glycines the soybean aphid adults are annual migration pests. These insects have high fecundity, large adult populations, large source regions, and have adapted a life cycle to fit annual weather patterns. Dispersal must have species survival value. Noctuid adults will fly south in the fall and avoid the winter kill.
Key words: dispersal, front, drop zone, frontal boundary, Noctuid adults.

Introduction

Agriculture in the vast majority of the United States has to manage around the winter weather. A cold winter season obviously prevents crops from growing, but it also produces a significant challenge for the pests that feed on these crops. Not only does their food source stop growing, but these pests are must somehow keep from freezing themselves. In order to survive the bitter cold, insects have one stage in their development (egg, larva, pupae or adult) that is especially adapted for winter conditions. The insect has mechanisms that reduce ice crystal formation, have fluids like antifreeze, or can freeze solid and still not be killed. Insects adapt. When the spring come the surviving stage will emerge and start a new cycle. Winter synchronizes pest populations by creating a common starting point.

Not all insect species are able to over-winter everywhere. Insects must rely on dispersal to re-infest northern areas or just develop methods to exploit the area they can survive the winter.

Understanding the impact of weather on insect population dynamics will enhance your pest management program. Through winter-synchronization and weather-driven migrations, pest management becomes a yearlong-process.

<u>The Winter Season: Defining the Conditions that Synchronize Pest Populations</u>

Winter might be a harsh season where you live, but it is not safe to assume severe winter weather equals high insect mortality. Sometimes, local conditions and over-wintering sites protect a pest population and favor their survival. Conversely, those same conditions could kill a different pest population. For instance, snow cover might shield a pest from harsh conditions if the pest were underground, or be warm and moist in the debris and rot the insect. It has been very difficult to make blanket survival predictions. Insects are killed by free water expanding to form ice crystals within their exoskeletons. With this in mind, we have found that a period of four or more continuous days with minimum daily temperatures 0°F (or colder provides a critical "winter kill" threshold (Figure 1).

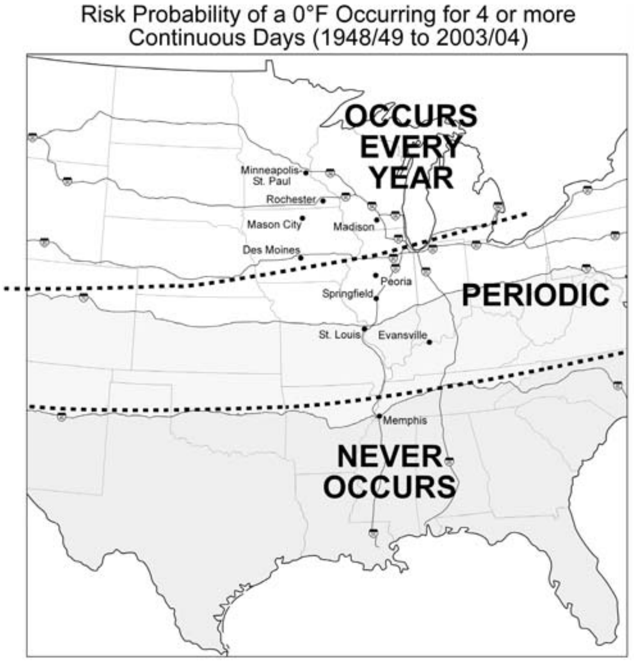

Figure 1. Annual winter probability of four or more consecutive days with a minimum temperature ≤ 0°F (Data courtesy of the Midwestern Regional Climate Ctr. and NIU Cartography Lab).

The use of USA Interstate highways is a practical benchmark to characterize pest/weather patterns. Locations north of I-80 experience at least one "winter kill" event *every winter*, while those between I-80 and I-40 experience them *periodically*. South of I-40 severe "winter kill" *never* occurs.

Despite never reaching the "winter kill" threshold, cold weather and frost will synchronize the crops and the pests south of Interstate 40. This region rarely experiences heavy (greater than 4 inches/event) snowfall. Therefore, the insect pests in this region are more susceptible to a one-time hard freeze with a minimum temperature of 28°F or lower (Figure 2).

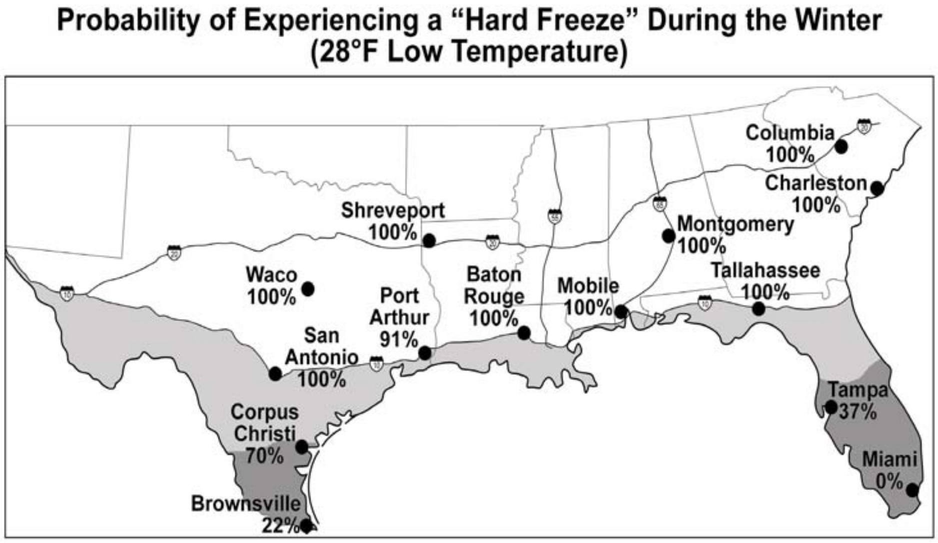

Figure 2. Probability of experiencing a 'hard freeze" during the winter (28F low temperature). (Data courtesy of the Midwestern Regional Climate Ctr. and NIU Cartography Lab).

The period of cold weather synchronizes the surviving pest stages. Based on this finding, pest insects will *always* be able to survive in extreme southern Florida and Texas, therefore, these regions are annual insect and disease pest source region.

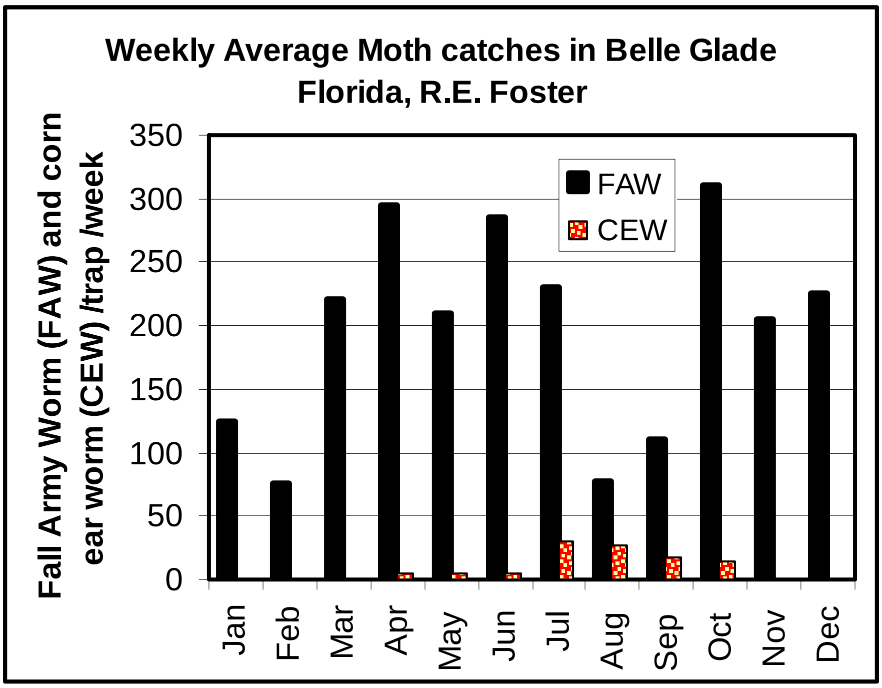

Figure 3. Fall army worm and corn earworm dispersal table from Belle Glade, Florida, USA.

Figure 3 shows the fall armyworm adults are present and dispersing year round while the corn earworm population is more seasonal, but at higher numbers when crops further north are more vulnerable. The fall armyworm is an annual pest along the eastern coastal areas.

Weather Patterns: Understanding How Pests Disperse and Migrate Northward

Insects will disperse locally and regionally (Figure 4). However, key issues facing much of the agricultural community in the upper Great Plains, Midwest, Ohio River Valley, Northeast and Eastern Coastal Plaines each growing season are the pests that migrate in from the south. The majority of these southern pest populations have been synchronized by frost, and so defined migration patterns can be estimated. In a 40-year recap of corn earworm black light catches in northern Illinois, a non-over wintering area, the average first significant flight varied by ± one week from the average night of the first significant flight. Figure 5 reflects a similar summer weather set-up that could during the summer months produce a dispersal flight from a source region.

There are several characteristic features of surface weather patterns. The first of these features is a "Low" pressure cell around which winds move in a counterclockwise direction ("into" the center of the Low). In the summer, "Lows" are usually located in the western Great Plains and sometimes have an associated frontal boundary located from its center eastward into the upper Midwest. The second feature is a "High" pressure cell of warm moist air. Winds move clockwise away from the center of the High. Highs can be located anywhere. Adult insects disperse in Highs. Within a High, the warm air creates convection currents that will move insects into the warm, moist air. A third weather feature is known as the frontal boundary. The frontal boundary represents the juncture between the cold, drier air moving in from the north and the warm, moist air from the High south of the front.

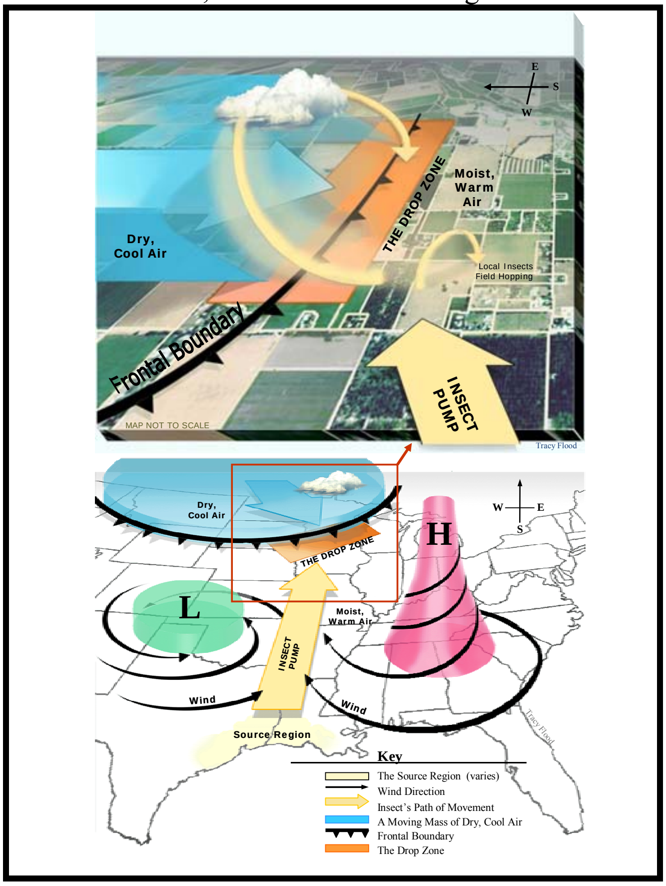

Figure 4. The primary weather patterns that impact dispersion both locally and regionally.

The Insect Pump

Local insect populations might not be the only pests dropping out of the sky. Frequently, during the growing season, weather conditions associated with a specific surface pattern cause widespread, northward migration of pests from their source regions. This migration occurs in a warm, moist air mass referred to as the "Pump". The surface weather patterns associated with the "Pump" primarily involve an area of high pressure (a "High") somewhere in the Southeast (See Figure 4) and a low pressure cell in the west. The cumulative effect of the wind directions around each of these pressure cells creates a strong current northward, low level jet stream.

The distance that these adult pests can travel within the pump (in the lowest levels of the atmosphere) is influenced by a number of weather-related factors including the wind speed within the pump, whether or not it encounters a "frontal boundary" (which will drop the pests out of the sky), and whether the s encounter rain that will flush them from the air mass. Typically, given an average northward airflow of approximately 15 MPH within the pump, a pest could move from northern Texas (I-20 corridor) to central Iowa (I-80 corridor) in approximately two days.

Local Field Hopping–(Inappropriate and Appropriate Landings per Dr. S. Finch et al)

The Drop Zone typically progresses into an area with hot and humid air. Before the cold air sets in, the insects actively move from field to field. The warm air lifts insects out of the crop canopy and into the air via convection currents. Local populations dispersing that are lifted by convection or flight are susceptible to the incoming frontal boundary. Once the frontal boundary passes, the cool, dry air passes over the fields. This cooler air encourages the insects to remain within the appropriate crop canopy.

The Drop Zone

The frontal boundary will have cloud cover, rainfall, thunderstorms, hail, snow and insects dropping out of the sky. The activity of the frontal boundary is one of the most important features in insect dispersal. First of all, the cold air behind the frontal boundary moves into an area like a wedge. This creates a lift upward and northerly. The warm, moist air of the High is pushed up over the cold air mass. Insects caught in the warm air are swept up as well. As it travels higher, the warm, moist air cools and the moisture in the air condenses into cumulus clouds (large and fluffy clouds). Eventually, air temperatures fall below 59°F and this causes insects caught in the "High" to drop out of the sky. We identify this area as the "Drop Zone", the more stationary the drop zone the larger potential for increased insect numbers due to the accumulation effects of the air masses.

What to Watch for: When a Pump Feeds into a Drop Zone

Use weather maps and forecasts to predict a pest migration in conjunction with: 1) knowing the pests status in locally and regionally 2) determining if surface winds can move more pests into your region, and 3) determining whether or not there is a frontal boundary nearby that would force the pests to fall out of the sky and onto your crops. It is important to be aware of the local and regional weather patterns in order to develop an appreciation and understanding of the crop/weather/ and pest interactions.

You cannot change the weather, but you can manage your crops better by understanding it. Now enjoy the day and, for the sake of your pest management program, keep your eyes on the weather.

References

Foster, R, and Flood, B.R. 2005. Vegetable Insect Management. Meister Pro Publ.

REACTION OF SNAP BEAN CULTIVARS AND ADVANCED BREEDING LINES TO APHID TRANSMITTED VIRUSES

Walter R. Stevenson[1/], Craig R. Grau[2/], and Thomas L. German[3/]

There are currently at least three aphid transmitted virus diseases that adversely affect processing beans in the Midwest. Beginning in 2000, when virus related symptoms began to appear in Wisconsin at epidemic proportions, we've seen varying levels of mosaic, plant stunting, distorted and discolored pods, blossom abortion and reduced yields depending on environmental conditions and aphid pressure present in each subsequent year. In Wisconsin, the majority of virus damage has been concentrated in southern and eastern areas along Lake Michigan, although there have also been localized pockets in other areas of the state where symptoms were severe in some years. In addition to the Wisconsin and Minnesota production areas, there have also been periodic reports of damage to processing beans in Michigan, New York and Ontario. The arrival of the soybean aphid in the upper Midwest in 2000 and subsequent fluctuations in aphid numbers from year to year appear to be correlated with virus damage on processing beans. All of the viruses currently identified from symptomatic processing bean plants (cucumber mosaic virus (CMV), alfalfa mosaic virus (AMV) and clover yellow vein virus (CYVV)) are all transmitted by aphids in a non-persistent manner. Thus in years when outbreaks of the soybean aphid are predicted, additional precautions are taken that include control of the aphid on soybeans, adjustments in planting schedules and changes in areas designated for early and late season production. While these efforts have undoubtedly helped to reduce losses, there is still a strong sense that we need better management tools for reducing the risk of virus infection in processing bean production.

One of the areas of research supported by the Midwest Food Processors Association is the search for resistance to aphid transmitted viruses in processing bean varieties and breeding materials. Having varieties with high levels of resistance to one or more of the viruses currently found in the Midwest would be an important tool in crop management. Thus, we've conducted field trials every year since 2001, evaluating symptom severity and incidence on a wide range of planting materials. This past year, we continued our field studies with a site at the West Madison Ag Research Station and grower sites near Markesan and Oostburg. These trials were strategically located in areas where aphid and virus pressure were high in previous years. Included in these trials were the most promising entries from the 2004 trial and additional cultivars and breeding lines bringing the total entries to 47 at Markesan and 43 at the W. Madison and Oostburg sites. In spite of early season predictions for the early arrival of the soybean aphid and concerns about

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high numbers of aphids at critical periods of the growing season, these concerns never materialized. Aphid numbers were low through most of the growing season and conse-quently, there was minimal virus incidence at Oostburg and low virus levels at West Madison. At the Markesan site, however, that is located in an area with abundant plantings of alfalfa and soybean, virus pressure was sufficiently high to obtain excellent data on the field susceptibility of the plot entries. We rated each entry for the presence of foliar symptoms, focusing mostly on mosaic and plant stunting. In addition, we also collected leaf samples from each entry at each location for virus assay back in Madison. Tom German's group used an ELISA procedure to check for the presence of CMV and AMV in samples collected on both dates and potyviruses (CYVV belongs to this virus group) in samples collected on the first sampling date. Table 1 outlines the plot details of the three planting sites.

Table 1. Details of the 2005 snap bean variety evaluation trials.

Snap bean variety trial – virus evaluation 2005

Three locations:
- **West Madison Agricultural Research Station**
- **Two commercial fields**

Arrangement:
- **2-row plots (UW breeding lines 1-row), 20' long**
- **3 replicates**

Data collected for each trial:
- **Leaf samples for ELISA virus assay - composite sample of 10 leaves/replicate from each trial, analyzed for AMV, CMV PotY.**
- **Two ratings for foliar symptom severity**

	Markesan	West Madison	Oostburg
Planted	7/16/05	7/11/05	7/8/05
Leaf sample 1 collected	8/23	8/24	8/23
Leaf sample 2 collected	9/6	9/7	9/6
Visual rating #1	8/23	8/24	8/23
#2	9/6	9/7	9/6
Number of lines planted	47	43	43

The incidence of foliar symptoms in 2005 was mild in comparison with previous years, especially at the West Madison and Oostburg sites. Thus rankings of plant susceptibility is based primarily on the field reaction of the plot entries at the Markesan site where we consistently observed severe mosaic symptoms on some of the plot entries and in some cases, a mild pod distortion (Fig. 1). We did not observe blossom drop on any of the plot site replications. The incidence of infection increased slightly in the two weeks between assessments (Table 2). None of the plot entries was completely free of symptoms at all locations, but several entries consistently exhibited a very low incidence of virus related symptoms. Cultivars such as Laguna, Redon, Sirio-LP, MV185 Arras, Alicante, Igloo, Fortune exhibited the lowest virus incidence at Markesan (<0.1 symptomatic plants per row ft), while other breeding lines exhibited as high as 2.2 symptomatic plants per row ft. Some of the lines exhibiting a low incidence of virus symptoms performed well in previous trials (Fortune, Laguna, MV185 Arras, Igloo, Sirio-LP and Redon). The incidence of symptomatic plants was highest at Markesan (Table 3), but when averaged out across all replications at all three sites, a similar pattern of susceptibility emerged (Table 4). ELISA testing revealed that viruses were present in a relatively high proportion of the samples assayed, in spite of the low incidence of symptomatic plants at the Oostburg and W. Madison sites (Table 5). Assay of leaf samples collected randomly from each plot entry and location revealed that both AMV and CMV were commonly detected in most entries, although there were a few entries where we failed to detect AMV (Table 6). CMV was the most commonly detected virus in 2005, as has been the case in our field trials since 2001. CMV was detected in every plot entry (Tables 2 and 7). The potyvirus assay indicated the presence of this group of viruses in only four entries (Alicante, ID802, PI 309881 and PI 599021) (Table 8).

The 2005 field trials focusing on host susceptibility is the fifth year where we've been able to evaluate a broad range of germplasm for the processing bean industry. Data from the 2005 trials indicate that the primary virus is CMV. While AMV is present in many of the samples and a potyvirus is rarely detected, it appears that CMV is the primary virus of interest. It is effectively transmitted by several aphid species including the soybean aphid and has a broad host range that apparently allows the virus to survive from season to season. It is still possible that other viruses are present in this virus complex, but to date, CMV, AMV and CYVV are the only viruses identified here in the Midwest.

Several breeding lines and cultivars have emerged as less susceptible than some of the standard cultivars such as Hystyle, Hercules and others. For some plot entries, we have observed consistently low incidences of symptomatic plants in field trials, even though ELISA diagnostic procedures have indicated the presence of either CMV, AMV or both viruses. This information should be helpful to breeders as they attempt to develop improved levels of resistance in future cultivars. The information should also be valuable to processors wishing to plant cultivars that exhibit reduced susceptibility to the virus complex.

These research trials have focused attention on short and long term solutions to the virus complex issues that have confronted the processing industry over the past few years. Processors have also altered their planting schedules and locations for late season production in addition to keeping a close eye on aphid and virus pressures. Production losses have been minimized by these changes in management and it is hoped that host resistance will become an active part of their crop and pest management plans.

Figure 1. Left – Severe mosaic and leaf crinkle symptoms on bean foliage. Right – Mild distortion of a snap bean pod on a plant with mosaic symptoms on the foliage.

Table 2. Incidence of symptoms and % of positive virus assays for lines tested in 2005 trials.

UW Trt No.	Entry Name	Source	In previous trials?	Incidence of virus symptoms (# of plants/foot)						% of samples over all 3 locations with positive reactions for virus					% of samples with positive reactions for virus
				Markesan		West Madison		Oostburg		24 Aug			8 Sep		
				23-Aug	5-Sep	23-Aug	7-Sep	23-Aug	5-Sep	amv	cmv	poty	amv	cmv	
1	Hystyle	Harris-Moran	2001 2002 2003 2004	0.1	0.2	0.04	0.00	0.01	0.07	33	33	0	33	44	29
2	Ulysses (EX 081020670)	Seminis	2003 2004	0.2	0.6	0.05	0.04	0.07	0.08	11	33	0	11	33	18
3	Alicante	Seminis		0.1	0.1	0.04	0.03	0.00	0.06	22	33	11	44	33	29
4	Sea Biscuit (EX 15330724)	Seminis		0.3	0.2	0.00	0.03	0.00	0.01	22	33	0	22	33	22
5	Valentino	Seminis		0.1	0.3	0.02	0.03	0.00	0.02	0	56	0	33	67	31
6	Yellowstone	Crites-Moscow	2004	0.1	0.4	0.03	0.05	0.00	0.06	22	33	0	22	44	24
7	Fortune	Crites-Moscow		0.0	0.1	0.02	0.02	0.00	0.10	11	33	0	11	56	22
8	Laguna	Crites-Moscow	2004	0.0	0.0	0.00	0.01	0.00	0.03	11	44	0	33	56	29
9	Shakira	Crites-Moscow		0.0	0.5	0.10	0.03	0.04	0.22	11	33	0	11	44	20
10	HMX 4953	Harris-Moran		0.0	0.1	0.03	0.02	0.00	0.05	0	33	0	11	44	18
11	HMX 5100	Harris-Moran		0.24	2.24	0.03	0.10	0.02	0.06	22	33	0	33	33	24
12	HMX 4954	Harris-Moran		0.24	1.46	0.05	0.15	0.02	0.00	33	44	0	11	44	27
13	MV185 Arras	Vilmorin	2001 2002 2003 2004	0.00	0.07	0.09	0.01	0.18	0.00	0	33	0	11	22	13
14	ORION	Brotherton Seed Co.	2002, 2003, 2004	0.01	0.14	0.02	0.03	0.00	0.04	11	33	0	0	33	16
15	BSC835	Brotherton	2004	0.07	0.37	0.01	0.00	0.02	0.00	11	33	0	33	44	24
16	HS906	Brotherton	2004	0.37	0.23	0.01	0.02	0.00	0.08	33	33	0	0	56	24
17	BSC864	Brotherton	no	0.04	0.14	0.07	0.09	0.04	0.07	11	33	0	33	33	22
18	PLS 87	Pure Line Seeds	2002 2003 2004	0.08	0.12	0.05	0.03	0.00	0.01	22	33	0	11	33	20
19	PLS 75	Pure Line	2002	0.04	0.22	0.16	0.12	0.00	0.12	33	33	0	22	33	24
20	PLS 99	Pure Line	2002 2003	0.22	0.21	0.06	0.01	0.01	0.05	11	33	0	33	67	29
21	Igloo	Pure Line	2002 2003	0.12	0.10	0.01	0.01	0.00	0.03	11	33	0	33	67	29
22	PI 309881	M Sass/Hort	2004	0.00	0.01	0.02	0.04	0.00	0.00	0	11	11	0	11	7
23	2313.9.1000	M Sass/Hort	2004	0.01	0.17	0.00	0.00	0.00	0.00	0	33	0	0	33	13
24	ID8011X	Del Monte	no	0.17	0.79	0.08	0.04	0.00	0.05	0	33	0	0	56	18

UW Trt No.	Entry Name	Source	In previous trials?	Incidence of virus symptoms (# of plants/foot)						% of samples over all 3 locations with positive reactions for virus					% of samples with positive reactions for virus
				Markesan		West Madison		Oostburg		24 Aug			8 Sep		
				23-Aug	5-Sep	23-Aug	7-Sep	23-Aug	5-Sep	amv	cmv	poty	amv	cmv	
25	IDC IX	Del Monte	2004	0.06	0.05	0.00	0.00	0.01	0.04	22	33	0	22	67	29
26	ID552	Del Monte	no	0.06	0.22	0.00	0.05	0.01	0.02	11	44	0	11	33	20
27	ID802	Del Monte	no	0.17	1.09	0.09	0.08	0.00	0.02	11	33	11	0	67	24
28	Sirio-LP	Syngenta	2002 2003 2004	0.02	0.07	0.02	0.00	0.00	0.02	11	33	0	0	56	20
29	Redon	Syngenta	2004	0.02	0.03	0.09	0.01	0.01	0.04	11	33	0	11	33	18
30	Stayton	Syngenta	no	0.07	0.14	0.00	0.02	0.00	0.02	11	33	0	11	33	18
31	PI 417782	UW Hort, M. Sass, J. Nienhuis	no	0.30	0.31	0.00	0.01	0.02	0.00	22	44	0	11	33	22
32	PI 288016	UW Hort	no	0.15	0.83	0.00	0.00	0.00	0.00	0	33	0	0	33	13
33	PI182000 (selection S)	UW Hort	no	0.10	0.07	0.01	0.02	0.01	0.02	22	33	0	22	56	27
34	PI 345581	UW Hort	no	0.08	0.18	0.02	0.00	0.00	0.00	0	33	0	0	44	16
35	PI 449412	UW Hort	no	0.08	0.43	0.00	0.00	0.00	0.00	0	33	0	0	56	18
36	PI 313458	UW Hort	no	0.00	0.18	0.00	0.00	0.00	0.00	0	33	0	22	33	18
37	PI 268110	UW Hort	no	0.12	0.61	0.02	0.00	0.00	0.00	0	22	0	0	33	11
38	PI 313833	UW Hort	no	0.00	0.25	0.00	0.00	0.00	0.02	11	33	0	0	33	16
39	PI 174997	UW Hort	no	0.06	0.06	0.00	0.00	0.00	0.00	22	33	0	0	33	18
40	PI 549853	UW Hort	no	0.00	0.25	0.02	0.02	0.00	0.02	0	33	0	0	44	16
41	PI 599021	UW Hort	no	0.12	0.57	0.02	0.00	0.02	0.02	0	33	11	0	44	18
42	PI 599014	UW Hort	no	0.08	0.08	0.00	0.02	0.00	0.00	0	33	0	11	33	16
44	PI 207180 **	UW Hort	no	0.10	0.33					0	67	0	0	100	33
45	PI 599026 **	UW Hort	no	0.02	0.04					0	100	0	0	100	40
46	PI 416468 **	UW Hort	no	0.37	0.55					0	100	0	0	100	40
47	PI 182000 (selection L) **	UW Hort	no	0.04	0.16					0	100	0	0	100	40
Pr>F				< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01						
LSD				0.12	0.46	0.07	0.06	0.03	0.06						

* includes both sampling dates, all three locations, all assays

** only at Markesan (percentages are adjusted for number of plots)

Table 3. Incidence of symptomatic plants among all entries at the Markesan site.

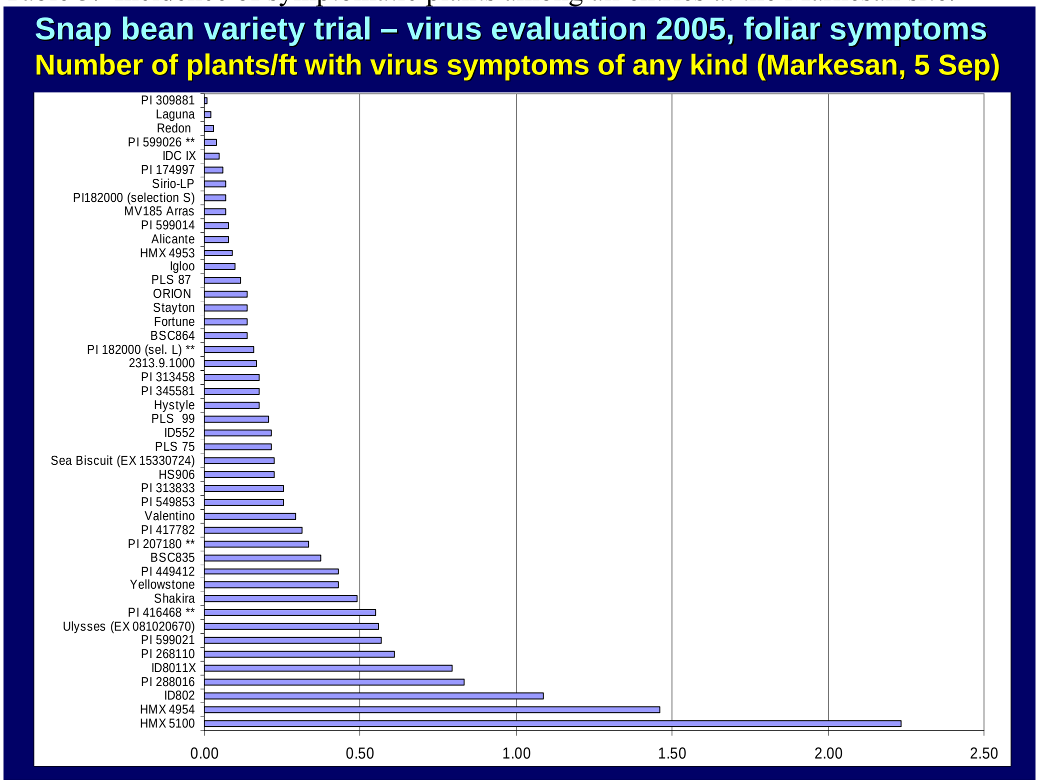

Table 4. The incidence of symptomatic plants among entries across all replications and Wisconsin locations.

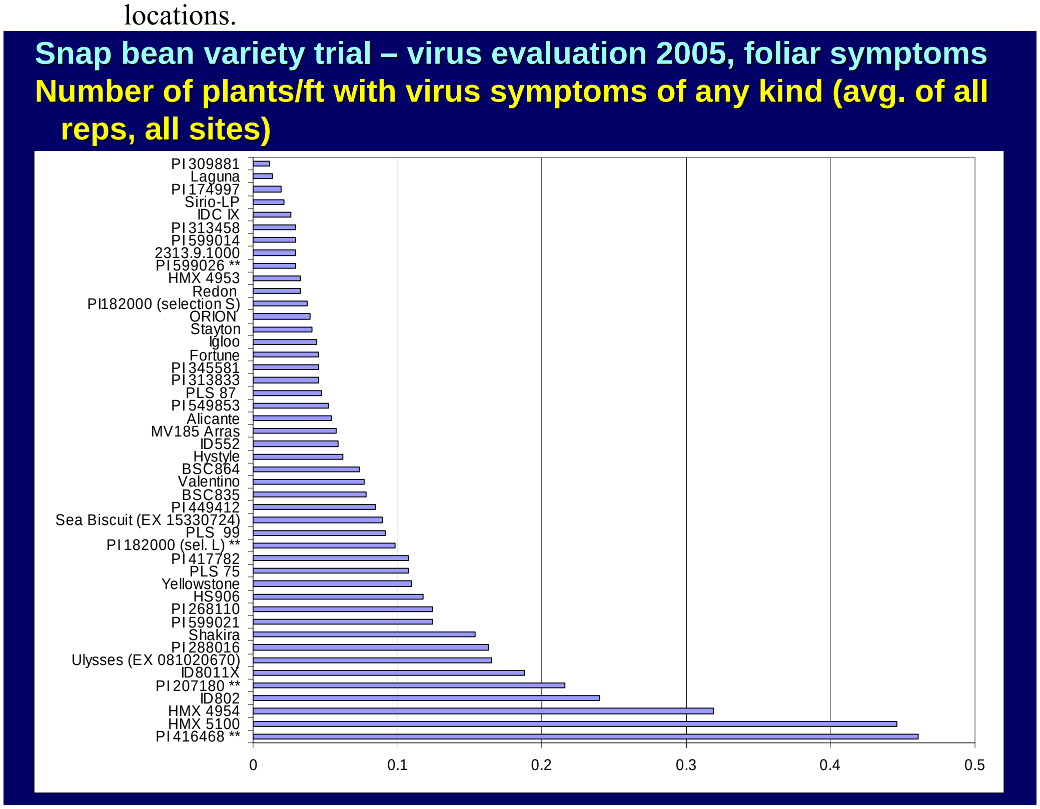

Table 5. Detection of virus in the 2005 field trials in Wisconsin.

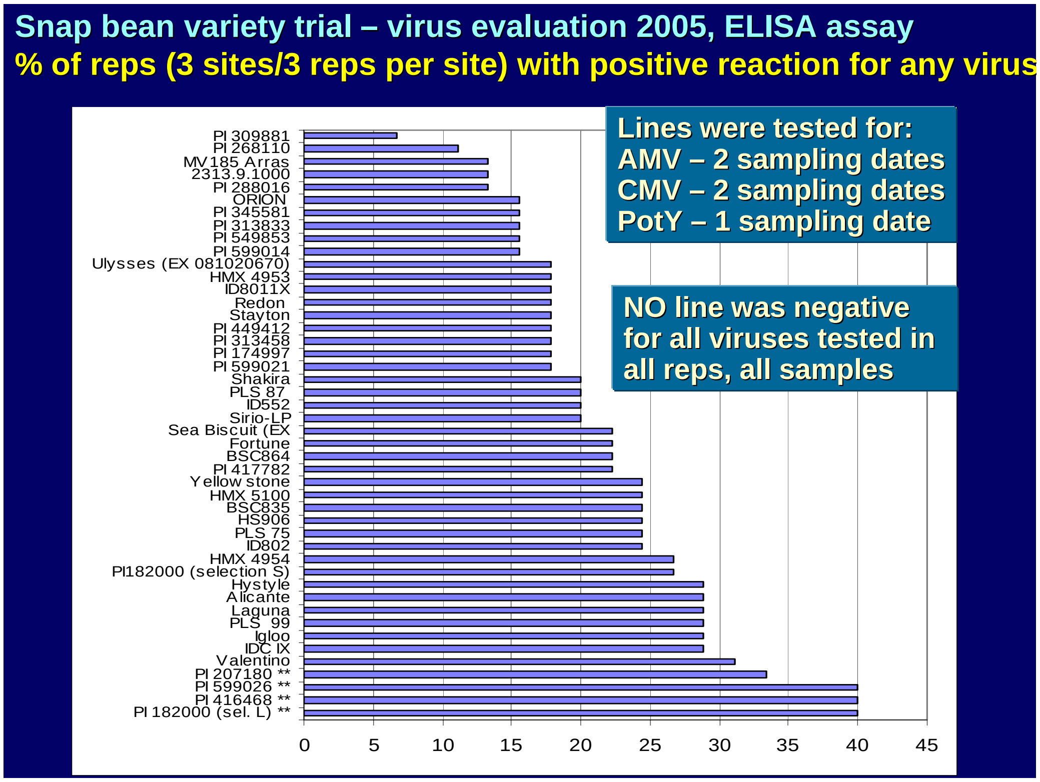

Table 6. Lines with the lowest levels of alfalfa mosaic virus on both sampling dates.

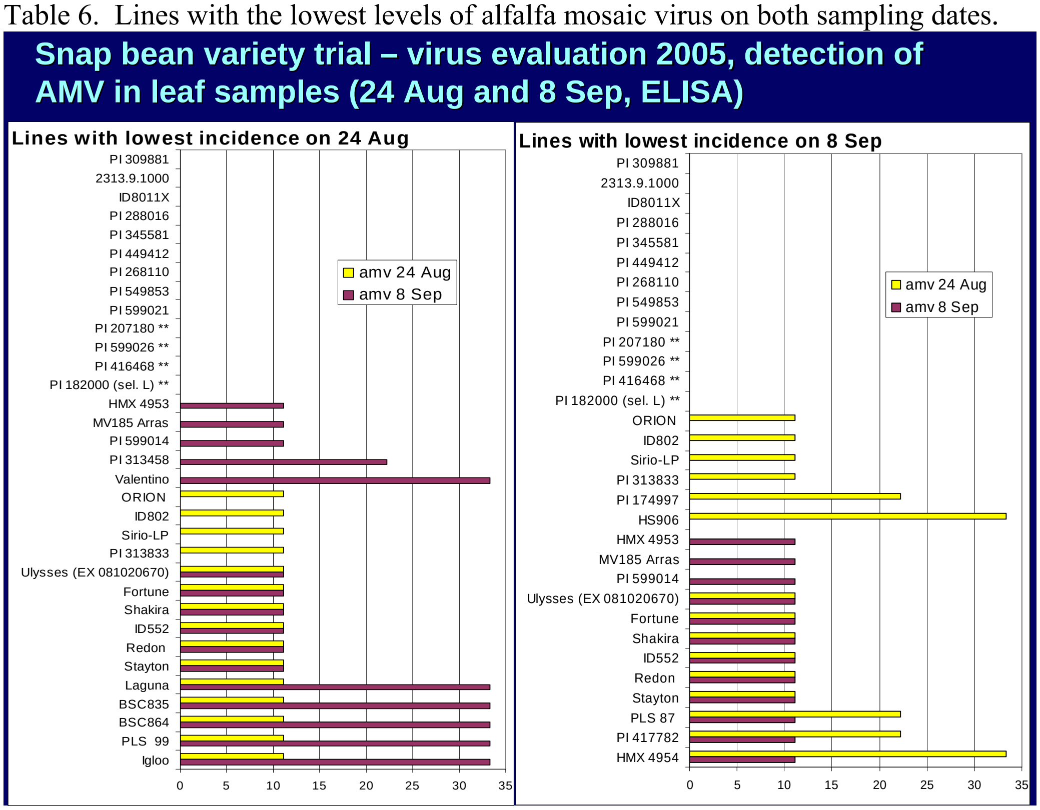

Table 7. with the lowest levels of cucumber mosaic virus on both sampling dates.

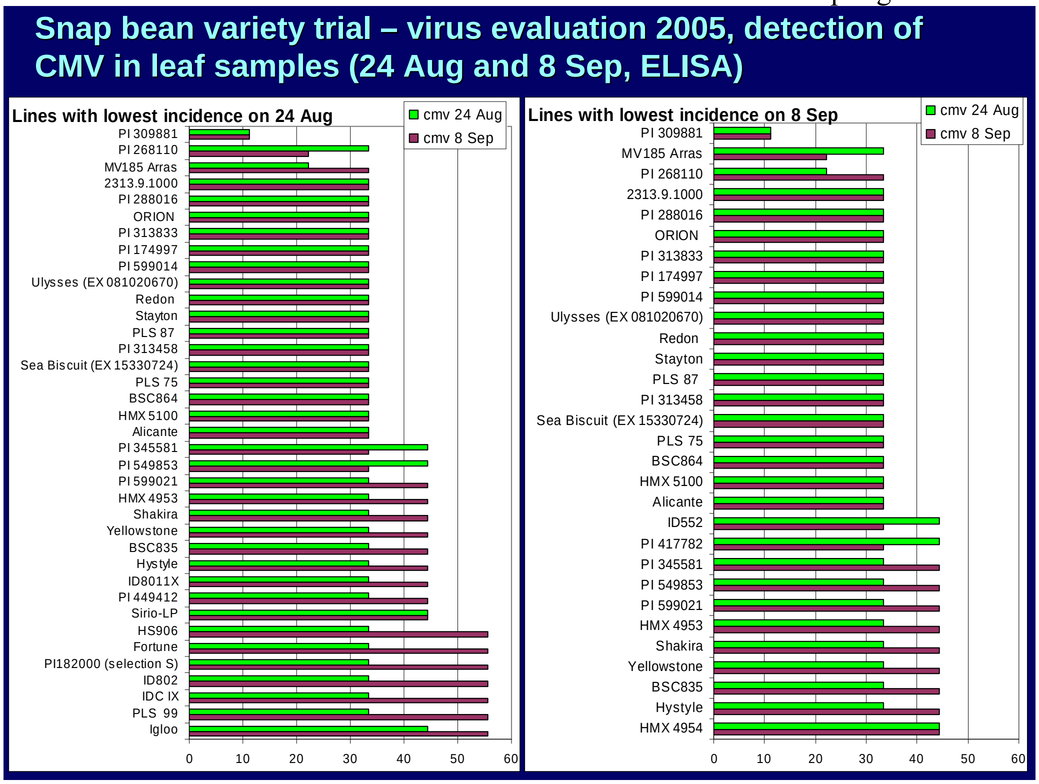

Table 8. A potyvirus was detected in only four plot entries at a single location.

Snap bean variety trial – virus evaluation 2005, detection of PotY in leaf samples 24 Aug (ELISA)

Lines with NO positive reaction for PotY

2313.9.1000	PI 174997	PLS 75
BSC835	PI 182000 (sel. L)	PLS 87
BSC864	PI 207180	Redon
Fortune	PI 268110	Sea Biscuit (EX 15330724)
HMX 4953	PI 288016	Shakira
HMX 4954	PI 313458	Sirio-LP
HMX 5100	PI 313833	Stayton
HS906	PI 345581	Ulysses (EX 081020670)
Hystyle	PI 416468	Valentino
ID552	PI 417782	Yellowstone
ID8011X	PI 449412	
IDC IX	PI 549853	
Igloo	PI 599014	
Laguna	PI 599026	
MV185 Arras	PI182000 (sel. S)	
ORION	PLS 99	

Lines with a positive reaction for PotY (one plot at one location)

Alicante
ID802
PI 309881
PI 599021

WISCONSIN IR-4 CENTER: STEP ONE TO A VEGETABLE CROP LABEL

Daniel J. Heider[1/]

In 2004, Wisconsin farmers grew 3.6 million acres of corn, 5 million acres of alfalfa and 1.6 million acres of soybeans. In sharp contrast, Wisconsin farmers grew only 30,000 acres of green peas, 73,000 acres of snap beans, 2,000 acres of onions and 4,200 acres of carrots (Wisconsin Ag Statistics, 2005). If you were going to invest $70-100 million on developing a new pesticide for one of the above crops, which would you choose? It doesn't take a financial wizard to realize that the return on investment has the potential to be disastrous from a low acreage crop. Nonetheless, the need for pest management tools on these minor acreage crops often equals or exceeds the large acreage field crops.

The Interregional Research Project No. 4 (IR-4 Program) was organized in 1963 by the Directors of the State Agricultural Experiment Stations (SAES) to obtain regulatory clearances for crop protection chemicals on specialty food crops when the incentives for the registrants precluded private sector investment. The objectives of the program were expanded in 1977 from just food crops to include registration of pest control products for the protection of nursery, floral, forestry, Christmas trees, and turf crops and again in 1982 when biopesticides were added. IR-4 operates as a unique partnership between the land grant university system and the USDA (ARS and CSREES). IR-4 Headquarters is located at Rutgers University in New Jersey. The U.S. is divided up into 4 regions with the North Central Regional staff located at Michigan State University. The Wisconsin IR-4 Center, Co-Directed by Dan Heider and Scott Chapman, is one of 24 IR-4 field research centers located throughout the U.S.

The IR-4 Process

Although many have heard of the IR-4 program, the actual process of moving a project through IR-4 and towards a minor crop label is rarely understood. The following gives a broad overview of the many steps involved.

1. <u>Identification of Needs</u> – Requests for specific pest management needs are made by minor crop growers, commodity groups, land grant university and USDA scientists and university extension personnel. This step requires the submission of a Project Clearance Request (PCR) which documents the crop, pest, pesticide, potential use patterns, any existing alternatives, and whether any initial performance data is available.
2. <u>Prioritization</u> – It is not uncommon for IR-4 to have over 1000 PCR's on file at any one time. Unfortunately IR-4 does not have sufficient resources to conduct research on all proposed researchable projects. Therefore, each fall a national Food Use Workshop (attended by numerous Wisconsin representatives) is held to prioritize the projects. These are open forums where specialty crop growers, commodity

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organization representatives, agricultural pesticide company representatives, and federal and state research scientists discuss every potential research project in detail looking at efficacy of alternatives, pest damage potential, performance of the proposed chemical and its IPM compatibility. In 2006, funding will allow work to begin on less than 50 IR-4 field projects selected from the 1000+ requests.

3. Final Workplan – The highest priority projects are selected for research based on resources available and agreed upon by Headquarters, Regional and ARS staff.
4. Implementation – All food use field and laboratory studies are conducted in full compliance with EPA's Good Laboratory Practice (GLP) requirements. Protocols are developed and assigned to Field Research Centers based on the EPA's geographical requirements. Crops are grown, pesticides applied and samples harvested for residue analysis. Ornamental and some biopesticide projects require only crop safety and efficacy data.
5. Petition Preparation – All data are critically reviewed, summarized and prepared as a petition at IR-4 Headquarters based on the field and laboratory results.
6. EPA Petition Review and Approval – Upon receipt, EPA Registration Division performs a preliminary review for completeness of the data submitted and initiates discussions with scientists in the Health Effects Division to schedule a comprehensive review of all IR-4 and Ag Chemical Company data submitted. If the data show that clearance of the proposed use would not expose consumers or the environment to unreasonable adverse effects, the EPA publishes a tolerance as a Final Rule in the Federal Register. This tolerance is the maximum safe limit of the agricultural chemical in or on the harvested crop that is considered safe and legally acceptable.
7. Product Availablility – The establishment of a tolerance by EPA allows the registrants (usually the agricultural chemical company) to put the minor crop uses on their existing product labels and make those specific uses available to minor crop growers.

How long does this whole process take? In an effort to streamline the process, IR-4 has a goal of completing steps 4 and 5 above within 30 months. Adding in several months up front from project selection to protocol approval, another year or more from data submission at EPA to setting a tolerance and additional time to incorporate a use onto a label, we are often looking at a 4-6 year timeframe at a minimum from the beginning of a project until a useable label is in hand. Quite simply, the amount of work that goes into each and every project necessitates this seemingly lengthy amount of time; which has been greatly shortened in recent years due to a more partnership-like relationship between all entities involved.

The Wisconsin IR-4 Center is extremely active in the IR-4 process. Our continued pesticide efficacy screenings for herbicides, insecticides and fungicides provide us with invaluable data allowing us to submit Project Clearance Requests very early in the process for pesticides which could benefit Wisconsin growers. At the prioritization workshop, Wisconsin representation ensures that we see a number of projects important to Wisconsin growers enter the field trials each year. The Wisconsin Center currently has two Field Research Directors responsible for conducting 25-30 residue field trials each year. That's quite an undertaking, considering the average residue field trial requires between 40 and 80 hours to complete.

Most often, you may not even realize that IR-4 has had a hand in a new minor crop use being registered. The following list is just a sampling of somewhat recent pesticide registrations that are a result of tolerances obtained due to IR-4 data submissions to EPA.

Dimethenamid-P / Outlook® – potato, garden beet, onion, horseradish
Sulfentrazone / Spartan® – mint
Flumioxazin / Chateau® – onion, mint
Halosulfuron-methyl / Sandea® – snap beans, lima beans
Imazamox / Raptor® – snap beans
Clethodim / Select® - mint

Since the inception of IR-4 in 1963, it has been responsible for residue data and other petitions to support over 8,300 food use clearances, more than 10,600 ornamental or non-food crop clearances and supported research on biopesticides which has resulted in over 300 biopesticide clearances. In fact, IR-4 clearances account for approximately 50% of all food use approvals granted by EPA. Additional information about the IR-4 program can be found at their website: http://ir4.rutgers.edu/.

If you have ideas for potential IR-4 projects, contact either of the Wisconsin IR-4 Center Co-Directors listed below:

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References

Wisconsin 2005 Agricultural Statistics. 2005. Wisconsin Agricultural Statistics Service, P.O. Box 8934, Madison WI 53708.

HERBICIDE LABEL UPDATE FOR VEGETABLE CROPS

Jed B. Colquhoun [1/]

While herbicide development in vegetable crops has been limited in recent years, a few products have been registered on several minor crops, including halosulfuron (Sandea®) and sulfentrazone (Spartan®). Research is underway to further expand the use of these herbicides in additional crops.

Halosulfuron is a sulfonylurea herbicide that controls weeds by inhibiting the acetolactate synthase (ALS) enzyme. This enzyme is responsible for the production of essential amino acids. Other common ALS-inhibitor herbicides include Accent®, Matrix®, Classic®, Beacon®, Raptor®, and Pursuit®. Recent registrations on the Federal Section 3 label include asparagus, cucumbers and melons, pumpkins and squash, dry and snap beans, tomatoes, eggplants and peppers. Halosulfuron controls weeds when applied prior to emergence or early-postemergence, depending on the target species. The weed control spectrum is rather broad, and includes common broadleaf weeds such as cocklebur, galinsoga, common groundsel, marestail, jimsonweed, kochia, ladysthumb smartweed, common lambsquarters, and wild mustard. In recent research, common ragweed control has been good when halosulfuron was applied early postemergence. Halosulfuron is also one of the only herbicides that will suppress horsetail (*Equisetum* spp.) when applied postemergence.

While the broad spectrum of residual weed control offered by halosulfuron is very advantageous, users should keep in mind that residual herbicides can sometimes have lengthy rotational restrictions for future cropping plans. Current rotational restrictions after halosulfuron application for common Wisconsin crops range from 1 to 36 months. Also, the long-term use of ALS-inhibitor herbicides, including halosulfuron, should be carefully managed to reduce the risk of herbicide resistance. Weed resistance to ALS-inhibitors has been observed in 93 species worldwide. In Wisconsin, resistance to this mode of action has been reported in black night-shade, common waterhemp, giant foxtail, green foxtail, and kochia.

Sulfentrazone is a protoporphyrinogen oxidase (PPO) inhibitor. Other PPO-inhibitor herbicides include Aim®, Goal®, Cobra®, and Blazer®. The PPO enzyme is required for the formation of chlorophyll, and when blocked, results in the buildup of highly reactive compounds that destroy cell membranes. Current crop registrations include soybean, processing cabbage, potato, horseradish, dry peas, and mint. Sulfentrazone may have a fit and future registration in more minor crops. This herbicide is taken up from soil solution by germinating seeds and seedlings. The use rate is determined by crop and soil type. Soils high in organic matter or clay adsorb sulfentrazone so that it is not readily available for plant uptake, and low soil pH reduces availability. The weed control spectrum includes several common broadleaf and grass weeds, such as pigweed species, galinsoga, jimsonweed, kochia, ladysthumb and Pennsylvania smartweed, common lambsquarters, black nightshade, common purslane, shepherdspurse, and waterhemp species. Sulfentrazone will partially control several other weeds, including hairy nightshade, cocklebur, velvetleaf, and several grass species (when combined with an appropriate grass herbicide). As with halosulfuron, careful long-term crop planning is important when using sulfentrazone. Rotational restrictions for commonly-grown crops are up to 36 months. As always, pesticide labels change frequently. Please consult the current label for updates prior to use.

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Experimenting with Soybean/Grass Combinations for Forage

Michael G. Bertram
Marshfield Ag. Research Station

Rationale

- Possibilities of feed shortages exist.
  - 500,000 alfalfa acres winterkilled in Spring 2003
- Limited research on soybean mixtures.
- New forage oat and forage soybean varieties available.
- Limited pearl millet research in Central Wisconsin.

Previous Wisconsin Soybean Forage Research

- Evaluated maturity groups, row spacing, population, and harvest timing.
- Can produce similar yield and quality as alfalfa.
- Increased yield with narrow rows with no quality change.
- Greatest yield at R7 stage, but decreased quality.
- Increased yield when planting one maturity group greater than normally planted for grain.

Hintz, et al., 1992

'Derry' Forage Soybean

- Released by USDA in 1997; MG VI
- Tall variety with good lodging resistance.
- Superior forage producing ability.
- MN 1995- 3.6 tn dm/A; 1996- 4.5 tn dm/A
- However, quality lower due to high proportion of stems and leaves.
- MN 1996; Only matured to R3 Stage
  CP- 15.2%; ADF- 41.3%; NDF- 48.6%

Scheaffer, et al., 2001

Forage dry matter yield of spring oat varieties harvested at late boot

Selected Varieties	Yield (tn/A) 2 loc 2003-05	CP (%) 2003-04	RFV 2003-04
Forage Plus	3.06	9.5	100.8
Leonard	2.48	10.1	99.4
Vista	2.43	10.0	98.4
Belle	2.36	9.9	106.1
Moraine	1.99	11.1	106.2
LSD (0.05)	0.11	0.7	3.5

Borges, et al., 2005

Pearl Millet

- Tall, warm season annual grass.
- 1.5 million acres planted in the U.S.
- High drought tolerance.
- No prussic acid production.
- 1989 ND Yield- 4.2 tn dm/a; Quality- CP- 15%, ADF- 39%, NDF- 48%, TDN- 52%
- Can do well for silage, hay, and pasture.

Sedivec and Schatz, 1991

Experimental Design

- Locations
  - Marshfield Ag. Research Station
  - Longwood, Clark County (Dennis Rose Farm)
- 3 Years
- Randomized Complete Block Design
- 4 Replications, Small plots
- Previous Crop
  - Alfalfa preferred, simulate winterkill situation

Experimental Design (cont.)

- Planting: Early June
- Fertilization: Use N credits
- Weed Control: If necessary
- Harvest: Done at optimum stage for each crop
- Data collected: Yield, Dry matter, Height, Days to harvest, Quality
- Quality: Performed by Marshfield Soil and Forage Analysis Lab

Planting

- Dates
  - 2003: June 1-2
  - 2004: June 7
  - 2005: May 31, June 2
- Rates
  - Oats: solo- 3 bu; mix- 2 bu
  - PM, BMR: solo- 25 lb; mix- 16 lb
  - Soybeans: solo- 225 K; mix- 150 K

Crops

- Grasses
  - Vista Oat (Oat)
  - Forage Plus Oat (FO)
  - Honey Sweet BMR Sorghum Sudangrass (BMR)
  - Leafy 23 Hybrid Pearl Millet (PM)
- Soybeans
  - NK S08-R4 0.8 RM (1S)
  - Dairyland DSR 184RR 1.8 RM (2S)
  - Derry Forage Soybean (FS)

Vista Oat

Forage Oat

Pearl Millet

BMR Sorghum Sudangrass

Soybean

Yield Results- Solo

Mean of 6 expts. (tn dm/A)

Crop	Yield	Range
Oat	1.64	0.86-2.89
FO	1.56	1.03-2.47
PM	2.80	1.58-4.82
BMR	3.02	1.71-5.31
1S	1.84	1.51-2.11
2S	2.11	1.63-2.61
FS	2.07	1.45-2.81

- No dif. for 5 expt
  FO greater 1 expt
- No dif. at 1 expt
  BMR greater 4 expt
- No dif. at 3 expt
  1S lowest 3 expt
  2S greatest 3 expt
  FS greatest 2 expt

Quality Results- Solo

Mean of 4 expts.

Crop	CP%	ADF%	NDF%	TDN%	RFQ
Oat	16.1	32.2	51.7	65.0	162
FO	16.7	29.3	47.9	69.4	188
PM	11.6	34.8	58.1	59.0	131
BMR	10.2	34.9	55.4	61.9	132
1S	16.3	29.9	41.5	63.7	157
2S	16.1	29.7	40.4	64.0	159
FS	14.8	30.9	39.9	62.5	158

Yield Results- Mixtures

Mean of 6 expts. (tn dm/A)

Crop	Yield	Range
Oat/None	1.64	0.86-2.89
Oat/1S	1.56	0.80-2.99
Oat/2S	1.55	0.75-2.93
Oat/FS	1.51	0.74-2.85
FO/None	1.56	1.03-2.47
FO/1S	1.59	0.94-2.97
FO/2S	1.50	0.91-2.42
FO/FS	1.49	0.90-2.46

- No difference at any of 6 expts.
- No difference at any of 6 expts.

Quality Results- Mixtures

Mean of 4 expts.

Crop	CP%	ADF%	NDF%	TDN%	RFQ
Oat/None	16.1	32.2	51.7	65.9	162
Oat/1S	16.6	32.1	51.1	65.3	162
Oat/2S	17.1	32.3	50.7	65.0	160
Oat/FS	16.9	32.2	50.5	65.2	164
FO/None	16.7	29.3	47.9	69.4	188
FO/1S	17.5	29.4	46.2	68.5	191
FO/2S	17.2	29.6	46.5	68.5	187
FO/FS	17.3	29.2	45.9	68.7	190

Yield Results- Mixtures

Mean of 6 expts. (tn dm/A)

Crop	Yield	Range
PM/None	2.80	1.58-4.82
PM/1S	2.66	1.78-4.33
PM /2S	2.74	1.87-4.47
PM/FS	3.01	1.68-5.22
BMR/None	3.02	1.71-5.31
BMR/1S	3.04	2.27-4.33
BMR/2S	3.07	2.17-4.96
BMR/FS	3.17	2.12-5.18

- No dif. 2 expts. PM/FS greatest 4 expts, PM/N lowest 3 expts.
- No dif. 1 expts. Each greatest 2-3 expts, lowest 2-3 expt

Quality Results- Mixtures

Mean of 4 expts.

Crop	CP%	ADF%	NDF%	TDN%	RFQ
PM/None	11.6	34.8	58.1	59.0	131
PM/1S	12.5	33.9	52.9	60.5	133
PM /2S	13.1	33.7	51.0	60.9	135
PM/FS	11.9	33.5	50.2	60.9	138
BMR/None	10.2	34.9	55.4	61.9	132
BMR/1S	11.3	34.2	53.6	62.5	139
BMR/2S	11.3	33.5	52.3	62.6	138
BMR/FS	10.4	33.9	52.3	62.8	138

Conclusions

- Late oat planting is risky. It is a better option to plant early.
- Soybeans didn't change oat quality. Peas are a better choice to enhance yield and protein.
- Forage oats didn't improve yield over a conventional variety with late planting.
- Pearl millet and BMR sorghum sudangrass both had good yield potential, but pearl millet generally yielded less and was more dependent on good growing conditions.

Conclusions

- Soybeans may enhance quality in PM and BMR, but results were inconsistent.
- Group 1 soybeans generally yielded less than Group 2, which did not differ from Forage.
- Soybean quality did not differ and was similar to alfalfa, although protein was low.
- These are a few of many options producers could consider when short of forage. Corn silage still has a much greater yield potential.

Acknowledgments

- WI CCA Board
- Marshfield Ag. Research Station
- Olds Seed Solutions
- Ron Weiderholt
- Clark County Forage Council
- Marshfield Soil and Forage Analysis Lab
- Wolf River Valley Seed

Roundup Ready Alfalfa

Dan Undersander [1/]

USDA-APHIS granted approval for sale and use of Roundup Ready alfalfa on June 14, 2005 and the following day the EPA approved the labels to use Roundup for weed control in Roundup Ready alfalfa forage and hay production. State approvals of labels for to use Roundup Original MAX and Roundup WeatherMAX herbicides on Roundup Ready alfalfa have followed (all except CA and NY have approved WeatherMAX labels).

Approvals by other countries are pending. Forage Genetics International (FGI) and Monsanto have secured hay import approvals for Mexico and for Canada, and are anticipating hay import approvals for Japan. Approvals are expected prior to the first harvest of Roundup Ready alfalfa forage in the spring of 2006. Regulatory submissions have also been made to other import markets, including Korea and Taiwan.

Such approvals, or lack thereof will not impact, Wisconsin much, but do impact both the alfalfa seed and hay industry of the West. Until clearances from other countries are received, no seed to be sold internationally may have the Roundup Ready gene, either intentionally or as a contaminate. Further, hay of Roundup Ready alfalfa may not be sold internationally until the receiving country had approved use of the gene.

Because necessary import approvals by regulatory agencies of other countries cannot be guaranteed, FGI and Monsanto are working together to initially commercialize Roundup Ready alfalfa through licensees under a "Limited Domestic Launch." Multiple Roundup Ready varieties will be sold to fit fall-dormant and non-dormant market needs.

Following are come key points about Roundup Ready Use in Wisconsin.

- The seed is guaranteed to have greater than 90% roundup ready seed. This means that 5 to 10% of the seed will not be roundup ready. It is anticipated that the first spraying in the seedling stage will take out the non roundup ready seedlings and their loss will not be noticed as stands thin naturally in the seeding year. This could be an issue if the alfalfa is not sprayed in the seedling stage.
- Roundup is easy to commonly available on farms and controls a broader array of both grassy and, and especially, broadleaf weeds than currently available herbicides.
- There is concern about development of Roundup Resistant weeds if all three crops in rotation are Roundup Resistant. However, the frequent mowing of alfalfa will reduce the likelihood of this being an issue.
- Roundup does not cause damage to the seedling alfalfa as observed with most other herbicides. Therefore more yield may be achieved in the seeding year.
- The harvest restriction is much shorter for Roundup applied to alfalfa in the seedling stage than for most other herbicides (see table below).

[1/] Professor, Dept. of Agronomy, Univ. of Wisconsin-Madison.

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

- The released Roundup Ready alfalfa varieties have excellent genetics and appear to have no yield drag. We have tested the eight varieties that are the first releases at the UW Arlington Research Station. The seeding year data are presented below.

RoundUp Ready Variety Trial, Arlington Research Station 2004 Seeding harvested in 2004

	Cut 1 2004	Cut 2 2004	2004
Entry	ton/acre	ton/acre	ton/acre
RR1	1.32	1.28	2.60
RR2	1.29	1.25	2.55
RR3	1.23	1.23	2.47
RR4	1.25	1.22	2.47
RR5	1.21	1.17	2.35
RR6	1.11	1.20	2.32
RR7	1.12	1.19	2.30
REBOUND 5.0	0.98	1.31	2.30
RR8	1.09	1.19	2.29
54V46	0.86	1.23	2.16
Mean	1.15	1.23	2.38
LSD(5%)	0.05	0.14	0.15
CV%	2.3	7.3	4.2

- The technology contracts will vary slightly among companies in terms of record keeping. Cropplan Genetics is requiring a GPS reading in each corner of each field. Most other companies are requiring no GPS reading in Wisconsin (some GPS readings required for those states in the West where seed is produced).
- The onetime technology fee per 50-lb bag of Roundup Ready alfalfa seed east of the Rocky Mountains is $125. West of the Rockies, it is $150 a bag. If a grower plants 12 lb/acre, the technology fee is approximately $30/A. Add to this the cost of the seed itself to get the total seed cost.

TILLAGE MANAGEMENT FOR THE CORN/SOYBEAN ROTATION ON ERODIBLE SOILS [1/]

Richard Wolkowski, Richard Cruse, and Hillary Owen [2/]

Abstract

A field research study was conducted at the Lancaster Agricultural Research Station in 2004 and 2005 to examine the relationship between tillage treatment and response to K fertilization. The purpose of the study was to evaluate the effectiveness of low disturbance, high residue tillage systems for first-year corn after soybean on erodible soils. Data collected and analyzed to date did not show a significant response to tillage or K fertilization with respect to corn silage or grain yield. Early growth tended to be greater in the strip-till and no-till systems, compared to fall chisel or spring field cultivator. There was a trend for an early season growth response where K fertilizer was applied in the row, compared to surface broadcasting or surface banding. Measured soil loss was greater in the chisel system compared to the strip-till system, especially in 2004 when heavy early-season rains occurred. Results from this research demonstrate that no-till and strip-till systems performed similarly to conventional tillage and resulted in much lower soil loss.

Introduction

Agricultural production systems have changed noticeably in Wisconsin over the past 25 years. This trend is very apparent in the Driftless Area of southwestern Wisconsin that also encompasses adjacent portions of Illinois, Iowa, and Minnesota. As small dairy herds disappear and cow numbers decline, more and more of the land is being planted in grain crops, often in a corn/soybean rotation. Figure 1 shows the change in dairy cattle numbers for Crawford, Grant, Iowa, and Lafayette counties since 1980. Animal reductions range from 50% in Crawford County to 23% in Grant County in this period. Table 1 outlines the change in distribution of corn, soybean, and alfalfa production since 1980 for these four southwestern counties, which is linked to the reduction in dairy farming. Acres planted to corn and alfalfa have declined somewhat in this time, with a phenomenal increase in soybean acres, especially since the late 1990s. Soil has been shown to have lower aggregate stability following soybean and is therefore more erodible. This is especially apparent on the loess-derived silt loam soils of southwest Wisconsin. Silt sized particles are typically comprised of the mineral quartz, which does not have surface charges to aid aggregation.

Much of this cropland located on C and D slopes and is farmed on the contour in strips. Without forage crops in the rotation no-till production is often required to satisfy conservation planning requirements. Some producers are reluctant to farm in a strict no-till scenario and therefore alternative tillage systems such as strip-tillage are gaining popularity in the Midwest. Strip-tillage is a very practical conservation tillage system because it loosens the seedbed and should overcome some of the concerns associated compaction. This system has been shown with

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[1/] Research support from the Wisconsin Fertilizer Research Council is gratefully acknowledged.

[2/] Extension Soil Scientist, Univ. of Wisconsin-Madison, and Professor and Graduate Research Assistant, respectively, Iowa State Univ.

Table 1. Trend in crop † acreage for four southwest Wisconsin counties since 1980 (Source: Wis. Agricultural Statistics).

	Crawford County			Grant County			Iowa County			Lafayette County		
Year	Corn	Soy†	Alf	Corn	Soy	Alf	Corn	Soy	Alf	Corn	Soy	Alf
	Acres (x 1000)											
1980	34	2	NR‡	137	1	NR	78	2	NR	117	4	NR
1985	39	1	NR	169	1	NR	124	2	NR	122	4	NR
1990	31	1	NR	140	5	NR	67	3	NR	115	10	NR
1995	23	2	48	120	16	122	57	9	75	110	10	72
2000	24	10	41	124	49	105	53	53	53	98	58	55
2004	26	13	36	126	52	93	56	55	55	101	54	52

† Soy, soybean; Alf, alfalfa. ‡ NR, not reported.

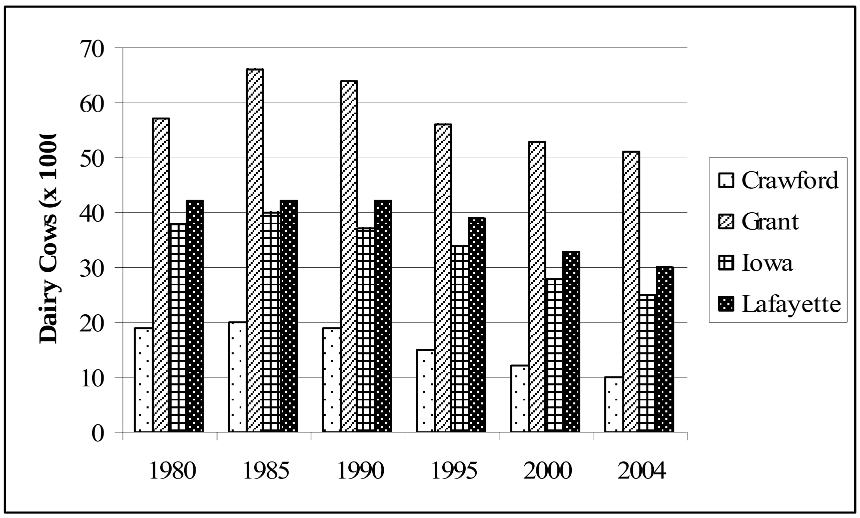

Figure 1. Change in diary cattle numbers for four southwest Wisconsin counties since 1980 (Source: Wis. Agricultural Statistics).

no-till planting such as imperfect planter slot closure, hair-pinning of residue, and to leave approximately 10 to 15% less residue on the surface when compared to no-till and because it results in minimal soil disturbance it is a very reasonable conservation tillage system. There has been no agronomic or soil erosion evaluation of strip-tillage systems on these soils. There continues to be considerable interest in P and K fertilizer placement among cash grain producers for several reasons. Growers are faced with low commodity prices and high costs for fertilizer, and are reluctant to spend extra money to build and maintain high soil test levels. While research shows the efficiency of planter-banded materials, the interest in row placement seems to have waned because of time and labor considerations associated with tending the corn planter. This has resulted in the broadcasting of materials, which may not be wise because of the risk of nutrient loss in runoff.

This paper summarizes the results of the first 2 years of a multi-state research project at the Lancaster Agricultural Research Station. The objective of this research is to examine the response of first-year corn following soybean to tillage and the placement of K fertilizer. Assessments of soil loss, early growth, and corn yield were made.

Materials and Methods

The tillage component of the study was established in October 2003 on a Rozetta silt loam soil in a 5-acre contour strip at the Lancaster Agricultural Research Station. The initial soil test values of this field measured in the spring of 2003 were pH 6.8, and P and K of 38 (excessively high) and 99 ppm (optimum), respectively. The field containing the study was previously in soybean, is 100 feet wide, and has an average slope of 8%. Half of the field was planted to corn in 2004 and received all the specific tillage and fertilizer treatments. The other half was planted to soybean (no-till drilled) and received 100 lb K_2O/acre applied prior to planting into the corn stubble. No measurements were taken from the soybean area. The study will rotate between these subfield areas.

Tillage treatments (fall chisel/spring field cultivator, spring field cultivator, fall strip-till, and no-till) were installed on the contour in the soybean residue. Each tillage treatment was 50 feet long, with 15-foot alleys separating the individual tillage treatments. The chisel system employed a twisted shank plow, followed by a single pass with a combination field cultivator in the spring. The same field cultivator was used for the field cultivator alone treatment. Strip-tillage was conducted with a four-row tool that features finger coulters, a ripple coulter, a mole knife that runs 7 to 8 inches deep, followed by closing disks that form a ridge about 6 inches high. Remlinger, Mfg. of Kalida, OH has loaned this tool to the Univ. of Wisconsin Department of Soil Science. A Kinze planter equipped with Yetter finger-coulter residue managers was used for the no-till treatment.[3/]

The subplot treatment was fertilizer placement (none, spring broadcast prior to tillage, surface strip following emergence, and row-placed with the planter) at rates of 30 and 60 lb K_2O/ acre as the sub-subplot. This higher rate of K fertilizer approximates the UWEX recommendation for 175 bu/acre of corn for an optimum soil test level. The corn received 120 lb N/acre preplant in the spring in accordance with UWEX recommendations (160 lb N/acre rec. – 40 lb N/acre soybean credit), plus 20 lb P_2O_5 in the row. Three replications of all treatments were established in a split-split plot treatment arrangement.

A full season corn hybrid (DeKalb DKC 50-20 RR, RM 100 days) was planted on 5 May 2004 and 28 April 2005 in 30-inch rows at a population of 35,000 seeds/acre. UWEX recommendations were followed for all non-treatment crop inputs. Spring tillage was conducted the same day as planting.

Measurements made include: (1) stand; (2) surface crop residue; (3) early growth and nutrient uptake; (4) routine soil test; and (5) silage and yield. Population counts were made by counting the number of plants in the middle two rows of each plot. Three crop residue measurements were taken using the line-transect method in each tillage main plot. Early season corn plant samples were taken at the V6 growth stage in corn by collecting 10 plants per plot; these were dried, weighed to determine dry matter content, and ground for analysis. Silage samples

[3/] Use of product names is for informational purposes only and does not represent an endorsement of the University of Wisconsin).

were collected at physiological maturity by cutting 10 plants at the second node, weighing them wet, followed by chopping with a stationary chopper, and subsampling. Soil samples were taken from the control, and 30 and 60 lb K_2O/acre broadcast treatments in all tillage systems. All samples were analyzed using UWEX Laboratory procedures. Grain yield measured by harvesting the middle two rows of the four row plots with a small plot combine.

Dr. Rick Cruse of Iowa State University and staff assisted in the setup and maintenance of "passive" runoff collectors that were placed in the study. Two each were placed in the strip-till and chisel system. The collectors were designed to receive runoff from an upslope area of 5 by 20 feet. Runoff first passed through a sediment basin where much of the sediment was deposited, and then was split by a factor of 1:10 twice, with any remaining runoff being collected in a container and the end of the collector. Sediment was collected following significant runoff events and soil loss was estimated by calculations based on the amount of sediment found at various locations within the collection area.

Data were analyzed with an analysis of variance for a strip-split plot treatment arrangement using SAS (Statistical Analysis System, Cary, NC). Where significance is found at the p=0.05 level a Fisher's LSD was calculated. Results for the unfertilized treatment for each parameter are shown, but data for these treatments were not included in the ANOVA.

Results and Discussion

The effect of tillage and K fertilization on the population of corn, which had been seeded at a constant rate, is shown in Table 2. There was a significant differences in plant stand due to tillage in 2005, where both strip-till and no-till had higher stands than chisel or spring field cultivation. Strip-till tended to provide a greater stand in 2004 also. It did not appear that the amount and nature of residue presented an impediment to planting. Residue measurements taken using the line-transect method showed the following results: In 2004, Chisel = 54%; Field cultivator = 55%; Strip-till = 59%; and, No-till = 71%; in 2005 Chisel = 43%; Field cultivator = 46%; Strip-till = 65%; and, No-till = 81%. The LSD values were 8 % and 7 % respectively, and the differences as determined by the ANOVA were highly significant (Pr>F = <0.01).

Early season growth is often affected by tillage and fertilization. Table 3 shows the weight of corn plants at the V6 growth stage as affected by tillage and K fertilization. Dry matter content per plant was approximately 3 g greater in the strip-till and no-till treatments in 2004 and tended to be higher for these tillage systems in 2005. The reason for this response is not readily apparent. Fertilizer placement affected dry matter accumulation at the p=0.09 level in 2004, with the 2 x 2 placement having the highest dry matter production. This response was not apparent in 2005. There were no differences due to the rate of K fertilization.

The effect of tillage and K fertilization on corn silage and grain yield is shown in Tables 4 and 5. Silage and grain yields were very good for this site, but were not affected by treatment in either year. This observation confirms the expectation that reduced tillage systems, if properly managed, can produce yields equivalent to conventional methods. This is especially important considering the current corn production economic situation where the value of the crop is low and input costs are high. Reducing the number and intensity of tillage would save money. The 2004 Wisconsin Custom Rate Guide shows a regional average of $23.30/acre for the combined use of chisel plowing and a single pass with a field cultivator. No-till planting was only $0.80/acre more than planting in mulch-till. Conservation tillage will also reduce the potential risk of soil loss by erosion.

Table 2. Effect of tillage and K rate and placement on corn population, Lancaster, Wisconsin, 2004 to 2005.

Placement	lb K_2O/acre	Chisel 2004	Chisel 2005	Field cultivator 2004	Field cultivator 2005	Strip-till 2004	Strip-till 2005	No-till 2004	No-till 2005
		plants/acre (x 1000)							
Control †	--	31.2	34.7	30.0	34.0	32.1	31.7	30.5	35.3
2 x 2	30	33.0	34.2	31.3	35.7	30.8	34.9	30.5	34.8
2 x 2	60	31.2	34.4	31.3	34.8	33.3	35.1	31.9	35.2
Broadcast	30	29.5	34.3	30.5	34.0	32.2	35.5	29.3	34.5
Broadcast	60	31.8	35.3	30.1	32.3	31.8	34.5	31.8	35.8
Surf. strip	30	30.1	33.2	31.3	34.1	33.2	34.5	31.9	36.1
Surf. strip	60	32.4	33.4	33.3	34.3	32.3	35.2	31.8	33.9

Significance (Pr>F)

Effect	2004	2005
Tillage	0.49	0.04
Placement	0.20	0.21
Rate	0.17	0.80
T*P	0.95	0.19
T*R	0.92	0.40
P*R	0.95	0.83
T*P*R	0.43	0.24

Main Effects

Tillage	plt/acre (x 1000) 2004	plt/acre (x 1000) 2005	Placement	plt/acre (x 1000) 2004	plt/acre (x 1000) 2005	Rate lb K_2O/a	plt/acre (x 1000) 2004	plt/acre (x 1000) 2005
Chisel	31.3	34.3	2 x 2	31.7	35.0	30	31.1	34.7
Field cult.	31.3	34.2	Broadcast	30.8	34.5	60	31.9	34.6
Strip-till	32.3	35.0	Surf. strip	32.0	34.4	LSD	NS ‡	NS
No-till	31.1	35.0	LSD	NS	NS			
LSD	NS	0.7						

† Control data not included in the ANOVA. ‡ NS, not significant.

Table 3. Effect of tillage and K rate and placement on corn dry matter accumulation at the V6 growth stage, Lancaster, Wisconsin, 2004 to 2005.

Placement	lb K_20/acre	Chisel 2004	Chisel 2005	Field cultivator 2004	Field cultivator 2005	Strip-till 2004	Strip-till 2005	No-till 2004	No-till 2005
		g/plant							
Control †	--	17.2	10.1	17.2	11.0	19.8	10.5	17.5	11.8
2 x 2	30	15.6	12.1	15.7	9.8	18.4	10.3	18.9	11.1
2 x 2	60	15.9	9.7	17.6	10.0	17.4	11.4	18.4	11.9
Broadcast	30	14.8	1.04	14.9	10.9	17.7	10.2	17.8	10.4
Broadcast	60	15.4	9.1	14.5	9.7	18.3	10.1	18.8	11.0
Surf. strip	30	15.9	10.1	14.3	10.3	18.3	12.7	17.1	12.7
Surf. strip	60	12.7	9.0	14.3	10.3	17.8	10.5	17.9	10.7

Significance (Pr>F)

Effect	2004	2005
Tillage	<0.01	0.34
Placement	0.09	0.47
Rate	0.89	0.13
T*P	0.89	0.70
T*R	0.76	0.63
P*R	0.67	0.51
T*P*R	0.58	0.62

Main Effects

Tillage	DM (g/plant) 2004	DM (g/plant) 2005	Placement	DM (g/plant) 2004	DM (g/plant) 2005	Rate lb K2O/a	DM (g/plant) 2004	DM (g/plant) 2005
Chisel	15.1	10.1	2 x 2	17.2	10.8	30	16.5	10.9
Field cult.	15.2	10.1	Broadcast	16.4	10.2	60	16.6	10.3
Strip-till	17.8	10.9	Surf. strip	15.9	10.8	LSD	NS ‡	NS
No-till	18.1	11.3	LSD	NS	NS			
LSD	1.4	NS						

† Control data not included in the ANOVA. ‡ NS, not significant.

Table 4. Effect of tillage and K rate and placement on corn silage yield, Lancaster, Wisconsin, 2004 to 2005.

Placement	lb K_20/acre	Chisel 2004	Chisel 2005	Field cultivator 2004	Field cultivator 2005	Strip-till 2004	Strip-till 2005	No-till 2004	No-till 2005
		t DM/a							
Control †	--	8.8	10.5	9.7	9.8	9.7	11.6	9.4	9.3
2 x 2	30	9.1	10.0	9.2	9.5	9.3	8.9	9.6	10.0
2 x 2	60	10.0	10.3	10.1	11.0	9.7	9.6	9.2	10.2
Broadcast	30	9.8	10.1	9.5	10.5	8.4	9.6	9.4	10.4
Broadcast	60	8.6	10.2	8.2	10.5	10.1	10.3	10.1	9.3
Surf. strip	30	10.0	10.0	9.0	10.5	9.5	9.7	8.6	9.6
Surf. strip	60	9.7	9.8	8.1	9.6	9.7	9.6	9.0	11.0

Significance (Pr>F)

Effect	2004	2005
Tillage	0.25	0.55
Placement	0.35	0.74
Rate	0.93	0.46
T*P	0.55	0.82
T*R	0.26	0.94
P*R	0.41	0.45
T*P*R	0.21	0.22

Main Effects

Tillage	Yield (t/acre) 2004	Yield (t/acre) 2005	Placement	Yield (t/acre) 2004	Yield (t/acre) 2005	Rate lb K_2O/a	Yield (t/acre) 2004	Yield (t/acre) 2005
Chisel	9.6	10.1	2 x 2	9.5	9.9	30	9.3	9.9
Field cult.	9.0	10.2	Broadcast	9.2	10.1	60	9.3	10.1
Strip-till	9.5	10.1	Surf. strip	9.2	9.9	LSD	NS ‡	NS
No-till	9.1	9.6	LSD	NS	NS			
LSD	NS	NS						

† Control data not included in the ANOVA. ‡ NS, not significant.

Table 5. Effect of tillage and K rate and placement on corn grain yield, Lancaster, Wisconsin, 2004 to 2005.

Placement	lb K_20/acre	Chisel 2004	Chisel 2005	Field cultivator 2004	Field cultivator 2005	Strip-till 2004	Strip-till 2005	No-till 2004	No-till 2005
		---- bu/acre ----							
Control †	--	193	207	194	182	195	189	196	178
2 x 2	30	207	190	211	175	198	174	186	180
2 x 2	60	197	185	207	173	190	171	197	205
Broadcast	30	212	184	191	183	202	213	191	183
Broadcast	60	179	202	194	190	202	198	201	170
Surf. strip	30	206	196	185	180	202	177	187	187
Surf. strip	60	219	213	200	195	203	195	203	191

Significance (Pr>F)

Effect	2004	2005
Tillage	0.52	0.62
Placement	0.59	0.23
Rate	0.85	0.34
T*P	0.27	0.32
T*R	0.22	0.92
P*R	0.20	0.56
T*P*R	0.67	0.75

Main Effects

Tillage	Yield (bu/acre) 2004	Yield (bu/acre) 2005	Placement	Yield (bu/acre) 2004	Yield (bu/acre) 2005	Rate lb K_2O/a	Yield (bu/acre) 2004	Yield (bu/acre) 2005
Chisel	203	195	2 x 2	200	182	30	199	185
Field cult.	198	183	Broadcast	197	190	60	200	191
Strip-till	200	187	Surf. strip	201	192	LSD	NS ‡	NS
No-till	195	186	LSD	NS	NS			
LSD	NS	NS						

† Control data not included in the ANOVA. ‡ NS, not significant.

Measurements of soil erosion were made by researchers from Iowa State in both 2004 and 2005 using a passive, small plot apparatus. Only four collectors of this type were available in each year, two of which were placed in the chisel and strip-till treatments. These samplers are relatively inexpensive to build, but are laborious to sample and require constant maintenance to keep them in a level position. Readers will recall that the early season of 2004 was affected by several intense, high volume storms prior to canopy closure, whereas storms of this type were non-existent in 2005 until much later in the season. Table 6 shows the rainfall amounts prior to runoff collection and the estimated sediment loss for each event. The reported soil loss is the average of two values. Note that intense rains did not occur in 2005 until after canopy closure. Clearly the soil loss potential was much greater in the chisel system compared to strip-till, especially when intense storms occurred early in the season before the soil reconsolidated and was protected by the crop canopy.

Table 6. Estimated soil loss in first-year corn after soybean in a chisel and strip-tillage system following runoff from significant rainfall events, Lancaster, Wisconsin, 2004 to 2005.

2004				2005			
Date	Rainfall †	Soil loss		Date	Rainfall †	Soil loss	
		Chisel	Strip-till			Chisel	Strip-till
	inch	-------- t/acre -------			inch	------- t/acre --------	
14 May	0.95	0.12	0.006	6 June	0.96	0.05	0.02
21 May	0.50	0.14	0	27 June	5.00	0.08	0.01
24 May	3.09	2.82	0.23	26 July	3.60	0.001	0
1 June	4.85	0.39	0.39	29 July	1.3	0.10	.12
17 June	2.51	0.71	0	19 Aug	3.28	0.05	0.01
12 July	1.24	0.27	0.009	19 Sep	1.44	0.02	0
4 Aug	1.11	0.22	0				
Total		4.67	0.28			0.30	0.16

† Runoff collected on 24 May 2004, 12 July 2004, and 26 July 2005 were the result of multiple precipitation events.

Summary

Crop production systems are changing in southwestern Wisconsin with a trend toward more corn/soybean rotation. Two years of research have been conducted on a Rozetta silt loam at the Lancaster Agricultural Research Station to examine tillage and K management of first-year corn after soybean. Results to date do not show significant yield differences between four tillage systems. Stand and early season growth tended to be greater in the high residue, low disturbance systems. Soil loss was much greater in a chisel system compared to strip tillage. Reduced tillage systems that maintain residue and soil consolidation should be encouraged on these soils.

MANAGING POTASSIUM FOR HIGH YIELD

T. Scott Murrell[1]

There are several issues that currently surround potassium (K) management. Awareness of them has increased in recent years as farmers and advisers have intensified their collection of field data. In particular, K management is facing many challenges under conservation tillage systems. These systems have led to stratification of soil test K, where K levels at or near the surface are significantly higher than those lower in the soil profile. Research efforts are currently trying to better our understanding of how K management may need to be altered to better fit these conservation tillage systems. This paper outlines some of the major issues currently faced.

An essential component of managing K is calculating a K budget. This budget compares the amount of K added to the amount removed by crop harvest. Potassium additions include both fertilizer and manure sources. In Wisconsin, alfalfa is often part of the crop rotation. This crop removes a significant amount of K. An example of K removal by a sequence of crops in a rotation representative of Wisconsin is shown in **Table 1**. This table demonstrates that alfalfa removes significantly more K per acre than does either corn or soybean. This occurs because only the grain is removed during corn and soybean harvest while most of the above-ground plant portion is removed when alfalfa is cut. When producers and advisers underestimate the amount of K removed in rotations containing alfalfa, unexpected declines in soil test K levels and associated K malnutrition problems can result.

Table 1. Example of potassium removal in a 5-year crop rotation.

Year	Crop	Yield	Yield units	K removal
		(units)		(lb K_2O/A)
1	alfalfa	2	tons	98
2	alfalfa	4	tons	196
3	alfalfa	6	tons	294
4	corn	150	bu	41
5	soybean	40	bu	52
Total				681

Nutrient removal rates are those compiled by Murrell (2005).

Nutrient budgets are commonly used to estimate how much K must be applied to keep up with crop removal rates. It is commonly thought that applying K at rates equal to crop removal will maintain soils at current test levels. In a Colorado study, this hypothesis was tested by applying various rates of K every year for 3 years in which alfalfa was grown (Fixen and Ludwick, 1983). The results, shown in Table 2, demonstrated that soil test levels could be maintained by applying rates that were sometimes much less than those of crop removal.

The reasons for this behavior have been attributed to the redistribution of K within the soil profile with K uptake by alfalfa. Figure 1, taken from the same Colorado study cited above, shows that after 3 years, K had been depleted in the lower depths while K soil test levels increased near the surface. Most of this redistribution occurred during the first year. This was attributed to the higher allocation of carbon to the root system that typically occurs in the first year of alfalfa establishment. The implication of this redistribution is that soil test results representative of only shallow depths will not detect these important changes in vertical

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distribution. In fact, the increase in soil test K near the surface combined with a decrease in soil test K below the surface can lead to unpredictable changes in soil test K over time, as measure by standard, shallow samples. In a Minnesota study, broadcast applications of K produced significant stratification when measured 2-3 months after fertilization (Moncrief et al., 1985). Potassium levels in the surface 2 inches were much higher in the no-till system compared to chisel tillage. Elevated levels of K near the surface resulted in higher 0-6 inches soil test K readings in the no-till system compared to the chisel tillage system, even though the rate of applied K was the same. This study helps explain why rates of K much less than those of crop removal can maintain soil test levels as demonstrated in Table 2.

Table 2. Amount of K needed to maintain soil test levels after 3 years of alfalfa cropping (Fixen and Ludwick, 1983).

Soil	Initial soil test K level (0-12 in. depth)	Average annual K_2O removed	K_2O required to maintain initial soil test level	Required/removed
	(ppm)	(lb K_2O/A)		
Keith SiL	555	323	244	0.75
Ravola L	126	358	80	0.22

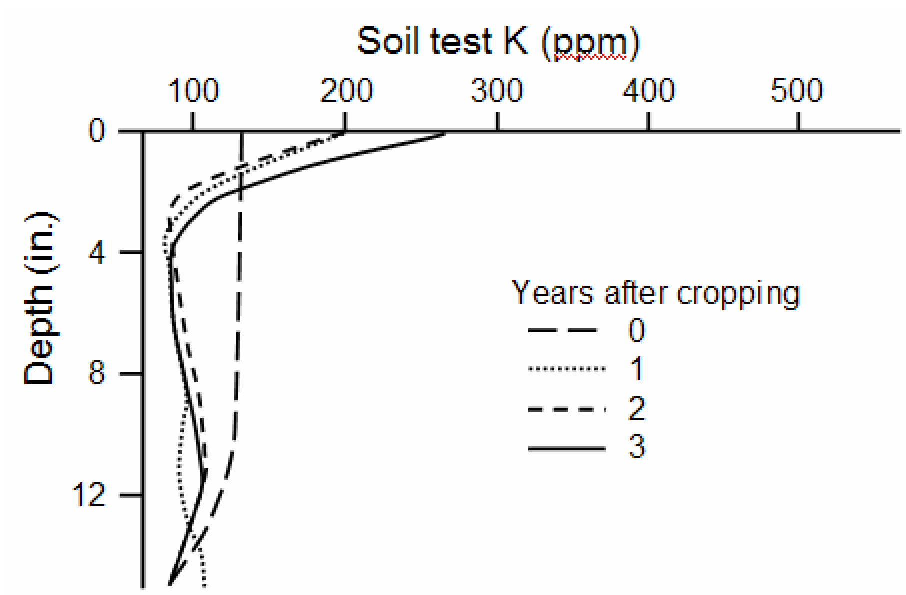

Figure 1. Change in soil test K after various durations of alfalfa cropping (Fixen and Ludwick, 1983).

The root system of alfalfa can extend very deep in the soil profile. Figure 2 shows graphically that alfalfa roots can extend downward 9 ft or more. Even so, a Wisconsin study demonstrated that that surface or near-surface applications of K result in higher recovery of applied K than bands placed deeper in the soil (Peterson et al., 1983). These findings indicate that higher root activity exists near the surface for alfalfa.

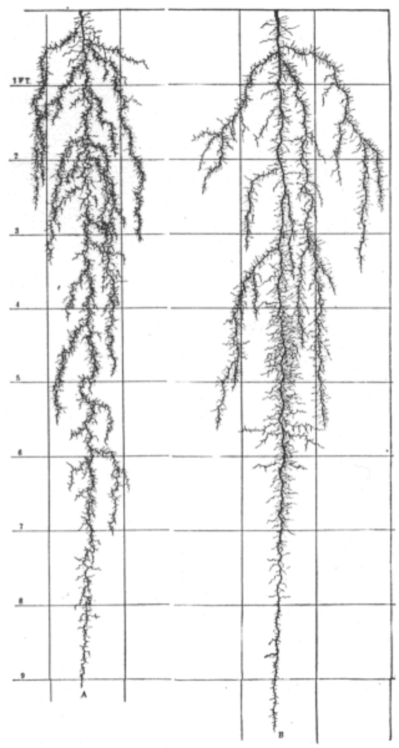

Figure 2. Root distribution of a 2 year old alfalfa stand in Nebraska under irrigated and dryland conditions (Weaver, 1926). Squares are 1 ft. x 1 ft.

When other crops are grown in rotation with alfalfa, there may be a need to place K lower in the profile, depending on the root grown habits of the crops, the soil test level, and the degree of stratification. Figure 3 shows how soybean roots are distributed in the soil profile early in the season. Most of the very early root growth is associated with elongation of the tap root which is then followed by the development of laterals in the upper part of the soil profile. At maturity, approximately 80% or more of the root system in upper 6 inches of the soil surface. As roots extend away from the plant, they grow downward to avoid competing for water and nutrients with roots from plants in adjacent rows.

Corn roots, as opposed to alfalfa and soybean roots, are fibrous (Figure 4). Early season root growth is associated with elongation of the radical and the lateral seminal roots. These roots grow at an angle relative to horizontal. Much of the development of laterals occurs on these roots. Thus, as opposed to alfalfa and soybean, little of the root system is directly below the plant early in the season.

In conservation tillage systems, the inequitable distribution of K with depth may lead to K malnutrition if zones of active uptake are not well coordinated with zones of higher soil test K. Consequently, placement of K below the soil surface may be more important in these systems.

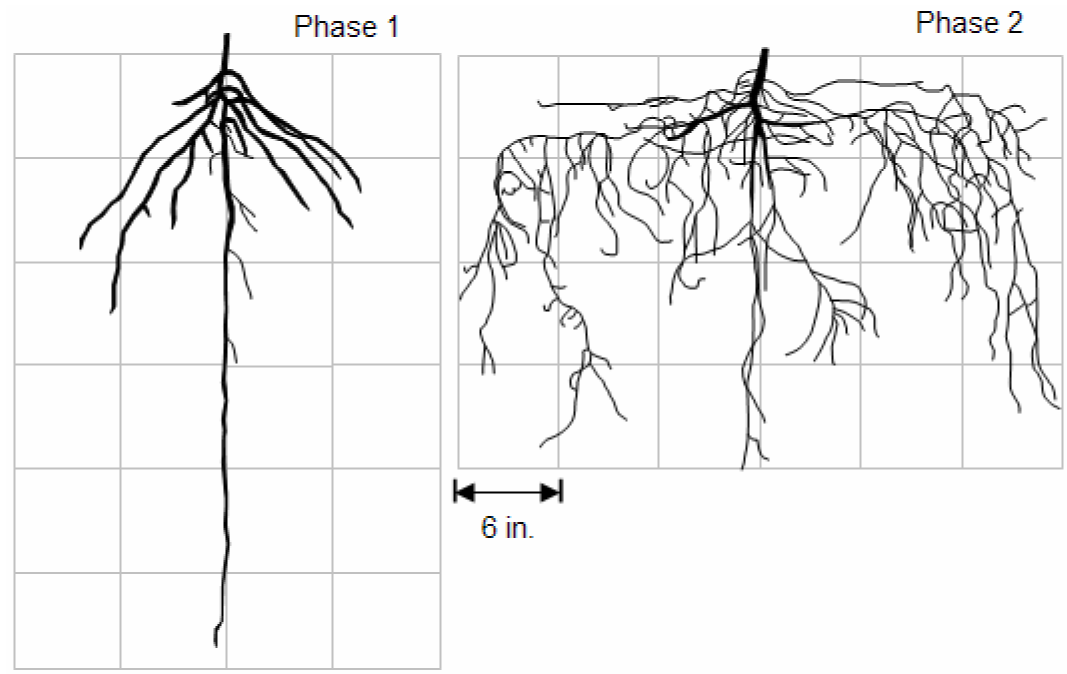

Figure 3. Phases I and II of the 3-phase root growth classification system developed by Mitchell and Russell, 1971.

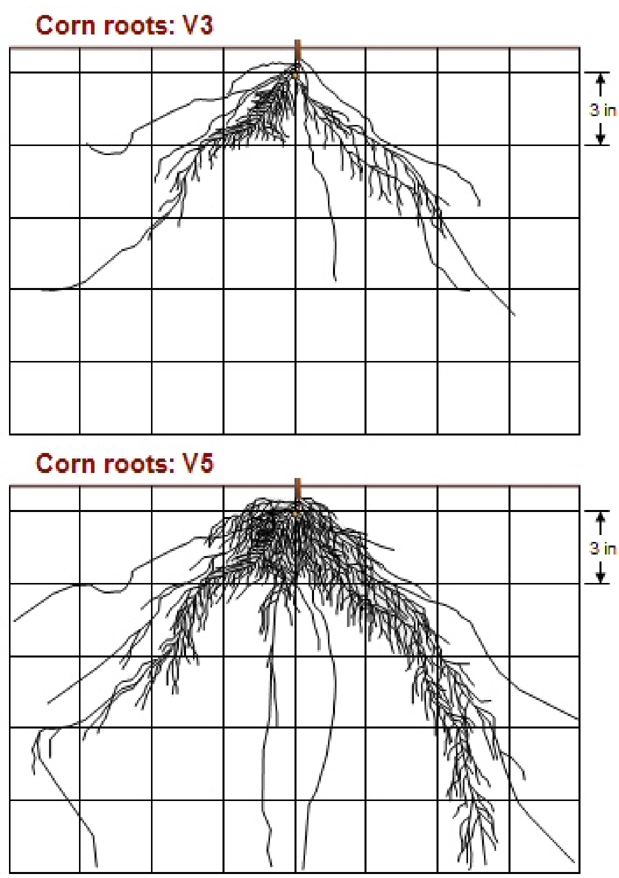

Figure 4. Generalized depiction of corn roots at growth stages V3 and V5.

Much of the current theory on best placement of P and K for corn and soybean was developed by Barber and associated scientists (Anghinoni and Barber, 1980b; Borkert and Barber, 1985b). Studies were conducted on early growth and nutrient uptake of corn and soybean. In pot studies, soil was mixed with various nutrients, including N and K. A portion of this soil was set aside and mixed with various rates of P. To study the impact of volume of soil fertilized with P, the P treated soil was placed in the same pot with non-treated soil. Phosphorus-treated and P-untreated soils were separated vertically in the pots by 16-mesh fiberglass screen, which minimized mixing of the two soils. A constant P rate per pot was applied, meaning that as the P-treated soil volume decreased, the concentration of P in that volume increased, as with field applications of banded fertilizer.

For both corn and soybean, these studies showed that maximum nutrient uptake and dry matter yield could be attained when a fraction of the soil volume was fertilized. Just how much volume needed to be fertilized with P varied with rate, shown conceptually in Figure 5. The model demonstrates that when a low P rate is applied to a low testing soil, a small fertilized soil volume (like that attained with banding), maximizes dry matter yield (dotted line in the graph). The reason for this is less soil-fertilizer contact, increasing the probability that more P will remain in more readily soluble forms. In addition, roots that find localized P supplies will proliferate. However, the localized P supply may not provide P to enough of the roots to maximize yield, compared to a higher rate of P broadcast and incorporated (solid line in the graph). Higher rates applied to a greater proportion of the soil provide P in positions that are available throughout the season.

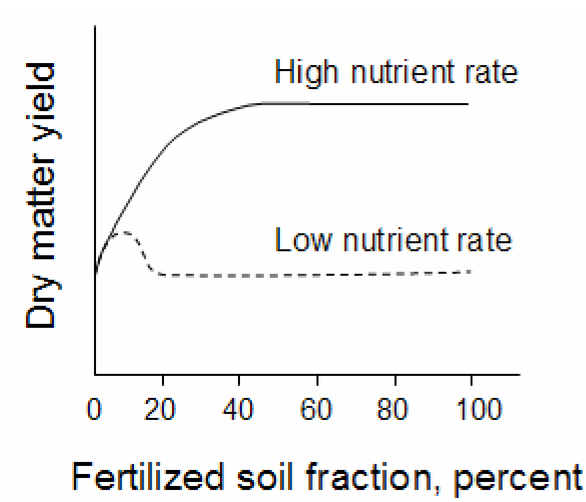

Figure 5. Conceptual model of the influence of fertilized soil volume and associated concentration affect crop dry matter yield (Anghinoni and Barber, 1980b; Borkert and Barber, 1985b).

Comparing the volumes necessary to maximize dry matter production for young corn and soybean plants reveals that soybean requires less fertilized soil volume than does corn (Figure 6). This figure combines information from separate studies using the same soil, fertilizer rates, and experimental procedures (Anghinoni and Barber, 1980a; Borkert and Barber, 1985a). This difference is due in part to the different P influx rates of corn and soybean. Corn has very high P influx rates early in the season, while soybean does not. For nutrient uptake, this means corn can take better advantage of concentrated supplies than can soybean; however, it also implies that a corn root can deplete a given supply of P that lies within short diffusion distances form it faster than can a soybean root exposed to the same conditions. This means that in shorter periods of time, more of the P supply for a corn root is coming from greater distances and may be harder to access, particularly in a concentrated zone where more competition exists by other roots. Since both corn and soybean allocate approximately equal proportions of their root system to enriched supplies of P, corn may require that more of its total root system be in close contact with P supplies. This reasoning may explain why small fertilized volumes maximize dry matter production for soybeans but do not do so for corn.

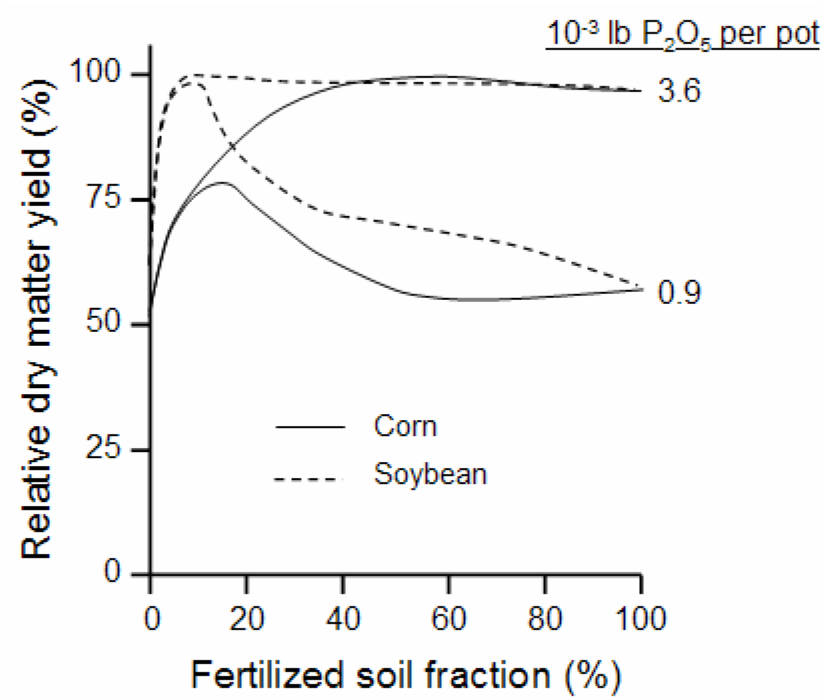

Figure 6. Differences in impact of fertilized soil volume on corn and soybean dry matter yield (Anghinoni and Barber, 1980a; Borkert and Barber, 1985a).

These concepts can be extended to K by noting some important differences. First, K can diffuse farther in soils than can P. That means a given plant root can take advantage of supplies farther from it for K compared to P. It also means that competition for uptake by other roots may be more important than for P, since roots can be farther away and still compete (Silburbush and Barber, 1983). Another important difference is that corn and soybean nutrient influx rates are much higher for K than for P (Figure 7). While the K influx rate of soybean roots is still much less than for corn early in the season, it is nearly as high as the P influx rate for corn early in the season and stays at elevated levels longer than does both the corn P and K influx rates. This implies that soybean may require higher volumes of soil enriched with K than it does with P.

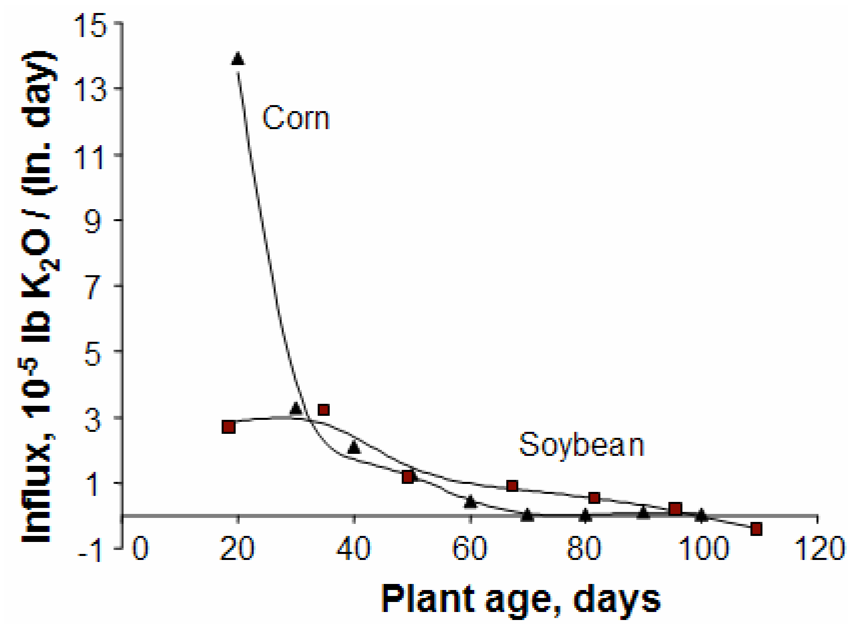

Figure 7. Changes in K influx with plant age for corn and soybean (Barber, 1978; Mengel and Barber, 1974).

Field research in conservation tillage systems is confirming the importance of subsurface banded applications of K for attaining higher yields (Bordoli and Mallarino, 1998; Borges and Mallarino, 2003; Borges and Mallarino, 2001; Yin and Vyn, 2003). While deep-banded K does not always result in improvements over broadcast applications, it is seldom inferior. The apparent agronomic need for K placed below the soil surface is consistent with the smaller soil volume that is enriched in K in reduced tillage systems utilizing only broadcast applications. Unlike broadcast applications, subsurface K applications actually end up fertilizing soil below and at the soil surface. Figure 1 demonstrates how crop uptake alone can redistribute K from lower to upper parts of the soil profile. Grain crops deposit back to the soil surface a significant amount of the total K they take up. For example, some studies have shown that soybean has approximately 54% of its total K in the grain while for corn, it is 31-44% (Hanway, 1962; Hanway and Weber, 1971). Potassium is leached from crop residues with precipitation. Unlike phosphorus and nitrogen, K is not immobilized in organic matter, so it is available much more quickly. So K below the surface ends up at the surface through leaching from crop residue as well as below the surface where it was originally placed. Over the long term, subsurface applications may lead to improved distributions of K in the soil profile, although this concept has yet to be tested in long-term studies.

References

Anghinoni, I., and S.A. Barber. 1980a. Phosphorus application rate and distribution in the soil and phosphorus uptake by corn. Soil Sci. Soc. Am. J. 44:1041-1044.

Anghinoni, I., and S.A. Barber. 1980b. Predicting the most efficient phosphorus placement for corn. Soil Sci. Soc. Am. J. 44:1016-1020.

Barber, S.A. 1978. Growth and nutrient uptake of soybean roots under field conditions. Agron. J. 70:457-461.

Bordoli, J.M., and A.P. Mallarino. 1998. Deep and shallow banding of phosphorus and potassium alternatives to broadcast fertilization for no-till corn. Agron. J. 90:27-33.

Borges, R., and A.P. Mallarino. 2003. Broadcast and deep-band placement pf phosphorus and potassium for soybean managed with ridge tillage. Soil Sci. Soc. Am. J. 67:1920-1927.

Borges, R., and A.P. Mallarino. 2001. Deep banding phosphorus and potassium fertilizers for corn managed with ridge tillage. Soil Sci. Soc. Am. J. 65:376-384.

Borkert, C.M., and S.A. Barber. 1985a. Soybean shoot and root growth and phosphorus concentration as affected by phosphorus placement. Soil Sci. Soc. Am. J. 49:152-155.

Borkert, C.M., and S.A. Barber. 1985b. Predicting the most efficient phosphorus placement for soybeans. Soil Sci. Soc. Am. J. 49:901-904.

Fixen, P.E., and A.E. Ludwick. 1983. Phosphorus and potassium fertilization of irrigated alfalfa on calcareous soils: I. Soil test maintenance requirements. Soil Sci. Soc. Am. J. 47:107-112.

Hanway, J.J. 1962. Corn growth and composition in relation to soil fertility: II. Uptake of N, P, K and their distribution in different plant parts during the growing season.

Hanway, J.J., and C.R. Weber. 1971. Accumulation of N, P, and K by soybean (*Glycine max* (L.) Merrill) plants. Agron. J. 63:406-408.

Mitchell, R.L., and W.J. Russell. 1971. Root development and rooting patterns of soybean (*Glycine max* (L.) Merrill) evaluated under field conditions. Agron. J. 63:313-316.

Mengel, D.B., and S.A. Barber. 1974. Rate of nutrient uptake per unit of corn root under field conditions. Agron. J. 66:399-402.

Moncrief, J.F., P.M. Burford, and J.B. Swan. 1985. The effect of tillage on interpretation and response to soil K. J. Fert. Issues 2:17-25.

Murrell, T.S. 2005. Average nutrient removal rates for crops in the Northcentral region [online]. Available at http://www.ppi-ppic.org/northcentral/nutrientremoval (verified 27 Dec. 2005).

Peterson, L.A., D. Smith, and A. Krueger. 1983. Quantitative recovery of alfalfa with time of K placed at different soil depths for two soil types. Agron. J. 75:25-30.

Silburbush, M., and S.A. Barber. 1983. Prediction of phosphorus and potassium uptake by soybeans with a mechanistic mathematical model. Soil Sci. Soc. Am. J. 47:262-265.

Weaver, J.E. 1926. Root development of field crops. McGraw-Hill, New York, NY.

Yin, X., and T.J. Vyn. 2003. Potassium placement effects on yield and seed composition of no-till soybean seeded in alternate row widths. Agron. J. 95:126-132.

THE HOW OF GREAT CORN YIELDS IN A DROUGHT YEAR

William L. (Bill) Bland[1]

The 2005 crop season was drier than usual: by April 19 the federal drought monitoring office marked the NE corner of the state as "Abnormally Dry," and by July 26 they mapped "Extreme" drought in the SE corner, "Severe" all along the eastern one-third of the state, and "Moderate" everywhere else (wwww.drought.unl.edu/dm/archives). Corn leaves were tightly curled across much of the state by mid-July; rainfall for the April-August period at the Arlington Agricultural Experiment Station was the third lowest (between 1989 and 1988; 1962 is the record low) in the 44 years of record there.

Yet remarkably the official USDA statewide average yield is predicted to be a new record, at 150 bu/acre, a nearly 5% increase over the previous record set in 1999. UWEX Corn Agronomist Joe Lauer (Lauer, 2005) reports that at 10 of 12 sites of the UW hybrid corn performance trials yields were solidly above the 10-year average, most by more than 10%. It was indeed a year in which the corn crop "pulled it off," delivering across much of the state great yields, inspite of what was officially a drought year. I share here some "back-of-the-envelope" calculations to show that this remarkable performance is understandable (at least in retrospect).

Grain yield depends on proper development of specific plant parts and the capture of sunlight, CO_2, mineral nutrients, and water. The development steps, like formation of ovules, tassel emergence, silking, and pollination, are to various degrees sensitive to environmental stress, but must have occurred successfully in fields that yielded well. There was widespread rainfall between July 21 and 25, probably just in the nick of time to allow pollination to occur in many fields. Subsequently concern turns toward resource capture, and here we consider sunlight and water.

Does it seem possible that resource capture following the late-July rains was sufficient to support the average yield at Arlington in the UW trials (227 bu/acre)? First, consider solar radiation. The amount of leaf area in a crop's canopy is often expressed as the "leaf area index" (LAI), which is the area of all the leaves, spread horizontally, above a given area of land. So if all of the leaves in a square yard of crop were cut and spread over the same land area, the number of times the land area could be covered is the LAI. For corn crops LAI can reach 8 (Figure 1). The role of this leaf area is, of course, to intercept and absorb solar radiation, thereby powering photosynthesis. Much research has shown that an LAI of 3.5 or 4 will effective absorb 90% or more of the incident photosynthetically-active radiation (PAR), so most crops typically have lots more leaves than are necessary from this perspective.

During the 40 days starting with August 1, some 425 MJ (megaJoules) of PAR fell on each m^2 around Arlington. The crop was certaintly in suffering water stress by mid-July, but in many areas growth until then had been reasonable. If by the time that the worst stress set in the crop had managed to grow to a LAI approaching 4, it would have been capable of absorbing almost all incident PAR after the late July rainfall permitted the leaves to unfurl. With corrections for incomplete absorption the crop could have captured about 370 MJ/m^2 during the 40 days following 1 August. The "radiation use efficiency" of corn, defined as the amount of biomass created per unit of PAR absorbed, is typically estimated to be about 3.7 g/MJ (Longquist et al. 2005), so the 370 MJ/m^2 absorbed could yield 1.37 kg/m2, which in terms of new biomass is equivalent to 242 bu/acre. Perhaps 10% of this photosynthesis went to grow the cob, though, so the equivalent corn grain growth is about 218, just 4% short of the 227 bu/acre observed yield.

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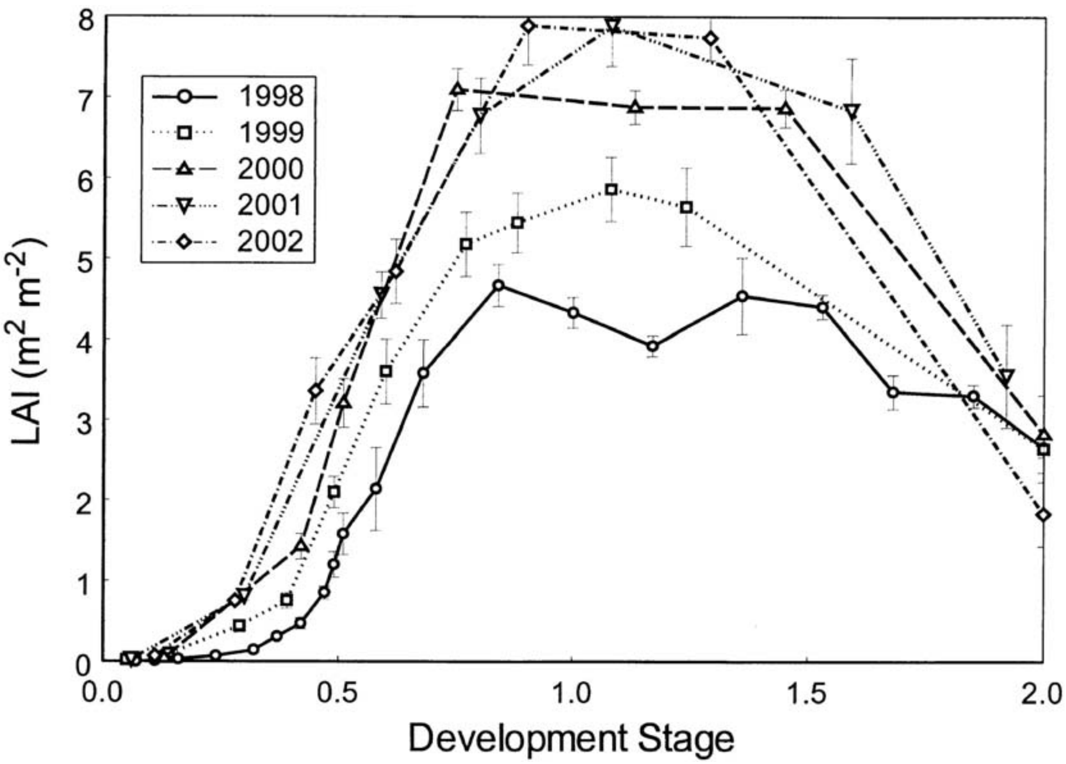

Figure 1. Development of LAI through several seasons in Nebraska (Lindquist et al. 2005)

The other resource we consider here is water. A crop growing under conditions of adequate soil moisture will extract soil water to meet the potential evapotranspiration demand imposed by the environment. In Wisconsin (and lots of other places) this can be estimated using the Priestley-Taylor equation, and values observed in 2005 were typical (Figure 2).

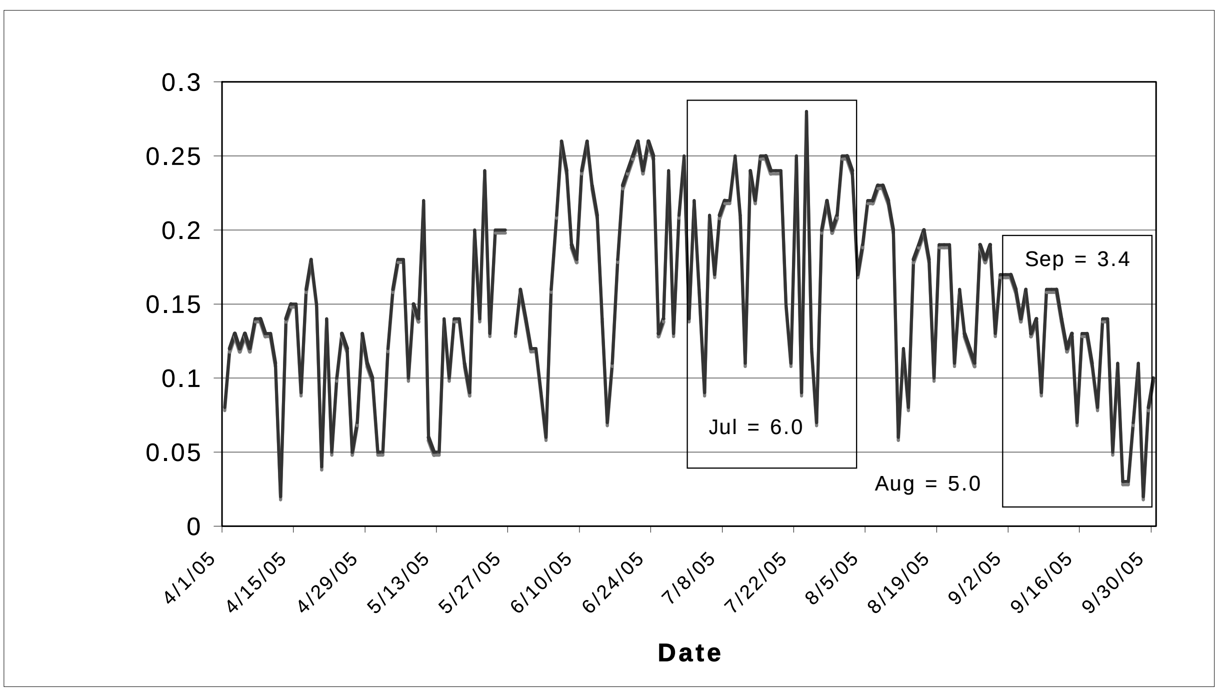

Figure 2. Estimated potential evapotranspiration at Arlington, WI, for 2005

The water demand placed on the corn crop during August and early September was about 6 inches (Figure 2). If the soil could provide this much water the corn could keep its stomates open and maintain photosynthesis. Rainfall at Arlington from late July through the end of August was approximately this (Figure 3; 13-6=7”).

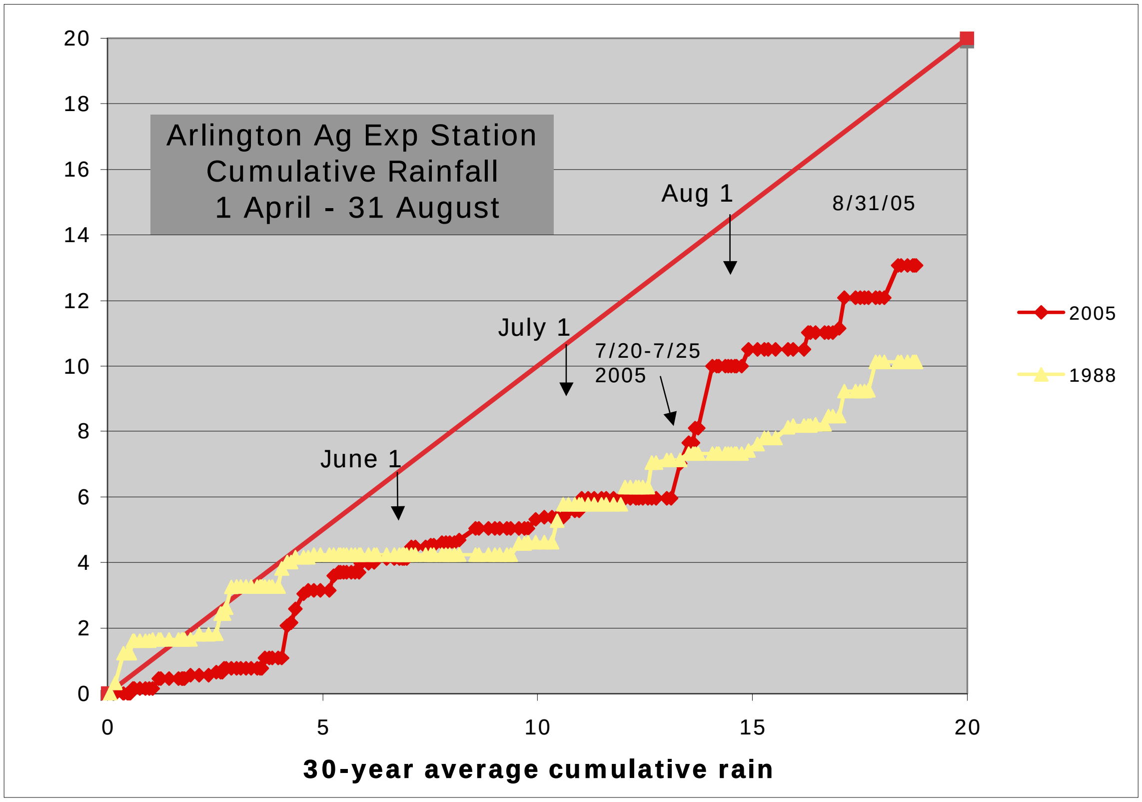

Figure 3. Cumulative rainfall during April-August at Arlington. If a particular year’s rainfall equals the 30-year average the points would follow along the 45-degree diagonal. Data from 2005 and 1988 are compared to the average, and both years had below-normal rainfall during this period.

The approximately 4-inch rainfall at the end of July fell on very dry soil, and likely flowed deeply into the cracked soil through macropores. The relatively dry season had encouraged deep root development, so this rainfall was accessible to the crop, but largely protected from evaporation directly from the soil surface.

The remarkable recovery from drought conditions of much of the 2005 corn crop in Wisconsin is testimony to the tremendous adaptability of this plant. If we assume that LAI had reached 4 or so by mid-July, we showed that there was adequate photosynthetically-active radiation and soil water for the crop to growth the observed yield.

References

Lauer, J. 2005. The yield march continues. Wisconsin Crop Manager, Dec. 15, 2005. Online at corn.agronomy.wisc.edu/WCM/2005/W177.htm (viewed 12/20/2005).

Lindquist, J.L., T.J. Arkebauer, D.T. Walters, K.G. Cassman, and A. Dobermann. 2005. Maize radiation use efficiency under optimal growth conditions.

MANURE NUTRIENT RESPONSE TO LIMIT FEEDING IN DAIRY REPLACEMENT RATIONS

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A study was conducted to evaluate the effect of limit-feeding on growth, feed efficiency and fecal excretion in gravid Holstein heifers. Gravid Holstein heifers (n=54) were randomly assigned to one of nine pens containing six heifers/pen. Heifers were fed one of three experimental diets for 111 d. Control heifers were ad libitum fed a diet containing 11.3% CP and 2.46 Mcals/kg of metabolizable energy (ME). Two experimental diets of increased nutrient density were formulated to contain 12.7 and 14.2% CP and 2.55 and 2.68 Mcals/kg of ME respectively. Feed intake of these diets was limited to 90 and 80% of control heifer feed intake. Nutrient intake, growth, fecal excretion, blood profiles, behavior and 90 d lactation performance of heifers were examined. Limit-fed heifers consumed less ($P<0.01$) DM (9.02, 8.30 vs 9,66 kg/d), similar amounts of net energy for gain (9.4, 9.5 vs. 9.4 Mcals/d) but slightly higher ($P<0.07$) amounts of CP (1.15, 1.17 vs. 1.10 kg/d) as compared to heifers fed ad libitum. Average daily gain or gain of body frame (height, hearth girth) was not different ($P>0.10$) between limit-fed and ad libitum fed heifers but feed efficiency was improved ($P<0.09$) by 1.04 kg DM intake/kg gain by limit-feeding. Limit-fed heifers excreted 0.36 and 0.86 kg less ($P<0.10$) DM but excreted similar amounts of N and P as compared to heifers fed ad libitum. Limit-fed heifers spent less ($P<0.05$) time eating, more ($P<0.01$) time standing without eating and vocalized more ($P<0.03$) than ad libitum fed heifers. Incidence of increased vocalization was minor and was negligible after 30 d. Limit-feeding did not influence blood glucose, total protein, albumin, P or Ca as compared to ad libitum fed heifers but linear increases ($P<0.07$) in blood urea nitrogen were observed in limit-fed heifers due to higher N intakes. Limit-feeding of gravid heifers may offer opportunity to reduce feed cost, control body condition and reduce fecal excretion without negative effects.

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SCALE OF MEASUREMENT EFFECTS ON PHOSPHORUS IN RUNOFF FROM CROPLAND [1]

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Abstract

As phosphorus (P)-based nutrient management planning becomes necessary for some farms in Wisconsin, it will be critical to have reliable, research-based planning tools. The Wisconsin P-Index provides one method for preparing P-based nutrient management plans. The P-Index was developed largely from small plot-scale data showing the relationships between various site and management variables and runoff P losses. This study was conducted to compare runoff composition measurements at the subwatershed scale with those obtained from natural runoff at the small plot (1 m^2) scale. We intend to use this information to refine the Wisconsin P Index estimates of P concentrations in runoff. Sediment, soluble P, and total P in natural runoff from small plots located in two subwatersheds instrumented to measure and sample runoff events over a 12-month period were compared with similar measurements from the subwatersheds. The subwatersheds, cropped with either corn or alfalfa, were located on a Tama silt loam in southwest Wisconsin. The total dissolved P relationships at the two scales of measurement were very good with the corn having an R^2 value of 0.86 and the alfalfa having a R^2 of 0.91. The sediment P enrichment ratios varied by crop and were similar in the small plot and subwatershed runoff. The agreement of small plot and subwatershed runoff dissolved P and sediment P concentrations supports use of small plot data in constructing the Wisconsin P index.

Introduction

Phosphorus-based nutrient management planning will likely be required for some farms in Wisconsin. Wisconsin has developed and is continuing to refine a P Index as a management tool to assess the risk of runoff P loss on a site-specific basis. The P Index, a component of the NRCS 590 Nutrient Management standard, uses a semi-quantitative modeling approach to estimate P losses from fields to surface waters. The Wisconsin P Index allows users to assess the effects of various management alternatives, such as crop rotation, tillage options, and P applications to reduce P losses where high P index values are found. Much of the information used to create the algorithms used in the P index comes from small plot simulated rainfall and natural runoff studies. Little information is currently available on how small plot runoff P data compares with field or sub-watershed scale measurements. The Wisconsin P Index uses the approach described in the following equations to estimate total P delivery to surface waters.

P Index= (Particulate P+Soluble P+Losses from surfaces applied P) x Field-to-stream P delivery ratio (Eq. 1)

Soluble P = (Runoff volume) x (Dissolved P concentration) (Eq. 2)

Particulate P = (Sediment load) x (Sediment P concentration) (Eq. 3)

Sediment-bound P=Soil total P x Sediment P enrichment ratio (Eq. 4)

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Sediment load values are found by using RUSLE2. Runoff volume (Eq. 2) is obtained using a modification of the NRCS system for rainfall runoff calculation and uses long-term winter runoff averages for calculating winter runoff. Small plot data has been used to develop the algorithms for dissolved P concentration (Eq. 2) and sediment P concentration (Eq. 3). Specifically, average total dissolved P concentrations in runoff are estimated using soil test P and soil type. Concentrations of P in eroded sediment (sediment-bound P) are based upon soil total P concentrations approximated using soil test P and soil percent organic matter and multiplied by a sediment P enrichment ratio (Eq. 4).

The objective of this project is to evaluate how well small plot runoff P loss measurements relate to actual field-scale P loss. Specifically, it is to ascertain whether the predictive equations developed from small plot data are valid at the subwatershed scale. The critical scale of measurement comparisons needed are those related to the annual average total dissolved P concentrations and sediment P concentrations in runoff. If differences in runoff P concentrations between small and subwatershed-scale exist, adjustments to the P Index will make the tool more realistic and improve its predictive value.

Materials and Methods

This study was located at the University of Wisconsin – Platteville's Pioneer Farm in southwestern Wisconsin. The research was initiated in spring 2004 on two subwatersheds, one planted in first year corn following alfalfa [7.2 hectares (ha), 17.7 acres (ac)], and the other in predominately first year alfalfa (12 ha, 29.7 ac). Existing subwatershed runoff collectors installed, monitored, and maintained by USGS personnel at the Pioneer Farm were used to collect year-around runoff at the subwatershed scale. Each monitoring station has a flume capable of measuring runoff volume and taking periodic runoff samples for analyses. Four small plot (1 m^2) runoff collectors were installed within each of these subwatersheds in June 2004. These collectors consisted of three galvanized steel panels (1 m long by 23 cm wide) inserted 15 cm deep in the soil on the upslope edges and sides of the plot. The other panel (1 m long by 15 cm wide) was placed flush with the ground level on the collector's down-slope edge. This panel was fitted with a galvanized steel gutter (1 m long) with a 3 cm diameter outflow tube connected to a copper hose (3 cm in diameter). Runoff was collected by gravity in a 115 L covered galvanized pail placed flush with the soil surface. A smaller 8 L polyethylene collection bucket covered with a coarse screen was placed in the pail. The gutter was covered with plexiglass to prevent precipitation from going directly into the collector.

Soil samples were collected near the small plots at 0 to 2, 2 to 5, and 5 to 15 cm depth increments. These samples were analyzed using Bray P1 (Frank et al., 1998), Mehlich III (Mehlich, 1984), and distilled water extraction (Pote et al., 1996) methods. These soil extracts were analyzed colorimetrically using the ascorbic acid method (Murphy and Riley, 1962). Total P also was measured in the soil using ICP analysis following nitric-perchloric digestion. The subwatersheds were grid sampled at two depths, 0 to 2 cm and 0 to 15 cm using a 100-foot grid size. These samples were analyzed for P using the Bray P1 method and selected samples were analyzed for total P. Bray P1 and soil total P values for corn and alfalfa subwatersheds and small plots are summarized in Table 1.

Table 1. Soil phosphorus levels in subwatersheds and small plots at the Pioneer Farm, Platteville, Wisconsin.

Field	Depth (cm)	Bray soil test P		Total P	
		Subwatersheds	Small plots	Subwatersheds	Small plots
		ppm			
Corn	0-2	49	31	613	490
	0-15	37	19	593	465
Alfalfa	0-2	133	141	827	784
	0-15	114	137	762	742

Runoff volumes from the subwatershed and small plot collectors were measured and samples taken for total dissolved P (TDP), total P (TP), and total solids (TS). For total dissolved P, filtered runoff samples were digested and analyzed colorimetrically using the ascorbic acid method. Unfiltered runoff samples were acidified with 0.01 *M* H_2SO_4 and analyzed for total P following ammonium persulfate and sulfuric acid digestion. Unfiltered runoff samples were weighed before and after drying at 105° C for total solids (sediment) determination. The four replicate small plot runoff volumes and concentrations were volume-weight-averaged for small plot runoff values.

The corn and alfalfa subwatersheds used in the scale of measurement studies were managed as a part of the total Pioneer Farm operation. In the corn subwatershed, this included fall chisel plowing and spring tillage with a soil finisher before corn planting in the spring. Solid manure (13.8 tons per acre) was applied to the subwatershed including the small plots in the fall before chisel plowing, and additional solid manure was applied at a low rate (5.9 tons per acre) in winter. Corn was harvested for grain in 2004 and the average yield was 181 bushels per acre. In the alfalfa subwatershed, three cuttings were harvested in 2004, and one cutting was taken in May 2005.

Results and Discussion

Phosphorus and sediment concentrations and loads in runoff from the corn and alfalfa subwatersheds and small plots are summarized in Tables 2 and 3, respectively. Runoff P concentrations were similar in small plots and subwatersheds, but varied by crop and season. From June 2004 to June 2005, there were nine runoff events in both the corn subwatershed and small plots and seven runoff events in both the alfalfa subwatershed and small plots. There were about twelve other dates with runoff in some of the small plots, but no runoff in the subwatershed. To separate winter and summer runoff events, periods when the soil is frozen are called winter and the rest of the year is designated as summer. Four of the runoff events in the corn subwatershed occurred when the soils were frozen (winter). Six of the alfalfa subwatershed runoff events happened with frozen soil. In both subwatersheds, most of the runoff volume occurred in the winter. Only 3% of the alfalfa runoff volume was collected in the summer while 37% of the corn runoff volume was collected in the summer. The precipitation levels during the summers of 2004 and 2005 were below average, while the winter of 2004-2005 had above average precipitation. The small plots had greater runoff volumes per unit area in all cases compared to the subwatersheds. Because of longer flow paths (transport distances) in the subwatershed, there are more opportunities for infiltration and deposition, resulting in lower per unit area runoff volumes (Table 2).

Table 2. Phosphorus and sediment concentrations in annual runoff from corn and alfalfa subwatersheds and small plots from June 2004 to June 2005 at the Pioneer Farm, UW-Platteville.

Field	Season	n	Scale	TDP[2]	TP[3]	TS[4]	Runoff
					-------ppm-------		L/m^2
Corn	Annual	9	Subwatershed	2.24	4.48	3920	31
			Small Plot[1]	1.85	2.87	1100	218
	Winter	4	Subwatershed	3.32	3.97	440	20
			Small Plot	2.12	2.92	380	186
	Summer	5	Subwatershed	0.45	5.33	9670	12
			Small Plot	0.22	2.59	5390	31
Alfalfa	Annual	7	Subwatershed	1.15	1.45	120	54
			Small Plot	1.74	2.36	220	176
	Winter	6	Subwatershed	1.13	1.43	120	52
			Small Plot	1.78	2.36	180	167
	Summer	1	Subwatershed	1.60	1.92	230	2
			Small Plot	1.14	2.31	860	9

[1] Small plot values are weighted-average of four replications in each subwatershed
[2]Total dissolved phosphorus
[3]Total phosphorus
[4]Total solids

For the whole year, the corn subwatershed had higher annual P concentrations, P loads, solid concentrations, and solid loads compared to the alfalfa subwatershed (Table 2 and Table 3). The corn subwatershed P concentrations were higher than in the small plots. However, the small plot loads were greater than the subwatershed loads in both corn and alfalfa subwatersheds due to the greater per unit area runoff volumes in the small plots. The TDP concentration and loads were higher in the winter than the summer for both scale sizes. This is most likely due to lower sediment losses during winter, greater dissolved P losses due to winter manure applications in corn, and possible soluble P leaching from plant material, especially in the alfalfa field. The fact that this seasonal change in TDP concentration was seen at both scales of measurement adds validity to use of small plot data for constructing P indices. Total P concentrations and loads and total solids (sediment) concentrations and loads were greater in the corn field than the alfalfa field. The absence of tillage and presence of high residue cover for most of the year effectively control sediment loss in the alfalfa subwatershed.

Table 3. Phosphorus and sediment loads in annual runoff from corn and alfalfa subwatersheds and small plots from June 2004 to June 2005 at the Pioneer Farm, UW-Platteville.

Field	Season	n	Scale	TDP[2]	TP[3]	TS[4]
					--------lb/ac-------	
Corn	Annual	9	Subwatershed	0.63	1.26	1097
			Small Plot[1]	3.59	5.58	2133
	Winter	4	Subwatershed	0.58	0.69	78
			Small Plot	3.53	4.86	627
	Summer	5	Subwatershed	0.05	0.56	1026
			Small Plot	0.06	0.72	1507
Alfalfa	Annual	7	Subwatershed	0.55	0.69	60
			Small Plot	2.73	3.69	340
	Winter	6	Subwatershed	0.52	0.66	56
			Small Plot	2.64	3.51	274
	Summer	1	Subwatershed	0.02	0.03	3.57
			Small Plot	0.09	0.18	67

[1] Small plot values are weight-averaged of four replications in each subwatershed.
[2]Total dissolved phosphorus
[3]Total phosphorus
[4]Total solids

The P Index dissolved P concentration equation (Eq. 2) is based on small plot research results showing that runoff total dissolved P increases with increasing Bray P1 soil test levels. This relationship is evident from the TDP values for the small plots and subwatersheds in Table 2. In the corn field, the subwatersheds had higher average Bray P1 soil test values than the small plots (Table 1). In each comparison, the corn subwatershed had higher TDP concentrations than the small plots. In the alfalfa subwatershed, the small plots had the higher Bray P1 soil test values and higher runoff TDP concentrations.

Relationships between the Small Plot and the Subwatershed Runoff P

Phosphorus runoff from small plots and subwatersheds were compared on an event by event basis using regression analysis (Table 4 and Figure 1). The annual runoff volumes at the two scales were related with R^2 values of 0.71 and 0.72 for the corn and alfalfa fields, respectively. For annual concentrations, the TDP relationships were highly correlated, with the corn having an R^2 value of 0.86 and the alfalfa having a R^2 of 0.91. However, as illustrated in Figure 1, the small plot vs. subwatershed relationships for TDP concentration were quite different in the corn and alfalfa subwatersheds. Alfalfa subwatershed and small plot data for TP and TS concentration were more closely related than the corresponding corn data. As expected, the runoff P load relationships between small plots and subwatersheds were generally not as strong as those found for runoff P concentrations.

Table 4. Relationship between small plot and subwatershed measurements of P concentrations and load in runoff from June 2004-2005.

Field	Season	Events n	Concentration TDP[1]	TP[2]	TS[3]	Load TDP	TP	TS	Runoff
			-------------	-------------	------------- R^2	-------------	-------------	-------------	-------------
Corn	Annual	9	0.86	0.35	0.44	0.96	0.55	0.24	0.71
	Winter	4	0.01	0.54	0.46	0.97	0.98	0.99	0.97
	Summer	5	0.98	0.32	0.13	0.23	0.44	0.22	0.57
Alfalfa	Annual	7	0.91	0.68	0.74	0.60	0.52	0.17	0.72
	Winter	6	0.93	0.82	0.67	0.56	0.49	0.24	0.72
	Summer	1	-	-	-	-	-	-	-

[1]Total dissolved phosphorus
[2]Total phosphorus
[3]Total solids

Sediment-based P Concentrations

Sediment P enrichment ratios indicate how the P concentration in sediment contained in runoff relates to the total P concentration of the original soil. The enrichment ratios are calculated by dividing sediment-bound P by soil total P. Enrichment ratios are often greater than one because finer sized soil particles usually have higher P concentrations than coarse soil particles and the fine particles are the most likely to be lost in runoff. In the summer runoff events from the corn subwatershed, sediment losses were relatively high (Table 5), and enrichment ratios were near 1.0, indicating little sorting of eroded particles during runoff. Runoff sediment P and total P concentrations for these events were similar. In contrast, for the winter events from the corn subwatershed and for all events from the alfalfa subwatershed, sediment losses in runoff were low and enrichment ratios indicate substantially higher P concentrations in eroded sediment than in the original soil. This concentration is likely due to selective transport of finer sized soil particles. Within crop and season variables, sediment P enrichment ratios were usually similar in small plot and subwatershed measurements.

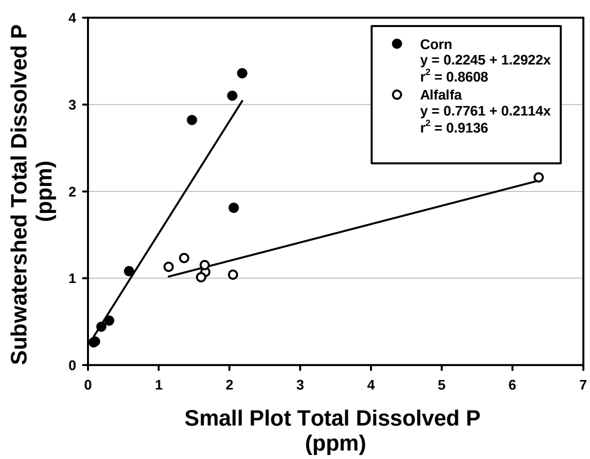

Figure 1. Relationships between corn and alfalfa subwatershed and small plot total dissolved P concentrations in runoff during June 2004-June 2005 at the Pioneer Farm, UW-Platteville.

Table 5. Sediment P enrichment ratios, sediment bound P concentrations, soil total P, and total solids concentrations in runoff from subwatersheds and small plots by crop and season, Pioneer Farm, UW-Platteville.

Field	Season	n		Sediment bound P[1]	Soil total P	Enrichment ratio[2]	Total solids
				ppm	ppm		ppm
Corn	Summer	5	Subwatershed	507	603	0.84	9670
			Small plot	484	490	0.99	5390
	Winter	4	Subwatershed	1467	603	2.43	440
			Small plot	1685	490	3.44	380
Alfalfa	Summer	1	Subwatershed	1382	795	1.74	120
			Small plot	1343	784	1.71	220
	Winter	6	Subwatershed	2455	795	3.09	120
			Small plot	3212	784	4.10	180

[1]Sediment bound P (mg/kg) = Particulate P load/Total solids load
[2]Enrichment ratio = Sediment bound P/Soil total P

Conclusions

Total dissolved P (TDP) concentrations in runoff were similar at the small plot and subwatershed scales. Crop and season effects on runoff TDP concentrations were reflected at both scales of measurement. Per unit area runoff volumes and sediment loads were higher in small plots than in subwatersheds. Phosphorus concentrations in eroded sediment varied substantially with crop and season, but were generally similar in the small plot and subwatershed measurements. Sediment P enrichment ratios also varied with crop and season of measurement, but were not greatly affected by scale of measurement. Since P index equations for predicting runoff soluble P and sediment P concentration are based on data from small plot measurements, the finding that these parameters are similar at plot and subwatershed scales of measurement lends support to use of plot scale data for the development of P indices.

Acknowledgments

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References

Bohl, N., L. Bundy, C. Baxter, T. Andraski, and L.W. Good. 2005. Scale of measurement effects on phosphorus runoff losses from cropland. In Proc. North Central Extension-Industry Soil Fertility Conference, Des Moines, IA, 16-17 November 2005. 21:130-137.

Frank, K., D. Beegle, and J. Denning. 1998. Phosphorus. p. 21-26. In J. R. Brown (ed.) Recommended chemical soil test procedures for the North Central Region. NC Regional Res. Publ. no. 221 (Rev.). Missouri Agric. Exp. Stn., Columbia, MO.

Good, L.W. 2005. Wisconsin Phosphorus Index [Online] http://wpindex.soils.wisc.edu/ (verified December 13, 2005).

Good, L.W., P. Karaaka, S. Porter, and K. Beckard. 2005. SNAP-Plus Wisconsin's Nutrient Management Software [Online] http://www.snapplus.net/ (verified December 13, 2005).

Mehlich, A. 1984. Mehlich 3 soil test extractant: A modification of Mehlich 2 extractant. Commun. Soil Sci. Plant Anal. 15:1409-1416.

Murphy, J., and J.R. Riley. 1962. A modified single solution method for the determination of phosphate in natural water. Anal. Chem. 27:31-36.

Pote, D.H., T.C. Daniel, A.N. Sharpley, P. A. Moore, Jr., D.R. Edwards, and D.J. Nichols. 1996. Relating extractable soil phosphorus to phosphorus losses in runoff. Soil. Sci. Soc. Am. J. 60:855-859.

EVALUATION OF THE BRAY P1 SOIL TEST ON EASTERN RED SOILS IN WISCONSIN

Angela Ebeling[1], Larry Bundy[1], Aaron Kittell[2], and Dan Ebeling[2]

Introduction

Soil testing for phosphorus (P) is used agronomically to determine the amount of P needed for crop production. Soil test P is also used for determining environmental risks associated with elevated levels of soil P. The Bray P1 soil test method is commonly used in Wisconsin for measuring plant available P and is the required test for regulatory agencies. The Bray P1 extracting solution consists of 0.03 N ammonium fluoride and 0.025 N hydrochloric acid. The ammonium fluoride extracts mostly aluminum bound-P, and no iron-P, and the hydrochloric acid extracts calcium-P (Tandon et al., 1967). Mehlich-3 and Olsen are also widely-used soil test P methods. Mehlich-3 was developed for a wide range of soils including calcareous soils (Wang et al., 2004; Lucero et al., 1998), and Olsen was developed primarily for calcareous soils (Olsen et al., 1954). A calcareous soil is defined as a "soil containing sufficient calcium carbonate (often magnesium carbonate) to effervesce visibly when treated with cold 0.1 N hydrochloric acid" (Brady and Weil, 1999). Mehlich-3 and Bray P1 soil test results are highly correlated in neutral to acid soils with Mehlich-3 extracting slightly more P than Bray P1 in most soils because Mehlich-3 uses a more acidic extracting solution (Tran et al., 1990, Beegle and Oravec, 1990, Lucero et al., 1998; Mallarino, 2003). The Bray P1 soil test method is intended for acid soils, and the validity of its use to predict plant available P levels on the eastern red soils (ERS) in Wisconsin has been questioned due to concerns that the weak acid Bray P1 extracting solution could be neutralized by reaction with carbonates in these soils. Previous studies have found that Bray P1 extracts less P at higher soil pH (Mallarino and Blackmer, 1992; Mallarino, 1997; Atia and Mallarino, 2002) and that Bray P1 does not correlate as well as with Mehlich 3 or Olsen in soils with higher calcium carbonate contents (Hooker et al., 1980; Mallarino, 2003; Hermin et al., 2004). Mallarino (1997) found that Mehlich 3, Olsen, and Bray P1 correlated well with each other until soils reached a calcium carbonate equivalent (CCE) of 4% or higher. Other research indicates that pH alone is not a good indicator of when Bray P will fail; data shows that carbonate content greater than 36 g kg^{-1} (3.6%) is important (Mallarino and Atia, 2005). Mehlich 3 and Olsen soil test P results are well correlated regardless of soil type.

Bray P1 inability to accurately measure available soil P on calcareous soils has generally been attributed to neutralization of the extracting solution by calcium carbonate ($CaCO_3$) followed by precipitation of dissolved calcium with the fluoride (Fixen and Grove, 1990). Soils having greater than 1.25% calcium carbonate equivalent (CCE) have the capability of neutralizing all of the HCl in Bray P1, therefore reducing its effectiveness (Hooker et al., 1980). The Mehlich 3 extracting solution has been found to be less neutralized by free carbonates than Bray P1 (Tran et al., 1990). The Mehlich-3 or Olsen P tests are generally viewed as more appropriate tests for high pH, calcareous soils.

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The eastern red soil (ERS) region of Wisconsin is found in the northeast part of the state. The soils there are known to have high pH values and they have traditionally been thought to have substantial carbonate contents. The studies described above suggest that the Bray P1 test may not perform well on ERS soils, and this research was conducted to evaluate the performance of the Bray P1 method relative to other P soil test methods on these soils.

Materials and Methods

Soil samples collected from the eastern red soil (ERS; n=27) region of Wisconsin were analyzed for soil test P, pH, and carbonate. Soils from Kansas (n=29), Iowa (n=9), and a subsoil formation in southwestern Wisconsin (Rountree; n=2) were included as comparison soils known to have high pH or high carbonate content. The Bray P1 soil test phosphorus method was compared to Mehlich 3 and Olsen performance on these soils.

Soil samples were air dried and ground to pass a 2-mm sieve. Soil P tests included Bray P1 (Frank et al., 1998), Mehlich 3 (Mehlich, 1984) and Olsen (Olsen, 1954). Bray P1 was determined by shaking 2.5 g soil with 25 mL of extractant (0.03 N NH_4F and 0.025 N HCl) for 5 minutes at 180 rpm. Mehlich 3 was determined by shaking 2.5g soil with 25 mL of extractant (0.2N CH_3COOH, 0.25N NH_4NO_3, 0.015N NH_4F, 0.013N HNO_3, 0.001M EDTA) for 5 minutes at 180 rpm. Olsen was determined by shaking 2.0 g soil with 20 mL extractant (0.5 M $NaHCO_3$, pH 8.5) for 30 minutes at 180 rpm. After shaking all samples were centrifuged at 2,000 rpm for 10 minutes and filtered through Fisher P5 filter paper. Phosphorus in the extracts obtained by each method was determined colorimetrically by the ascorbic acid method (Murphy and Riley, 1962) on a Perkin Elmer Lambda 25 UV/VIS spectrometer.

Soil pH was measured in a 1:1 soil to water slurry. Carbonate was measured following the titrimetric method of Bundy and Bremner (1972). Samples between 3 and 8 g of soil were precisely measured into a stoppered 240-mL French square bottle, into which 20 mL of 2M HCl was injected to release the carbonate as carbon dioxide (CO_2). Five milliliters of a 2M solution of KOH was used to capture the CO_2, which was then titrated to determine inorganic carbon content. Percent calcium carbonate equivalent (%CCE) was calculated from the inorganic carbon (IC) content using this equation: g IC/g soil * 100.09 g $CaCO_3$/12.011g IC * 100 = %CCE.

Results and Discussion

Figure 1 shows the relationship between pH and carbonate content for all soils evaluated. The pH ranged between 5.4 and 8.3 and the carbonate ranged from 0 to 16.1 %CCE. The pH range of the eastern red soils ranged between 5.3 and 7.6. Most of the ERS soils (hollow diamonds) had less than 2% CCE, with the highest only reaching slightly above 4%. The comparison soils (solid squares) however had carbonate contents up to 16%. These data indicate that soils with high carbonate contents will have pH values above ~7. However, a high soil pH value does not necessarily mean that the soil will have high carbonate content (e.g., some high pH soils have low carbonate contents).

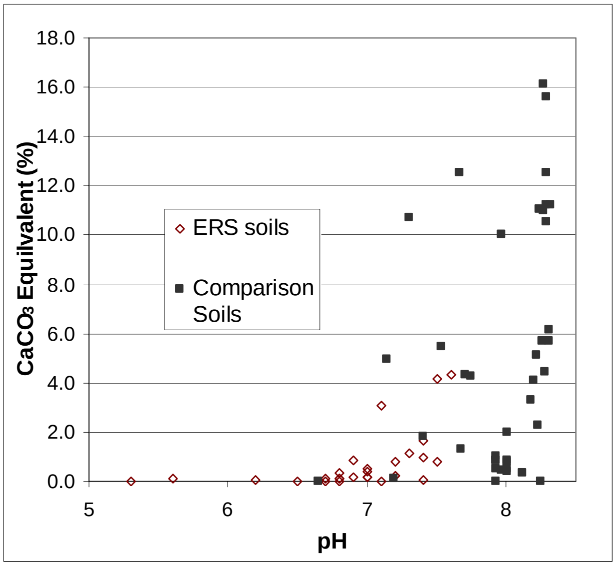

Figure 1. Relationship between pH and %CCE for Wisconsin eastern red soils (ERS) and comparison soils.

Figure 2 shows the relationship between Olsen and Mehlich 3 soil test P values on all soils. The solid circles are those soils with carbonate contents greater than 4% and the hollow squares are those soils with carbonate contents less than 4%. Based on the knowledge of the chemistry of the extractants, both the Olsen and the Mehlich 3 P tests should perform well on most soils including those with substantial carbonate contents. This assumption is supported by the data in Figure 2 showing a generally close linear relationship between soil test P values obtained by the two tests regardless of the soil carbonate content.

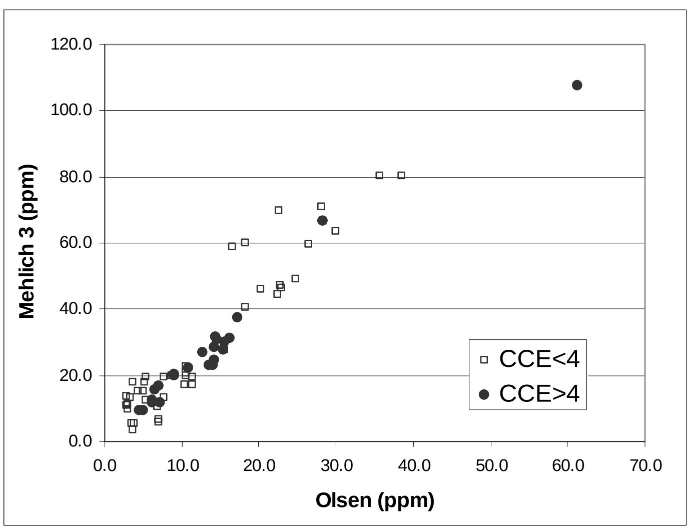

Figure 2. Relationship between Olsen and Mehlich 3 soil test P values for Wisconsin eastern red soils and comparison soils.

Figure 3 shows the relationship between Bray P1 and Mehlich 3 soil test P values on all soils. For many of the soils with carbonate contents greater than 4%, Bray P1 is underestimating the soil test P value likely due to neutralization of the extractant by carbonate. For example, for a substantial group of soils shown in the lower left corner of Figure 3, the Mehlich 3 soil test P values were in the 20 to 30 ppm range while the comparable Bray P1 values were 0 to 10 ppm .

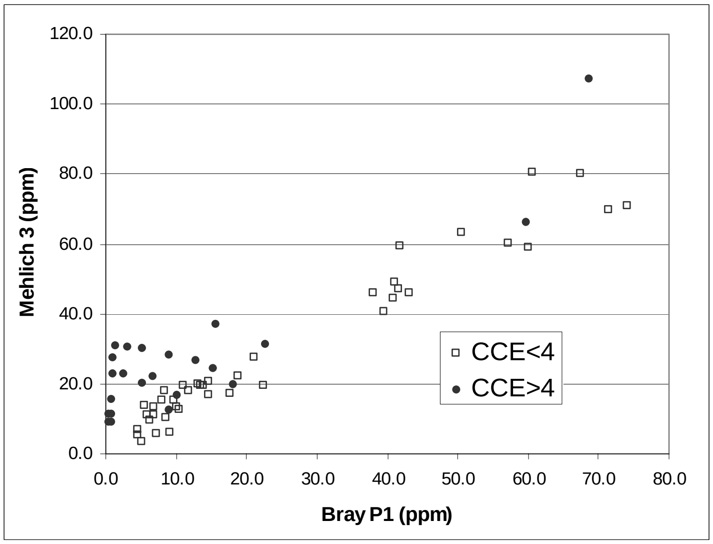

Figure 3. Relationship between Bray P1 and Mehlich 3 soil test P values for Wisconsin eastern red soils and comparison soils.

Figure 4 illustrates the relationship between Bray P1 and Olsen soil test P values on all soils. These results are similar to those shown in Figure 3 for the Bray P1 versus Mehlich 3 relationship in that Bray P1 is underestimating P availability on a substantial number of soils with high carbonate contents.

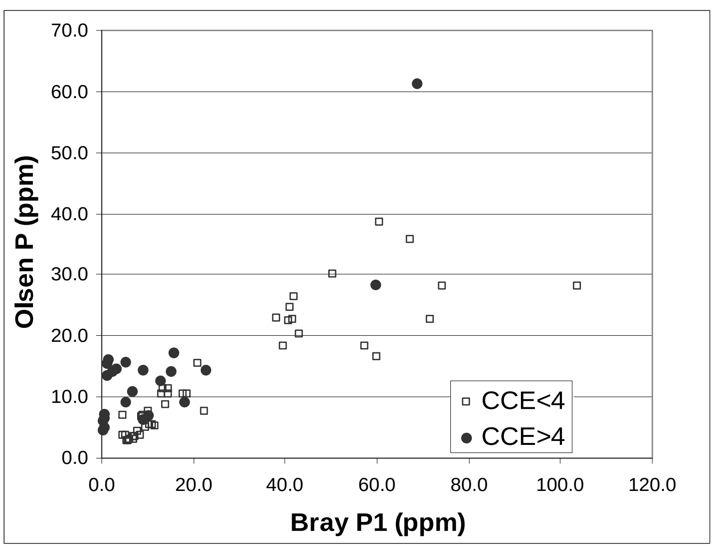

Figure 4. Relationship between Bray P1 and Olsen soil test P values for Wisconsin eastern red soils and comparison soils.

Table 1 summarizes the r^2 values for the soil test P relationships illustrated in Figures 2-4. The r^2 values were similar for the Mehlich 3/Olsen relationship (0.89 compared to 0.88) For the two relationships including the Bray P1 test, the r^2 values decrease from 0.96 to 0.83 when high carbonate soils are included in the analysis. Similarly, in the Bray P1/Olsen relationship, r^2 values declined from 0.77 to 0.66 when high carbonate soils are included. These data indicate that the Bray P1 soil test is unreliable in soils with high levels of carbonate.

Table 1. Compilation of r^2 values for the relationships between soil test P values obtained with various methods for all soils and excluding soils with high carbonate contents.

Comparison	Soils with CCE<4%	All Soils
	------------------------- r^2	-------------------------
M3/Olsen – Figure 2	0.89	0.88
BP1/M3 – Figure 3	0.96	0.83
BP1/Olsen – Figure 4	0.77	0.66

To return to our initial objective of evaluating Bray P1 soil test performance on eastern red soils, Figure 5 shows the relationship between Bray P1 and Mehlich 3 soil P tests for eastern red soils in Wisconsin. The very strong relationship (r^2 = 0.99) indicates that the Bray P1 is a valid P test for these soils. The excellent relationship between Bray P-1 and Mehlich 3 tests is likely due to the fact that most of the ERS soils had low carbonate contents.

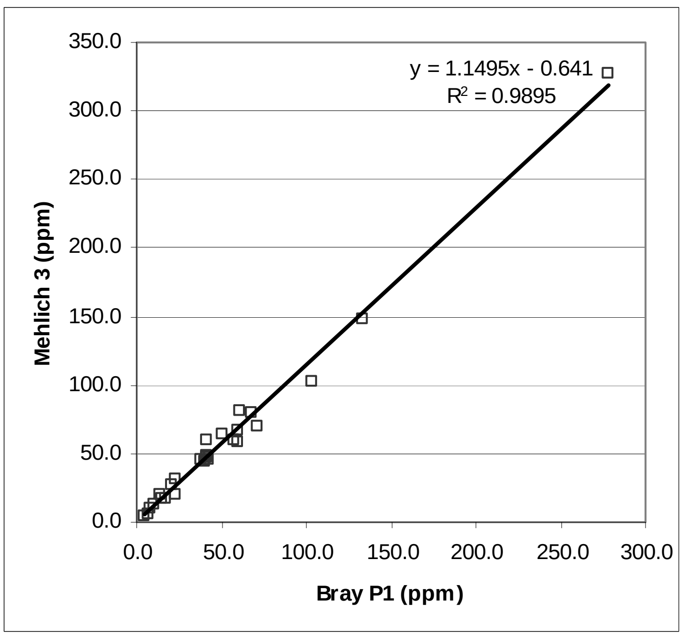

Figure 5. Relationship between Bray P1 and Mehlich 3 P soil test methods on eastern red soils.

Conclusions

The results of this research indicate that the Bray P1 soil P method is not appropriate for assessing P availability in soils with high calcium carbonate contents (over 4% calcium carbonate equivalent). While calcareous soils often have high pH values, pH alone is not a good indicator of soil carbonate carbon content (i.e. some high pH soils have low carbonate contents). Soils analyzed from the eastern red soil region of Wisconsin did not contain enough carbonate to affect Bray P1 soil test performance. Based on this preliminary research, Bray P1 soil test results should still be considered valid estimates of plant available P in this region. Additional analysis of soil samples from the eastern red soil region will continue to verify this conclusion.

References

Atia, A.M., and A.P. Mallarino. 2002. Agronomic and environmental soil phosphorus testing in soils receiving liquid swine manure. Soil Sci. Soc. Am. J. 66:1696-1705.

Beegle, D.B., and T.C. Oravec. 1990. Comparison of field calibrations for Mehlich 3P and K with Bray-Kurtz P1 and ammonium acetate K for corn. Commun. Soil Sci. Plant Anal. 21:1025-1036.

Brady, N.C., and R.R. Weil. 1999. The nature and property of soils 12th ed. Prentice Hall. Upper Saddle River, NJ.

Bundy, L.G., and J.M. Bremner. 1972. A simple titrimetric method for determination of inorganic carbon in soils. Soil Sci. Soc. Am. Proc. 36:273-275.

Fixen, P.E., and J.H. Grove. 1990. Testing soils for phosphorus. p. 161-164. *In* Soil testing and plant analysis, 3rd ed. SSSA Book Series no. 3. Chapter 7. Soil Sci. Soc. Am., Madison, WI.

Frank, K., D. Beegle, and J. Denning. 1998. Phosphorus. p. 21-26. *In* J.R. Browning (ed.) Recommended chemical soil test procedures for the North Central Region. NC Regional Res. Publ. no. 221. Missouri Agric. Exp. Station, Columbia MO.

Herman, J.C., J.R. Massey, D.F. Leikam, and S. Harrold. 2004. Relationship of Mehlich-3 ICP and Mehlich-3 colorimetric phosphorus determinations with the Bray P1 extractant. North Central Extension-Industry Soil Fertility Conference, Des Moines, IA. 20:166-172.

Hooker, M.L., G.A. Peterson, D.H. Sander, and L.A. Daigger. 1980. Phosphate fractions in calcareous soils as altered by time and amounts of added phosphate. Soil Sci. Soc. Am. J. 44:269-277.

Lucero, D.W., D.C. Martens, J.R. McKenna, and D.E. Starner. 1998. Comparison of Mehlich3- and Bray 1-extractable phosphorus levels in a Starr clay loam amended with poultry litter. Commun. Soil Sci. Plant Anal. 29:1133-1142.

Mallarino, A.P. 1997. Interpretation of soil phosphorus tests for corn in soils with varying pH and calcium carbonate content. J. Prod. Agric. 10:163-167.

Mallarino, A.P. 2003. Field calibration for corn of the Mehlich-3 soil phosphorus test with colorimetric and inductively coupled plasma emission spectroscopy determination methods. Soil Sci. Soc. Am. J. 67:1928-1934.

Mallarino, A.P. and A.M. Atia. 2005. Correlation of a resin membrane soil phosphorus test with corn yield and routine soil tests. Soil Sci. Soc. Am. J. 69:266-272.

Mallarino, A.P., and A.M. Blackmer. 1992. Comparison of methods for determining critical concentrations of soil test phosphorus for corn. Agron. J. 84:850-856.

Mehlich, A. 1984. Mehlich III soil test extractant: A modification of Mehlich II extractant. Commun. Soil Sci. Plant Anal. 15:1409-1416.

Murphy, J., and J.R. Riley. 1962. A modified single solution method for the determination of phosphate in natural waters. Anal. Chem. 27:31-16.

Olsen, S.R., C.V. Cole, F.S. Watanabe, and L.A. Dean. 1954. Estimation of available phosphorus in soils by extraction with sodium bicarbonate. Circular no. 939, U.S. Dept. Agric., Washington, DC.

Tandon, H.L.S., H.L. Motto, and L.T. Kurtz. 1967. Composition of dilute-acid-fluoride (Bray P1) extracts of Illinois soils. Soil Sci. Soc. Am. Proc. 31:168-171.

Tran, T.S., M. Giroux, J. Guilbeault, and P. Audesse. 1990. Evaluation of Mehlich-III extractant to estimate the available P in Quebec soils. Commun. Soil Sci. Plant Anal. 21:1-28.

Wang, J.J., D.L. Harrell, R.E. Henderson, and P.F. Bell. 2004. Comparison of soil-test extractants for phosphorus, potassium, calcium, magnesium, sodium, zinc, copper, manganese, and iron in Louisiana soils. Commun. Soil Sci. Plant Anal. 35:145-160.

CASE HISTORIES OF WEED RESISTANCE TO GLYPHOSATE

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Introduction

Weed management has changed dramatically in the last 10 years. Since the introduction of glyphosate-resistant (Roundup Ready) soybean in 1996, varieties with the Roundup Ready trait have been grown on an increasing number of acres, totaling more than 65 million acres in the US in 2004 (Anonymous, 2005). Corn hybrids with the Roundup Ready trait have also increased in popularity since their introduction in 1998, and were planted on more than 8 million acres in the U.S. in 2004 (Anonymous, 2005). With this dramatic increase in Roundup Ready trait acreage, glyphosate use for in-crop weed management has also increased, and will likely increase further with expected increases in Roundup Ready corn and alfalfa acreage. Although glyphosate offers the perceived benefits of safe, simple, and effective weed management to growers, it is subject to many of the same pitfalls as other herbicides, including resistant weeds.

About the time that Roundup Ready technology came to the market, strong arguments were proposed against the likelihood of weeds developing resistance to glyphosate (Bradshaw et al., 1997). However, resistance to glyphosate has occurred (Heap, 2005). The first confirmed case of weed resistance to glyphosate was rigid ryegrass in Australia (Pratley et al., 1996). Since then, resistance has been confirmed in seven other weed species (Heap, 2005), including several species in the U.S. In 2000, glyphosate-resistant horseweed was confirmed in Delaware (Van Gessel, 2001) and has since been found in 13 other states (Heap, 2005). More recently, resistance of common ragweed in Missouri (Bradley, 2005a) and Palmer amaranth in Georgia (Culpepper, 2005) to glyphosate has been confirmed.

Potential resistance of other important weed species to glyphosate has also recently been reported including common waterhemp in Missouri (Bradley, 2005b), common lambsquarters in Ohio (Loux and Stachler, 2005), and giant ragweed in Ohio (Stachler et al., 2005). In Wisconsin, weed resistance to glyphosate has not been confirmed, but since 2002, there have been many reports of variable or inconsistent responses of common lambsquarters to glyphosate in Roundup Ready soybean fields (Boerboom, 2004). Re-treatment of common lambsquarters escapes with glyphosate has typically resulted in adequate control, but the cause of less than optimal control, and in some cases poor control, has yet to be fully explained.

Resistance to herbicides other than glyphosate has been selected for in several weed species found in Wisconsin, including resistance to ALS (acetolactate synthase) inhibitors in eastern black nightshade (Volenberg et al., 2000), giant foxtail (Volenberg et al., 2001), and green foxtail (Volenberg et al., 2002), resistance to ACCase (acetyl-coenzyme A carboxylase) inhibitors in giant foxtail (Stoltenberg and Wiederholt, 1995) and large crabgrass (Wiederholt and Stoltenberg, 1995), and resistance to triazine herbicides in several broadleaf weed species (Stoltenberg, 1995).

The development of weed resistance has typically been associated with reliance on a single herbicide chemistry over time, i.e. a high level of herbicide selection intensity (Volenberg et al., 2000, 2001, 2002; Stoltenberg and Wiederholt, 1995; Wiederholt and Stoltenberg, 1995). That is, repeated exposure of a weed community to a specific herbicide chemistry (or related chemistries)

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has selected for weeds resistant to that chemistry. Once such herbicide use has selected for resistant individuals, continued herbicide use (i.e. continued selection intensity) favors resistant plants over susceptible plants. Over time, the frequency of resistant plants in a weed population increases, representing a potentially serious long-term weed management problem.

Although herbicide selection intensity is a critical factor in the development of weed resistance, predicting what species will develop resistance, when it will happen, where it will happen, and the rate of spread of resistance once it has occurred, has been very difficult. This has been due in large part to many factors (including herbicide selection intensity) that play a role in the selection for herbicide-resistant weeds (Stoltenberg, 2004).

Can we learn from some of these occurrences of glyphosate-resistant weeds, such that we can minimize the potential for resistance to glyphosate developing in Wisconsin? In the case of confirmed weed resistance to glyphosate, what has been the glyphosate selection intensity (e.g. frequency of use, rate, and other weed management factors)? How does the selection intensity in these cases compare with how we're using glyphosate in Wisconsin? If we consider some cases of weed resistance to glyphosate, it may help us assess the potential for selection of glyphosate-resistant weeds in Wisconsin.

Case Histories

Glyphosate-Resistant Horseweed

Within 3 years of using only glyphosate for weed control in a no-tillage, glyphosate-resistant soybean production system, glyphosate failed to control horseweed in several fields in the mid-Atlantic region (Van Gessel, 2001). Glyphosate applied preplant and in Roundup Ready soybean was the sole control method in 1998, 1999, and 2000. In 2000, several horseweed plants were not affected by glyphosate applied at 1.5 lb ae/acre, and were not controlled with an additional treatment of glyphosate applied at 1.5 lb ae/acre. Progeny of surviving plants exhibited 8- to 13-fold resistance to glyphosate compared to susceptible seedlings.

Glyphosate-resistant horseweed has spread rapidly since 2001. Since then, it has been found in 13 other states (Heap, 2005). The rapid increase in occurrence of glyphosate-resistant horseweed is likely due in part to the widespread adoption of no-tillage, Roundup Ready soybean production systems, but it is also likely due to horseweed biology. The reproduction, dispersal, and germination characteristics of horseweed make it a species likely to infest adjacent and distant fields (Holm et al., 1997). Horseweed produces a large number of small seeds, whose wind dispersal is the most likely means for the spread of resistance (Van Gessel, 2001). Horseweed seeds are able to germinate and establish in non-disturbed soils, providing the potential to colonize both no-tillage crop fields and non-disturbed, non-crop sites. Also, outcrossing can occur between horseweed plants, increasing the potential for movement of resistance traits within and among horseweed populations.

What have been the management implications following the discovery and spread of glyphosate-resistant horseweed in the eastern corn belt? The rapid spread of horseweed has resulted in the need to treat all horseweed as glyphosate-resistant plants (Van Gessel et al., 2004). In Delaware, Maryland, and Virginia, extension specialists do not recommend the use of glyphosate for preplant weed control in Roundup Ready soybeans (Van Gessel et al., 2004). Since glyphosate will likely be used at least once after soybeans are planted, it is their recommendation to vary the mode of action of herbicides used for controlling horseweed, e.g. dicamba or 2,4-D based programs. This is particularly critical for management of horseweed, as it has evolved resistance to many herbicide chemistries (triazine, amide, bipyridilium, imidazolinone, and sulfonylurea herbicides) in more than 10 countries worldwide, and is considered one of the 10 most important herbicide-resistant weeds (Heap, 2005). Horseweed plants in Ohio have developed multiple-resistance to glyphosate and ALS-inhibiting herbicides. For this reason, the use of herbicides that contain the active ingredient cloransulam for preplant horseweed control is not recommended by extension specialists in the mid-Atlantic region (Van Gessel et al., 2004).

Van Gessel et al. (2004) recommend that a diversity of weed management tactics be used for controlling horseweed. Risk for selecting glyphosate-resistant horseweed is greater when soybeans are planted on a frequent basis. Planting soybeans one out of two years appears to lessen the risk of developing horseweed resistance to glyphosate compared to continuous soybean, but this does not eliminate the risk. They discourage planting Roundup Ready soybeans more than three out of six years. If soybeans are planted more frequently than three out of six years, periodic use of tillage is recommended; specifically, tillage in two out of six years is encouraged to minimize the impact of developing glyphosate-resistant biotypes. They have found that spring tillage is a very effective option for controlling horseweed. As a general rule, Van Gessel et al. (2004) recommend not planting Roundup Ready crops in the same field two years in a row. The use of non-glyphosate based weed control programs (a soil-applied preemergence herbicide program followed by an appropriate postemergence herbicide when needed) should be used periodically in combination with tillage and crop rotation when and where possible.

Glyphosate-Resistant Common Ragweed

In 2002, a population of common ragweed was discovered in central Missouri that was inadequately controlled following several applications of glyphosate over six years (Pollard et al., 2004). This population was identified in a no-tillage soybean field that had been in continuous soybean production (with some double-cropped wheat) for many years and in Roundup Ready soybean since 1996 (Bradley, 2005a). In greenhouse experiments, progeny of suspected resistant plants were nearly 10-fold resistant to glyphosate compared to known susceptible plants. Under field and greenhouse conditions, glyphosate-resistant plants typically grow slower and exhibit shortened internodes, reduced stature, and an overall bushy appearance compared to susceptible plants (Sellers et al., 2004). Although differences in morphology between resistant and susceptible plants have been shown to affect interception of glyphosate spray solution, this has not fully accounted for the reduced glyphosate activity on resistant plants. Most of the glyphosate-resistant common ragweed plants have remained concentrated in a 50-acre area within the field of origin, but recent evaluation has shown that resistant plants have spread along a roadside at least 200 feet away from the infested field (Smeda et al., 2005).

Following the discovery of glyphosate-resistant common ragweed, management recommendations from University of Missouri extension specialists have included tank mixing glyphosate with another mode of action herbicide in burndown treatments (e.g. 2,4-D) when glyphosate is to be applied in the subsequent crop, tank mixing glyphosate with another mode of action herbicide (e.g. lactofen or Cobra) for standard in-crop glyphosate use, alternating glyphosate use with other herbicide modes of action between years, and other integrated weed management practices (Bradley, 2005a).

Glyphosate-Resistant Palmer Amaranth

The most recent addition to the list of glyphosate-resistant weeds is Palmer amaranth (Culpepper, 2005; Heap, 2005). It is known to infest about 500 acres of cotton in central Georgia and has demonstrated resistance to extremely high rates of glyphosate applied in the field under excellent growing conditions. Numerous field and greenhouse studies completed in 2005 indicated probable Palmer amaranth resistance to glyphosate, but heritability studies to determine whether the resistance trait is passed on to progeny have been completed and confirm resistance of this population to glyphosate. This development is considered a serious threat to future cotton production throughout the region. Palmer amaranth is considered a very troublesome weed in cotton production systems due its high competitive ability with neighboring crop plants and its potential to interfere with cotton harvest. Palmer amaranth resistance to glyphosate is also of considerable concern because this species commonly hybridizes with other closely related pigweed species, including redroot pigweed and smooth pigweed (Stubbendieck et al., 1994).

Since the introduction of cotton with the Roundup Ready trait in 1997, glyphosate has been the most effective tool to manage Palmer amaranth; most alternative control options are much less effective than glyphosate in controlling typical (susceptible) populations (Culpepper, 2005). Consequently, farmers have relied heavily on glyphosate to control weeds in cotton (Culpepper, 2005). About 94% of Georgia's 1.21 million acres of cotton were Roundup Ready in 2005. The long-term effects of glyphosate-resistant Palmer amaranth on cotton production are unknown, but if this weed species can no longer be controlled with glyphosate, alternative herbicide chemistries and aggressive tillage may once again have to be used for management, increasing both time and costs to growers (Culpepper, 2005).

Potential Resistance to Glyphosate – Common Lambsquarters

Although the variable response of common lambsquarters to glyphosate has received widespread attention in the Midwest including Wisconsin (Boerboom, 2004) over the last few years, it probably has been more of a prominent issue in Ohio than elsewhere. Confirmation and characterization of common lambsquarters resistance to glyphosate has been difficult. As early as 2003, Ohio State University weed scientists characterized several common lambsquarters populations as having reduced sensitivity to glyphosate; subsequent research on additional common lambsquarters biotypes found several of these resistant to glyphosate (Loux and Stachler, 2005). However, these biotypes demonstrated a relatively low level of resistance to glyphosate, especially compared to the high level of resistance exhibited by most ALS-inhibitor resistant weed species. For glyphosate-resistant common lambsquarters, a glyphosate rate of two to four times the labeled rate (0.75 lb ae/acre) is typically needed to obtain the same response as for susceptible or sensitive biotypes. Smaller resistant plants are typically more easily controlled than larger resistant plants, but some small plants may survive treatment with four times the labeled rate (Loux and Stachler, 2005).

Ohio State University weed scientists have concluded that some common lambsquarters populations in Ohio are developing resistance to glyphosate, and expect no abatement of this trend due to the selection pressure resulting from the over-reliance on glyphosate in weed management programs (Loux and Stachler, 2005). However, they acknowledge that several other factors have likely contributed to the variable response of common lambsquarters response to glyphosate, including glyphosate rate, adjuvant use, plant stage of growth (size and age), and environmental conditions. Results from 2004 field experiments indicated that common lambsquarters may be more sensitive to glyphosate formulation and surfactant rate, and possible surfactant type, than other weed species. In a recent summary of their greenhouse, growth chamber, and field research, Loux et al. (2005) indicated that there appears to be reduced sensitivity of some common lambsquarters biotypes to rates of glyphosate up to 3 lb ae/acre, but that such expression of this response varies among studies. Results of a single 2005 field study did not corroborate those from greenhouse and growth chamber studies. They concluded that reduced sensitivity of some common lambsquarters biotypes to glyphosate may be an evolved response, and could be a contributing factor to poor performance of postemergence glyphosate treatments occasionally observed in growers' fields (Loux et al., 2005).

Loux and Stachler (2005) recommend that the simplest and most effective method for avoiding problems with postemergence common lambsquarters control may be to include an herbicide that provides residual control in preplant or preemergence burndown treatments in soybean. Their suggestions for maximizing glyphosate activity on lambsquarters include the following:

- Apply glyphosate when common lambsquarters are less than 6 inches tall
- Increase glyphosate rate to at least 1.1 lb ae/acre if plants are taller than 6 inches
- Increase glyphosate rate to at least 1.1 lb ae/acre and add surfactant when plants are under stress associated with non-favorable environmental conditions
- Consider use of additional surfactant for spray volumes more than 15 gpa
- Include 2,4-D ester with glyphosate applied preplant

Potential Resistance to Glyphosate – Common Waterhemp

Inconsistent control of common waterhemp populations with glyphosate has been the focus of much research, including populations found in Iowa (Hartzler et al., 2002; Owen, 2002) and Illinois and Missouri (Smeda and Schuster, 2002). Results from these studies suggest that individual common waterhemp plants within populations are resistant to glyphosate, but as noted above for common lambsquarters, these results have also been variable, making it difficult to confirm resistant to glyphosate at the population level.

However, common waterhemp with potential resistance to glyphosate has recently been found in two soybean fields in northwest Missouri (Bradley, 2005b). The potentially resistant weeds were found in fields planted to Roundup Ready soybeans continuously since 1996, and where glyphosate had been the sole herbicide used. Problems developed with common waterhemp control over the last three years at one of these sites, and the grower continued to use glyphosate at greater rates. In greenhouse studies, waterhemp plants (from seed collected in 2004) continued to grow after being treated with glyphosate at rates as high as 6 lb ae/acre. Studies have been initiated to determine whether a resistance trait is present in seeds collected from plants that survive glyphosate treatment. This development of glyphosate-resistant common waterhemp is of considerable concern in Missouri as this weed species is their No. 1 problem in corn and soybean production.

Potential Resistance to Glyhosate – Giant Ragweed

In Ohio, giant ragweed control with glyphosate in soybean has reportedly become more variable in recent years, indicating a potential change in the sensitivity of giant ragweed populations to glyphosate (Stachler et al., 2005). Several separate samples of giant ragweed seed were collected in 2004 from a field where glyphosate had been the sole herbicide used for at least four years, and where glyphosate appeared to less effective over time. The results of recent studies using these seed samples suggest that a giant ragweed biotype with reduced sensitivity to glyphosate has been selected (Stachler et al., 2005). This biotype survived treatment with glyphosate at rates up to 3 lb ae/acre in greenhouse studies, and multiple treatments with glyphosate totaling more than 4.5 lb ae/acre in field studies. Plants that survived treatment in the field with glyphosate at rates up to 3 lb ae/acres produced viable seeds. Stachler et al. (2005) concluded that reduced sensitivity of this giant ragweed biotype to glyphosate may be an evolved response (suggesting a resistance trait or traits), which could likely occur in other fields with similar glyphosate selection intensity.

Summary

The number of glyphosate-resistant weed species has steadily increased to eight species since the introduction of soybean, corn, and cotton cultivars with Roundup Ready traits in the 1990's (Heap, 2005). Perhaps the most notable case is glyphosate-resistant horseweed, which has spread to 13 other states since its discovery in no-tillage soybean production systems in Delaware in 2001 (Van Gessel, 2001). Common ragweed resistance to glyphosate has occurred in a long-term soybean production system in Missouri (Bradley, 2005a; Smeda et al., 2005). Also of note is the recent confirmation of glyphosate-resistant Palmer amaranth in Georgia (Culpepper, 2005); although this weed species is rare in the upper Midwest, it readily hybridizes with species that are common in our cropping systems such as redroot pigweed and smooth pigweed (Stubbendieck et al., 1994). The variable response of other troublesome weed species such as common lambsquarters, common waterhemp, and giant ragweed to glyphosate has also become an important issue in several states across the Midwest (Boerboom, 2004; Bradley, 2005b; Loux and Stachler, 2005, Stachler et al., 2005).

These cases of weed resistance to glyphosate suggest that there may be far fewer constraints to the evolution of weed resistance to glyphosate than were proposed not that long ago (Bradshaw et al., 1997). These cases of weed resistance or variable response to glyphosate do not appear to be extraordinary. Although it is very difficult to quantify the selection intensity or pressure associated with glyphosate use in these cases, it seems that intensive use of glyphosate over time is a common factor. With the popularity of Roundup Ready soybean, the apparent increasing acreage planted to Roundup Ready corn, and the recent introduction of Roundup Ready alfalfa, the potential exists for an increasing intensity of selection for glyphosate-resistant weeds in Wisconsin. To sustain glyphosate as a useful, weed management tool, it seems that these cases suggest that selection associated with glyphosate must be reduced by integration with other weed management practices.

References

Anonymous. 2005. Monsanto biotechnology trait acreage: Fiscal years 1996 to 2004. Monsanto. 1 page.

Boerboom, C. 2004. Glyphosate management for Wisconsin. Proc. Wis. Fert. Aglime and Pest Mgmt. Conf. 43:278-280.

Bradley, K. 2005a. Glyphosate-resistant weeds. Univ. of Missouri Ext. Internet: http://ipm.missouri.edu/ (January 2005).

Bradley, K. 2005b. Waterhemp 'potentially resistant' to herbicide found northwest Missouri soybean fields. Univ. of Missouri Ext. Internet: http://muextension.missouri.edu/ (October 2005).

Bradshaw, L.D., S.R. Padgette, S.L. Kimball, and B.H. Wells. 1997. Perspectives on glyphosate resistance. Weed Technol. 11.189-198.

Culpepper, S. 2005. Resistant pigweed plagues central Georgia cotton. Univ. of Georgia. Internet: http://www.plantmanagementnetwork.org/ (September 2005).

Hartzler, B., J. Kolin, and D. Refsell. 2002. Variable glyphosate tolerance in Iowa waterhemp. Iowa State University Weed Science Online. Internet: www.weeds.iastate.edu (January 2003).

Heap, I. 2005. International survey of herbicide resistant weeds. Herbicide Resistance Action Committee, North American Herbicide Resistance Action Committee, and Weed Sci. Soc. Am. Internet: http://www.weedscience.org/ (December 2005).

Holm, L., J. Doll, E. Holm, J. Pancho, and J. Herberger. 1997. World Weeds: Natural Histories and Distribution. New York: J. Wiley. Pages 226-235.

Loux, M., and J. Stachler. 2005. Lambsquarters control issues in Roundup Ready soybeans. Crop Observation and Recommendation Network. Ohio State Univ. Internet: http://extension.osu.edu/ (January 2005).

Loux, M., J.M. Stachler, B.A. Miller, and J.B. Taylor. 2005. Response of common lambsquarters to glyphosate in the greenhouse and growth chamber. North Central Weed Sci. Soc. Abstr. 60.202.

Owen, M.D.K. 2002. Glyphosate resistant waterhemp in Iowa. North Central Weed Sci. Soc. Abstr. 57:210.

Pollard, J.M., B.A. Sellers, and R.J. Smeda. 2004. Differential response of common ragweed to glyphosate. North Central Weed Sci. Soc. Abstr. 59.27.

Pratley, J., P. Baines, R. Eberbach, M. Incerti, and J. Broster. 1996. Glyphosate resistance annual ryegrass. Page 126 *in* J. Virgona and D. Michalk, eds. Proc. 11th Annual Conf. Grasslands Soc. of New South Wales. Wagga Wagga Australia: The Grasslands Soc. of NSW.

Sellers, B.A., J.M. Pollard, and R.J. Smeda. 2004. Comparative biology of glyphosate-resistant and glyphosate-susceptible common ragweed. North Central Weed Sci. Soc. Abstr. 59.54.

Smeda, R.J., J.M. Pollard, and B.A., Sellers. 2005. Documenting the extent of glyphosate-resistant common ragweed. North Central Weed Sci. Soc. Abstr. 60.152.

Smeda, R.J., and C.L. Schuster. 2002. Waterhemp resistance to glyphosate: fact or fiction? North Central Weed Sci. Soc. Abstr. 57:209.

Stachler, J.M., M.M. Loux, B.A. Miller, and J.B. Taylor. 2005. Response of a giant ragweed population to glyphosate. North Central Weed Sci. Soc. Abstr. 60.199.

Stoltenberg, D.E. 1995. Herbicide-resistant weeds in Wisconsin and the Midwest. Proc. Wis. Fert. Aglime and Pest Mgmt. Conf. 34:225-235.

Stoltenberg, D.E. 2004. Forces driving the development of herbicide-resistant weeds. Proc. Wis. Fert. Aglime and Pest Mgmt. Conf. 43:282-286.

Stoltenberg, D.E., and R.J. Wiederholt. 1995. Giant foxtail (*Setaria faberi*) resistance to aryloxyphenoxypropionate and cyclohexanedione herbicides. Weed Sci. 43:527-535.

Stubbendieck, J., F.Y. Friisoe, and M.R. Bolick. 1994. Weeds of Nebraska and the Great Plains. Nebraska Dept. of Agric. Lincoln, NE. 589 pages.

Van Gessel , M.J. 2001. Glyphosate-resistant horseweed from Delaware. Weed Sci. 703-705.

Van Gessel, M., B. Majek, and R. Ritter. 2004. Management of glyphosate-resistant horseweed (or marestail) in no-tillage soybeans. Internet: http://ag.udel.edu/extension/agnr/weeds.htm (December 2005).

Volenberg, D.S., D.E. Stoltenberg, and C.M. Boerboom. 2000. *Solanum ptycanthum* resistance to acetolactate synthase inhibitors. Weed Sci. 48:399-401.

Volenberg, D.S., D.E. Stoltenberg, and C.M. Boerboom. 2001. Biochemical mechanism and inheritance of cross-resistance to acetolactate synthase inhibitors in giant foxtail. Weed Sci. 49:635-641.

Volenberg, D.S., D.E. Stoltenberg, and C.M. Boerboom. 2002. Green foxtail (*Setaria viridis*) resistance to acetolactate synthase inhibitors. Phytoprotection. 83:99-109.

Wiederholt, R.J., and D.E. Stoltenberg. 1995. Cross-resistance of a large crabgrass (*Digitaria sanguinalis*) accession to aryloxyphenoxypropionate and cyclohexanedione herbicides. Weed Technol. 9:518-524.

GLYPHOSATE USE PATTERNS IN WISCONSIN

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GLYPHOSATE RESISTANCE STRATEGIES AND MANAGEMENT RECOMMENDATIONS FOR PROBLEM WEEDS

Chris Boerboom[1]

Introduction

Several common weeds within Wisconsin have the potential to develop glyphosate-resistance based on their evolution of glyphosate-resistance or reduced sensitivity in other Midwestern states. These weeds include horseweed, common lambsquarters, waterhemp, common ragweed, and giant ragweed, but other weeds also have the potential for developing resistance. Some of these weeds also pose problems in obtaining consistent control even without any type of herbicide resistance and are considered "problem weeds".

Problem Weed Management vs. Herbicide Resistance Management

In discussing management options, a clear distinction should be made between recommendations that are intended to prevent or delay herbicide resistance and recommendations that will improve the control of problem weeds. These two sets of recommendations may share some of the same tactics, but the goals are different. Management tactics to control problem weeds may use multiple application timings to reduce the risk of poorly timed herbicides or to control late emerging weeds. The result is to reduce risks and increase yield protection. For instance, a preemergence herbicide might be used and followed with a postemergence herbicide application to improve giant ragweed control. Or, an early postemergence application might be followed with a later postemergence application. However, depending on the herbicides used in the system, there may still be moderate or high selection intensity for herbicide resistance.

The selection intensity for glyphosate resistance depends on the frequency of use and the number of acres or number of weeds treated. Applying glyphosate as the sole herbicide each year creates a high selection intensity and is certainly a poor management plan. A better alternative is to rotate herbicide modes of action between years. Adding a preemergence residual herbicide may reduce the total number of weeds treated postemergence with glyphosate, but many plants may still be treated postemergence with glyphosate. Using this approach on an annual basis reduces the selection intensity, but does not provide the best management option to delay resistance. The best resistance management scenario might be to use alternate herbicide modes on action in one year and rotate with a program where a preemergence herbicide is followed with glyphosate in the second year. A range of glyphosate resistance management strategies certainly exist. I will continue to argue that Wisconsin should use the best alternatives to reduce the selection intensity for glyphosate and a key tactic is rotating among herbicide modes of actions.

Proactive vs. Reactive Herbicide Resistance Management

Despite the clear evidence that glyphosate-resistance can develop in key Midwestern weeds, Wisconsin growers still need to decide if they should use tactics to delay or prevent resistance. Two general management strategies can be considered – reactive management or proactive management.

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Reactive management is the strategy of using the herbicide until resistance develops. Only after resistance occurs will the grower react to manage the herbicide resistant weed. It is reasonable to assume that the cost of weed control will increase after resistance develops because an additional herbicide will be needed or weed control may not be as good. In the context of glyphosate, a scenario could be relying on single or multiple glyphosate applications every year until glyphosate-resistant develops. The additional future cost with this strategy is that weed control costs will be higher in future years when an herbicide tank mixture is required. In addition, yield losses may occur during the year or two when glyphosate fails to control the weed and other herbicide options are applied too late to achieve adequate control.

The proactive management strategy employs resistance delaying tactics prior to the development of resistance. This strategy will likely increase the current cost of management if the tactics used to delay resistance include herbicide tank mixtures or preemergence herbicides. Even herbicide rotations may increase these short-term costs depending on the herbicide programs used. The economic choice between these two strategies depends on the number of years that it takes for resistance to develop, the cost of the delaying tactics, the cost of controlling the resistant weed after it develops, and the interest rate. Reactive management is economically wise if resistance is not likely to occur for a long time into the future. However, investing in proactive management makes more sense if resistance is likely to occur in a shorter time frame or if the cost of controlling the herbicide resistant weed is high.

Waterhemp management in soybean was recently used as a case study for this economic decision (Mueller et al. 2005). In the case of proactive management, the authors proposed switching from two in-season glyphosate applications to a preemergence residual herbicide program followed by one in-season glyphosate application. Thus, proactive management increased total cost by $3.66/a in the soybean year or $1.83/a when averaged across a corn-soybean rotation. If glyphosate-resistant waterhemp developed, the authors estimated it would cost an additional $35.83/a to control waterhemp in soybean. Thus, the cost of resistant waterhemp would be $17.91/a when averaged across a corn-soybean rotation. Based on these costs and assuming an 8% interest rate, the benefit of proactive vs. reactive management can be calculated in relation to the number of years for resistance to develop. With the low cost of proactive management and high cost of controlling glyphosate-resistant waterhemp, proactive management is a better economic choice if resistance happens in less than 28.5 years. Even if the cost of controlling glyphosate-resistant waterhemp was only an additional $10/a in soybean (or $5/a averaged over 2 years), proactive management is still a better choice if resistance develops in 12 years or less.

A simple matrix to compare proactive management costs against the cost of controlling a glyphosate-resistant weed is shown in Figure 1, which is based on the equation used by Mueller et al. (2005). It is logical to just wait until resistance occurs if the cost to control a resistant weed is very low. In contrast, the benefit of investing to prevent resistance is great if the cost of controlling a resistant weed is high, even if the resistance does not occur for many years into the future. This suggests that weeds that are currently difficult or expensive to control without glyphosate may be the best targets for proactive management.

Figure 1. Matrix of proactive management costs vs. the costs of controlling glyphosate-resistant weeds.

		Additional annual cost for proactive management				
		$2/a	$4/a	$6/a	$8/a	$10/a
Additional annual cost to control the glyphosate-resistant weed	$2.50/a	3	-	-	-	-
	$5/a	11	3	-	-	-
	$10/a	20	11	6	3	-
	$20/a	29	20	15	11	9

Proactive management pays if resistance occurs before the number of years listed in the table

This example assumes a discount rate of 8%.

The increasing frequency of glyphosate-resistant weeds over the past few years should provide additional justification for proactive management strategies. Proactive management strategies can incorporate several approaches such as herbicide mode of action rotation, crop rotation, and tillage or cultivation. However, for any individual tactic to be successful, it must reduce the selection intensity for glyphosate.

Management of Specific Problem Weeds

Common lambsquarters: The consistency of common lambsquarters control in soybean seems to be more variable in recent years. The simplest and most economic tactic to include another herbicide with glyphosate would be to tank mix Harmony GT with glyphosate. However, some people are concerned with the risk of injury from Harmony GT and the application should be made to smaller lambsquarters to obtain the most activity from the Harmony GT. Alternatively, it may by more logical to use a soil-applied herbicide like Sencor, Valor, Intrro, Prowl, or Turbo to reduce early season common lambsquarters control prior to applying glyphosate postemergence. The use of soil-applied herbicides will probably have a greater benefit in row soybean as compared to drilled soybean. Several good non-glyphosate herbicides are available to control common lambsquarters in corn. Shifting to a non-glyphosate program in corn would be a good approach to reducing the selection intensity for glyphosate resistance in common lambsquarters.

Waterhemp

Waterhemp has a high probability of being ALS resistant in Wisconsin. As a consequence, few postemergence options for non-glyphosate herbicides are available in soybean. Sencor, Valor, Intrro, Prowl, and Turbo are some of the more economical soil-applied herbicides that should improve the postemergence timing of glyphosate applications in soybean. Because waterhemp emerges later than several other common weeds, an early season residual herbicide will allow glyphosate to be delayed slightly. Postemergence options other than glyphosate are limited to Cobra, Flexstar, and Ultra Blazer. Several good non-glyphosate herbicides are available to control waterhemp in corn. Alternating to a non-glyphosate program in corn would be a good approach to reducing the selection intensity for resistance in waterhemp.

Horseweed

As a winter annual, horseweed is a primary threat in no-till production. Tank mixing 2,4-D with glyphosate and making applications before horseweed exceeds 4 to 6 inches in height are standard recommendations. This is a low cost, proactive tactic.

Giant Ragweed

Giant ragweed is a challenge in both corn and soybean because preemergence herbicides do no give adequate or consistent control, the rapid growth rate of seedlings makes the timing of postemergence herbicides challenging, and ALS-resistant populations limit herbicide options in soybean (e.g., resistance to FirstRate). In corn, a two pass program is necessary for adequate control of moderate infestations of giant ragweed. Preemergence herbicide options include atrazine, Hornet, Camix, Lumax, or acetanilide plus atrazine premixes. These herbicides could be followed by several effective postemergence herbicides. To reduce glyphosate selection intensity, a non-glyphosate herbicide could be used in corn because glyphosate may have greater value if used in soybean. FirstRate is the most effective preemergence herbicide in soybean if the giant ragweed is not ALS resistant. Most other soil-applied soybean herbicides will only suppress giant ragweed. However, they may still have value in stunting the ragweed so that postemergence applications are more effective. FirstRate, Cobra, and Flexstar are the most effect-tive postemergence options in soybean other than glyphosate.

Common Ragweed

Common ragweed has not been a major problem in Wisconsin with the exception of ALS-resistant populations. However, common ragweed warrants our attention because of the potential for glyphosate resistance. Many of the soil-applied herbicides used to control common lambsquarters will be effective with common ragweed with the exception of Prowl, which does not control ragweed. Valor will also be less effective on ragweed than lambsquarters. Several good non-glyphosate herbicides are available to control common lambsquarters in corn. Alternating to a non-glyphosate program in corn would be a good approach to reducing the selection intensity for resistance in common ragweed.

Reference

Mueller, T.C., P.D. Mitchell, B.G. Young, and A.S. Culpepper. 2005. Proactive versus reactive management of glyphosate resistant or –tolerant weeds. Weed Technol. 19:924-933.

ATRAZINE REINTRODUCTION

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PESTICDE REREGISTRATION

Dave Fredrickson [1/]

ABSTRACT

Pesticide registration is the domain of the Federal Environmental Protection Agency, (EPA). Registration is intended to maximize the benefits from pesticide use while minimizing the risks to users, the food supply and the environment. Pesticide registration is a requirement of the Federal Insecticide, Fungicide and Rodenticide act, (FIFRA), which was last revised in 1996 by the Food Quality Protection Act, (FQPA). FQPA made some big changes in FIFRA, revising the law from a risk/benefit approach to a de minimis risk, (meaning to minimize risks to persons from the food supply) process for establishing tolerances for pesticides in food and for mitigating risks from registered pesticides. One of the biggest tasks assigned to EPA was to reregister all pesticide active ingredients and review their uses within 10 years.

EPA is currently on track to complete review of all active ingredients by the end of this year, at which time a new process of rereview will begin. The impact to users of pesticides has been and will continue to be dealing with new label provisions that are designed to mitigate the risks to users and the environment. The presentation will discuss how reregistration is completed, what role states or the general public can play in reregistration decisions, and what applicators should watch for on labels as reregistration decisions are implemented.

Rereview of pesticides will be required at least once every 15 years in the future, but EPA has not decided whether the schedule will be driven by need, or will be done chronologically. EPA has instituted cumulative reviews for active ingredients that have a similar mode of action, such as the cumulative review recently completed for the Organophosphate insecticides. The rereview process and reregistration will impact what crops can be treated with individual pesticides and how the pesticides must be used. Applicators should expect more labels to have maximum annual application rates and more complex labeling aimed at preventing damage from pesticide use. The recent decisions on 2,4-D will be presented and discussed as an example of how EPA registration activities will impact pesticide users.

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ALLELOPATHY IN WEEDS AND CROPS: MYTHS AND FACTS

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Allelopathy is defined as the effect of one plant on another through the release of a chemical compound into the environment (Bhowmik and Inderjit, 2003). Allelopathic compounds, often considered plant-produced herbicides, can inhibit growth of nearby plants of the same and/or other species. The observation of allelopathic plant suppression is not new. Theophrastus observed that chickpea reduced nearby weed growth as early as 300 B.C., and Plinus Secundus (1 A.D.) reported that corn was "scorched" by chickpea, barley, and bitter vetch (Singh et al., 2001). While the concept of allelopathy is not original, effective demonstration of allelopathy on plant growth and the subsequent reliable application in agricultural pest management have been relatively minimal.

Many crop and weed species have been observed to have allelopathic properties (Table 1). Over 240 weed species have been reported to be allelopathic to other nearby plants of the same species (autotoxicity) or other crop and weed species. The use of allelopathy to favor the crop over weeds has been investigated in three aspects: 1) as an allelopathic winter cover crop that suppresses weeds prior to the cropping season; 2) as a living mulch during the cropping season to reduce weed interference; and, 3) as an isolated compound from an allelopathic plant, applied as an herbicide. To date, the use of allelopathic cover crops, such as rye and oat, has resulted in the greatest application of this concept in agriculture. Rye residue has been reported to reduce green foxtail, redroot pigweed, common ragweed, and common purslane emergence by 80, 95, 43, and 100%, respectively (Putnam and DeFrank, 1983). Oat allelopathy differs among crop cultivars. Grimmer and Masiunas (2005) reported that 20 of 24 tested oat cultivars reduced common lambsquarters germination, but that the amount of reduction ranged from 10 to 86% among cultivars. The timing, growth stage, soil type, and climatic conditions during cover crop growth also affect the amount observed allelopathy.

Table 1. Selected common crops and weeds with reported allelopathic properties. Adapted from Qasem and Foy (2001) and Batish et al. (2001).

Crops		Weeds
alfalfa	soybean	Canada thistle
asparagus	sunflower	cocklebur
barley	tomato	common lambsquarters
bean	wheat	field bindweed
beet		foxtail sp.
broccoli		jimsonweed
cabbage		kochia
clover		pigweed sp.
corn		quackgrass
cucumber		ragweed sp.
oat		smartweed sp.
pea		velvetleaf
potato		wild mustard
rapeseed		wild oat
rice		yellow nutsedge
rye		

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The effect of allelopathic crops on weed growth has been very difficult to isolate. Weed suppression by neighboring plants is a combination of allelopathy and physical interference. Physical interference includes impedance of light, water, nutrients, and other resource by the cover crop residue or living mulch. Allelopathic compounds are often very complex and short-lived, and therefore are difficult to isolate and identify. Allelopathy research conducted in greenhouses often doesn't account for the effect of microorganisms, climate, and soil type, and thus often exaggerates the potential weed suppression compared to field conditions. In field research, the effect of physical interference is difficult to separate from allelopathy. Despite these difficulties in research methodology, a few studies have demonstrated allelopathic effects of cover crops on weed growth. Creamer et al. (1996), for example, compared physical suppression by rye and barley residue that had been leached of allelopathic compounds with similar residue containing allelopathic compounds. Yellow foxtail emergence reduction by rye residue was attributed to physical suppression alone, while a combination of physical suppression and allelopathy in barley reduced yellow foxtail emergence by 81%. Petersen et al. (2001) reported that isolated allelopathic compounds from turnip-rape plants suppressed several weed species, including smooth pigweed, spiny sowthistle, and barnyardgrass.

Allelopathic species have also served as the source of plant-derived herbicides. The synthetic herbicides mesotrione (Callisto®) and glufosinate (Rely®, Liberty®) were originally derived from allelopathic compounds. Mesotrione is derived from leptospermone, a compound isolated from the callistemon or bottle brush plant. Glufosinate is derived from a compound found in microbes. The ability to develop more herbicides from allelopathic compounds is limited by several factors. Allelopathic compounds tend to be short-lived in the environment, complex, and unpredictable. Additionally, they are often non-selective in their control, expensive to synthesize, and in some cases, present potential mammalian toxicity, carcinogenic, and allergenic concerns. Despite these limitations, herbicides based on allelopathic compounds often represent novel target sites important in managing pesticide resistance, are water soluble, and are perceived as more "environmentally-benign."

Over 2,900 papers have been published on allelopathy for weed control, dating back to 300 B.C., yet weeds continue to be a concern in allelopathic crops. While allelopathic weed control has often proven difficult to research and demonstrate, it can be applied as a component in an integrated pest management system. In addition to weed suppression benefits, several allelopathic compounds also suppress pathogen and nematode pressure. Current research to increase the reliability of allelopathic pest suppression and to breed for increased allelopathy in crops may improve the practical applications of this concept.

References

Batish, D.R., H.P. Singh, R.K. Kohli, and S. Kaur. 2001. Crop allelopathy and its role in ecological agriculture. p. 121-162. *In* R.K. Kohli, P.S. Harminder, and D.R. Batish (ed.) Allelopathy in Agroecosystems. Food Products Press, New York.

Bhowmik, P.C., and J. Inderjit. 2003. Challenges and opportunities in implementing allelopathy for natural weed management. Crop Protection 22:661-671.

Creamer, N.G., M.A. Bennett, B.R. Stinner, J. Cardina, and E.E. Regnier. 1996. Mechanisms of weed suppression in cover crop-based production systems. HortScience 31:410-413.

Grimmer, O.P. and J.B. Masiunas. 2005. The weed control potential of oat cultivars. HortTechnology 15:140-144.

Petersen, J., R. Belz, F. Walker, and K. Hurle. 2001. Weed suppression by release of isothiocyanates from turnip-rape mulch. Agron. J. 93:37-43.

Putnam, A.R., and J. DeFrank. 1983. Use of phytotoxic plant residues for selective weed control. Crop Protection 2:173-181.

Qasem, J.R., and C.L. Foy. 2001. Weed allelopathy, its ecological impacts and future prospects: a review. p. 43-120. *In* R. K. Kohli, P. S. Harminder, and D. R. Batish (ed.) Allelopathy in Agroecosystems. Food Products Press, New York.

Singh, H.P., D.R. Batish, and R.K. Kohli. 2001. Allelopathy in Agroecosystems: an overview. p. 1-42. *In* R.K. Kohli, P.S. Harminder, and D.R. Batish (ed.) Allelopathy in Agroecosystems. Food Products Press, New York.

AUTHOR INDEX