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

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2010 NUTRIENT WATCH LIST

Carrie A.M. Laboski [1/]

Introduction

Nitrogen is a very important nutrient for corn production and agronomists invest a lot of time in determining an appropriate application rate/time, assessing N credits from manure and legumes, and worrying about N losses. All aspects of N management impact profitability and environmental quality. Phosphorus is another agronomically important nutrient, which, in recent years, has become a driving force in nutrient management plans. So much focus is placed on N and P, that at times, other nutrients may not be given adequate attention. The goal of this paper is to highlight two nutrients, which will likely have increasing agronomic importance in Wisconsin cropping systems.

Potassium

It should come as no surprise that potassium is on the 2010 Watch List. While potash prices today are substantially less than a year ago, potash prices are still approximately four times greater than ten years ago. A direct result of high potash prices is reduced or eliminated application rates. In 2009, 40 and 41% of alfalfa samples submitted as abnormal and normal in appearance, respectively, for plant analysis at the UW Soil and Plant Analysis Lab (SPAL) were below optimum in K concentration. Low concentrations of alfalfa tissue K occurred in 17 and 14% of samples submitted as abnormal and normal, respectively, in 2008. Of all corn samples submitted for plant analysis 18 and 14% were low in K in 2009 and 2008, respectively. These data suggest that K is becoming a bigger problem in alfalfa and corn. In addition, there have been increasing observations of K deficiency in soybean throughout Wisconsin.

Potassium deficiency is characterized by yellowing of leaf margins on older leaves of corn and soybean, and yellow dots on alfalfa leaf margins. Photos 1, 2, and 3 depict K deficiency in alfalfa, corn, and soybean. Remind growers that K is an essential macro-nutrient and it should not be ignored to for many years. Potassium deficiency will result in yield loss, and for alfalfa reduces stand persistence. For growers in cash limited situations that have manure, work with them to determine how best to allocate the K in manure between fields.

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Photo 1. Potassium deficiency in alfalfa. Photo credits: E. Birschbach.

Photo 2. Potassium deficiency in corn. Photo credits: R. Wolkowski


Photo 3. Potassium deficiency in soybean. Photo credits: C.A.M. Laboski

Sulfur

The second nutrient on the 2010 Watch List is sulfur. Historically, Wisconsin has had a “free” source of S for crop production. That source was atmospheric deposition of sulfate, which was a result of industrial air pollution. Since the passage of the Clean Air Act in 1970, S emissions have been reduced. Figure 1 shows sulfate deposition in 1985 while Figure 2 shows sulfate deposition in 2008. There has been a substantial reduction in S deposition over Wisconsin in the past 20+ years and this may impact the need for S fertilization in the future. In fact, 85% of alfalfa tissues samples submitted to SPAL as abnormal in 2009 were low in S; while 44% of the normal samples were low in S. A similar trend occurred in 2008 where 67% of abnormal and 39% of normal alfalfa samples were low in S. Less than 10% of all corn samples were low in S over the same time period.

Sulfur deficiency in alfalfa appears as a yellowing of newer growth along with stunted growth (Photo 4). In corn S deficiency results in general yellowing of the foliage with newer leaves being lighter in color and perhaps also having interveinal chlorosis (Photo 5). Symptomology of S deficiency in soybean is similar to alfalfa (Photo 6). Sulfur deficiency is more likely to be observed on fields with low organic matter, several years since the last manure application, and soils with low subsoil sulfur. Past Wisconsin research found that when sulfur is deficient, application of 25 lb S/a could increase alfalfa yields 0.1 to 0.5 tons/a (Kelling et al., 2002), making application of S economically beneficial.

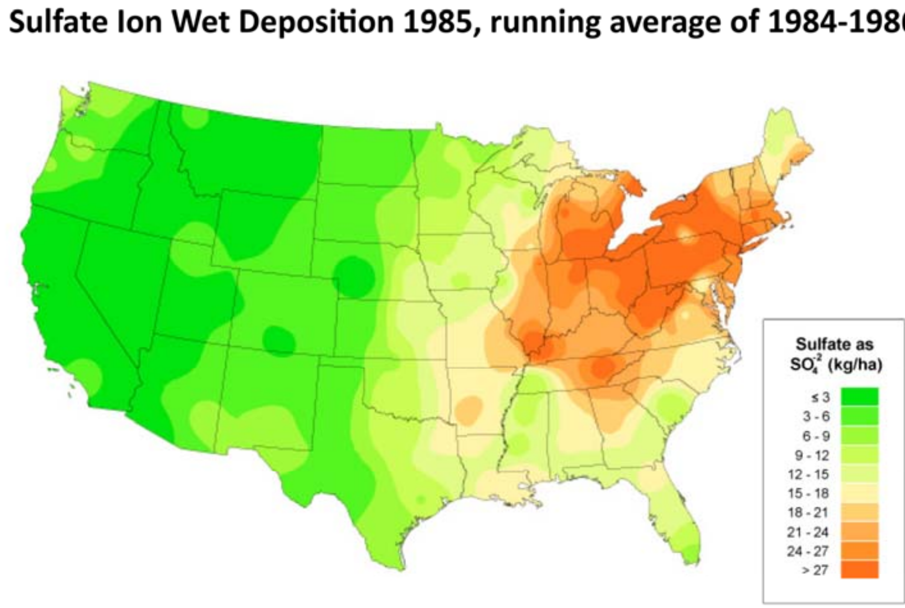

Figure 1. Sulfate ion wet deposition in 1985, presented as a running average of 1984-1986.

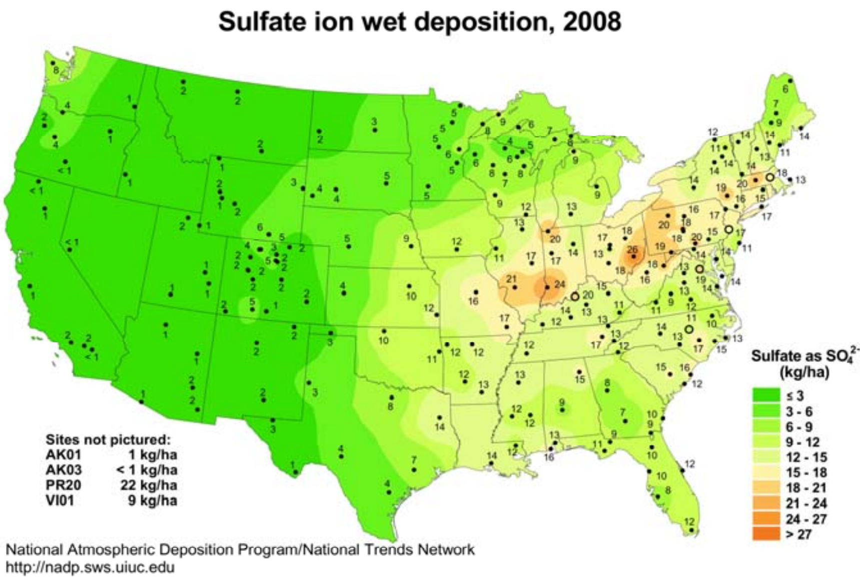

Figure 2. Sulfate ion wet deposition in 2008.

Photo 4. Sulfur deficiency in alfalfa (left). Photo credits: Montana State Univ.

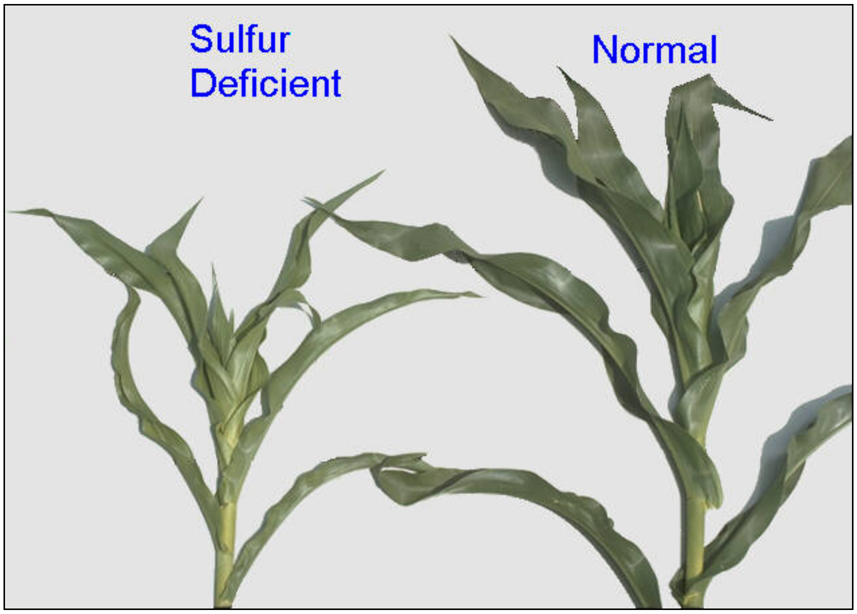

Photo 5. Sulfur deficiency in corn. Photo credits: R. Hoeft

Photo 6. Sulfur deficiency in soybean. Photo credits: Better Crops 1997. Vol. 81 (3):8-13.

Summary

Sound nutrient management planning requires that all nutrients, not just nitrogen and phosphorus, are managed to ensure long term farm profitability. Potassium and sulfur are two nutrients that may be limiting crop yield now and in the future. Use soil and tissue analysis to determine fields that may benefit from application of these two nutrients.

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THE SOYBEAN APHID/POTASSIUM RELATIONSHIP

David B. Hogg and Claudio Gratton [1/]

Soybean aphid population dynamics are influenced by a number of factors, most notably the "top down" effects of natural enemies (predators, parasitoids, and pathogenic fungi) and the "bottom up" effects of the host soybean plant. As for the latter, host plant effects can include things such as plant stage or maturity, and plant nutritional status. For example, plant nitrogen has been found to be an important factor in cotton aphid growth and reproduction on cotton plants (Nevo and Coll, 2001). In the case of the soybean aphid, following the 2000 discovery of this pest in Wisconsin, entomologists and agronomists noticed that infestations in soybean seemed to be more severe in potassium deficient fields.

Subsequent research has proved the association of potassium deficiency with soybean aphid infestations, plus we now have a better understanding of why this occurs (Myers et al., 2005; Myers and Gratton, 2006; Noma et al., 2010). What happens is that low potassium actually makes soybean plants more nutritious for soybean aphids, promoting higher aphid reproduction and leading to more rapid aphid population increase. To give an idea of how this might work, under field conditions in a potassium deficient field an aphid infestation can increase from 10 per plant to 230 per plant in 10 days; in a field with adequate potassium, that same population would increase from 10 to 150 aphids per plant. Further research (Walter and DiFonzo, 2007) suggests that potassium deficient beans have a greater percentage of asparagine in the plant phloem where the aphids are feeding. Asparagine is known to be an important amino acid for aphid nutrition. We also think the yellowing associated with potassium deficient soybean leaves may preferentially attract migrating soybean aphids, placing potassium deficient fields at a further disadvantage. The color yellow has been generally shown to be highly attractive to aphids.

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[1/] Professor and Associate Professor, Dept. of Entomology, Univ. of Wisconsin-Madison, 1630 Linden Dr., Madison, WI 53706.

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2009 WHITE MOLD AND SOYBEAN: IMPACTS AND RECOMMENDATIONS

Paul Esker[1], Angie Peltier, Nancy Koval, John Gaska, Mark Martinka, and Shawn Conley

Across Wisconsin in 2009, the number one soybean disease observed was Sclerotinia stem rot (SSR), or white mold. Weather conditions around flowering were quite favorable for infection and subsequent development of SSR in 2009 (Figure 1). In Figure 2, we show examples of differences in symptoms we observed throughout the state for SSR and these symptoms will be discussed in more detail in the next section.

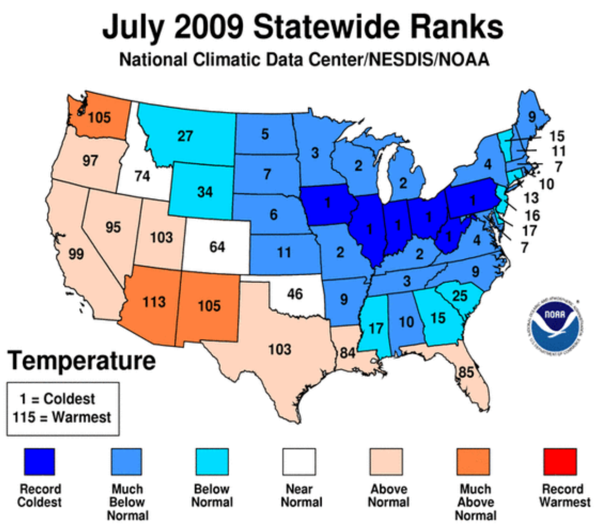

Figure 1. Statewide ranks for July 2009 air temperature across the U.S. (Source: NCDC/NESDIS/NOAA.)

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Figure 2. Symptoms of Sclerotinia stem rot, as observed in fields around Wisconsin in 2009.

Symptoms:

Within the canopy, symptoms may be observed from 3-4 weeks to 6 weeks after flowering, depending on weather, canopy microclimate, and variety. Soybean flowers are infected by spores that are released from apothecia under favorable conditions. Initial lesions that are gray to white in color can be observed at the nodes. Rapidly, these lesions progress above and below the nodes and can encircle the whole stem. The most common symptom is the appearance of the white fluffy mycelium that covers the lesions. As the severity of symptoms progress, black sclerotia can be observed in lesions or inside the stem.

Risk Factors:

SSR is heavily dependent on weather conditions during flower and early pod development. Consideration for both seasonal risk factors and long-term risk factors is important for properly managing SSR. Seasonal risk factors include: (i) cool temperatures (< 85ºF), (ii) normal to above rainfall, increased soil moisture conditions, or prolonged periods of leaf wetness during flowering/early pod, (iii) early canopy closure, (iv) previous history of white mold, and (v) soybean variety. Long-term risk factors include the field or cropping history, weed management, field topography, and the introduction of the pathogen via equipment or windblown spores from areas outside of the field. Many of these factors coincided in 2009, especially cool temperatures.

Yield Loss Due to SSR in 2009:

The overall effect of this disease in 2009 was variable, however, we estimated that the statewide yield loss due to SSR was 10% (based on a 60-bushel per acre soybean harvest). What this really means is that in some situations, yield loss was negligible, while in others fields, yield loss was very high (or even a total loss).

When we examined all of the UW soybean variety trials, we found that the expected yield loss for every 1% increase in SSR was 0.38 bu/a, which was similar to what we have observed in the past where expected yield loss for every 1% increase in SSR was from 0.25 to 0.50 bu/a (Figure 3). Interestingly, it also appears that the most substantial yield loss would be expected once we have approximately 20-25% incidence. When we stratified the results from the different variety trials, we can see that not all field trials had similar levels of SSR nor was there always yield loss due to SSR. In the white mold variety trials, varieties did show a differential response, and overall, there was a good correlation between white mold incidence and yield (r = -0.59), whereas in the soybean cyst nematode, southern region, and central region variety trials, there was no correlation.

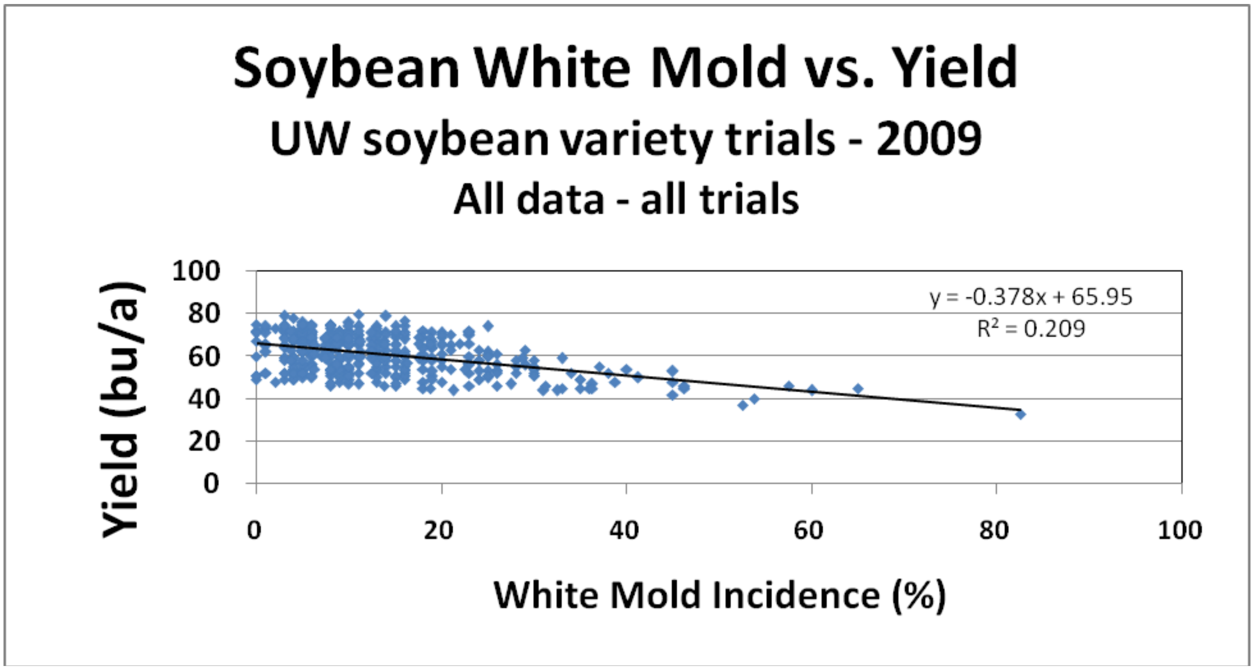

Figure 3. Plot of yield as a function of white mold incidence in 2009 across all UW soybean variety trials. The slope of the regression indicated that for every 1% increase in the incidence of SSR, yield would decrease by approximately 0.38 bushels/a. All data were collected at the R6-R7 growth stage.

Fungicide Trial – Marshfield:

A foliar fungicide trial was conducted at the Marshfield ARS in 2009. In this trial, a susceptible soybean variety was used and five products were examined, including two experimentals. All applications were made at flowering (R1) and at that time of assessment, there were negligible levels of disease as would normally be expected. Disease incidence (plot scale) was measured on 9 September, and disease severity (plant scale) was measured on 29 September. Results from this trial indicated that there was no evidence of an effect of foliar fungicide on the incidence of SSR in early September, however, by the end of September, there were some differences being observed. In particular, Omega (fluazinam; currently not labeled for use in soybean) did show some reduction in the levels of SSR at some rates as did some of the experimental products. Overall, there was no evidence of any differences in the treatments when we analyzed grain yield data.

Table 1. Results from the SSR fungicide trial conducted at the Marshfield ARS in 2009.

Treatment	Incidence (%)	Severity (%)	Moisture (%)	Yield (13%) (bu/a)	Protein (%)	Oil (%)
UTC	15.9	15.9	13.6	39.3	35.6	16.6
Exp1, 16 oz/A	18.8	18.0	13.9	38.0	35.6	16.5
Exp1, 31 oz/A	16.3	36.0	13.9	38.3	35.6	16.6
Exp2, 8 oz/A	14.3	20.8	14.0	39.5	35.7	16.4
Exp2, 16 oz/A	23.8	32.3	14.4	35.2	35.8	16.4
Exp2, 24 oz/A	18.8	33.8	14.2	37.0	36.3	16.1
Topsin, 1 lb/A	21.3	29.5	14.3	38.0	35.2	16.6
Domark, 5 oz/A	17.5	19.8	13.9	37.7	35.9	16.5
Omega, 0.5 pt/A[z]	22.5	27.8	13.5	35.3	34.9	16.8
Omega, 0.75 pt/A	9.0	12.0	13.4	34.6	34.8	17.0
Omega, 1 pt/A	14.3	17.3	13.5	36.8	35.4	16.9
P-value	0.2569	0.0794	0.0046	>0.5	0.1842	0.0713
LSD (10%)	NSD	14.5	0.44	NSD	NSD	0.43
CV (%)	43	53	3	10	2	2

[z]Omega is currently not labeled for use on soybean.

Biological Control for SSR:

We received numerous questions during this past growing regarding the efficacy of using Contans WG for control of SSR. We have written a Soy Report blog article (Dated 30 November 2009) that discusses the current state of knowledge and conditions that may affect efficacy of Contans WG like application timing, application rate, and tillage.

Briefly though, Contans WG is commericial formulation of a fungal pathogen of *Sclerotinia sclerotiorum*, *Coniothyrium minitans*. The mode of action of *C. minitans* is such that it must come into contact with a sclerotium and then through a process of chemical etching can cause the sclerotium to disintegrate.

Currently, we commenced with several studies that examine Contans WG specifically for the questions identified above. Prior to application of Contans WG at our trial sites, we soil sampled and tested for *C. minitans* and found that there is a very low native population of *C. minitans*. Continued measurement of the soil populations of this fungus will help us to monitor establishment and population dynamics over time. Also, our results from trials that were conducted in conjunction with our fungicide trial at Marshfield indicated no effect of Contans WG on SSR incidence or severity with a single year application in the soil. This was not surprising since much of the literature has indicated it takes upwards of three years for complete establishment.

Recommendations for 2010:

Effective control of SSR integrates multiple factors, from knowledge of the field history, variety selection, canopy management, crop rotation, tillage, and weed control. Consult Soyhealth (http://www.plantpath.wisc.edu/soyhealth or http://www.youtube.com/watch?v=rdc7ac60R0M) for core recommendations for managing SSR based on field history. For variety tolerance information please refer to the University of Wisconsin white mold variety test at www.coolbean.info.

SNAP-PLUS UPDATE AND ROUNDTABLE DISCUSSION

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

Use the Rotation Wizard and save data entry hours

The 2009 release of Snap-Plus has features that can make setting up new farms in Snap-Plus and updating nutrient management plans significantly quicker and easier. Almost all field management information can now be entered through the Rotation Wizard for multiple fields and years at a time, saving many hours of data entry, particularly for large farms with many fields and long rotations. You can use the Rotation Wizard to enter planned manure and fertilizer applications along with crops and tillage for all years in a rotation for any number of fields. You can also update previously entered crop, tillage, soil test, and application information. For a complete description and instructions, look for the link in the "Important News" (red) box on the Snap-Plus home page www.snapplus.net.

New version releases will be one-per-year

To avoid the problems that software updates during plan preparation can cause planners, new version releases are going to be limited to one per year. They will be scheduled for late May to avoid conflicts with the planning season. In addition, version changes will be available through the Snap-Plus website for a month-long comment period before the release.

Next release - improved reports, "P excess flags", and field feature documentation

The release scheduled for May 2010 will include improved sets of reports with some designed for producers and others to meet agency needs. One report for producers will contain all the information needed to understand the field nutrient requirements and make modifications during the crop year. Another report meant for agencies will provide comprehensive documentation that the plan for each field meets the requirements of the 590 standard.

This new version will flag excess applications of commercial phosphorus fertilizers. Many planners may not know that the P Index and P_2O_5 Balance checks already in Snap-Plus are for planning manure phosphorus applications. The 590 standard states that commercial P fertilizers shall not be applied to soils with P tests in the nonresponsive range for the crop being grown (with the exception of not more than 20 pounds per acre P_2O_5 as starter for corn or recommended rates of starter P_2O_5 for potatoes and other vegetable crops, Section V.A.1.d.). Frozen soil P applications that exceed removal rates for the following crop will also be flagged.

The Field screen in Snap-Plus will be modified to give planners a place to record direct conduits to groundwater and other field features that may require special consideration for manure spreading. Compliance with restrictions associated with these features will also be documented in the new agency 590 report described above.

Drafts of the new reports and field screen changes are available for your review on the Snap-Plus web site (www.snapplus.net). Look for the link in the "Important News" box.

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SOIL MICRONUTRIENTS: FROM B to Z

Scott J. Sturgul [1]

Introduction

Soil nutrients that are essential to plants are categorized into three broad groupings:

(1) Macronutrients: carbon (C), hydrogen (H), oxygen (O) - supplied by air and water – nitrogen (N), phosphorus (P), potassium (K).

(2) Secondary Nutrients: calcium (Ca), magnesium (Mg), sulfur (S).

(3) Micronutrients: boron (B), chlorine (Cl), copper (Cu), iron (Fe), manganese (Mn), molybdenum (Mo), nickel (Ni), zinc (Zn).

Regardless of category, all these elements are critical to crop production. The only variance is the relative demand level of plants for the given nutrient. Macronutrient requirements of plants are relatively high; whereas, the secondary nutrients are often added to soils incidentally with lime, manure, precipitation, etc. and usually do not limit crop growth as frequently as N, P, or K deficiencies. Soil micronutrients, on the other hand, are needed by plants in small quantities. This does not diminish their importance in crop production. This paper will focus on the major micronutrients and their role in crop production.

Crop deficiencies of one or more micronutrients are most likely caused by soil conditions that render the element unavailable to the plants. Example of such soil conditions include: extreme soil pH levels, eroded soils, soil texture extremes (sands and heavy clays), soil organic matter content (too high or too low), soil moisture (too wet or too dry), and temperature (too cool).

While a deficiency of any essential element will reduce plant growth, the overuse of some micronutrients can also be detrimental and may be more difficult to correct than a deficiency. The danger of building up toxic levels is greater on coarse-textured soils such as sands, loamy sands, and sandy loams.

Micronutrients should never be applied routinely as part of an annual soil fertility regime. Parameters that should be assessed prior to the consideration of any micronutrient application include:

- Is the soil test low for the given nutrient?
- Do micronutrient deficiency symptoms appear on the plant <u>and</u> is the deficiency confirmed with plant analyses?
- Is the demand by a specific crop for the given micronutrient high (Table 1)?

A renewed interest in fertilizer micronutrients has occurred in the agricultural supply sector over the past few years due to a number of factors. These include:

(1) Perceived increase in crop need driven by more intensive grain production over the past three growing seasons which was spurred by the high commodity prices of 2007 and 2008. Additionally, new corn varieties with higher yield potential may be removing greater amounts of soil micronutrients than in the past.

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(2) Increased availability of precision nutrient application equipment that allows soil micronutrients to be applied accurately and uniformly at relatively low rates.

(3) Ease and convenience of adding micronutrients to multiple-input tank mixes of herbicides, fungicides, etc. already destined for field application.

(4) The potential for increasing retailer profit margins with the sale of micronutrient products.

(5) An increased awareness of soil nutrient deficiency occurrences by producers and their crop advisors.

Table 1. Relative micronutrient requirements of some Wisconsin crops.

Crop	**Micronutrient**				
	Boron	**Manganese**	**Zinc**	**Molybdenum**	**Copper**
Alfalfa	**High**	Medium	Low	Medium	Medium
Corn	Low	Medium	**High**	Low	Medium
Soybean	Low	**High**	Medium	Medium	Low
Wheat	Low	**High**	Low	Low	Medium
Oat	Low	**High**	Low	Low	Medium
Potato	Low	Medium	Medium	Low	Low
Beet	**High**	Medium	Medium	**High**	**High**
Cabbage	Medium	Medium	Low	Low	Low
Lettuce	Medium	**High**	Medium	**High**	**High**
Onion	Low	**High**	Low	**High**	**High**
Pasture (legume-grass)	**High**	Low	Low	**High**	Medium
Small grain silage	Low	**High**	Low	Low	Medium
Sorghun-sudan forage	Low	**High**	Medium	Low	Medium

Source: Laboski et al., 2006. Nutrient application guidelines for field, vegetable, and fruit crops in Wisconsin. UW-Extn pub. A2809.

Soil Micronutrients

Boron (B)

Role in plants: B is needed by plants for cell division, cell wall synthesis, and pollen germination. B deficiencies in Wisconsin are more widespread than deficiencies of any other micronutrient. Only 0.5 to 2.5% of boron in the soil is available to plants. Soils may contain 0.5 to 2.0 parts per million (ppm) of available boron, but more than 5.0 ppm of available boron can be toxic to many agronomic crops. Plants take up less than 0.5 lb B/a.

Susceptible crops: Forage legumes and of some vegetable crops grown in Wisconsin are susceptible to B deficiency. Deficiency of B is the major micronutrient problem in alfalfa production. Specific crops with high requirements include alfalfa, trefoil, beet, canola, cauliflower, celery, sunflower, tomato, and forage brassicas. Those with medium requirements are apple, asparagus, broccoli, brussels sprouts, cabbage, carrot, lettuce, melons, radish, red clover, spinach, tobacco, and vetch.

Deficiency symptoms: In alfalfa, B deficiency is often evidenced with a yellowing or reddish color of the leaves at the top of the plant with a bunched or bushy appearance of the new growth due to shortened internode growth. If the deficiency continues, the plants' growing points can stop developing and may eventually die. Obviously, lack of B can severely reduce the yields of crops.

With forage legumes, B deficiency symptoms tend to be evident after first cutting, especially with dry weather. Because B is an immobile soil nutrient, the deficiency symptoms will occur on the new (top) growth and the lower leaves may remain green. This can be mistaken for leafhopper injury.

Susceptible soils: Sands and other soils low in organic matter are more likely to be deficient in boron than other soils. The storehouse for most of the boron is the soil organic matter. As a result, most of the available B is in the plow layer, where organic matter is highest. Sandy soils tend to be deficient in B more often than fine-textured silts and clays due to the fact that B is not readily held by the soil particles and moves down through coarse-textured soils, often leaching below the root zone of many plants.

Dry soils are also prone to temporary B deficiency. When the soil surface dries out, plants are unable to feed in the zone where most of the available B is present. This can lead to deficiency. When rain or irrigation moistens the soil, the plants can again feed from the surface soil and the B deficiency often disappears.

Diagnosis: Soil test. Optimum ranges are 0.5-1.0 ppm B for sands and 0.9-2.0 ppm B for other soils.

Corrections: On alfalfa and other forage legumes, the easiest way to apply B is in combination with topdressed fertilizers. If a soil tests low in available B or if a deficiency appears, apply 0.5-1.0 lb/a of B each year or 2 lb/a once in the rotation as a topdressing. For forage legumes grown on sandy soils, an annual application of 1.0 lb/a of B minimizes the leaching effect. Never use a borated fertilizer in the row for corn or soybean, or in the drill for small grains. The B concentrated in a band is toxic to germination of these crops and may cause severe injury.

Chlorine (Cl)

Role in plants: Plants require chlorine for certain photo-chemical reactions in photosynthesis. Cl uptake affects the degree of hydration of plant cells and balances the charge of positive ions in cation transport. Cl deficiency has never been observed under field conditions in Wisconsin.

Susceptible soils: Response to Cl, expressed as reduced incidence of disease and higher yield in small grains, has been observed in a few studies in Oregon and the Dakotas. The soils in these states have high levels of potassium so potassium chloride fertilizer (0-0-60) is seldom applied. Because Wisconsin soils tend to be inherently low in potassium, application of potassium chloride fertilizer and manure has prevented any known Cl deficiency.

Diagnosis: Plant analysis, but this is rarely done. A soil test does exist for Cl, but research calibrating crop response to Cl has not been necessary in Wisconsin.

Copper (Cu)

Role in plants: Cu serves as an activator of several enzyme systems in plants. In addition, Cu plays a role in seed and chlorophyll production and formation. It is present in soils at concentrations of 2 to 100 ppm with an average value of about 30 ppm.

Susceptible crops: Cu deficiency is rare in Wisconsin. Beets, lettuce, onion, spinach, sunflower, and tomato have moderate Cu requirements. Small grains (wheat, oats and barley) may respond to small additions of Cu if they are grown on susceptible soils.

Deficiency symptoms: Symptoms of Cu deficiency in small grains are a light green to yellowing of the crop along with leaf tips that may die back and become twisted. In severe cases, growth of small grains decreases and plants may die.

Susceptible soils: Occurrences of Cu deficiency are generally only seen on acid, organic soils. Organic matter binds Cu more tightly than any other micronutrient. Also, soils high in zinc may exasperate Cu deficiency. Cu is not easily leached from soils and usually remains in a plant-available form. Cu toxicity in some sandy soils has resulted from repeated use of copper-containing fungicides over many years. Cu toxicity problems are difficult to correct.

Diagnosis: Plant analysis. A soil test does exist for Cu, but only as part of a heavy metal screening. Soil test research calibrating crop response to Cu has not been conducted in Wisconsin.

Corrections: Band applications of inorganic Cu at rates of 1-2 lb/a on sands, 2-3 lb/a on other mineral soils, and 2-4 lb/a on organic soils. Broadcast applications of 4-10 lb/a on sands, 8-12 lb/a on other mineral soils, and 12-13 lb/a on organic soils. If copper chelates are used, reduce application rate to 1/6 of above.

Foliar applications of Cu can be an effective way to correct Cu deficiencies in small grains. Results from research in northwestern Minnesota indicate that applications at the tillering stage are most effective in correcting deficiencies. Copper sulfate is the most commonly used material for foliar applications.

Iron (Fe)

Role in plants: Fe is required for synthesis of chlorophyll by plants and is also an enzyme activator.

Susceptible crops: Fe deficiency has rarely been observed on field or vegetable crops in Wisconsin, except that iron chlorosis has occasionally been observed on soybeans grown on alkaline soils (pH above 7.0). Fe deficiency in soybean is observed more often on the calcareous soils of Iowa and Minnesota. Turfgrass, pin oak trees, and some ornamentals such as yews occasionally develop Fe deficiency when grown on alkaline soils.

Deficiency symptoms:
Fe is very immobile in plants, so deficiency symptoms appear on new growth (youngest upper leaves). The veins of young leaves remain green, but the area between the veins becomes yellow (chlorotic). Each new leaf emerges paler than the one before. Eventually, new leaves, including the veins, are creamy white, devoid of chlorophyll.

Susceptible soils: Alkaline (high pH), calcareous soils.

Diagnosis: Plant analysis. A soil test does exist for Fe, but only as part of a heavy metal screening. Soil test research calibrating crop response to Fe has not been conducted in Wisconsin.

Corrections: The deficiency can be corrected by spraying the foliage several times with ferrous sulfate or an iron chelate. Soil applications are not very effective because of the rapid transformation of Fe contained in fertilizer to unavailable forms in the soil. Another option for correcting Fe deficiency is to decrease soil pH – if practical.

Manganese (Mn)

Role in plants: Manganese (Mn) functions as an enzyme activator for steps in photosynthesis and is also involved in nitrogen metabolism in plants. It is an element found in plant tissue at concentrations ranging from 10 to 500 ppm or more. In most plants, it is deficient at less than 10 ppm and toxic when the concentration exceeds about 300 ppm.

Susceptible crops: Deficiency symptoms are most common in soybean, oats, and snap bean grown on high pH (6.8 or greater) mineral soils and neutral to alkaline organic soils. Other crops with high Mn requirements include lima beans, lettuce, onion, radish, raspberry, spinach, sorghum-sudan, and wheat. Crops with medium Mn needs are barley, beet, broccoli, brussel sprout, cabbage, carrot, cauliflower, celery, corn, cucumber, pea, potato, tobacco, and tomato.

In 2007, there was an unusual spike in the occurrence of Mn deficiency in soybeans grown on the eastern side of Wisconsin. All confirmed cases were grown on high pH and/or high organic matter soils (i.e. soils susceptible to Mn deficiency). In addition, most of these sites were planted with glyphosate-resistant soybean varieties (Conley & Laboski, 2008). Researchers from various states have identified a link between Mn deficiency and glyphosate-resistant soybean. Specifically, it is speculated that soybean root uptake and/or metabolism of Mn is reduced by either the glyphosate gene in soybean, the glyphosate application itself, or a combination of both (summarized in Lamb, 2008). At the very least, the potential for Mn deficiency on susceptible soils is amplified when glyphosate-resistant varieties of soybean are grown.

Crops susceptible to Mn toxicity include asparagus, forage legumes, mint, and pea. Mn toxicity of potato has also been identified on extremely acid soils (pH less than 5.0).

Deficiency symptoms: Symptoms appear as interveinal chlorosis (veins remain dark green but the tissue between turns yellow to white) of the younger leaves (new growth) because Mn is an immobile element. Severe cases can also cause cupping of broadleaf plants. In oats, the symptoms show up as specks of dead tissue, giving the deficiency the name “gray speck disease.”

Susceptible soils: High pH (6.8 or greater) mineral soils and neutral to alkaline organic soils or mucks (>6% OM). Cool weather during the growing season may also induce Mn deficiency in high demand crops.

Mn availability increases as soil pH decreases and Mn toxicity is common in acid soils below pH 5.5, especially when these soils are low in organic matter and/or temporarily waterlogged. Acid, sandy soils are likely to contain high Mn levels.

Diagnosis: Soil test for soils with organic matter contents of 6% or less. Optimum ranges for all soil textures are 11- 20 ppm Mn. For high organic matter soils, Mn soil test category is based on soil pH values: >6.9 is low; 6.0 – 6.9 is optimum; < 6.0 is high.

Corrections: One of the main reasons for liming acid soils, especially in legume production, is to prevent Mn toxicity. The amount of Mn in solution decreases 100-fold for each unit rise in soil pH (i.e. from 5.0 to 6.0). Where Mn deficiency exists as a result of the high pH of a soil, it is easier to correct the deficiency by adding a Mn fertilizer than by attempting to acidify the soil.

Broadcast applications of Mn fertilizer, as well as attempts to build-up soil test Mn levels over time, are not recommended due to the soil's capacity to rapidly fix (bind) Mn. Band or in-row applications of Mn reduces fixation by reducing contact with soil particles.

For crop with a medium or high Mn requirement grown on low testing soils, apply 3-5 lb Mn/a. Chelated forms of Mn are not effective when soil-applied. They are effective forms on Mn for foliar applications. To correct in-season Mn deficiencies, foliar applications at rates of 1-1.25 lb Mn/a or 0.15-0.2 lb Mn/a in the chelate form are recommended. More than one foliar application may be necessary.

Molybdenum (Mo)

Role in plants: Molybdenum (Mo) is required for symbiotic nitrogen fixation and for converting nitrate ions into organic nitrogen in plants. Plants need extremely small amounts of Mo. Normal tissue concentrations are 0.03 to 1 ppm.

Susceptible crops: Mo deficiency (or toxicity) in Wisconsin crops is rare. Table beets, broccoli, cauliflower, lettuce, onion, spinach, and forage brassica have a high requirement for Mo. Legume crops grown on very acid soils are likely to be Mo deficient.

Deficiency symptoms: The first symptom of Mo deficiency is nitrogen deficiency symptoms. If the deficiency is severe, the leaf edges of some vegetable crops may become brown and curl upward. Cupped leaves also show interveinal chlorosis. Mo deficiency in cauliflower leads to a condition known as whiptail, in which leaves sometimes appear crinkled or withered.

Susceptible soils: Soil acidity has a major influence on the availability of Mo. As soil pH decreases, the availability of Mo decreases. Liming alone is usually enough to correct a Mo deficiency.

Diagnosis: Plant tissue analysis is more reliable for diagnosing Mo status in crops. Soil testing is not sufficiently calibrated for predicting the supply of Mo in Wisconsin soils.

Corrections: Soil applications of Mo are not recommended because of the extremely low amounts that would be required. Seed treatment or foliar sprays are the recommended application techniques. Follow Mo recommendations closely because excess Mo in feed or forage can cause animal health problems (molybdenosis).

High Mo demand crops grown on soils with a pH of 5.5 or lower should be seed-treated with 0.2 oz Mo/a as ammonium or sodium molybdate. Foliar applications at 0.8 oz Mo/a are alternative treatments.

Nickel (Ni)

Role in plants: Ni is needed by plants to form the enzyme urease which breaks down urea-nitrogen for plant use. Ni is also involved in the uptake by plants of iron from soil. Concentrations of Ni in plants typically run from 0.1 to 10 ppm. Only recently, relatively speaking, has Ni been classified as an essential soil micronutrient.

Susceptible crops: Deficiencies of Ni are not known to exist in Wisconsin.

Susceptible soils: In other areas of the country Ni deficiency is associated with high soil pH levels. Generally, there is greater concern about Ni toxicity, particularly on soils where sewage sludge has been applied.

Diagnosis: Plant analysis, but this is rarely done. A soil test for Ni exists, but only as part of a heavy metal screening. Soil test research calibrating crop response to Ni has not been conducted in Wisconsin.

Zinc (Zn)

Role in plants: Zn is required for the synthesis of a growth hormone (indoleacetic acid) by plants. It also functions as an enzyme activator in carbohydrate metabolism and protein formation. Crops generally take up less than 0.5 lb/a of Zn, yet when Zn is deficient, crop yields are reduced markedly.

Susceptible crops: Zn is the most common micronutrient deficiency of corn. Other crops with high Zn requirements include onion, spinach, and grain sorghum. Those with medium requirements are barley, beans, beets, cucumber, lettuce, potato, radish, sorghum-sudan forage, soybean, tobacco, and tomato. In Wisconsin, Zn deficiencies have been observed on corn, snapbean, and a few other vegetable crops.

Deficiency symptoms: Zn is an immobile soil nutrient; therefore deficiency symptoms usually appear first on the young leaves (at top of the plant) early in the growing season. On corn, a broad band of bleached tissue appears on either side of the midrib. The deficiency begins at the base of the leaf and usually stays in the lower half of the leaf. Zn deficiency also causes a shortening of the internodes on the corn stalk – which stunts the plant.

In broadleaf plants, Zn deficiency results in a shortening of internodes (rosetting) and a decrease in leaf size. Snapbean develops interveinal chlorosis. However, it is very difficult to distinguish between Zn and manganese deficiencies in this crop.

Susceptible soils: Soil acidity (pH) influences the availability of Zn more than any other factor, with lower Zn solubility as the pH increases. Zn deficiency usually is limited to soils with a pH above 6.5. Overliming of soils, especially sands, may induce Zn deficiency. Scalped or severely eroded soils are more apt to be Zn deficient. Also, sands, sandy loams, and organic soils are more likely to be Zn deficient than other soil types. Severe soil compaction can also reduce Zn availability. Also, cool weather during the growing season may also induce Zn deficiency in high demand crops. Researchers in Iowa state that high P fertilizer applications on soils that are low in Zn can cause Zn deficiencies, but high soil P levels alone do not create Zn deficiency.

Diagnosis: Soil test. Optimum Zn soil test ranges are 3.1–20 ppm for all soil textures. The need for supplemental Zn applications should be confirmed with plant analysis.

Corrections: Supplemental Zn can be applied with either band or broadcast applications. Rates of 2-4 lb Zn/a if banded or 4-8 lb Zn/a if broadcast should correct any deficiency. Rates for chelated forms of Zn should be 0.5-1.0 lb/a in a band or 1-2 lb/a broadcast. Alternatively, Zn can be foliar applied using Zn-sulfate at 1 lb Zn/a of Zn chelate at 0.15 lb Zn/a.

Conclusion

Micronutrient deficiencies are rare in Wisconsin, but they can present themselves on occasion, particularly on sandy soils, soils extremely high or low in organic matter, soils with pH values outside of the optimum range for a specific crop, and during deviations from typical weather. Application of micronutrients should only be considered when their need is confirmed by a soil test report, plant analysis result, visual deficiency symptoms, and a crop with a proven high demand for a given micronutrient.

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UNDERSTANDING THE VALUE OF SLOW-RELEASE FERTILIZERS

Matt Ruark [1/]

The purpose of this article is to provide an overview of three often-asked questions related to slow-release nitrogen: (1) what are slow-release fertilizers, (2) why should I use slow-release fertilizers and (3) when should I use slow-release fertilizers? It is important to note that products mentioned in this paper do not reflect an endorsement of the product, but simply to inform which products are currently available for crop production in WI. Likewise, a lack of mention of specific products does not imply that a product is not recommended or available for use.

What Are Slow-Release Fertilizers?

Slow-release is an often overused term that encompasses several N fertilizer products which include: uncoated slow-release fertilizers (SRF), coated SRF, and bio-inhibitors. The term “controlled-release” is often used synonymously with slow-release, but has also been used to identify coated SRF or more specifically, polymer-coated urea (PCU, often referred to as poly-coated) products. Thus, a more appropriate nomenclature that encompasses all of these products is *fertilizer technologies*. The debate will continue for some time regarding how much “control” each technology has on releasing N to the plant.

Uncoated Slow-Release Fertilizers

Uncoated SRF are identified as those that slowly release N into the soil environment through chemical recalcitrance. There are two categories of such products, urea-formaldehyde reaction products and isobutylidenede diurea (IBDU). Urea-formaldehyde reaction products, such as urea-formaldehyde (ureaform) and methylene urea, rely on microbial decomposition and hydrolysis (chemical reaction with water) to release plant-available N into the soil environment. Ureaform typically has less than 15% of the total N in an immediately available form, while methylene urea has between 15 and 30% of the total N in an immediately available form. The ultimate determinant of how slowly the N will be released is based on the extent of the reaction process which produces polymer-chain molecules of varying lengths. Examples of methlyene urea containing products on the market are Nitamin® and Nitamin Nfusion® (Georgia Pacific, Atlanta, GA), which are blends of methylene urea and triazone. The IBDU is a reaction product of urea with isobutyraldehyde and relies solely on hydrolysis to release N.

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Coated Slow-Release Fertilizers

There are two popular coated SRF products: sulfur-coated urea and PCU. Sulfur-coated urea releases N into the environment through biological oxidation of the S coating, fractures in the S coating, and dissolution through the moderately porous membrane. The PCU products encapsulate urea granules with polymers. Over time, water moves through the polymer coating, dissolving the urea. The N solution then slowly dissolves out through the polymer coating. The PCU products are considered "controlled" release because the thickness of the polymer coating effectively controls the release rate and delay (soil temperature is also a controlling factor). Types of PCU include ESN® (Agrium Inc, Calgary, AB), Polyon® (Agrium Inc, Calgary, AB), and Nutricote® (Chisso-Asahi Fertilizer Co., Ltd, Tokyo, Japan).

Bio-inhibitors

Products that inhibit enzyme activity seek to delay the breakdown of urea or the conversion of ammonium to nitrate (i.e. nitrification). Nitrification inhibitor products such as nitrapyrin [2-chloro-6-(trichloromethyl)-piridine] and dicyandiamide (DCD) kill or interfere with the metabolism of the soil bacteria nitrosomonas, which are responsible for the first step of nitrification, the conversion of ammonium to nitrite. However, these products only kill or inhibit growth in a localized area around the granule. Once soil bacteria repopulate into the zone the nitrification process is no longer hindered. Nitrapyrin is sold as N-Serve ® and Instinct™ (Dow AgroSciences LLC, Indianapolis, IN).

Urease inhibitor products [e.g. Agrotain® (Agrotain, Inc., LLC, Corydon, KY)] contains N-(n-butyl) thiophosphoric triamide (NBPT) which neutralizes the effectiveness of the soil enzyme urease, which is a catalyst for the transformation of urea to ammonium. Again, this only inhibits urease activity in a localized zone around the granule. Once soil enzyme levels increase near the urea granule, urea begins to break down rapidly. Products may also be marketed as urease and nitrification inhibitors [e.g., SuperU® (Agrotain, Inc., LLC, Corydon, KY) and Nutrisphere® (SFP, Leawood, KS)].

Why Use Fertilizer Technologies?

There are two potential benefits for using fertilizer technologies: an increase in yield using a standard N application rate or maintenance of yields by applying less N. This improves net profits by increasing output or decreasing input. In either case, the result is an increase in the nitrogen use efficiency (NUE). Improving NUE is an important goal for improving the sustainability of agricultural systems. The NUE is a determining factor in economic productivity and environmental impacts of crop production. The NUE encompasses several components such as:

1. Agronomic Efficiency = (increase in yield from N fertilizer application / N fertilizer applied)

2. Nitrogen uptake efficiency = (increase in total N uptake from N fertilizer application / N fertilizer applied)

3. Nitrogen removal efficiency = (increase in grain N from N fertilizer application / N fertilizer applied)

The fundamental flaw of bulk applying N for crop production is that plants to not take up N in bulk amounts. The N fertilizer applied is subject to environmental losses (e.g., runoff, leaching, gas flux), reducing the percentage of applied N that can be used by the crop. Slow-release or bio-inhibitor fertilizers, by attribute of slowly releasing N into the environment or inhibiting microbial processes that would convert the N into forms that can be lost to the environment, decrease the potential for N loss and increase the potential for improved NUE.

When to Use Fertilizer Technologies

Before deciding whether to use a fertilizer technology, it is important to understand the main factor affecting the NUE in your system. Each category of fertilizer technology has advantages and disadvantages depending on environmental conditions, namely, soil type and seasonal weather patterns. Urease inhibitors provide the most benefit when urea is surface applied and not immediately incorporated or irrigated. A common example is in no-till corn production. If there is no potential for N volatilization, then there is little potential benefit to urease inhibitors. Nitrification inhibitors have been shown to increase yields and decrease nitrate leaching losses (Nelson and Huber, 1992), but not in all situations. When seasonal conditions are such that there is little potential for N leaching losses, then the potential benefit of nitrification inhibitors is low. Coated and uncoated SRF are beneficial when attempting to improve the NUE on your field. However, it is important to evaluate your current program to see if major improvements could be made to justify the increased cost of the SRF product. Knowing the nutrient content of the crops you are harvesting can help you determine if improvements can be made. If crop removal of N is equal to your fertilizer input of N, then improving NUE will be difficult (Bruulsema, 2009).

Another consideration is whether the product can be incorporated into your existing program. Different products are available for inclusion with dry fertilizer, liquid fertilizer, and manure. If you are interested in using one of these products, field testing is always recommended. This can be done through use of replicated strip trials. In-field replications are always preferred as they will give a more accurate assessment of the product value. Contact your county extension agent or state extension specialist if you'd like more info on specific products or information related to their testing in your area.

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TROUBLESHOOTING FIELDS USING PLANT ANALYSIS

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Introduction

Plant analysis can be a useful tool for troubleshooting plant nutrition related crop production problems during the growing season. From a troubleshooting standpoint, plant analysis can confirm visual symptomology of nutrient deficiencies or toxicities, reveal early stages of nutrient deficiencies, and determine the availability of nutrients for which a reliable soil test does not exist or soil test calibration has not been completed. Plant analysis can also be used to assess a crop's response to applied nutrients, particularly where different treatments may have been applied in the same field (e.g., strips with and without sulfur addition).

Over the past several years, agronomists have become increasingly interested in using plant analysis to help troubleshoot problem fields or identify slight nutrient deficiencies that might hinder a producer from achieving high yields. This is evidenced by the fact that plant samples submitted to the UW Soil & Plant Analysis Lab doubled each year since 2007 (Table 1). While plant analysis sample submission has increased, the number of soil samples submitted in conjunction with plant samples has remained relatively steady since 2005. An analysis of some of the plant analysis data since 2005 revealed that plant analysis may not be well understood by some agronomists. Therefore, the objective of this paper is to describe the use and limitations of plant analysis for troubleshooting fields.

The Basics of Plant Analysis

As previously stated, plant analysis can detect nutrient deficiencies and assess a crop's response to applied nutrients. However, in order for plant analysis results to be a useful diagnostic tool a few guidelines must be followed.

First, take good notes. When visiting a field, take written notes describing any visual symptomology paying attention to where on the leaf and plant the symptoms occur. For example, yellowing of leaf margins on older leaves, new leaves appear ok. Also note where in the field the symptoms occur and if any pattern is apparent as you look across the landscape. Sketch a map of the affected area noting drainage, topography, soil color, soil texture, and other features that might affect plant growth. Photographs including close-ups and panoramas can be very useful to document how a field looked at a particular point in time. In panoramic photos, try to include a landmark (such as a house, telephone pole, grove of trees, etc.) that will be visible as the crop continues to develop. This can be useful when

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you go back to the field to make sure you are looking at the same areas. If possible, you could leave a flag or other marker or use GPS to mark the boundaries of the abnormal and normal areas.

Table 1. Number of plant samples submitted to the lab in various crop categories along with the number of soil samples submitted to the UW Soil and Plant Analysis Lab from June 1 through August 31 in each year from 2005 through 2009.

	Year				
Crop or Soil	2005	2006	2007	2008	2009
	Number of observations, n				
Alfalfa	23 (5, 18)†	59 (4, 55)	21 (10, 11)	13 (6,7)	47 (20, 27)
Corn	69 (32, 37)	114 (39, 75)	86 (24, 62)	111(37,74)	567 (119, 448)
Soybean	19 (15, 4)	28 (13, 15)	34 (19, 15)	135 (24, 111)	230 (39, 191)
All vegetables	25 (16, 9)	2 (1, 1)	14 (5, 9)	33 (7, 26)	30 (13, 17)
Cranberry	84 (0, 84)	53 (0, 53)	54 (18, 36)	93 (2, 91)	236 (3, 233)
Grape	15 (0,15)	17 (2, 15)	19 (2, 17)	49 (1, 48)	40 (2, 38)
Fruit, other	161 (6, 155)	39 (3, 36)	57 (8, 49)	132 (4, 128)	40 (3, 37)
Other‡	19 (12, 7)	12 (10, 2)	7 (3, 4)	55 (13, 42)	65 (11, 54)
Total Crop	415	324	292	621	1255
Total Soil	275	243	169	287	245

† Total number of samples followed by the number of samples identified as being abnormal and normal in appearance, respectively, in parenthesis where appropriate.
‡ Other includes wheat and other small grains, forage legumes other than alfalfa, tobacco, trees, grasses, and unreported crops.

In addition to assessing the plant's foliage, look at the plant's roots by carefully digging up a plant or two. If the crop is a legume, determine if nodules are present and active (inside of nodule is pink). Also look for signs of soil compaction, which include pancaked roots, overly thickened roots, roots that are gnarled, poor soil structure and/or stunted plant growth. Other information that should be noted include: weather conditions throughout the growing season along with current growing conditions; crop management practices (planting date, hybrid/variety, tillage, pest management, etc.); and field history (crop rotation, manure application, past problems, etc.). All of this information can be helpful in interpreting plant analysis results and making a decision on what can be done to remedy the problem. Sometimes the most challenging diagnostic situations are those where background information is either incomplete or inaccurate.

Second, when troubleshooting a field, obtain plant samples from both abnormal and normal parts of the field AND take soil samples that correspond to these areas. The reason to sample normal and abnormal parts of the field is to compare the results. Nutrient concentrations for a crop may vary somewhat by hybrid/variety, soils, and local growing conditions. Thus, comparing an abnormal sample to a good sample for the same field may be more useful than using sufficiency range interpretation categories alone. Soil samples from the abnormal and normal areas are extremely helpful in assessing if the diagnosed nutrient deficiency is related to low availability of the nutrient in the soil or weather or field conditions that limited nutrient uptake. An example of this is where soil compaction has limited potassium uptake and resulted in potassium deficiency even though the soil test level is optimum throughout both the normal and abnormal areas. This is also an example of why assessing at plant roots and weather conditions are useful. Another example is where plant analysis reveals manganese toxicity and the soil test reveals that the pH is 4.8. Without the soil test, you might assume low pH is a problem but you would not know for certain.

Third, sample the appropriate part of the plant for a given growth stage and collect an adequate number of samples. The concentration of nutrients in plant tissue generally decreases as the crop becomes more mature. Sufficiency ranges and to some extent DRIS indices were developed based on a specific plant part sampled at a specific growth stage.

Sampling the incorrect plant part for a growth stage will lead to inaccurate interpretation of the plant analysis. In addition, a sample should be comprised of tissue taken from an adequate number of plants such that the sample is representative of the area and enough tissue is collected for the lab to analyze. Table 2 outlines the plant parts to sample at each growth stage and the number of plants that should comprise one sample. The growth stages for each crop listed in Table 2 are the only ones for which there is an interpretation of the plant analysis results. If a crop growth stage is not listed in Table 2, then a plant analysis interpretation is not available.

Fourth, place the sample in a paper envelope and send to the laboratory. Placing plant samples in a plastic bag is not acceptable. If soil has splashed onto plant tissue brush it off, but do not wash the leaves, before placing the sample in the bag. Clearly label samples and fill out sample submission forms completely. Failure to fill out a sample submission form completely or accurately can result in incorrect interpretations. Contact your laboratory in advance to obtain more information on how the lab would like samples submitted.

Fifth, review plant and soil analysis results in conjunction with field notes. Ask yourself if the plant analysis interpretations make sense based on your field assessment. If your answer to this is no or you aren't sure, then contact your local County Extension office and/or soil fertility specialist for assistance.

Table 2. Plant part to sample and number of plants that comprise one sample for crop growth stages that have plant analysis interpretations. From UW Soil & Plant Analysis Lab's plant sample submission form.

Field Crops	Stage of Growth		Plant Part Sampled		Number of Plants
Alfalfa	**1**	Bud to first flower	**A**	Top 6 inches	30-40
Alfalfa hay	**2**	Harvest	**B**	Whole plant	15-20
Barley	**12**	Prior to heading	**L**	Newest fully developed leaf	30-40
Beans, dry lima	**8**	Prior to or at initial flowering	**H**	4th petiole and leaflet or 4th petiole only	20-25
Beans, snap	**8**	Prior to or at initial flowering	**H**	4th petiole and leaflet or 4th petiole only	20-25
Beans, soy	**8**	Prior to or at initial flowering	**H**	4th petiole and leaflet or 4th petiole only	20-25
Birdsfoot trefoil	**1**	Bud to first flower	**A**	Top 6 inches	30-40
Brome grass	**12**	Prior to heading	**L**	Newest fully developed leaf	30-40
Canary grass	**12**	Prior to heading	**L**	Newest fully developed leaf	30-40
Clover, red	**1**	Bud to first flower	**A**	Top 6 inches	30-40
Clover, red hay	**2**	Harvest	**B**	Whole plant	15-20
Crown vetch	**1**	Bud to first flower	**A**	Top 6 inches	30-40
Corn, field	**3**	12 inches	**C**	Whole plant	10-15
	4	Pre-tassel	**D**	Leaf below whorl	15-20
	5	Tassel to silk	**E**	Ear leaf	15-20
	6	Ensiled/chopped	**F**	Whole plant	10-15
Corn, sweet	**7**	Tassel to silk	**G**	Ear leaf	15-20
Oats	**12**	Prior to heading	**L**	Newest fully developed leaf	30-40
Orchard grass	**12**	Prior to heading	**L**	Newest fully developed leaf	30-40
Peas, canning	**8**	Prior to or at initial flowering	**H**	4th petiole and leaflet or 4th petiole only	20-25
Peas, chick	**8**	Prior to or at initial flowering	**H**	4th petiole and leaflet or 4th petiole only	20-25
Potato	**9**	Prior to or at initial flowering	**I**	4th petiole and leaflet or 4th petiole only	40-50
	10	Tuber bulking	**J**	4th petiole and leaflet or 4th petiole only	40-50
Rye	**12**	Prior to heading	**L**	Newest fully developed leaf	30-40
Sorghum, grain	**13**	Prior to heading	**M**	2nd fully developed leaf	15-20
Sorghum, sudan	**14**	Prior to heading	**N**	Newest fully developed leaf	15-20
Triticale	**12**	Prior to heading	**L**	Newest fully developed leaf	30-40
Wheat	**11**	Tillering	**K**	Newest fully developed leaf	30-40
Wheat	**12**	Prior to heading	**L**	Newest fully developed leaf	30-40

Fruits	Stage of Growth		Plant Part Sampled		Number of Plants
Apple	**15**	Current season's shoots	**O**	Fully developed leaf at midpoint of new shoots	10-20
Cherry	**15**	Current season's shoots	**O**	Fully developed leaf at midpoint of new shoots	10-20
Cranberry	**18**	Aug 15 to Sept 15	**R**	Current season's growth above berries	35-50
Raspberry	**17**	Aug 10 to Sept 4	**Q**	6th & 12th leaf blade and petiole from trifoliate	10-20
Strawberry	**16**	At renovation before mowing	**P**	Fully developed leaflets and petioles	10-20

Vegetables	Stage of Growth		Plant Part Sampled		Number of Plants
Cabbage	**22**	Midseason	**V**	Wrapper leaf	10-20
Cauliflower	**20**	Midseason	**T**	Youngest mature leaves	10-20
Carrots	**20**	Midseason	**T**	Youngest mature leaves	10-20
Celery	**20**	Midseason	**T**	Youngest mature leaves	10-20
Ginseng	**20**	Midseason	**T**	Youngest mature leaves	10-20
Lettuce	**22**	Midseason	**V**	Wrapper leaf	10-20
Onion	**19**	Midseason	**S**	Tops, no white	10-20
Pepper	**23**	Prior to or at early fruit development	**W**	Petiole and leaflet	10-20
Tomato	**21**	Midseason	**U**	Newest fully developed leaf	10-20

Limitations of Plant Analysis

Plant analysis is not without limitations. In fact many of the guidelines in the previous section are based on these limitations. The ability to remediate a nutrient deficiency identified by plant analysis is another limitation. For example, the deficiency may have already caused yield loss; the crop may not respond to additional nutrients at the growth stage tested; the crop may be too large for nutrient application; and/or the weather may be unfavorable for fertilization and/or for crop to benefit. In these situations, plant analysis can be a decision making guide for the next season’s crop.

Analyzing plant analysis data from samples submitted to the UW Soil and Plant Analysis Lab from 2005 through 2009 suggests that there are a few areas for improvement in sampling for plant analysis. First, the percentage of plant samples submitted with corresponding soil samples has decreased over the past couple years (Table 1). Second, the percentage of plant samples submitted as normal, as opposed to abnormal, in 2009 was 57%, 79%, and 83% for alfalfa, corn, and soybean, respectively. Without surveying everyone who submitted plant samples, the first two points suggest that agronomists are sampling fields looking for potential problems or sample submission forms were not filled out accurately. When looking for potential problems care must be taken not to over interpret nutrient concentrations that might fall just below the sufficiency range and assessing the bigger picture (economics and temporal/weather patterns effect on nutrient availability) is important in determining if remedial action is required. Third, a large percentage of soybean samples submitted in 2009 were submitted from mid-July thorough late-August. The appropriate sampling time for soybean is prior to or at initial flowering (R1). It is very likely that these soybeans were beyond R1 and thus, the interpretation of the plant analysis would be inaccurate.

Summary

Plant analysis can be a very helpful diagnostic tool when used properly. Thoroughly researching field history and assessing the present problem are just as important as taking samples properly to obtain a correct diagnosis. Failure to follow plant analysis sampling guidelines may result in inaccurate interpretation of results. Plant analysis is not a substitute for a consistent soil sampling program followed by appropriate lime and nutrient applications.

For additional information on plant analysis see:

Kelling, K.A., S.M. Combs, and J.B. Peters. 2000. Sampling for plant analysis. UW Soil and Plant Analysis Lab. http://uwlab.soils.wisc.edu/madison/index.htm?../forms.htm&contents.asp

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EFFECT OF SAMPLING TIME ON SOIL TEST POTASSIUM LEVELS

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Introduction

Soil tests are an important tool to guide farmers in determining an appropriate fertilizer application rate. The interpretation of K soil test results are complicated by the fact that STK levels are known to fluctuate throughout the year (Blakemore, 1966; Childs and Jencks, 1967; Liebhardt and Teel, 1977). Therefore, the time of soil sampling may impact fertilizer recommendations. Fluctuations in soil test K (STK) have been attributed to clay mineralogy and environmental conditions, like soil moisture status, wetting and drying cycles, and freezing and thawing cycles (Childs and Jencks, 1967).

Soils high in 2:1 type clay minerals (micas and vermiculites) have the ability to fix K (i.e., trap K in the clay interlayer) or release potassium depending on the STK level and soil moisture status (Goulding, 1987). Soil tests only measure the solution and exchangeable forms of soil potassium, and do not measure the potassium that is 'fixed' in the interlayer of 2:1 clay minerals. Leubs et al. (1956) measured exchangeable K levels in the top ½ inch of two Iowa fields from June through August and found exchangeable K to be inversely related to soil moisture. In laboratory investigations, an increase in the number of wetting and drying or freezing and thawing cycles has been found to either increase or decrease the magnitude of fixation or release of potassium (Graham and Lopez, 1969; Zeng and Brown, 2000). However, the response of STK levels to environmental conditions differs widely among different soils; therefore it is important to evaluate how STK levels may fluctuate in the major soil groups of Wisconsin.

Currently, the University of Wisconsin does not specify what time of the year soil sampling should be done, but suggests that soil should be sampled consistently at the same time of the year (Laboski et al., 2006). If fluctuations in soil test K levels can be attributed to a particular time of the year or to particular weather/environmental conditions, then soil test interpretations could be fine-tuned. Of particular interest is whether soil test levels change significantly between the fall and the spring, since these are the times when soil is most likely to be sampled. Further, freezing and thawing and the return of K to the soil from plant residue over the winter may change soil test levels between the fall and the spring.

The change in STK with the addition of fertilizer and/or the removal of K is related to the potassium buffer capacity (KBC) of the soil. Currently, the University of Wisconsin assumes the mineral soils of Wisconsin to have a KBC of 6 or 7 lb K_2O/a per 1ppm soil test K, depending on soil group (Laboski et al., 2006). These approximations of KBC are used in the calculation of fertilizer application rates for low and very low testing soils. A better understanding of soil buffer capacity in the field will assist in improving fertilizer recommendations and in interpreting fluctuations in STK levels.

The objectives of this study were:

- Determine if STK levels fluctuate significantly throughout the three-year study.
- Determine if soil test levels change significantly between the fall and the spring.

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- Evaluate if changes in STK affect soil test interpretation and fertilizer recommendations.
- Assess KBC at each location in terms of drawdown and buildup of STK.

Materials and Methods

Field plots were established in the spring of 2006 at Arlington, Hancock, Lancaster, and Marshfield Agricultural Research Stations, and a private farm in Fond du Lac County. These five locations represent five pedogenically unique mineral soils of Wisconsin (Laboski et al., 2006). The soil names, initial Bray-1 soil test K and P levels, organic matter content, pH, previous crop, and N fertilizer rates for each location are presented in Table 1.

The duration of the experiment was three growing seasons, 2006 through 2008. The experimental design was a split-plot with corn harvest management as the whole plot factor (grain and silage) and potassium fertilizer rate as the subplot factor with four replications. All locations received seven different K rates (0, 67, 134, 201, 268, 335, 401 lb K_2O/a) except Fond du Lac, which received only four rates (0, 67, 134, 201 lb K_2O/a). Potassium fertilizer (0-0-60) was preplant surface broadcast and incorporated in the spring of 2006 to a depth of 8 inches. No additional fertilizer was applied in 2007 or 2008.

The sites were cropped to corn in 2006, soybean in 2007, and corn again in 2008. Tillage was spring or fall chisel, except at Hancock which was moldboard plowed. Plot size was 10 ft in width (except at Hancock which was 12 ft in width) and 35 ft length. Best crop and pest management practices were followed at each location.

Table 1. Selected characteristics of soils and field sites.

		Initial soil test values†					N rate	
Location	Soil name	K	P	pH	OM	2005 crop	2006	2008
		—— ppm ——			%		— lb N/a —	
Arlington	Plano silt loam	123	33	6.7	4.0	Soybean	120	160
Hancock‡	Plainfield sand	40	97	6.6	0.8	New seeding red clover	200	215
Lancaster	Fayette silt loam	70	12	6.9	2.7	August alfalfa after oats	160	160
Marshfield	Withee silt loam	111	32	7.1	3.4	Soybean	120	110
Fond du Lac	Kewaunee clay loam	95	17	7.6	3.2	Soybean	120	120

†Bray-1 extracted K and P. K, P, pH, and OM determined for air-dried soils sampled in the spring of 2006, 0-20cm in depth.
‡ Irrigated.

For the corn grain harvest plots, soil samples were collected a total of 11 times at each location for the three-year duration of the experiment. Soil sampling occurred five times in 2006, four times in 2007, and twice in 2008. In 2006, soil was sampled late April or early May (prior to fertilizer application), June, July, September, and after harvest in October. In 2007, soil was sampled before planting in May, twice during the growing season in June and August, and after harvest in October.

In 2008, soil was sampled before planting in May and after harvest. The corn silage harvest plots were sampled prior to planting and after harvest each year. The different locations were not all sampled on the same day for each sampling event, but were all sampled within 1 to 14 days of each other.

Six soil cores, 0- to 8-inch depth, were collected from each plot and mixed to make a composite sample. Soil samples were homogenized, sieved to 0.08 inch, oven-dried at 95°F, and extracted with Bray-1. Extraction and analysis of potassium followed procedures outlined in Peters (2009). In 2006 and 2007 potassium was determined using atomic absorption flame spectroscopy, while ICP-OES was used in 2008.

The effect of sampling time on STK levels was determined for the 0 K rate and highest K rate silage and grain harvested plots at each location using a repeated measures ANOVA model in PROC MIXED of SAS (SAS Inst., Inc., Cary, NC). Contrasts were used to determine if soil test K levels differed significantly between the fall and spring of 2006-2007 or the fall and spring of 2007-2008.

Two different calculations of potassium buffer capacity (KBC) were made: a drawdown KBC and a buildup KBC. Drawdown KBC was calculated as the slope of the net K_2O removed (K_2O applied- cumulative K_2O removed) verses the change in STK (STK post-harvest 2008- STK before fertilizer application in spring 2006). Buildup KBC was calculated as the slope of the K_2O applied verses the change in STK (STK 6 weeks after fertilizer application in spring 2006- STK before fertilizer application in spring 2006). *T*-tests were used to compare KBC values from this study to KBC values assumed in Laboski et al. (2006).

Results and Discussion

Soil test potassium levels were found to be significantly (P<0.05) affected by time of soil sampling in the silage harvested plots at Arlington, Hancock, and Marshfield where no K was applied; at Arlington and Lancaster for the highest K rate; and in the grain harvested plots at Hancock, Marshfield, and Fond du Lac at both the highest K and no K applied rates (Fig. 1). For some treatments, fluctuations in STK were quite large but were not statistically significant because of variability between replicates.

Soil test K levels decreased in most of the unfertilized plots after three years of cropping; however, soil test K levels increased 8 and 10 ppm for the unfertilized grain harvested plots at Lancaster and Fond du Lac, respectively (Fig. 1). Soil test K levels remained greater at the end of three years compared to initial STK when 401 lb K_2O/a was applied at some locations but not at others. At Marshfield, for example, STK increased 31 ppm; while soil test K decreased 30 ppm at Arlington (grain harvested plots). After three years of cropping, STK decreased the most for the unfertilized grain and silage harvested plots at Arlington, compared to the unfertilized plots at the other locations; however, plant uptake of K was also greatest at this location.

Soil test K levels were significantly (P<0.05) greater in the spring than in the fall for the no K rate silage harvested plots at Hancock in 2006-2007, and the highest K rate silage harvested plots at Lancaster in 2007-2008 (Table 2). Soil test K levels were significantly (P<0.05) lower in the spring than in the fall of 2006-2007 for the highest K rate silage harvested plots at Arlington. Changes in soil test levels were relatively large for some treatments (a decrease in STK of 28 ppm in 2007-2008 at Marshfield in the silage harvested plots with the highest K rate, for example), but were not statistically significant because of the variability between replicates.

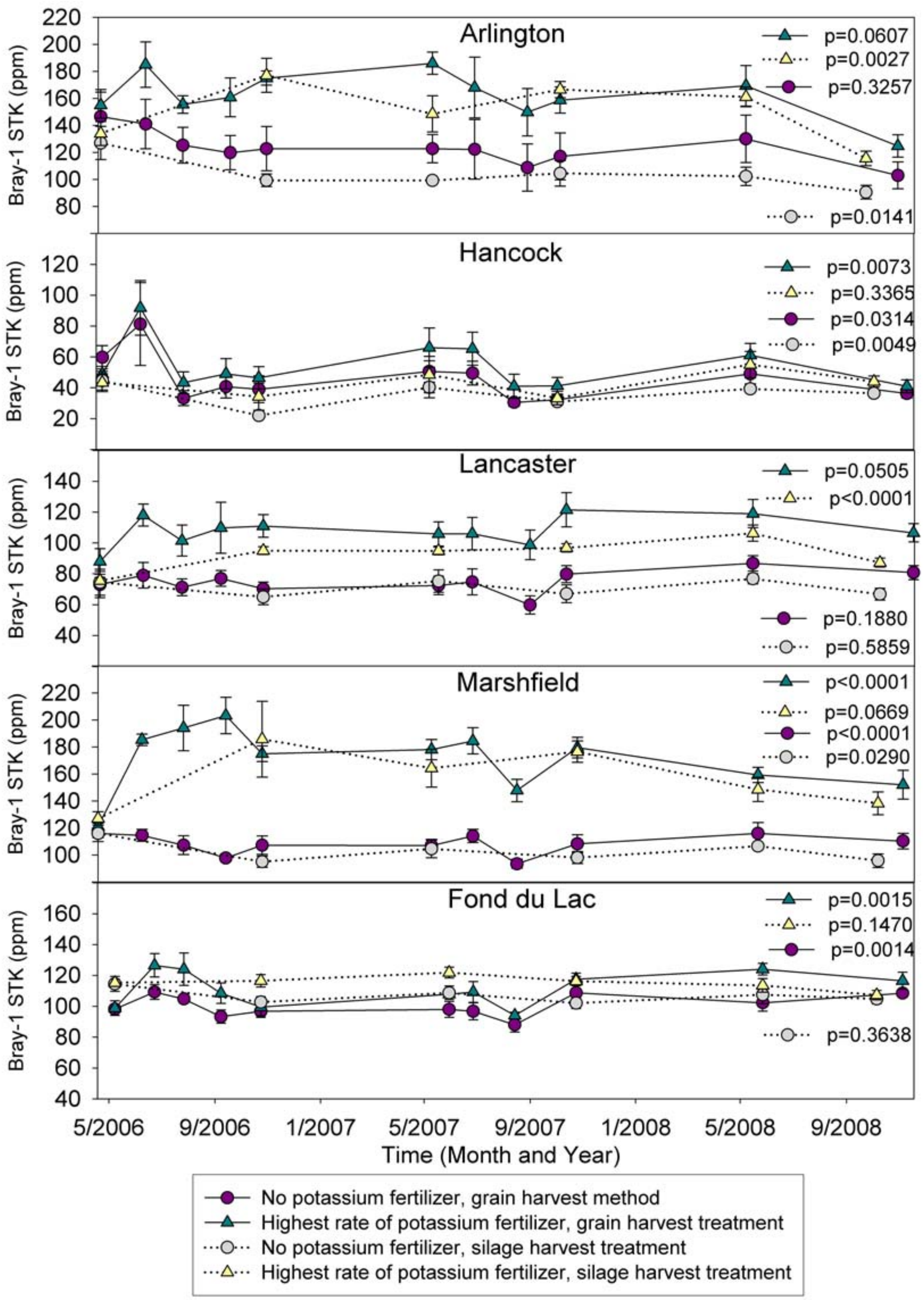

Figure 1. 2006-2008 oven-dried Bray-1 soil test potassium (STK) levels for fertilized (401 lb K_2O/a at all locations except Fond du Lac, which had 201 lb K_2O/a) and unfertilized plots harvested as grain or silage at five Wisconsin locations. P-values are given for the effect of time on Bray-1 STK.

Although fall verses spring sampling was not found to be statistically significant for many of the treatments, changes in STK between fall and spring were frequently large enough to affect soil test interpretation categories (Table 2) and subsequently the recommended rate of K fertilizer. STK interpretation categories were greater in the spring than the fall in 2006-2007 for the highest K rate corn silage and corn grain plots and no K rate corn grain plots at Hancock; the no K rate corn silage plots at Marshfield; and the highest K rate corn grain plots at Fond du Lac. In 2007-2008, STK interpretation categories were greater in the spring for the highest K rate corn silage and corn grain plots and the no K rate corn grain plots at Hancock; and for the highest K rate corn silage plots and no K rate corn grain plots at Lancaster. STK interpretation categories were lower in the spring than in the fall for the highest K rate corn silage plots at Arlington in 2006-2007; and for the highest K rate corn silage and corn grain plots and no K rate corn silage plots at Marshfield in 2007-2008.

Table 2. Changes in STK between fall and spring soil sampling, and its effect on soil test category.

Location	Harvest method	Rate	2006-2007			2007-2008		
			Change in STK†	Fall soil test category‡	Spring soil test category‡	Change in STK†	Fall soil test category‡	Spring soil test category‡
		lb K_2O/a	ppm			ppm		
Arlington	Silage	0	0	Opt	Opt	-2.25	Opt	Opt
		401	-28.5*	EH	H	-5.5	EH	EH
	Grain	0	0	H	H	13	H	H
		401	11	EH	EH	10.5	EH	EH
Hancock	Silage	0	18.25*	VL	VL	8.25	VL	VL
		401	14.25	VL	L	21.75	VL	L
	Grain	0	11.5	VL	L	16.75	VL	L
		401	19.5	L	Opt	19.75	VL	L
Lancaster	Silage	0	10.25	L	L	9.75	L	L
		401	-0.25	Opt	Opt	9.5*	Opt	H
	Grain	0	2.25	L	L	7	L	Opt
		401	-5.25	H	H	-2.5	H	H
Marshfield	Silage	0	9.5	L	Opt	8.5	L	Opt
		401	-21.5	EH	EH	-28	EH	H
	Grain	0	-0.25	Opt	Opt	7.75	Opt	Opt
		401	3	EH	EH	-20.25	EH	H
Fond du Lac	Silage	0	6	H	H	5.5	H	H
		201	5.25	Opt	Opt	-2.75	H	H
	Grain	0	1.25	Opt	H	6.25	H	H
		201	8.25	Opt	Opt	6.5	Opt	Opt

†Change in STK calculated as spring STK minus fall STK.
‡Soil test categories given in Laboski et al. (2006). Soil test categories include very low (VL), low (L), optimum (Opt), high (H), and excessively high (EH). For simplification, soil test categories are assumed for a corn grain crop.
*Indicates significantly different (P<0.05).

Potassium buffer capacity calculated as a drawdown (crop removal) resulted in greater values than KBC calculated as a buildup (Table 3). This may be caused in part to crops obtaining K from the subsoil. KBC drawdown values for Lancaster and Marshfield were significantly (P<0.05) greater than 7 and 6 lb K_2O/a per 1 ppm STK, respectively. KBC buildup values were not significantly different from either 6 or 7 lb K_2O/a per 1 ppm STK at any location. KBC could not be calculated for some of the locations/ harvest management systems because the slope of the regression was not significant (P>0.05).

Table 3. Potassium buffer capacity calculated as a drawdown and a buildup.

Location	Harvest management system	KBC drawdown	KBC buildup†
		lb K_2O/a per 1 ppm soil test K	lb K_2O/a per 1 ppm soil test K
Arlington	Grain	17.7	7.0
	Silage	12.5	
Hancock	Grain	20.9	9.3
	Silage	––§	
Lancaster	Both‡	16.1*	––§
Marshfield	Both‡	10.7*	4.9
Fond du Lac	Grain	––§	––§
	Silage	––§	

† KBC buildup was calculated for grain plots only.
‡ Data from grain and silage plots were combined.
§ The regression slope was not significant (P>0.05), therefore KBC could not be calculated.
*Indicates KBC is significantly different than the value of 6 or 7 lb K_2O/a per 1 ppm soil test (Laboski, 2006).

Conclusion

When interpreting the results of soil tests, it is important to consider that time of soil sampling may impact STK levels. Soil test K levels were found to be significantly affected by time of soil sampling during the 3-year period. Soil test K levels were significantly different between fall and spring soil sampling dates in 2006-2007 for the highest K rate silage harvested plots at Arlington and the no K rate silage harvested plots at Hancock, and in 2007-2008 for the highest K rate silage harvested plots at Lancaster. Although not statistically significant, differences in STK between fall and spring soil sampling dates were frequently large enough to change soil test categories, and thus impact fertilizer recommendations. The results of this study suggest that changes in STK levels between fall and spring sampling dates are not consistent from year to year, at a given location. Thus, the present recommendation to sample at the same time of year whenever possible is useful to reduce the variability in interpretation when soil is sampled at different times of the year.

Preliminary evaluation of KBC in the field revealed that buildup values were not significantly different than the values (6 or 7 lb K_2O/a per 1 ppm STK) currently used in determine nutrient application rates for low and very low K testing soils. However, KBC drawdown values were significantly greater than 6 and 7 lb K_2O/a per 1 ppm STK at Marshfield and Lancaster, respectively. Data from a laboratory investigation on KBC for these soils are currently be analyzed, and may help with interpretation of results from the field.

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OPTIMIZING HERBICIDE PERFORMANCE THROUGH ADJUVANTS: RESOLVING MISCONCEPTIONS AND CONFUSION

Richard Zollinger[1]

Spray Adjuvants

POST herbicide effectiveness depends on spray droplet retention, deposition, and herbicide absorption by weed foliage. Adjuvants and spray water quality influence POST herbicide efficacy. Adjuvants are not needed with PRE herbicides unless weeds have emerged and labels include POST application.

Spray adjuvants generally consist of surfactants, oils and fertilizers. The most effective adjuvant will vary with each herbicide, and the need for an adjuvant will vary with environment, weeds, and herbicide used. Adjuvant use should follow label directions and be used with caution as they may influence crop safety and weed control. An adjuvant may increase weed control from one herbicide but not from another. To compare adjuvants and determine adjuvant enhancement herbicide rates should be used at marginal weed control levels. Effective adjuvants will enhance herbicides at reduced rates and provide consistent results under adverse conditions. However, use of below-labeled rates exempts herbicide manufacturers from liability for nonperformance.

Surfactants are used at 0.125 to 0.5% v/v (1 to 4 pt/100 gal of spray solution). Surfactant rate depends on the amount of active ingredient in the formulation, plant species and herbicides used. The main function of a surfactant is to increase spray retention, but surfactants also function in herbicide absorption. When a range of surfactant rates is given, the high rate is for use with low rates of the herbicide, drought stress and tolerant weeds, or when the surfactant contains less than 90% active ingredient. Surfactants vary widely in chemical composition and in their effect on spray retention, deposition, and herbicide absorption.

Silicone surfactants reduce spray droplet surface tension, which allow the liquid to run into stomata on leaves ("stomatal flooding"). This entry route into plants is different than adjuvants that aid in absorption through the leaf cuticle. Rapid entry of spray solution into leaf stomata from use of silicone surfactants often does not result in improved weed control. Silicone surfactants are weed and herbicide specific just like other adjuvants.

Oils generally are used at 1% v/v (1 gal/100 gal of spray solution) or at 1 to 2 pt/A depending on herbicide and oil. Oil additives increase herbicide absorption and spray retention. Oil adjuvants are petroleum or methylated vegetable or seed oils (MSO) plus an emulsifier for dispersion in water. The emulsifier, the oil class (petroleum, vegetable, etc.), and the specific type of oil in a class all influence effectiveness of an oil adjuvant. MSOs have been especially effective with most all herbicides but generally are equal to or better than petroleum oils with most herbicides, except glyphosate, Ignite, and Cobra. Results vary when comparing specific adjuvants, even within a class of adjuvants.

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Fertilizers containing ammonium nitrogen increase effectiveness of most herbicides formulated as a salt. Fertilizers should be used with herbicides only as indicated on the label or where experience has proven acceptability. AMS is recommended at 8.5 to 17 lb/100 gal spray volume (1 to 2%) on most glyphosate labels. Enhancement of glyphosate, and many other herbicides, from AMS is most pronounced when spray water contains relatively large quantities of certain ions, such as calcium, sodium, and magnesium. AMS may contain contaminants that may not dissolve and then plug nozzles. Use spray grade AMS to prevent nozzle plugging. Commercial liquid solutions of AMS are available and contain approximately 3.4 lb of AMS/gallon. For 8.5 lb of AMS/100 gallons of water add 2.5 gallons of liquid AMS solution. AMS at 4 lb/100 gal (0.5%) is adequate to overcome most salt antagonism. AMS at 0.5% has adequately overcome antagonism of glyphosate from 300 ppm calcium. Use at least 1 lb/A of AMS when spray volume is less than 12 gpa. Ammonium ions also are involved in herbicide absorption and have enhanced phytotoxicity of many herbicides in absence of antagonistic salts in the spray carrier. Herbicide enhancement by nitrogen compounds appears most pronounced in most species like velvetleaf or sunflower. AMS enhances phytotoxicity and overcomes salt antagonism for most salt formulated herbicides, including dicamba, glyphosate, Poast, and 2,4-D amine. Liquid 28% UAN fertilizer is effective in enhancing weed control from many POST herbicides and overcoming sodium but not calcium antagonism of glyphosate. Sodium bicarbonate antagonism of Poast is overcome by 28% UAN, ammonium nitrate, and AMS. AMS or 28% UAN does not preclude the need for an oil adjuvant. Adjuvants vary in enhancement of herbicide action. The precise salt concentration in water that causes a visible loss in weed control is difficult to establish because weed control is influenced by other factors.

Some water pH modifiers are used to lower (acidify) spray solution pH because many insecticides and some fungicides degrade under high water pH. Most solutions are not high or low enough in pH for important herbicide breakdown in the spray tank. pH-reducing adjuvants (example: LI-700) are sometimes recommended for use with herbicides because of greater absorption of weak-acid-type herbicides when the spray solution is acidic. However, low pH is not essential to optimize herbicide absorption. Many herbicides are formulated as various salts, which are absorbed as readily as the acid. Salts in the spray water may antagonize formulated salt herbicides. In theory, acid conditions would convert the herbicide to an acid and overcome salt antagonism. However, herbicides in the acid form are less water soluble than in salt form. An acid herbicide with pH modifiers may precipitate and plug nozzles when solubility is exceeded, such as with high herbicide rates in low water volumes. Antagonism of herbicide efficacy by spray solution salts can be overcome without lowering pH by adding AMS or, for some herbicides, 28% UAN.

Basic pH blend adjuvants are non-oil based and increase spray solution pH. They contain nitrogen fertilizer to overcome antagonistic salts; a surfactant to aid in spray retention, spray deposition, and herbicide absorption; and a buffer to increase water pH. Basic pH blend adjuvants increase water pH, which increases water solubility of most ALS and HPPD inhibitor herbicides. For example, Accent solubility at water pH 5 is 360 ppm, at pH 7 is 12,200 ppm, and pH 8 is 39,200 ppm. Basic pH blend adjuvants reduce precipitation problems with Betamix*/ Betanex*/ Betamix Progress plus UpBeet at low rates by increasing water pH. Research has shown that basic pH blend adjuvants enhance weed control similar to MSO type adjuvants. They may be used in those situations where oil adjuvants are restricted. For example, some dicamba labels restrict oil adjuvants when used alone or in tank-mix with Accent on corn. Basic pH blend adjuvants are less expensive at field use rates than MSO type adjuvants.

Antagonism of glyphosate by calcium in a spray solution was overcome by sulfuric but not nitric acid, indicating that the sulfate ion was important, but not the acid hydrogen ion. The importance of the sulfate ion explains the effectiveness of ammonium sulfate, and not 28% UAN, in overcoming calcium antagonism of glyphosate. Other herbicides that become acid at a higher pH than glyphosate may realistically benefit from a reduced pH as has been shown for Poast. However, Poast does not require a low pH for efficacy. Spray solution pH of 4 has overcome sodium antagonism of Poast, but nitrogen fertilizer or AMS also will overcome sodium antagonism of Poast without lowering the pH. The ammonium ion provided by these fertilizers is apparently the important ion.

In summary, adjuvants that are designed specifically to reduce pH generally are not required for herbicide efficacy. The type of acid or components of buffering agents and the specific herbicide all need to be considered before using pH-modifying agents.

Choosing Adjuvants with Herbicides

Several POST herbicides allow use of nonionic surfactant, petroleum oil additives, methylated seed oil additives, and nitrogen fertilizer. Questions about adjuvant selection are common. MSO additives have often given greater weed control than petroleum oil additives and nonionic surfactants (NIS) but cost two to three times more. The added cost of MSO and increased risk of crop injury when used at high temperatures have deterred people from using this class of adjuvants. Using reduced herbicide rates with MSO can enhance weed control while lowering risk of crop injury.

Some herbicide labels restrict use of oil adjuvants and recommend only use of NIS alone or combined with nitrogen based fertilizer solutions. Follow label directions for adjuvant selection. Where labels allow use of oil additives, petroleum oil based adjuvants (COC) or methylated seed oil (MSO) adjuvants may be used. The term crop oil concentrate is misleading because the oil type in COC is petroleum based oil and not a crop vegetable based oil.

NDSU research has shown wide difference in adjuvant enhancement of herbicides. However, in many studies, no or small differences occur depending on environmental conditions at application, growing conditions of weeds, rate of herbicide used, and size of weeds. For example, under warm, humid conditions with actively growing weeds, NIS + nitrogen fertilizer may enhance weed control the same as oil additives. The following are conditions where MSO type additives may give greater weed control than other adjuvant types:

1. Low humidity, hot weather, lack of rain, and drought-stressed weeds or weeds not actively growing due to some condition causing stress.
2. Weeds larger than recommended on the label.
3. Herbicides used at reduced rates.

4. Target weeds are somewhat tolerant to the herbicide. For example, control of wild buckwheat, biennial wormwood, lambsquarters or ragweed with Pursuit or Raptor, or control of yellow foxtail with Accent.
5. When university data support reduced herbicide rates. Most herbicides except glyphosate give greater weed control when used with MSO type adjuvants. Oil adjuvants should not be used with glyphosate only when research or experience shows no reduction in weed control.

Adjuvant Use in Low Gallonage Spray Volumes

In certain instances, spray adjuvant rates should be adjusted for low sprayer volumes. For example, oil adjuvants are applied with ALS, ACCase, and HPPD inhibitor herbicides and other POST herbicides at 1% v/v or 1 gal/100 gal water. At 15 to 20 GPA, 1% oil adjuvant would provide adequate adjuvant load. However, in aerial applications at 5 GPA, 1% v/v may not provide enough adjuvant for optimum herbicide enhancement.

Some herbicide labels contain information on adjuvant rates for different spray volumes. For example, Pursuit and Raptor labels require oil adjuvants to be added at 1.25% v/v or 1.25 gal/100 gal water for aerial application (5 GPA). To insure sufficient adjuvant concentration, add oil adjuvant on an area basis. Instead of using oil adjuvants at 1% v/v, apply at 1.25 to 2 pt/A at all spray volumes. Surfactant at 0.25% v/v or 1 qt/100 gal water is sufficient across all water volumes. Basic pH blend adjuvants are recommended at 1% v/v regardless of spray volume. Data indicate basic blend adjuvants at 1% v/v from 5 to 20 GPA will provide adequate adjuvant enhancement for similar weed control.

Spray Carrier Water Quality

Minerals, clay, and organic matter in spray carrier water can reduce the effectiveness of herbicides. Clay inactivates paraquat, diquat, and glyphosate. Organic matter inactivates many herbicides, and minerals can inactivate the activity of most salt formulated herbicides, including 2,4-D amine, MCPA amine, Achieve, dicamba, Ignite, glyphosate, and Poast.

Water in North Dakota, South Dakota, and Montant is often high in sodium bicarbonate, which does not normally occur in other areas of the U.S. Sodium bicarbinate reduces the effectiveness of most salt formulated herbicides, including amine phenoxys, ALS, ACCase, dicamba, Ignite, and glyphosate. Water with 1600 ppm sodium bicarbonate can occur, but antagonism of above herbicides occurred at or above 300 ppm. The antagonism is related to the salt concentration. At low salt levels, loss in weed control may not be noticeable under normal environmental conditions. However, antagonism from low salt levels will cause inadequate weed control when weed control is marginal because of drought or partially susceptible weeds.

High salt levels in spray water can reduce weed control in nearly all situations. Calcium and magnesium are antagonistic. Calcium antagonism may occur at 150 ppm. Sulfate ions in the solution have reduced the antagonism from calcium and magnesium, but the sulfate concentration must be three times the calcium concentration to overcome antagonism. Natural sulfate in water can be disregarded.

Water often contains a combination of sodium, calcium, and magnesium, and these cations generally are additive in the antagonism of herbicides. Many adjuvants are marketed to modify spray water pH, but low pH is not essential to the action of most herbicides. AMS, granular or liquid, and 28% UAN fertilizer help overcome antagonistic salts in spray carrier water. Generally, 4 gal of 28% UAN/100 gal of spray has been adequate. UAN overcomes mineral antagonism of most herbicides, but not glyphosate. AMS and 28% UAN enhance herbicide control of certain weeds even in water without salts. Nitrogen fertilizer/surfactant blends may enhance weed control of most herbicides formulated as a salt.

Understanding a Water Quality Analysis Report

Water quality is important to herbicide efficacy and spray problems. However, the issue is complex as each herbicide may respond differently to water quality.

1. Water pH

High and low pH can reduce efficacy of pesticides and cause nozzle plugging with some herbicides. Some insecticides are degraded rapidly in extreme pH. Most SU (sulfonylurea) herbicides are hydrolyzed by high and low pH. However, this is not normally a problem when sprayed within a normal time period but efficacy could be reduced when mixed in water with extreme pH for a day or more. Low pH forces salt formulated herbicides into the acid state that may not be soluble in the amount of water being sprayed and thus plug nozzles and reduce efficacy.

High and low pH can increase the efficacy of certain herbicides. Some adjuvants for glyphosate formulations lower pH, but glyphosate is soluble at low pH and maintains efficacy. In addition, the low pH overcomes antagonism from salts in the water (water salts will be discussed later). Herbicides need to be in solution for absorption into plant foliage. Sulfonylurea herbicides are more soluble at high pH so water with high pH may increase their efficacy. This is especially true for Accent, but certain minerals (sodium) in water may not allow the total benefit from the high pH.

2. Total Dissolved Solids and Electrical Conductivity

The major mineral constituents in northern plains water and their ionic chargers are:
Cations (+ charge) = calcium (Ca), magnesium (Mg), sodium (Na), potassium (K), and iron (Fe).
Anions (- charge) = sulfate ($SO_{4)}$, chloride (Cl), bicarbonate (HCO_3), and nitrate (NO_3).

The sum of all the minerals dissolved in a sample of water is normally referred to as the total dissolved solids (TDS). The higher the TDS, the more electric current water can conduct. Because of this characteristic, a measure of the electrical conductivity (EC) is often used to provide a quick, economical estimate of the TDS in water. If the EC is less than 500 umho/cm, water quality problems for herbicides are very unlikely. Water EC values in ND and western U.S. run between 1000 and 2,500. Usually hardness and cation concentration, not TDS, are used to evaluate water quality on herbicide performance.

3. Hardness

Water hardness is caused by potassium, calcium, magnesium, and iron. These minerals can react and antagonize water soluble formulations of many weak acid herbicides like glyphosate, 2,4-D amine, MCPA amine, dicamba, Basagran, Curtail, etc. The ester formulations of herbicides are oil soluble and do not react directly with the salts in the water. However, these oil type formulations need an emulsifier so that the formulation will mix with water and sometimes these emulsifiers may be ineffective when in water with salts and cause an oil-like scum or precipitate in the spray water reducing efficacy and plugging nozzles.

Sodium contributes to water hardness but functions to soften water similar to home water softener systems. Hardness levels are reported in mg/L (ppm) of calcium carbonate (CaCO3). Hardness values are calculated by adding meq/L of Ca and Mg then multiplying by 50. Hardness of individual cations can be confusing because they can be reported as milliequivalents/L (meq/L), milligrams per liter (mg/L), parts per million (ppm), or grains per U.S. gallon (gpg). The mg/L and ppm are considered equal, and 1 grain per gallon is equal to 17.1 mg/L or ppm.

To convert meq/L to ppm, multiply meq/L x atomic number of the atom: K meq/L x 39.102, Na x 22.991, Mg x 12.156, Ca x 20.04. Water hardness values in MT, ND, and MN run between 0 and 2,000 ppm. There are variations in water hardness classifications but the following scale can be used: Soft = <75 ppm; Moderately hard = 75 – 150 ppm,;Hard = 150 – 300 ppm; Very hard = >300 ppm.

The amount of AMS needed to overcome antagonistic ions can be determined as follows:

lbs AMS/100 gal = (0.002 X ppm K) + (0.005 X ppm Na) + (0.009 X ppm Ca) + (0.014 X ppm Mg) + (0.042 X ppm Fe).

This does not account for antagonistic minerals on the leaf surface on some species like lambsquarters, sunflower, and velvetleaf, which may require additional AMS.

4. Sodium Absorption Ratio

Water high in sodium, when added to clay soils, may have a detrimental effect. Excess sodium will attach to clay particles and displace other ions, namely chloride and sulfide. A high SAR may indicate a limited ability for plants to extract water from the soil. The adjusted SAR has reference to bicarbonates. Some water in the northern plains is very high in bicarbonates, which increases the SAR problem. Water quality standards for SAR are as follows:
Excellent = <3, Good = 3 – 5, Permissible = 5 – 10, Doubtful = 10 – 15, Unsuitable = >15.

5. Residual Sodium Carbonate

Values greater than 0 increase the sodium hazard.

6. Bicarbonates

Since bicarbonate is anionic (-) it is always associated with a cation (+) like sodium or calcium to make sodium or calcium bicarbonate in ground water. The corresponding cation (Ca, Na) may have a greater role in herbicide antagonism than the bicarbonate. High sodium and sodium bicarbonate antagonism of herbicides is usually overcome by ammonia type adjuvants. Small amounts of antagonistic salts do not appear to reduce herbicide efficacy with full use rates. This is because the use rate was established for efficacy using various waters. However in principle to optimize herbicide efficacy, any amount of antagonistic salts will have some effect and to optimize efficacy for all conditions one may wish to consider taking action to overcome even low amounts of antagonistic salt.

Water with high bicarbonate levels may have low levels of other anions like chloride and sulfate. Calcium chloride is also antagonistic and spray water pH should be below 7. Bicarbonate levels greater than 500 ppm may reduce herbicide efficacy of Achieve, Poast, Select, MCPA amine, and 2,4-D amine. When using water with more than 500 ppm bicarbonates the high rate of these herbicides should be used and applied at the most susceptible weed stage for efficacy. Bicarbonate also increases water pH and high bicarbonate levels may also be associated with high water pH (See #1 above). Water bicarbonate levels in mid-west, plains and northern plains range from 200 to 1,000 ppm.

Analysis of spray water sources can determine water quality effects on herbicide efficacy. Water samples can be tested at (analysis is approximately $25.00 to $29.00):

U.S.Postal Service: NDSU Dept 7680, Fargo, ND 58108-6050,
UPS and Physical Address: NDSU Soil and Water Laboratory, Waldron Hall 202,
1360 Bolley Dr. NDSU, Fargo, ND 58102. 701 231-7864.

The analysis may report salt levels in ppm or grains. To convert from grains to ppm, multiply by 17 (Example: 10 grains calcium X 17 = 170 ppm calcium). AMS at 2% (17 lb/100 gallons water) will overcome antagonism from the highest calcium and/or sodium concentrations in water. However, AMS at 4 lb/100 gal is adequate for most water sources in the U.S. Iron is also antagonistic to many herbicides but not abundant in water in the mid-west or northern plains.

TRENDS IN WISCONSIN SPECIALTY CROPS AND HERBICIDE DRIFT RISK

Jed Colquhoun [1]

Pesticide drift to sensitive sites is a very rare occurrence, but can involve a high liability when it does occur given the value of specialty crops. The topic of pesticide drift has been addressed for many years in Wisconsin, and applicators are generally very aware of such risk. However, the landscape is changing in Wisconsin and therefore warrants a reminder of the extent and distribution of sensitive specialty crops in the state.

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

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

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

The number and acreage of organic farms is also increasing rapidly in Wisconsin. The number of organic farms in Wisconsin increased from 712 in 2005 to 1,099 in 2009. Wisconsin ranks second, behind California, in the number of organic farms. The acreage has similarly increased, from 41,245 acres in 1997 to 147,120 acres in 2007. Herbicide use near certified organic production can be particularly challenging. Herbicide drift to any non-target crop, grown "conventionally" or organically, is illegal. However, organic production can be particularly at risk given that farm certification, and subsequently the ability to sell the crop as organic, can be compromised by pesticide drift. Recent cases demonstrate the high liability associated with pesticide drift on organic farms. For example, the Jacobs Farm in California recently won a $1 million dollar judgment against the applicator based on a case of organophosphate drift to organic Brussels sprouts.

[1] Associate Professor, Dept. of Horticulture, Director of Agricultural Systems Programming, College of Agricultural & Life Sciences, Univ. of Wisconsin-Madison, 1575 Linden Dr., Madison, WI 53706.

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

Again, the intent of this presentation is to serve as a gentle reminder to get to know your neighbors and areas surrounding a pesticide application. While no application technique or equipment can completely mitigate the risk for drift, awareness of surroundings can go a long way to understanding the risks in the changing Wisconsin landscape. Please reference the following presentation on pesticide-related investigations by the Department of Agriculture, Trade and Consumer Protection, as well as subsequent presentations on nozzle selection and application techniques.

Reference

Association of American Pesticide Control Officials. 2005. Pesticide drift survey. Accessed online (December 2, 2009): http://aapco.ceris.purdue.edu/htm/survey.htm.

A HIGH-TECH APPROACH TO NOZZLE AND ADJUVANT SELECTION

Eric Spandl[1/]

Evaluating and choosing the right spray nozzles and adjuvant for crop protection applications can be a challenge. Many factors, like nozzles and adjuvants, affect the spray pattern and droplet distribution and subsequently potential for drift and product efficacy. Personal observations and field experience are quite useful in evaluating results. Visual evaluation of nozzles of spray pattern and droplet distribution in real time can be useful but provides limited information. You can observe large changes in pattern distribution and if there is significant drift or movement of spray droplets.

Some "high tech" equipment has allowed us to evaluate in much greater detail the affects of nozzles, adjuvants, and other factors on spray droplet size, distribution pattern and movement. A laser analyzer provides a concise measurement of spray droplet size and quantity within a given range. This is especially useful for showing how much of the spray is small droplets, such as those under 105 microns. Droplets this size have a higher potential to move off-target. Laser droplet analysis is useful for showing how various factors affect droplet size. However, presentation is usually limited to tables or graphs.

Other technology has allowed us to develop visual evaluations that support the laser analysis. A high speed camera and strobe provided pictures illustrating individual droplets within a spray pattern. In addition, spray patterns were recorded with a high-speed video camera and played back in slow motion to demonstrate droplet distribution and movement.

TeeJet AI, AIXR, and XR nozzles and various spray mixtures were analyzed with the laser. The above nozzles plus many others were photographed or videotaped. Spray mixtures included water alone, glyphosate herbicide, a simulated adjuvant system for glyphosate, and various adjuvants. In addition, wind absence or presence, was included for photographs and video.

The high speed photography and video provided excellent detail of the spray droplets and distribution in the spray patterns. Individual droplets were visible on photos and could be tracked on videos as they left the nozzle and were moved by wind. Photos and video provide a level of detail not seen by the eye in real time. These forms of evaluating spray pattern and droplet movement provide very obvious and visual evidence that supports the quantitative analysis provided by the laser.

Many factors like nozzles type, nozzle setting (e.g., pressure), spray mixtures, and wind significantly impacted results. However, product performance can be optimized and the potential for drift reduced by selecting the proper nozzle type, adjusting nozzle pressure, and adding the proper adjuvant.

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SOYBEAN APHID RESEARCH UPDATE

Christian H. Krupke [1/]

Soybean aphid has been a pest of soybeans in the upper Midwest for nearly a decade. There have been some significant changes over that time, both in the biology of this pest and in the way we manage it.

An overview will be given of some of the newest information in soybean aphid biology and management, with focus on discussing what happened in 2009 — a remarkable year in our short history with this insect. This will include discussion of aphid overwintering hosts, both past and present, and focus on interpreting the 250 aphid/plant threshold at advanced growth stages (R5-R6).

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TILE BASICS AND DISCOVERY FARMS TILE FINDINGS

Eric T. Cooley, Matthew D. Ruark, and John C. Panuska [1/]

Subsurface drainage is used for agricultural, residential and industrial purposes to remove excess water from poorly drained land. An important feature statewide, drainage enhances Wisconsin agricultural systems, especially in years with high precipitation. Drainage systems improve timeliness of field operations, enhance growing conditions for crop production, increase crop yields on poorly drained soils and reduce yield variability. In addition to agronomic benefits, subsurface drainage can improve soil quality by decreasing soil erosion and compaction. To maintain agricultural productivity and protect water quality, producers, consultants and agency personnel must understand tile drainage, locate drainage systems and properly maintain them.

In Wisconsin, drainage systems were originally constructed using short (1-foot) segments of clay or cylindrical concrete "tiles." Tiles were initially installed manually, requiring hand excavation. Modern drain tiles are corrugated, perforated plastic pipes typically installed mechanically using a trencher. These plastic pipes are available in a variety of diameters to accommodate different flow rates. They are typically installed at a depth of 3 to 6 feet below the soil surface and discharge into drainage ditches, streams or wetlands. The majority of tile-drained land in Wisconsin is located in the eastern and southern portions of the state, although county records indicate that tile drainage is prevalent statewide. In Wisconsin's rolling landscape, tile drains are often installed in a random pattern, following depressional areas.

Locating Tile Drains

Knowing the location and extent of tile drains is a challenge facing producers, consultants and agency personnel. Records of main, lateral and outlet tile locations are often lacking. To properly use and maintain an existing tile drainage system, producers must be able to locate tile lines and outlets. Although it is often hard to identify old tile systems in agricultural settings, there are a number of resources available to help. The local Natural Resources Conservation Service or Land Conservation Department offices may have maps or other materials if a previous land owner worked with these agencies. Information from these maps should be field-verified.

There are also three readily identifiable drainage features that can indicate the presence of tiles: vents, surface inlets and outlets. Modern tile systems often include vents to increase water removal efficiency and maintain atmospheric pressure within the drain system. Air vents consist of a perforated orange or white pipe protruding a few feet above the ground. Surface water inlets look similar to air vents and are typically installed in low areas lacking a surface outlet. Surface inlets are designed with above ground openings to allow surface water to directly enter tile. Producers must take special care when applying manure, fertilizers and chemicals close to inlets, given the high potential for direct entry into the system and into surface waters.

Another identifiable feature is a tile outlet, where the tile system discharges to drainage ditches, waterways, streams and/or wetlands. Tile outlets should be located and marked in the field

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for future reference. Producers should inspect outlets and clear debris that could impede flow. A sink hole can occur when a tile outlet is blocked. Blockage creates back pressure within the tile, and the surrounding soil becomes saturated. When the pressure within the drain drops, the saturated soil next to the pipe will get sucked into the tile, resulting in a sink hole.

Maintaining Tile Drains

Tile drainage systems should be inspected annually, preferably at peak flow times that typically occur during spring melt and after heavy rainfall events. Inspection should include checking outlet pipes to ensure that rodent guards are in place and working properly. Rodent guards prevent nests and debris introduced by rodents from plugging tile outlets. A tile outlet with a rodent guard can be quickly cleaned by sliding your hand inside the pipe under the guard and removing any trapped material. Tile outlets should also be inspected for excessive erosion and broken or crushed pipe. A good indicator of tile drain performance is a change in field moisture conditions, such as when traditionally well-drained areas exhibit prolonged periods of wetness. In this case the tile line should be inspected for a possible mid-field blockage and to verify that the drainage outlet exists and is of adequate in size.

On-going maintenance of fields and waterways with tile systems should include visual observations for animal burrows, tile blowouts or sink holes. These features range in size from a few inches to several feet and can be hard to find. The direct pathways created by these features can result in large amounts of sediment, debris, manure, fertilizer or chemicals entering tiles. Blowouts result from excessively high flow velocity or pressure inside the tile, causing it to crack or burst. Blowouts are common at tile junctions, fittings or weak spots. Blowouts will often create a sink hole when the surrounding material is drawn into the tile and transported downstream. Sink holes can be observed during high flow periods by water upwelling or going into the ground and during lower flow by the hole left in the ground. Blowouts should be repaired promptly by knowledgeable individuals. Improper repairs and quick fixes can result in on-going problems with blockages. Always contact Digger's Hotline, 1-800-242-8511, prior to excavation for tile repairs.

Modifying or Installing New Tile Drainage Systems

NRCS standard practices (NRCS Code 606) should be followed when designing, modifying or installing tile drainage systems. A detailed installation plan should be developed addressing specific drainage needs. This plan requires assistance from knowledgeable individuals, such as an engineer or experienced tile installer, and should consider crop and soil types as well as site topography. A sub-surface drain system is composed of lateral, sub-main and main line piping. Laterals are the initial collectors of excess water from the soil. Several laterals convey flow to a main or sub-main. A sub-main carries flow to a main line that typically drains to the outlet.

When enlarging lines or adding new laterals to existing drainage systems, be certain main lines are adequately sized to accommodate the additional flow, thus avoiding backpressure and blowouts. Air vent installation is recommended to maintain atmospheric pressure throughout the system. This allows for maximum flow capacity and relief from backpressure conditions. Tile system vents are open at the ground surface in order to expose the system to the atmosphere.

Good record keeping is an essential part of any drainage maintenance program. The location of tile lines, vents, surface inlets and outfalls is critical for trouble shooting and design modifications. Modern GPS technology has become an indispensable tool for mapping tile lines. Tile system mapping should be conducted when new tiles are installed and whenever information becomes available for existing systems (e.g., during routine maintenance). Tile location records should be stored in a safe, readily accessible location.

This information is part of a more detailed fact sheet series on “Tile Drainage in Wisconsin” For more information visit: http://www.uwdiscoveryfarms.org

LIQUID MANURE IN TILE DRAINS: PATHWAYS AND RISK REDUCTION STRATEGIES

John Panuska [1/] and Peter J. Kleinman [2/]

Land application is the most common method of animal waste management in Wisconsin. A significant risk of land spreading manure is its entry into streams, lakes and groundwater. Oxygen demanding organic matter, bacteria, pathogens and nutrients from manure can be transported into surface and groundwater posing significant public health and environmental risks. The most common and readily apparent transport pathway for surface-applied liquid manure into surface waters is via surface runoff. To reduce odors and runoff risk and to capture maximum fertilizer value, many producers inject liquid manure directly into field soils. For non-tiled fields surface application and injection are appropriate methods of manure application when soil conditions (moisture, slope, frost, etc.) are right and when done at application rates appropriate for soil assimilation. The existence of tile drains may, however, render surface application and injection inappropriate by providing direct transport pathways for liquid manure to surface waters. Manure can enter tile drains via surface inlets, open cavities created by tile blow-outs and via soil macro-pores (earthworm holes, soil structural cracks and former root channels).

Management to reduce the risk of manure entry into surface inlets is to avoid surface applications on fields with tile surface inlets, replace surface inlets with closely spaced sub-surface tile laterals or use injection. To reduce the risk of manure entering open cavities from tile blow-outs, repair blow-outs properly and/or make the necessary tile system design changes to prevent blow-outs from re-occurring. The risk of manure leaching through macro-pores can be reduced by tillage timing and equipment type. For both surface and sub-surface application, high soil moisture (near or above field capacity) and tile flow during application significantly increase the risk of leaching losses. Pre-application tillage over tiles reduces surface application risk, but adds time, cost and requires accurate knowledge of tile line location. Completely avoiding tiled areas with manure application reduces loss risk, but limiting the manure application land base is also not practical. Recent research (summer 2009) on one type of tillage equipment suggests manure leaching via macro-pores can be significantly reduced by using an ant-leach sweep injector shank operated at a ~ 6 in injection depth. The sweep simultaneously applies manure and aggressively mixes it with soil. This method showed significantly less leaching for a swine manure slurry (~ 1% solids) applied at an 8,000 gal/acre rate when compared to shallow injection and surface application. Other types of tillage equipment are also effective at sealing soil macro-pores during manure application, thus reducing leaching. Careful attention to field conditions, application rate and soil moisture along with use of appropriate application equipment can reduce the risk of liquid manure leaching into tile drains and shallow groundwater, thus reducing environmental risks.

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A PRELIMINARY ANALYSIS OF 300 MANURE INCIDENTS IN WISCONSIN[1]

Eric T Ronk[2] and Kevin A Erb[3]

Since 2002, the Professional Nutrient Applicators Association of Wisconsin (PNAAW) and UW Extension have conducted 15 live action field events to train applicators, farmers, first responders and agency staff how to respond in the event of a manure spill or release. As these sessions have evolved and training materials developed, the question of how many spills or incidents occur per year and what impact they actually have on the environment is repeatedly asked. While many citizen groups and agency staff collected some information, there is no comprehensive Wisconsin-specific database of manure-related incidents available to help farmers and applicators prepare for and prevent manure spills.

The only comparable research available in the North Central States is a 2003 Ohio Extension summary of manure incidents. This analysis of 98 incidents highlighted numerous commonalities between spills, created a top ten list of reasons why problems occur, and helped the industry pinpoint ways to reduce the risk.

This past spring, PNAAW funded a research project to inventory all of the manure incidents in Wisconsin during the past 5 years (2005-2009). The goals of the project were to:

1. Determine the root causes of manure spills/incidents.
2. Develop simple strategies the manure application and livestock industries can use to prevent and reduce the severity of future incidents.
3. More clearly define what a manure spill or manure incident actually is.
4. Develop a better tracking system to help farmers, applicator and agencies learn from manure incidents.

This is a mid-project summary as of December 10, 2009. As the data are verified and more incidents added to the database, the conclusions may change. Hence the focus of this summary paper is on the methodology, barriers and general results. The formal presentation will include more specifics not available as of the proceedings deadline.

Data Collection

To get the most accurate picture of incidents, we started by gathering all of the publically available data on manure incidents from state agencies, including WDNR and DATCP. At WDNR, these sources included files and records within a number of Programs, including but not limited to:

- Ag Runoff (including Ag Waste)
- Drinking Water
- Environmental Enforcement
- Law Enforcement
- Spills/R&R

[1] Partial funding for this project was provided by the Professional Nutrient Applicators Association of Wisconsin (PNAAW).
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Some of these Programs may have up to 5 different filing or tracking systems within a DNR region, so each incident was cross-referenced with any available files both within and between programs. For example, in the Spills Program, information may be located in one of two electronic sources –SERTS (recent, open incidents) or BRRTS (database of closed incidents), and/or in a paper file which may be supplemented with digital photos and other electronic documentation located on multiple computers and file servers.

Data collection was initiated by reviewing written and electronic records and phone/in person interviews of agency staff around the state. A screening test was then applied to determine if each incident was significant enough to be included in the database (unsubstantiated complaints, odor issues, etc, were removed from consideration). Records from the Manure Management Task Force were provided by DATCP and incorporated into the dataset. To protect the farmer and responsible parties, any incident with potential enforcement action pending was marked and handled in a way to protect those involved.

As the data were consolidated, it was entered into a secure, password protected web-based tracking system (Checkbox), which allows for rapid data entry and export in a format that can be used by Excel and SPSS for future statistical analysis.

When the agency file review was complete, draft copies of each incident's summary were sent to the county Land Conservation Department for updating/correction/local verification. Counties have also been asked to provide information on incidents not in our dataset. Once this is complete (Winter 2009/2010), contact will be made with as many of the responsible parties (RP) as possible (farmer, manure applicator) to error check the data, unless a reason exists not to make the contact (pending enforcement, privacy concerns).

Data Collection Challenges

As noted above, there currently is no uniform tracking system between agencies, much less within a single agency. There is a wide variety of tracking systems (from through to almost non-existent) across the WDNR regions.

State law is very clear that if a release of a substance occurs that has the potential to impact the resources of the state (air, water, soil), it must be reported immediately to the WDNR. The Spills/R&R program maintains a 24-hour hotline for reporting of spills/one-time emergency situations with an impact to human health or the environment. When a call comes into this 24-hour hotline (800-947-0003), notification is made to the local WDNR warden and Regional Spills Program staff, who assess the situation.

Farms with WPDES permits are required to immediately notify their WDNR Ag Waste Specialist when an incident occurs—if they are unable to reach them in person, the permit requires them to contact the Spills Hotline or other DNR staff to report the incident. Citizens often call these same Ag Waste/Runoff specialists to report incidents or ongoing problems.

Some counties have set up their own system (Oconto, Manitowoc, Kewaunee are examples) where farmers/applicators/citizens may call 911 and report locally. The 911 center notifies the county Land Conservation Department and may notify local law enforcement (for traffic control). Some 911 centers will notify the WDNR Warden, others will not unless requested. Still other counties request reports be made directly to the Land Conservation Department, while some counties have no policy in place. LCDs are often the first call for citizens concerned about ongoing, chronic problems.

No matter how or to whom these reports are made, we have found that the initial report is often inaccurate. This is due to the nature of the spill (excitement of the incident, reporting person not on site or familiar with the equipment), and that the facts have not been verified. The quantity released is often reported at unknown, or at best an estimate at the time of the initial notification — citizen complaints tend to overestimate the volume of manure and scope of the problem, while those responsible often downplay the incident when reporting it. Since responsibility for going to the site is shared by different WDNR programs (and staff, depending on workload, incident severity and other incidents occurring the same day) these initial reports are not updated in a timely manner (or at all) to reflect what is seen in the field. Sometimes the information is updated in one, but not in other parts of the multiple record keeping systems.

After the initial report, information on an incident may be scattered in one or more of 11 different tracking systems within WDNR. As noted before, some are electronic and readily searchable, others are paper and filed within an organized system, and still others are only notations in remotely related records (for example, the only record of manure pump failure was a printout of an email in a folder that contained technical drawing for a farm's reception pit).

Even when the records are in an electronic format, the systems may not be easily searchable or the information in the system may be incomplete/inaccurate (manure labeled as "other" or "septage"). They often reference documentation kept in non-searchable formats. The electronic tracking systems are not cross-linked to allow one-step updating and elimination of duplicate information

Another challenge is that many incidents go unreported. While state law says that all spills that "have the potential to impact surface or groundwater" must be reported, we suspect that many are cleaned up by the farmer and not reported to the WDNR. Permitted livestock operations (CAFOs) are required by their permit to report any incident, and that is reflected in the total number and the fact that many reported CAFO incidents are of a minor nature when compared to non-CAFO farms.

County LCDs also have varying levels of tracking incidents. Some (such as Dane) have a very detailed system in place for tracking both complaints and manure incidents. Others do not have a central registry, but include notes in the farmer's file if action (repair of storage, etc) was needed, or the record was obtained by interviewing staff. The majority of counties have no system in place.

Manure Incident Summary

It is important to note that this is a mid-project summary. We are 85% complete reviewing the WDNR files and about halfway through the LCD information. As noted above, the actual event is often different from the initial report, and every event is undergoing a final review before we attempt to contact the farmer/responsible party. It is also important to note that since farms who are under public scrutiny for perceived or past problems are more likely to self report incidents AND smaller farms are less likely to report, the data is skewed towards incidents from CAFOs.

With these caveats in mind, the dataset includes information on just over 300 incidents. The most surprising result is that less than one third of the incidents occurred in the field where manure was applied. As shown in Figure 1, More than 40% of the incidents occurred at the farmstead itself, with the remaining 30% occurring during transportation from the farmstead to the field. Of the incidents at the farmstead, 37% involved manure storage overtopping and 18% were related to manure runoff from livestock production areas. April and August were the most likely months for manure storage overflows.

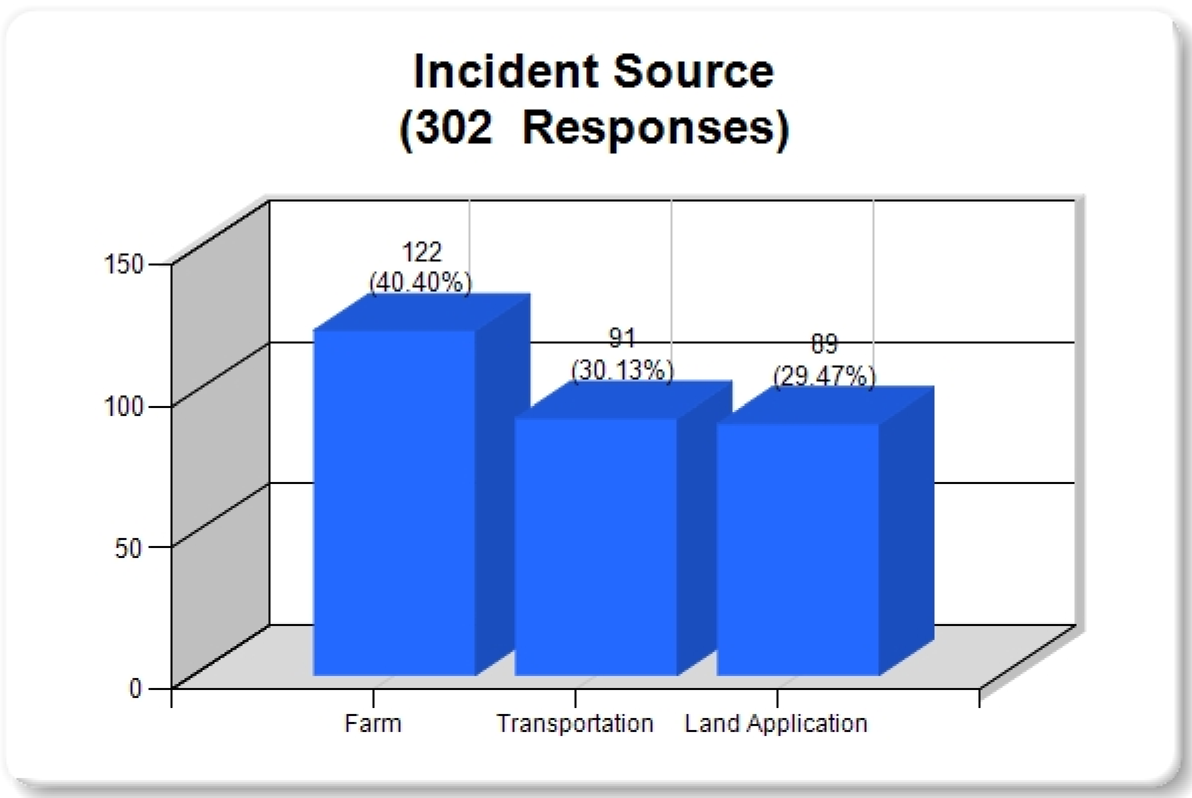

Figure 1. Manure incidents (2005-2009) by location. Farm means the incident occurred at the farmstead (such as a pit overtopping, line break, etc). Transportation includes both road/tanker issues and dragline issues occurring between the manure storage and the application site. Land application includes incidents that occurred during and after application (such as off-site movement in rain event the next day).

Another surprise was when incidents occur. We expected February (Figure 2) to be a high incident month, but it came in 4th. We attribute some of this to the decrease in manure applications on frozen soil over the past few years as famers and applicators have become more aware of the risk of snowmelt/precipitation driven runoff.

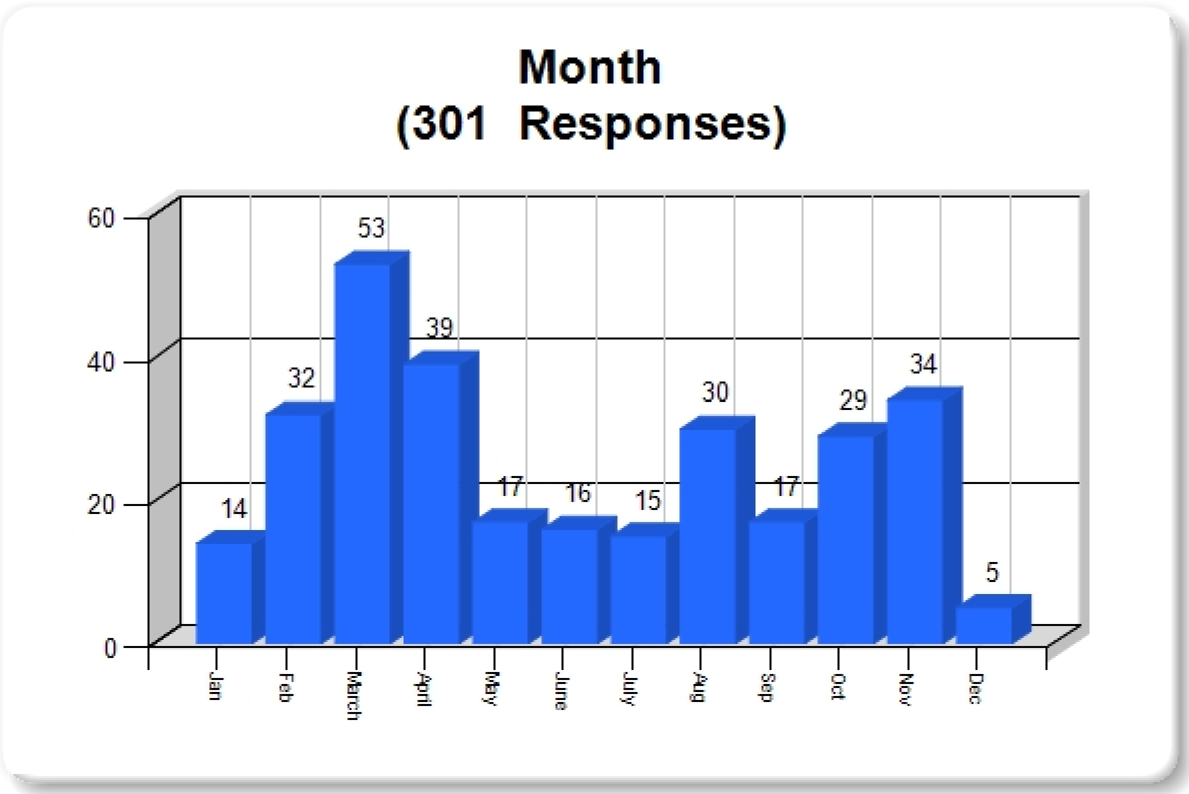

Figure 2: Manure incidents (2005-2009) by month. The spike in August can be attributed in part to manure storage overtoppings that occur (April and August are the most common months for storage issues).

As noted earlier, the incident rate at CAFOs was higher than at non-CAFOs, and this may be attributed to both the mandatory reporting required by the permit and the desire of permit holders to self report rather than be reported by neighbors. Additional factors may include the fact that citizens watch CAFOs more carefully, neighbors are more willing to report a CAFO compared to a smaller neighbor and the fact that larger farms pump, haul and apply a much larger volume of manure than a smaller farm. As noted in Figure 3, there is an upward trend in the number of spills. WDNR and UWEX staff attribute part of this increase to an increased willingness of professional applicators and farmers to self-report problems to the WDNR, as well as greater vigilance by concerned citizens.

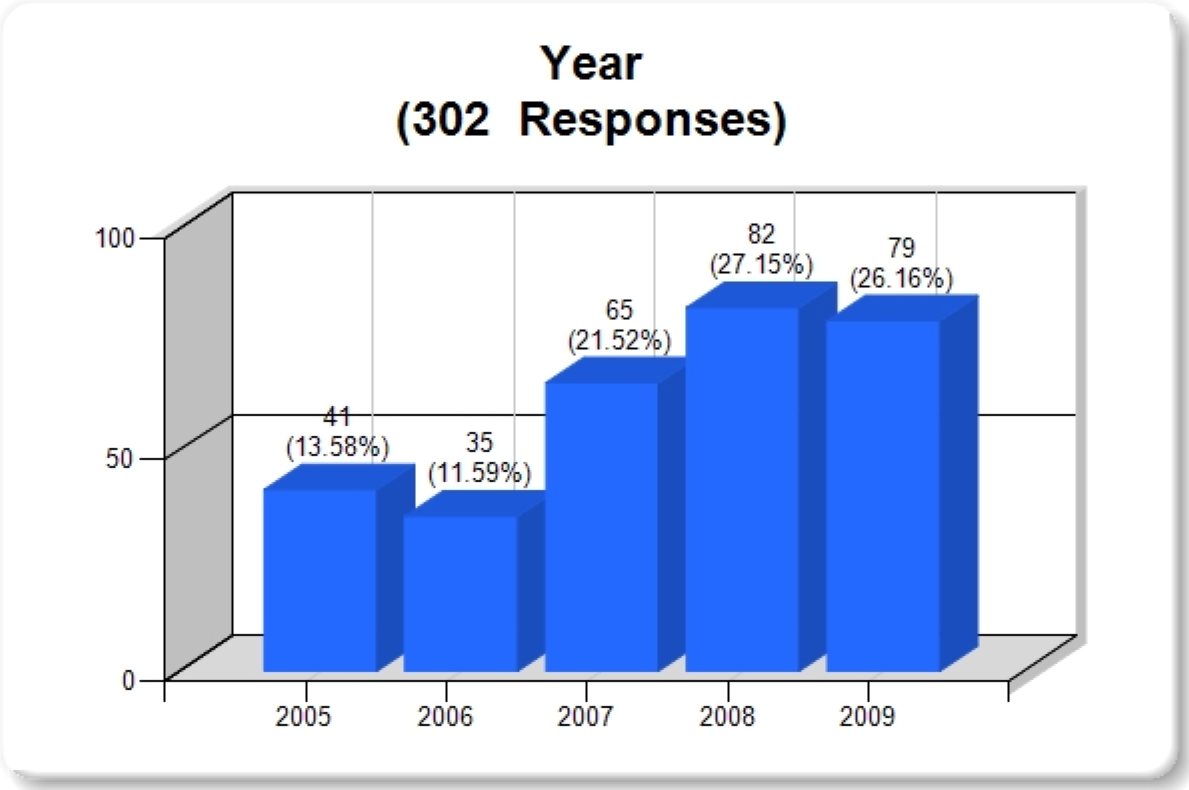

Figure 3: Manure incidents (2005-2009) by year. 44% of the 2005 incidents occurred in February and March., while only 30% of 2009 occurred during that same time period.

Fifty-five percent of the incidents were determined to have no official environmental impact to surface or groundwater. 43% did have a surface water impact, however any manure released into a road ditch was included in this category even if the manure was cleaned up before it could leave the site. Only 4% of incidents resulted in a fish kill

Future Directions

One goal of this project is to create a better working definition of a spill. A ranking system is being considered that will help all parties determine the level of response that is needed to an incident.

We will continue to add to and refine the database as the project concludes. It is hoped that the data gathered will guide the efforts of professional applicators, farmers, CCAs and regulatory staff as we work together to reduce manure's environmental impact.

This project would not have been possible without the cooperation of WDNR, DATCP, and LCD staff around the state, as well as farmers, CCAs, and professional applicators.

WHAT DO WE DO WITH ALL THESE YIELD MAPS?

Joe Lauer and Justin Hopf [1]

Identifying management zones (MZs) within a field is challenging because crop yields typically vary over space and time (Lamb, 1997). In-field variability is the focus of precision agriculture – how to manage it, diminish it, or overcome it. In-field variability reduces the ability to determine consistent yield patterns, and thus management zones.

Producers have expressed frustration in obtaining value from yield maps. Griffin (2000) states, "farmers were struggling to find direct benefits from the yield information that they were spending time and effort gathering." Reasons yield maps are often not generated include: (i) the yield monitor might not be accompanied by GPS, (ii) problems associated with the data analysis, and (iii) owner operators who do little or no field work do not benefit as much from yield maps as those having direct experience with field conditions (Griffin, 2004). Reasons for not utilizing generated data such as yield maps are numerous and include; time to learn electronic skills in order to operate equipment and software, lack of training for producers and industry, uncertainty with using analyzed data to influence decision making, lack of local experts for technical assistance, working with data of differing formats, lack of basic research on yield and soil relationships, and need for a precision agricultural equipment (Kitchen, 2002). Griffin (2004) states, "the inability to process the gathered yield information into meaningful decisions, leads to apathy and discontinuance of future data collection."

A multitude of intrinsic and extrinsic properties can influence crop grain yield, of which, nutrient availability and water stress are most important. Proper fertilizer management can diminish nutrient stress, which leaves spatial variations in water stress responsible for yield variation across fields (Jaynes, 1995). Water stress can occur from either droughty conditions, or excessive moisture conditions.

Over an extended period, multiyear grain yield data can cover the range of grain yields expected, and thus can be used to predict future yields (McBratney, 2000; Pierce, 1997; Tiffany ,2000). A data set of 5 years or more of grain yield data is sufficient to represent a range of expected grain yield outcomes under various weather conditions (Lamb, 1997). Although multiyear data can provide inconsistent and confusing yield patterns, it can provide a foundation by which producers can begin to understand variability. Hopkins (1999) states, "uncertainty should not preclude site specific decisions any more than uncertainty should preclude decisions in any other facet of farm management." Long-term experiments offer unique possibilities to study the effects of management practices on crops and soils over time.

Temporal variation in yield patterns is due to dynamic interactions among climate, landscape, soils, plants, and management practices (Jaynes, 2003). Temporal variability may greatly influence how spatial variability is expressed in a given field. Yield maps, which are used as an indication of past management in site-specific cases, may not be useful in making future management decisions when temporal variability is great (Eghball, 1997).

The deficient temporal stability for yield patterns, makes creating statistical relationships between spatial yield patterns and soil properties difficult at best (Eghball and Varvel, 1997).

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However, a relationship between spatial yield data and soil properties is still observed. Classification of cotton yield was based on six soil properties (pH, extractable Ca and Mg, K saturation, clay content, and soil N/P ration), and the prediction was correct 73% of the time (Ping, 2005). Consistently low, average, and high yield classification can be found for fields when using multiple years of yield data (Cox and Gerard, 2007).

When soil properties and topographic properties can be correlated to differences in grain yield, these soil properties were not consistent across fields (Cox and Gerard, 2007). Although soil properties can be correlated to yield in some cases, proper acquisition of these soil properties can be timely, expensive and can have highly variable results. Grid soil sampling is typically used for establishing management zones for site-specific application of nutrients. The geo-statistical procedures used to estimate values between sample locations require samples to be taken close enough together that they are correlated to one another.

Rather than trying to predict specific yields within a field, we may be more successful in identifying areas within a field that behave similarly among years (Lark and Stafford, 1997; Boydell and McBratney, 2002). Based on yield history, low, average and high yielding classifications can be found for management zones within a given field (Cox and Gerard, 2007). Jaynes (2003) states, "for farming by management zones to be practical, one would like to identify a limited number of temporal yield patterns within a field, and the areas of the field exhibiting similar patterns should form spatially similar, contiguous areas." Lamb (1997) found that the effect of a particular growing season was approximately 100 times greater than location and spatial effect. Lamb (1997) states, "The use of several years of grain yield information in intensively managed corn production was not as precise as needed in determining yield goals for future management decisions."

Predictable patterns of grain yield variability are necessary for implementation of variable rate technology. The objective of this study is to use a database of geo-referenced multi-year grain yield and grain moisture information from multiple fields to:

1. Determine if geo-referenced management zones within a field vary with respect to grain yield or grower return class from year to year, and if so, how much, and is the amount biologically and economically significant.
2. Determine if multi-year grain yield data can be used to accurately predict the following year's grain yield.
3. If grain yield prediction is achievable, can variable rate starter fertilizer prescriptions, based on management zone grain yield classes be either agronomical or economical.

Materials and Methods

Yield maps were collected over a 12 year period on one field (Field A) in Walworth County, WI (42°31'N, 88°38'W) on a Plano silt loam soil (fine-silty, mixed, mesic, Typic Agriudoll). Mean annual temperature and precipitation are 9.4°C and 941mm, respectively. The crop rotation was an alternating corn-soybean rotation. Corn was grown in 1995, 1997, 1999, 2001, 2003, and 2005. Soybean was grown in the alternate years. This field represents a unique dataset due to the high quality spatially referenced grain yield and grain moisture data.

Fields were divided into spatially referenced MZs of 538 ft^2, which remained consistent within a field across years. Means for grain yield and grain moisture were calculated for each MZ within a field for each year data was collected. Combines equipped with commercially available yield sensing systems were used to collect data from 1994-2007.

Individual points were determined unreliable based on several criterions. First, all negative values for grain yield and grain moisture were deleted. Points with GPS positional errors were deleted. Outside headlands were deleted, to avoid significant changes in grain flow while entering and exiting the field. Grain moisture points that were abnormally high, and were not associated with normal grain harvest practices were deleted. Finally, grain yield points that were deemed higher than the agronomical potential for a field under a set of management practices ($\geq$ 18.8 Mg ha^{-1}) were deleted.

Means of grain yield and grower return were calculated for each MZ, within each field, within each year. Overall means were calculated for each MZ, within each field, across all corn or soybean years. Classification of a MZ based upon grain yield and grower return, was achieved by grouping MZs using one standard deviation from the mean into high, medium and low classes. A MZ greater than or equal to one standard deviation above the mean were classified as high, MZs that fell within one standard deviation of the mean were classified as medium, and the MZs less than or equal to one standard deviation below the mean were classified as low. Variance for each MZ, within each field was calculated with the following formula:

$$s^2 = \frac{\sum (X - M)^2}{N - 1}$$

where M is the mean for an individual MZ within a field across years, X is the mean for the same MZ, within the same field, for a particular year, and N is the number of years.

Once a MZ was assigned a grain yield class based on multiyear grain yield data, yield during the following year could be predicted. With combined years' data, each MZ, within each field, was assigned a grain yield class (High, Medium, and Low) and also a grain yield variance class (High, Medium, and Low) for a particular crop. This provides nine treatment cohorts; High Yield-High Variance, High Yield-Medium Variance, High Yield-Low Variance, Medium Yield-High Variance, Medium Yield-Medium Variance, Medium Yield-Low Variance, Low Yield-High Variance, Low Yield-Medium Variance, and Low Yield-Low Variance.

During the last growing season in which corn was grown the producer implemented variable rate starter fertilizer applications. Variable rate fertilizer prescriptions were applied onto fields before management zones (MZs) were established and classified. The variable rate fertilizer prescriptions were based on the intuition of the producer - portions of the field thought to have high yield potential received a high fertilizer treatment, areas of a field thought to have medium yield potential were given a medium fertilizer treatment, and low yielding portions of the field according to producer perception were treated with the low fertilizer treatment. The field received starter with an N-P-K fertilizer analysis of 10-34-0. There were three starter fertilizer rates, which consisted of low, 100 lb/A; medium, 125 lb/A; and high, 150 lb/A.

Once MZs were established, the producer's variable rate fertilizer prescriptions for each field were assigned to the established MZs within each field. For comparison purposes only, variable rate fertilizer prescriptions based on MZs classified using multiyear grain yield and moisture data were created. High yield class MZs would have received the high fertilizer treatment, medium yield class MZs would have received the medium fertilizer treatment, and low yield class MZs would have received the low fertilizer treatment. This allows for a unique comparison between producer intuitions about grain yield potential of a field with actual grain yield potential of a field based on multiyear grain yield data (Figure 1). Soil test results were conducted during the 2006 growing season indicated the field had phosphorus and potassium levels that were both characterized as Excessively High.

Data were analyzed as a completely randomized design using PROC MIXED (SAS Institute, Cary, NC). PROC UNIVARIATE was used to test that data was normally distributed. The experimental unit, a management zone (MZ) was classified based on previous years grain yield data and was not randomly assigned. For the analysis of an individual field for yield prediction, fixed effects were Yield Class, Variance Class and Yield Class x Variance Class interaction, with no random effects. For the analysis on individual fields for variable rate fertilizer application, fixed effects were Cohort (Yield Class-Variance Class), Fertilizer and Cohort x Fertilizer interaction, with no random effects. For the combined analysis across fields, for yield prediction, fixed effects were Yield Class, Variance Class and Yield Class x Variance Class interaction, with field as a random effect. For the combined analysis across fields, for variable rate fertilizer application, fixed effects were Cohort (Yield Class-Variance Class), Fertilizer and Cohort x Fertilizer interaction, with field as a random effect. Effects were considered significant when $P \leq 0.05$. The LSD procedure was used to separate means when the F-Test was significant ($P \leq 0.05$).

Results and Discussion

Temporal variability most likely associated with different weather conditions from year to year did affect consistency of a management zone within the same grain yield or grower return class (Figure 1). Some management zones were consistently in the same high, medium or low grain yield or grower return class across all years, but other MZs changed class depending on growing conditions of a particular year.

Due to the large amount of temporal variation that a particular MZ undergoes, it is important and necessary to have a multiyear dataset that provides information about the performance of a particular MZ across as wide of a rage of weather conditions as possible. A single year's result reflects that particular year's weather pattern. Multiyear data helps to relieve temporal variation by capturing data across extremes of weather patterns. MZs can then be classified within a field using grain yield class or grain yield variation class across all years (Figure 2).

Yield-Management Zone Classification

Management Zones were classified into yield-variance cohorts based on grain yield data collected prior to the year of variable rate fertilizer application. Yield-variance cohorts were analyzed to determine if the magnitude of grain yield differences between them were biologically and economically significant. Corn yield classes are averaged across variance classes. In field A the high yield class, producing 185 bu/A, was higher yielding than the medium yield class (178 bu/A), and both the high and medium yield classes were higher yielding than the low yield class, which produced 172 bu/A (Table 1). The difference between the highest yielding group and the lowest yielding group was 13 bu/A.

Soybean yield classes are averaged across variance classes. In field A the high yield class, producing 48 Mg ha^{-1}, was higher yielding than the medium yield class (46 bu/A), and both the high and medium yield classes were higher yielding than the low yield class, which produced 43 bu/A (Table 1). The difference between the highest yielding group and the lowest yielding group was 5 bu/A. If there were no differences amongst yield classes, this would indicate a lack of variability within a particular field; however, this field had enough variability that it was both biologically and economically significant and worthwhile to manage.

Corn Yield-Management Zone Prediction

During the growing season of variable rate fertilizer application corn grain yield was measured. MZs were previously assigned a yield-variance cohort classification, and yields from either the 2005 or 2006 growing season were used to determine how well MZs were classified. Yield classes are averaged across variance classes. In field A the high yield class, producing 153 bu/A, was higher yielding than the medium yield class (140 bu/A), and both the high and medium yield classes were higher yielding than the low yield class, which produced 123 bu/A (Table 2).

During the growing season following variable rate fertilizer application, prediction of soybean grain yield was measured. MZs were already assigned a yield-variance cohort classification, and yields from either the 2006 or 2007 growing season were used to determine how well MZs were classified. Yield classes are averaged across variance classes. In field A the high and medium yield classes, producing 53 bu/A and 51 bu/A, were similar to one another, and higher yielding than the low yield class, which produced 49 bu/A.

Yield-Variable Rate Fertilizer Evaluation

An evaluation of fertilizer application rate treatments (High, Medium, and Low) averaged across all nine yield-variance cohorts, revealed that variable rate fertilizer significantly affected field A but the high fertilizer rate did not correlate with high yield (Table 2). Previous research **(**Bermudez and Mallarino, 2007), concluded that on average, variable rate application of phosphorus, reduced phosphorus application by 12.4% over a fixed rate application. Variable rate application did not increase yield compared with a fixed rate application.

There was an interaction between yield-variance cohort and fertilizer (data not shown). Within the high yield-high variance cohort, medium fertilizer treatment produced 22 bu/A more than the high fertilizer treatment. Within the high yield-low variance cohort, high fertilizer treatment produced 21 bu/A more than the low fertilizer treatment. Within the low yield-high variance cohort, high fertilizer treatment produced 29 and 25 bu/A more grain yield than the medium and low fertilizer treatments. Within the low yield-low variance cohort, the high and low fertilizer treatments produced 22 and 27 bu/A more grain yield than the medium fertilizer treatment.

Soybean was planted into fields the growing season following the variable rate fertilizer application; however differences among fertilizer treatments were still observed (Table 2).

Conclusions

Annual weather conditions affected classification of cells into cohorts. The range between the highest and lowest yielding MZ within a field averaged 26 bu/A across all fields. Predicting grain yield of MZs across all fields during the year of variable rate fertilizer application was successful. Corn grain yield of MZs based on corn grain yield produced 174, 166, and 150 bu/A in the high, medium and low yield classes. Prediction of grain yield across all fields during the year of variable rate fertilizer application was successful. The magnitude of yield differences within a field was substantial and predictable, but variable rate fertilizer application was not effective in applying inputs to confidently produce a yield response. Averaged across all fields, variable starter fertilizer treatment did not impact corn grain yield.

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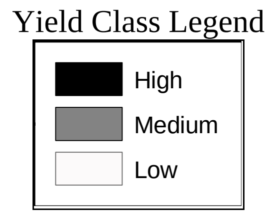
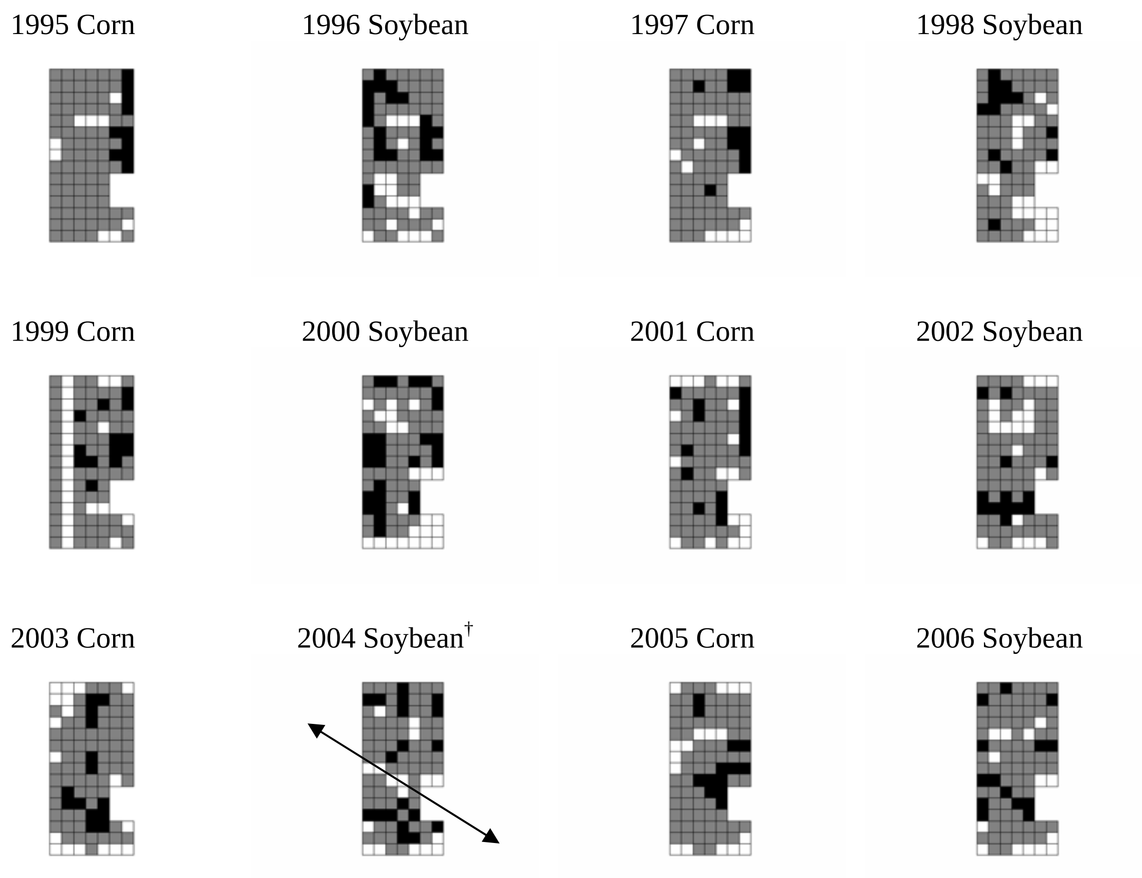


Figure 1. Corn and soybean yield classes for Field A.



† - Missing Data: Gas Pipeline Placed Through Field

Figure 2. Corn and soybean yield classes, variance classes, treatment cohorts of Field A. Data are combined over years.

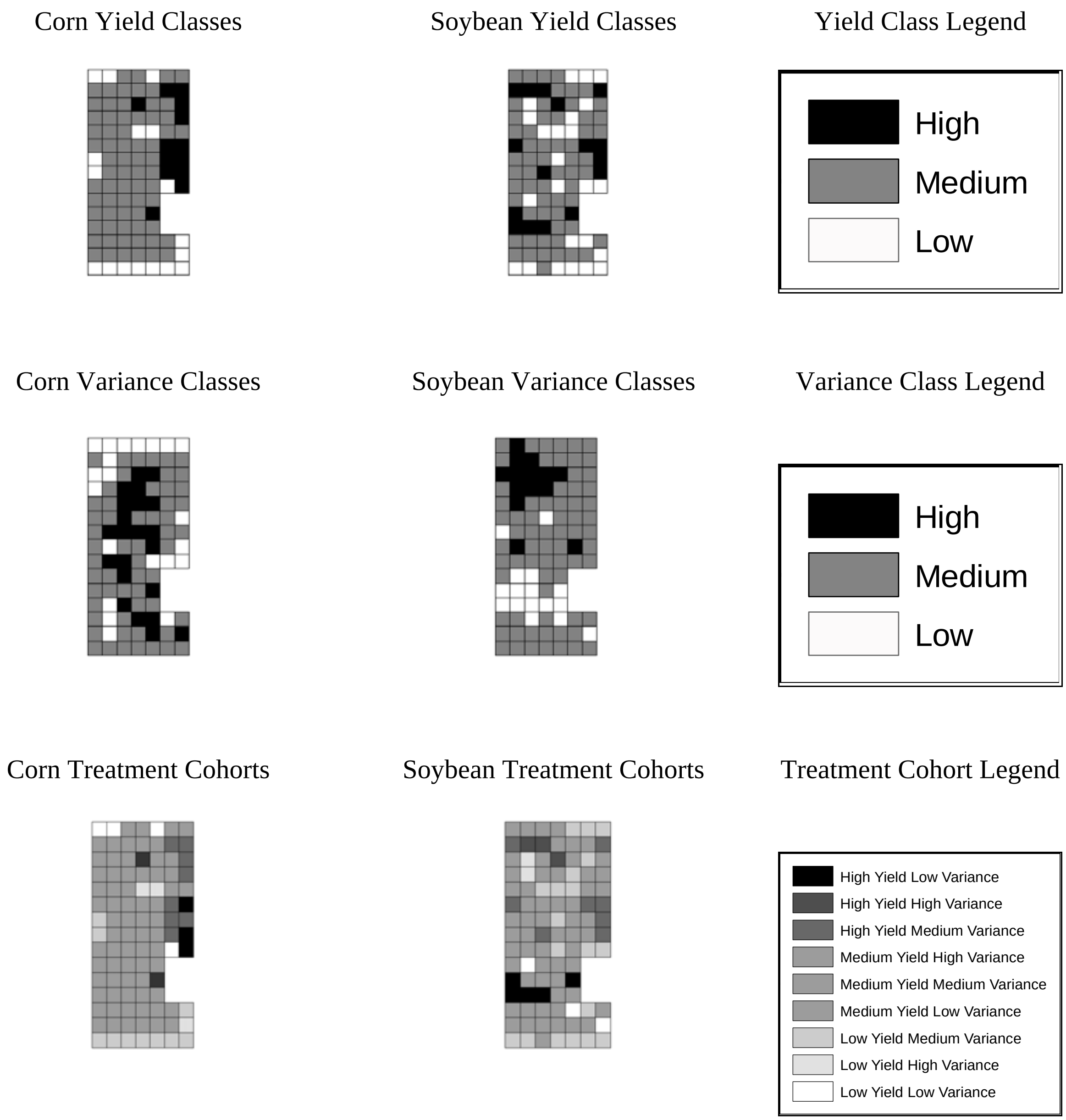


Table 1. Corn grain yield mean and variance of each yield-variance cohort. Values are based upon yield points averaged within a MZ each year and then averaged across years to calculate mean and variance.

		Corn		Soybean	
Yield cohort	Variance cohort	Mean	Standard deviation	Mean	Standard deviation
			bu/A		
High	Low	186	11	48	6
	Medium	185	16	48	7
	High	181	21	48	9
Medium	Low	177	16	46	6
	Medium	178	19	46	7
	High	178	22	46	9
Low	Low	172	13	43	7
	Medium	172	19	43	9
	High	172	27	43	10
LSD(0.05)		3	2	1	1

Table 2. Corn and soybean grain yield of yield-variance cohorts following variable rate application of fertilizer during 2006 and 2007. Cohorts were classified using grain yield and moisture data from five previous growing seasons.

		Grain yield	
Yield cohort	Variance cohort	Corn 2007	Soybean 2006
		Mg ha^{-1}	\$ ha^{-1}
High	Low	148	53
	Medium	153	54
	High	159	51
Medium	Low	143	52
	Medium	142	51
	High	138	51
Low	Low	110	48
	Medium	129	50
	High	127	49
LSD(0.05)		11	2

MONITORING YOUR YIELD MONITOR

M. Digman[1] and J. Phelan[2]

Yield monitors have become very common on combines in the last decade. The primary goal of these devices is to help the producer monitor variability occurring in his or her fields. Utilizing GPS, this data can be saved spatially and downloaded to the producer's computer to build an almanac that may be used to better understand how field inputs and growing conditions over a number of years (e.g., wet years, dry years) affect yield variability. Producers have also used this technology to conduct on-farm trials assessing economic return of various hybrids or management inputs.

The combine automates yield monitoring by aggregating data from various sensors, including speed, position, header height and width, mass-flow and moisture. Each of these sensors contributes an essential piece of data necessary to the production of an accurate yield map.

The first piece of information needed is the area harvested. Various machines solve this problem differently, but generally the yield monitor knows that the harvest has commenced by first verifying the separator is on and then if the header height is in the harvest position. This brings us to the first important adjustment. Different operators and varying harvest conditions require positioning the header higher or lower. The operator must inform the yield monitoring system when the header is at the harvesting height so it can determine if the machine is harvesting or making another maneuver (e.g., headland turn). The header position assigned to harvesting works in conjunction with the activated separator, like an on/off switch for the yield monitor. The value is usually set through the monitor itself and can be represented as a percent of height or angle measured between the header attachment point and the ground.

Now that the yield monitor knows that the operator is serious about harvesting (separator on, header down) the monitor must know the width being gathered into the combine. Surprisingly, most machines have not automated this process. Therefore, the operator must enter the number of rows being harvested or, in the case of a cutting platform, width of the header used (e.g., feet).

Harvest width combined with forward travel speed allows the combine to calculate area harvested per unit time, usually represented as acres per hour. For example, a 6-row (15 ft) corn head, fully utilized, traveling at 5 miles/hour would result in an area productivity of about 9 acres/hour (5 MPH multiplied by 15ft and divided by 8.25 to convert the units). For those using GPS there is no need for speed calibration; however, those using a wheel speed pickup or a ground-speed radar system need to calibrate their speed sensor. Once again, the

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procedure varies by machine, but in general it requires traveling a known, measured distance under field conditions (proper header attached, half-tank of grain). This distance is used in conjunction with the sensor's output to correct its calibration.

With area harvested precisely known, we just need to measure the amount of grain harvested for that area. This might be done by simply weighing the grain, but engineers have had difficulty coming up with cost-effective and accurate on-board weighing systems. So this task is accomplished indirectly with a grain mass-flow sensor. This type of sensor measures the mass per time (lb/sec) of grain that is carried by the clean grain elevator to the grain tank. Various mass-flow sensors have been used in the past, but today, two types are being utilized. The first type measures the height of the grain on each paddle of the clean grain elevator as the paddle passes by (Fig. 1, left). Using this height, the volume of grain on the paddle is estimated and, by multiplying by the grain density (mass of grain per volume), the weight of the grain on the paddle is estimated. The grain density is calculated by adding up the individual paddle volumes during a calibration load and dividing by the scale ticket weight for the load.

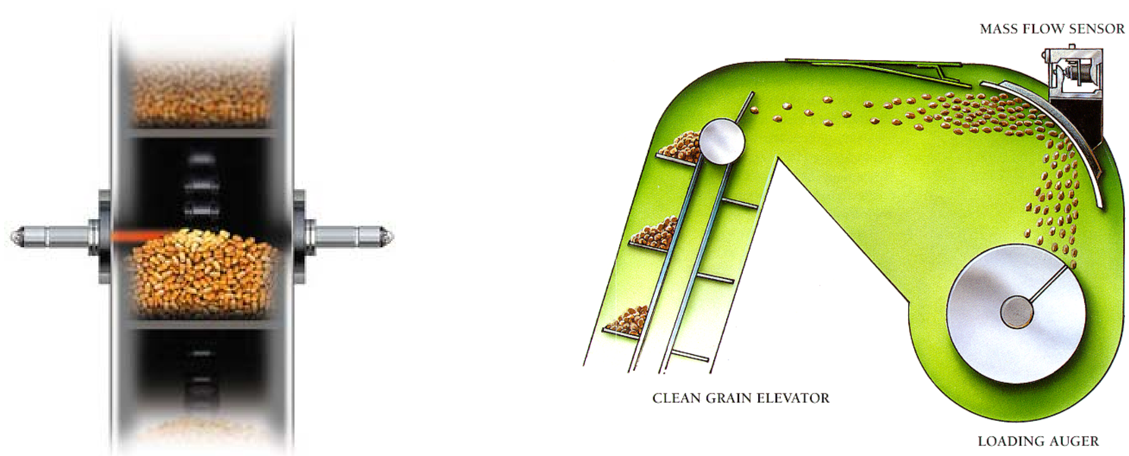

Figure 1: Volumetric (left) and impact plate (right) mass flow sensors [3].

This approach can be accurate if the relationship between weight and volume is constant, but unfortunately, as in most biological products, nothing stays the same for too long. Changes in grain variety, moisture content and individual kernel density can lead to measurement error. It is recommended that a calibration load be run every 2-3 weeks, or more often, if there are noticeable changes in crop condition.

Another more common type of mass-flow sensor measures the force that the grain being ejected from the top of the clean grain elevator applies to an impact plate as it moves towards the bubble-up auger (Fig. 1, right). The estimated mass flow rate of the grain is

[3] Image sources: Deere & Company and Claas of America. Mentions of trade names in this paper are made solely to provide specific information and do not imply endorsement of the product or service by the Univ. of Wisconsin-Madison or the authors.

computed from this force and the speed of the elevator. The idea is to add up the estimated mass flow rate over time to determine the accumulated weight. This, too, is an indirect measurement of weight requiring calibration to ensure good accuracy. Before considering calibration, it is prudent to inspect not only the sensor for wear but also the clean grain elevator paddles. Bent or broken paddles could result in grain falling before being thrown against the impact plate. Also, worn paddles may not cause the grain to follow the top of the conveyer to the impact plate, resulting in low readings. Some machines allow for an adjustment of paddle height at the top of the clean grain elevator. The manufacturer's instructions should be followed carefully as this adjustment affects how the grain hits the impact plate and can have a significant influence on sensor consistency. It is also a good idea to inspect the clean grain elevator speed sensor.

With impact-plate sensors, the relationship between sensor output and grain mass flow rate is usually non-linear. This means that the sensor output isn't quite proportional to grain flow rate (Fig. 2). For example if this relationship were linear, then an output of 1 volt (V) might be produced by 10 lb of grain per second, 3V by 20 lb/s, 5V by 30 lb/s, etc. However, due to friction and not all of the grain hitting the impact plate at high flow-rates, the relationship is non-linear. So, in our previous example, 1V might be produced by 10 lb/s, 3V by 20 lb/s, and 4.25V by 30 lb/s. What this means for the operator is that if the sensor is calibrated at just one flow rate, it will be less accurate at flow rates that are significantly different.

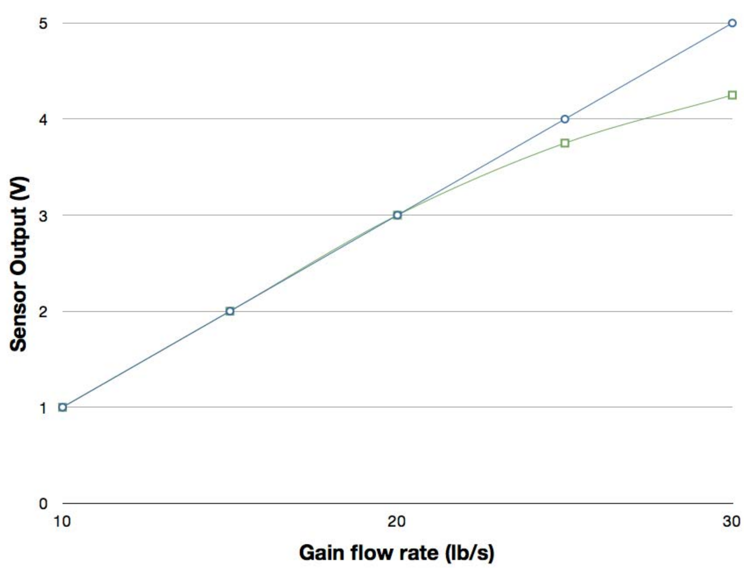

Figure 2: Simulated sensor linear (circles) vs. non-linear (squares) response to grain at various harvest (flow) rates.

Calibration load recommendations vary depending on manufacturer. Some may have the operator find a level, consistently yielding area of the field and harvest at an average rate while others have the operator harvest at varying rates throughout the calibration load. Several manufacturers offer the capability to perform multiple calibration loads at different flow rates to correct for nonlinear effects (described above). These systems typically require the operator to harvest more than one calibration load, with each load harvested at a different rate (speed). Most operators' manuals provide step-by-step instructions. It is important to follow the instructions specified by your operator's manual. This process may seem involved, but most machines allow the operator to continue harvesting until the calibration load weigh ticket returns so harvesting is not impeded by a calibration update.

Most yield mapping software allows you to enter actual load weights after the harvest is complete in order to fine-tune the maps. Even if you already weigh all of the loads from the field and plan to do this post-harvest correction, it is still recommended that you calibrate the mass-flow sensor in the field in order to correct for the nonlinear effects described above. This is especially important when there are large yield or speed variations in the field.

The final piece of the yield data is moisture. Grain yields must be corrected for moisture, otherwise wetter, heavier grain will skew the yields higher while drier, lighter grain will appear to decrease yield. Current technology moisture sensors need periodic adjustment as conditions change. This process usually includes taking a few representative samples from the grain tank to the elevator for analysis; the moisture readings from the elevator are then used to update the moisture sensor calibration on the combine.

Although time investment may seem significant, calibrating your monitor is necessary to ensure accurate yield maps and subsequent management decisions. For more grain production-related information please visit the Univ. of Wisconsin–Extension Team Grain website at: http://www.uwex.edu/ces/ag/teams/grains/.

KEEPING PACE WITH Bt CORN: FROM STACKED TRAITS TO BLENDED REFUGES

Christian H. Krupke [1/]

Since the release of the first Bt corn hybrids targeting rootworms in 2003-04, the technology has undergone numerous changes, including novel traits, stacking of traits with other Bt toxins and herbicide tolerance, and alterations to the refuge structure. Although Bt hybrids generally provide excellent control of larvae, there is consistent adult emergence from these plants meaning that a refuge is critical to delay resistance development. In fact, full resistance to these toxins has been generated in just a few generations of rearing Western corn rootworm in laboratory studies. Once it has developed, this resistance is fixed, meaning that the beetles will not revert to the susceptible type once that type of Bt corn is no longer planted.

Preserving the efficacy of existing Bt toxins is critical. We do not fully understand how insects survive, but they do albeit in relatively low numbers currently. The risk of resistance is real and there are several possible paths for widespread resistance to develop, including sub-lethal exposure. This type of exposure may be favored by a number of scenarios including exposure to low-toxin level plants (volunteer corn) and/or exposure to Bt hybrids late in larval life, when the larvae are able to withstand a greater dose of toxin.

Data will be presented on the risk factors that may help explain how stacking traits and altering refuge structure may affect the potential for resistance, both positively and negatively, and the best practices that producers and consultants can employ to maximize the durability of these traits will be discussed.

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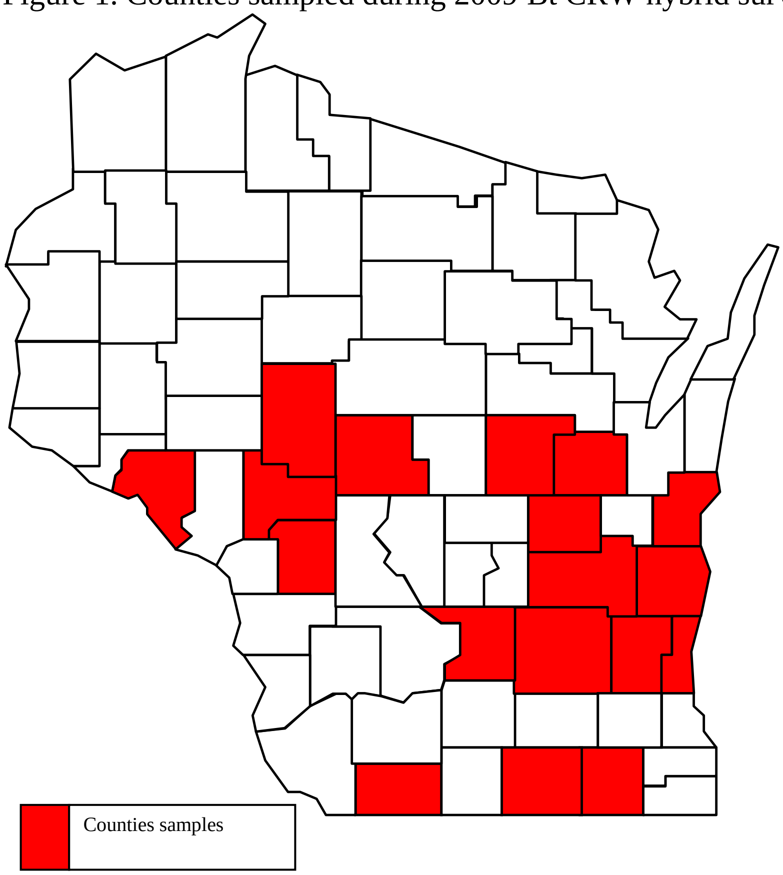
2009 Bt CRW HYBRID SURVEY RESULTS

Mike Ballweg, Ted Bay, Greg Blonde, Joe Bollman, Carl Duley, Bill Halfman, Richard Halopka, Mike Rankin, Peg Reedy, Nick Schneider, Jim Stute, and Trisha Wagner [1]

Corn rootworm larval damage has been suspected or confirmed in Wisconsin corn fields planted to Bt CRW hybrids. This has prompted concern among crop advisors regarding recognition, severity and distribution of the problem. To help answer these concerns, a survey was conducted to evaluate corn rootworm larval damage to Bt CRW hybrids. Cooperators were asked to submit five (5) corn roots/field that were at least second year corn and planted to a Bt CRW hybrid. Field background requested from each field included, county, hybrid and Bt event. There were no attempts to single out commercial hybrids or Bt events. Approximately 110 fields were surveyed in 18 counties (Fig. 1). Range of fields sampled/county were from 1 to 21.

Figure 1. Counties sampled during 2009 Bt CRW hybrid survey.



[1] University of Wisconsin Cooperative Extension Service county-based faculty and staff from Sheboygan, Grant, Waupaca, Columbia, Buffalo, Monroe, Clark, Fond du Lac, Walworth, Winnebago, Rock, and Jackson counties.

Corn roots were examined for larval damage using the Iowa State Nodal Root Rating System. This rating system is based on a decimal system where the number to the left of the decimal equals the number (or equivalent number) of full nodes pruned to within 1½ inch of the stalk. The number to the right of the decimal refers to the percentage of the next root node pruned to within 1½ inch of the stalk. For example, a root rating of 1.5 means one full node of roots (or the equivalent of one node) is pruned back to within 1½ inch of the stalk and 50% of the next node is pruned. The highest rating recognized by this system is 3.0. Midwest entomologist generally agree that root ratings below 0.25 would not have economic loss from rootworm feeding while ratings greater than 0.75 would suffer economic loss. Ratings between 0.25 and 0.75 are in a gray area and economic loss would depend on factors which include, but are not limited to, hybrid vigor and environment.

Of the fields surveyed, 67% of the fields had average root ratings between 0.0 and 0.05, 21% had average ratings between 0.06 and 0.1 and 4% of the fields had an average rating between 0.1 and 0.25. Approximately 8% of the fields had ratings between 0.25 and 2.7. A more detailed explanation of these high fields can be found in Table 1.

Discussion

A field was considered "a confirmed failure" if the agent, grower, crop consultant and/or seed sales representative's follow up indicated no other explanations for high level of feeding damage.

As a result of this survey, there does not appear to be a widespread problem with Bt CRW efficacy. Although three fields had economic losses and one field had marginal damage. The vast majority of fields were not injured or the amount of rootworm injury was considered to be within acceptable limits (nodal root ratings <0.25). There were, however, four false-positive fields. That is, fields which had elevated feeding levels that the grower mistakenly thought were Bt hybrids. Further investigation proved other factors (i.e., seed mix, poor records) were the cause. This situation does highlight the need to quickly follow up on injury claims prior to significant root regeneration. Other factors, including insect, disease and weather, will cause corn to "lodge". To separate these factors from corn rootworm larval feeding you must dig, wash and evaluate roots for injury.

It also must also be noted that rootworm populations were generally considered to be low to moderate in most areas of the state. As a result, we will be conducting this survey again during the 2010 growing season to gain a better understanding of the situation.

Table 1.

Field #	Root Rating		County	Bt event	Remarks
	Fiel d Ave.	Range			
1	0.35	0.05-0.7	Winnebago	YieldGard	This rating is in the "gray" area for economical damage. It was not a seed mix of non-Bt and Bt seed.
2	0.52	0.1 – 1.0	Rock	YieldGard	This hybrid was an old YieldGard event which is no longer commercially available
3	1.38	0.0 – 2.6	Lafayette	Yieldgard	No explanation available for high ratings. Therefore it is considered a failure
4	1.50	1.0-2.0	Lafayette	YieldGard	No explanation available for high ratings. Therefore it is considered a failure.
5	1.8	0.8 – 2.6	Lafayette	N/A	This field was later confirm NOT to be a Bt hybrid
6	1.1	0.0-2.2	Sheboygan	N/A	This field was later confirmed to be a mixture of Bt and non-Bt seed. Therefore it is not considered a Bt failure.
Field #	**Root Rating**		**County**	**Bt event**	**Remarks**
	Field Ave.	**Range**			
7	2.16	2.0-2.5	Rock	N/A	The grower lost the field records and confirmation was not possible.
8	2.7	2.0-3.0	Lafayette	N/A	This field was later confirm NOT to be a Bt hybrid

USE OF FUNGICIDES IN HAIL-DAMAGED CROPS

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

Hail damage is common across many soybean and corn producing areas in the United States (National Crop Insurance Service, 2008). Since 2003, the National Crop Insurance Service has paid claims on an average of 2.3 million acres of soybean per year at an average cost of $53.5 million. Over the same period of time, the NCIS estimates approximately $36 to $59 million in annual claims due to hail damage in corn (Bradley and Ames, 2010). With increasing global temperatures, more extreme and unpredictable weather patterns have been suggested; therefore; grower risk for severe hail damage may increase (Kajfez Bogataj, 2005).

In 2009, severe hail damage was reported in Southwest WI and across large sections of Iowa. Following this hail event, growers, retailers, and agronomists alike were asking if these acres needed to be treated with a fungicide. Much of this was prompted by BASF's supplemental label for Headline® that states, "the plant health benefits may include improved host plant tolerance to yield-robbing environmental stresses, such as drought, heat, cold temperatures, and ozone damage" and for corn, "improved stalk strength and better harvestability, inducted tolerance to stalk diseases, better tolerance to hail, more uniform seed size."

Prior to EPA's approval of the BASF plant health label, Bradley and Ames (2010) initiated an experiment to quantify the effect of Quinone outside inhibitor (QoI) foliar fungicides on hail damaged corn. Using a hand-held gas powered string mower Bradley and Ames simulated hail damage at V12 corn. At the VT growth stage, plots were either treated with azoxystrobin (Quadris; Syngenta Crop Protection, Greensboro,NC) at 109 g a.i./ha or pyraclostrobin (Headline; BASF Corp.) at 110 g a.i./ha, or not treated (nontreated control). Disease ratings were taken ~3 weeks after fungicide application and grain yield was collected at maturity. Both Headline and Quadris decreased disease incidence in 2007, however no differences in disease control were noted in 2008. No yield benefit was shown in either year.

Wisconsin Corn Trial

In 2009, many trials at the Lancaster ARS were impacted by hail damage on 24 July (pea to marble size). In particular, we had a corn study established to assess the effect of fungicide active ingredient and fungicide timing on the risk of anthracnose stalk rot. This

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trial was inoculated at planting with *Colletotrichum graminicola* and was conducted in a field area known to have anthracnose. The trial was sprayed at R1 on 29 July and monitored for disease throughout the rest of the growing season. Results of late season assessments for stalk quality and yield indicated that there was no effect of foliar fungicide on late season occurrence of anthracnose or on grain yield (Table 1). Overall, yield in this trial was reduced by hail and anthracnose by approximately 20 bu/A from what might have been expected in most normal growing seasons at the Lancaster site.

Table 1. Effect of fungicide applied prior to hail damage on corn, Lancaster WI, 2009.

Treatment	Late Penetrometer	Stalk Rating	Yield 15.50%
	(kg-Force)	(0-5)	(bu/A)
UTC	13.5	1.7	107.3
Quilt (R1 app'n): 14 oz/A	12.4	2.7	108.8
Quilt Xcel (R1 app'n): 10.5 oz/A	13.5	1.7	118.7
Quilt Xcel (R1 app'n): 14 oz/A	10.6	2.4	93.2
Headline (R1 app'n): 6 oz/A	12.9	1.2	93.2
Stratego (R1 app'n): 10 oz/A	12.8	1.4	141.3
Quilt Xcel (V6 app'n): 10.5 oz/A	14.3	1.3	117.4
Headline @ 3 oz./A at V6 followed by Headline @ 6 oz./A + NIS @ 0.25% v/v at R1	13.6	1.5	117.0
Headline @ 3 oz./A at V6	12.2	2.8	106.7
Headline @ 6 oz./A + NIS @ 0.25% v/v at R1	15.2	1.0	128.3
Headline @ 6 oz./A at V6 followed by Headline @ 6 oz./A + NIS @ 0.25% v/v at R1	12.0	1.9	109.6
Headline @ 6 oz./A at V6	14.2	1.1	115.1
P-value	0.0755	0.2975	>0.5
LSD	2.112	NSD	NSD
CV (%)	13.5	65.1	25.1

Wisconsin Soybean Trial

Following the significant hail event that occurred on July 24 at the Lancaster research station, we examined several fields to find uniformly damaged areas where we could initiate a hail experiment in soybean. The field sites were assessed on August 1 and sprayed on August 5. The gap between the hail date and the application date was to allow for sufficient new leaf growth so we wouldn't just be treating bare branches. The area that we chose experienced an average loss of three total nodes (from 15 down to 12) and 80% defoliation. The soybeans were at the R3 growth stage at the time of the hail event. The products chosen are shown in Table 2 and applied in a RCB design with four reps in plots sized 10 feet by 25 feet. There was no yield response to foliar fungicides following hail in this trial.

Table 2. Soybean hail fungicide trial
Lancaster, WI.

Treatment	Product	Rate	Grain Yield
			bu/A
1	UTC		55.6
2	Quilt	14 fl oz/A	51.0
3	Headline	6 fl oz/A	53.1
4	Stratego	10 fl oz/A	50.7
Means			52.6
Probability %			33.6
LSD 10%			NS
CV%			8

The results from the two Wisconsin studies and Bradley and Ames (2010) suggest variable disease response and no yield response to fungicide following severe hail damage in corn or soybean. Given the significant yield loss that can occur from hail events, we have not seen any benefit from foliar fungicide applications to severely hail damaged corn or soybean.

Literature Cited

Bradley, C.A., and K.A. Ames. 2010. Effect of foliar fungicides on corn with simulated hail damage. Plant Dis. 94:83-86.

Kajfez Bogataj, L. 2005. Climate change and agriculture vulnerability. Acta Agriculturae Slovenica 85:25-40.

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NEMATICIDE EFFICACY AND NECESSITY

Paul Esker and Shawn Conley [1/]

As seed input prices increase in 2010, there are many questions regarding the use and need of seed treatment fungicides, insecticides, and nematicides. There are both new seed treatments that will be out for the 2010 growing season for some companies (Accerlon™ from Monsanto (soybean and corn) and Avicta® from Syngenta (corn)) or will be forthcoming for the 2011 growing season from other companies. With a continued increase in the number of products available, the decision-making process can become very confusing. This is especially relevant when considering if a nematicide seed treatment is warranted.

Realistically, understanding the need for a seed treatment nematicide begins with understanding some of the complexity of these organisms. The nematodes that impact corn and soybean differ (i.e., *a nematode is not only just the soybean cyst nematode (SCN)*) There exists some excellent information in addition to material provide on The Soy Report blog (http://thesoyreport.blogspot.com) and Wisconsin Crop Manager (http://ipcm.wisc.edu/Default.aspx?tabid=53) to help facilitate the decision-making process. Some of those include:

> "Nematodes in corn production: A growing problem?", http://www.ipm.iastate.edu/ipm/icm/2007/2-12/nematodes.html
>
> "Ten Things You Should Know about Corn Nematodes", http://agronomyday.cropsci.illinois.edu/2008/tours/corn_nematodes/
>
> "Nematodes", http://pdc.unl.edu/agriculturecrops/corn/nematodes
>
> "Fall Is A Great Time To Sample for SCN, But Not Corn Nematodes", http://www.extension.iastate.edu/CropNews/2009/1005tylka.htm

Understanding the complexity with nematodes and how best to manage them includes: (i) recognizing that other forms of corn and soybean stress may be misdiagnosed and are due to nematodes, (ii) submitting soil samples at the time of year that allows for the most appropriate information for your field history, (iii) recognizing that there exists > 1 corn nematode, (iv) checking labels closely to see if there is efficacy to nematodes, and (v) recognizing that cropping practices like continuous corn may increase populations. Also, as we highlighted that a nematode is not only just the soybean cyst nematode, most nematodes of corn do not attack soybean (or only at low levels) and SCN does not do well on corn. During this talk, we will also highlight some of the recent findings on new seed treatments from around the region and synthesize how those findings fit into the framework of decision management.

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2009 WISCONSIN CROP DISEASE SURVEY

Anette Phibbs[1], Adrian Barta[2]

This is a summary of disease surveys conducted by plant pathologists at the Department of Agriculture, Trade & Consumer Protection (DATCP). In 2009, field surveys focused on the following crops and diseases: Phytophthora Root Rot of Soybean Seedlings, Viruses of Snap beans, Foliar Diseases of Winter Wheat; and Stewart's wilt of Seed Corn. Laboratory diagnosis was provided by DATCP's Plant Industry Laboratory.

Phytophthora Root Rot of Soybeans Seedlings

2009 was the second consecutive year, the pest survey team conducted a statewide survey for Phytophthora root rot (*Phytophthora sojae*) of soybeans. Cool spring conditions deferred the start of the survey to the second week of July. From July 6 to17, fifty randomly selected soybean fields in early vegetative stages were sampled throughout Wisconsin. While fields were selected randomly, surveyors chose seedlings from areas within each field that showed declining soybean seedlings. Symptomatic seedlings were carefully dug up and transported to DATCP's Plant Industry Laboratory for testing.

Seedling roots were tested for the presence of the root rot pathogen *Phytophthora* by culturing on semi-selective media and molecular methods. Results of culturing revealed only 3 out of 50 samples tested positive (6%). Results from molecular testing (PCR=polymerase chain reaction) of DNA extracted from cleaned root tissue showed 9 of 50 samples (18%) tested positive for *Phytophthora sojae*. For comparison, in 2008, 10 of 50 samples (20%) tested positive by PCR and only 4 (8%) cultures could be identified by morphology. PCR is not surprisingly the more effective method to determine seedling infections with this pathogen.

P. sojae infected fields were found in all soybean growing regions of the state. Roughly one fifth of randomly chosen fields surveyed, tested positive for *P. sojae* consistently over two years. More information on soybean plant health and root rot caused by *P. sojae* can be found at this University of Wisconsin website: http://www.plantpath.wisc.edu/soyhealth/prr.htm.

Viruses of Snap Bean

The DATCP pest survey team, in cooperation with processors and fresh market producers conducted a survey for snap bean diseases caused by plant viruses. A total of 101 fields were sampled between July 6 and August 13, 2009.

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

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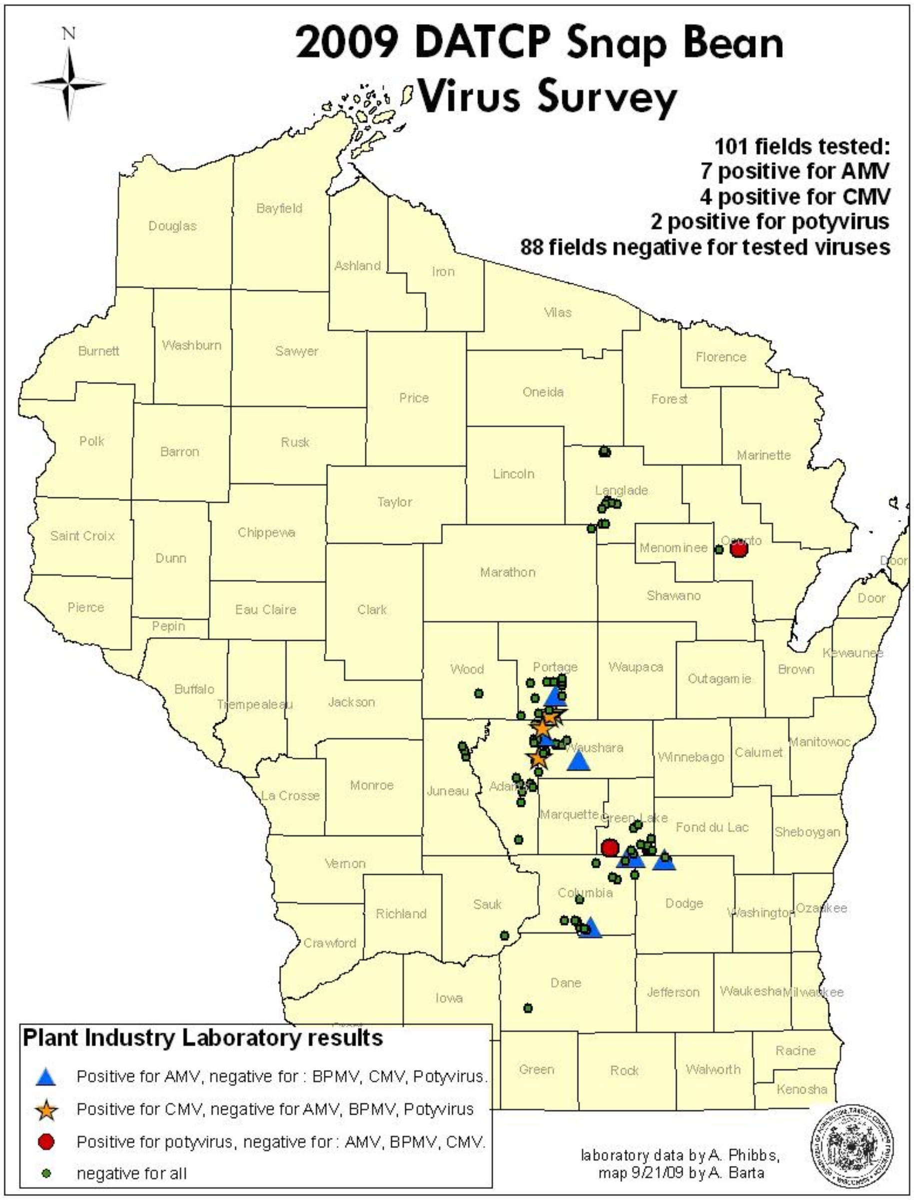


Foliage was tested for the following viruses: alfalfa mosaic virus (AMV), bean pod mottle virus (BPMV), cucumber mosaic virus (CMV), and the potyvirus group that includes bean common mosaic virus and bean yellow mosaic virus. Most of these viruses are seed transmitted to some degree and can also be spread by aphids.

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

Survey staff observed eleven fields with symptoms of white mold infection. Aphid counts were negligible throughout the sampling period. Laboratory results showed seven fields positive for AMV, no finds of BPMV, four fields positive for CMV and two for potyviruses that were not further characterized (Table 1).

Table 1. Snap bean virus summary from 2003 to 2009

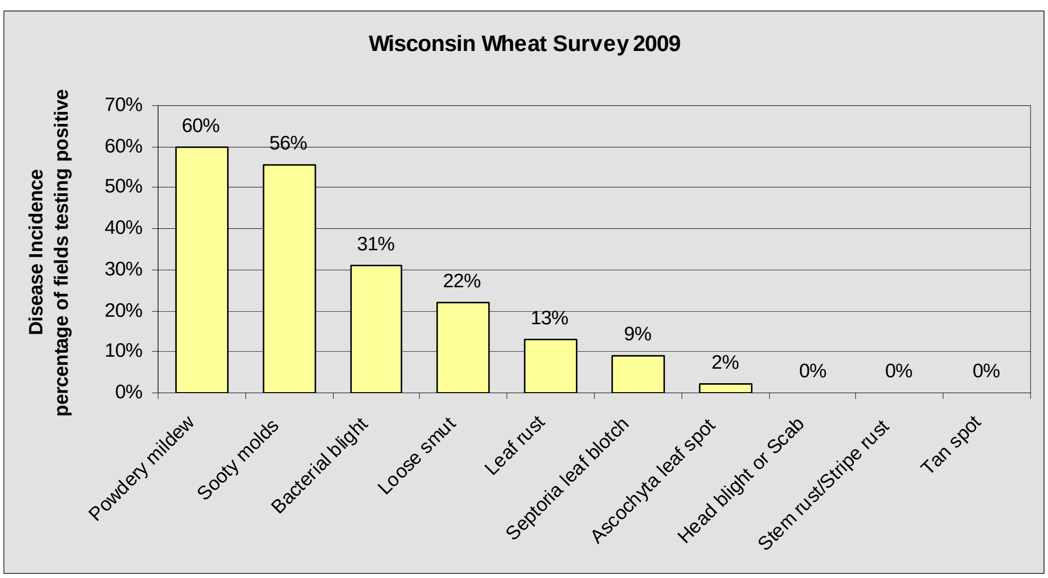
Year	Total No. of Fields Surveyed	AMV (%)	BPMV (%)	CMV (%)	Potyvirus group (%)
2003	25	NA	0	**72**	**4**
2005	33	NA	0	**3**	**9**
2006	62	NA	0	0	0
2008	25	**4**	0	**8**	0
2009	101	**7**	0	**4**	**2**

(%) Positive testing field over total number of fields tested.

Foliar Diseases of Winter Wheat Survey

In June 2009, 45 wheat fields in 13 Wisconsin counties, showed very low disease incidence overall. Wheat fields ranged in maturity from Feekes Stage 8 (flag leaf visible) to Feekes 10.5.3 (flowering complete to base of spike). Powdery mildew (*Blumeria graminis)* and sooty molds were commonly observed, in 60 and 56% of fields, but severity was very low. Powdery mildew increased in severity after the middle of June with 12 out of 23 fields, reaching or surpassing threshold levels (average of 1-5 pustules per flag leaf). Bacterial blight infected leaves showed characteristic yellow striping or stippling. Laboratory testing confirmed the presence of the bacterium *Pseudomonas syringae* in 31% of fields including one field infected with *Xanthomonas campestris*. Traces of leaf rust (*Puccinia triticina*) were found in 13% of fields, no stem (*P. graminis*) or stripe rust (*P. striiformis*) was detected.

Loose smut (*Ustilago tritici*) showed up in 22% of fields compared to 2% in 2008, but at trace levels only. Ascochyta leaf spot (*Ascochyta tritici*) was observed only in 2% of fields compared to 12 % last year. Septoria leaf blotch (*Septoria tritici*) infected 9% of fields in 2009 compared to 26% in 2008. Staff collected foliar samples for future virus and phytoplasma testing. Seventy-six percent of fields showed at least trace levels of reddish-purple streaked leaves symptomatic for several viruses or aster yellows phytoplasma. Scab (*Fusarium spp*.) or tan spot disease (*Pyrenophora tritici-repentis*) were not observed during the survey period.



Seed Corn Survey

Corn field inspections for export regulatory pests were performed on 62 sites in Columbia, Dane, Eau Claire, Grant, Rock, Portage and Pierce Counties. Four of the locations in Dane and Eau Claire Counties test positive for Stewart's wilt (*Pantoea stewartii*). Gray leaf spot (*Cercospora zeae-maydis*) was detected in one field each in Grant and Pierce counties.

NITROGEN MINERALIZATION AND UPTAKE IN SNAP BEAN AND SWEET CORN

A.J. Bussan, Michael Copas, and Michael Drilias[1/]

Wisconsin is one of the leading producers of vegetable crops for processing in the United States. Wisconsin ranks third nationally in potato production, first in snap bean production, and third in sweet corn production, and result in $304 million in gate receipts for Wisconsin framers. Proper nitrogen supply is critical to all crop growth, but is particularly important in high input vegetable systems due to a shortened season for snap bean and sweet corn and a lower rate of return on investment relative to potatoes. Nitrogen is also a problem in much of the vegetable production areas due to its susceptibility to leaching rains resulting in groundwater contamination by nitrates. The price of nitrogen has been extremely volatile in recent years and producers have searched for alternative management strategies to reduce their reliance on fertilizer nitrogen.

Annual and perennial cover crops have shown the potential to provide alternative sources of nitrogen to vegetable crops. In 2006 and 2007, perennial cover crops supplied between 50 and 100% of the required nitrogen for a sweet corn crop at Hancock. The management practices required to implement these cover crops into existing vegetable rotations is currently being addressed in several cover crop studies. One of the management needs of this system is determining how much nitrogen is available for vegetable crop plant uptake that is provided by the cover crops.

Cover crops have the potential to increase the nutrient use efficiency of the vegetable crops of the rotation through improvement of various soil quality parameters. Cover crops have been shown to increase soil organic matter, soil water holding capacity, cation exchange capacity, and soil structure all of which can contribute to better plant nitrogen uptake and efficiency.

Nutrient use efficiency can be calculated by four different methods to determine nitrogen uptake and utilization of the fertilizer nitrogen.

1) Nitrogen use efficiency $NUE = (TN_{Full}-TN_{Zero}) / (NA_{Full}-NA_{Zero})$
2) Agronomic use efficiency $AUE = (TDM_{Full}-TDM_{Zero}) / (NA_{Full}-NA_{Zero})$
3) Agronomic efficiency $AE = (Y_{Full}-Y_{Zero}) / (NA_{Full}-NA_{Zero})$
4) Nitrogen harvest index $NHI = (\text{Fruit } N_{Full}-\text{Fruit } N_{Zero}) / (TN_{Full}-TN_{Zero})$

Deviations in these measurements within a cover crop system versus no cover crops would indicate the influence of the cover crop on nutrient use efficiency. Annual cover crops did not improve nutrient use efficiency versus the no cover crop control. There was no

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conclusive evidence that annual cover crops could serve as an alternative source of fertilizer nitrogen for a vegetable crop rotation. Sweet corn produced yields that were 50 to 100% of the no cover crop control and it is believed that this was primarily due to nitrogen provided by decomposing cover crop residue and nitrogen released from the growing legume cover crop species. There was evidence in the perennial cover crop system that cover crops changed the nutrient use efficiency values compared to where no cover crops were present. A perennial cover crop system holds immediate potential as a production system, while annual cover crop benefits may only be realized under a long term rotation.

VINE CROP PEST MANAGEMENT AND POLLINATORS

Russell L. Groves[1/], David Lowenstein[1/], and Bill Halfman[2/]

Abstract.

Wisconsin has a history in the production of fresh market and processing fruits and vegetables including cucurbit crops such as melons, cucumber, squash, and pumpkins. While acreages and crops have changed over the years, growers have adapted and remained leaders in several crops. Additionally, small-acreage fresh market production, particularly organic, continues to expand in Wisconsin. A special focus of this section of the research will emphasize surveys of domestic and native pollinators. To date, we have documented significant reductions in both populations of cucumber beetles and the bacterial pathogen they transmit in susceptible vine crops using these tactics. In addition, we have identified several species of native pollinators which appear to be regularly abundant in fields treated for cucumber beetles. The seasonal abundance and species composition of insect pollinators varied among farm locations with *Apis* and *Bombus* spp occurring most frequently. We have demonstrated the ability to significantly reduce the reliance on broad spectrum insecticides by incorporating IPB-based, cultural practices that prevent damaging beetle feeding.

Background and Rationale

Wisconsin Agricultural Statistics report vegetable production on over 112,000 acres in Wisconsin with a total of 2,850 reported processed and fresh market growers. Fresh market vegetables are grown and packaged for direct market sales (road-side stands & farmers markets), produce auctions throughout the state, and for large emerging produce cooperatives emphasizing locally sourced, value-added products (Organic Valley, LaFarge, WI). While acreages and crops continue to evolve in response to market demands and production limitations, growers have adapted and remained leaders in several crops. Although no "official" statistics are collected on fresh market production, the Wis. Fresh Market grower association estimates nearly 1,500 small-acreage producers rowing over 50 crop cultivars in the state. Recent increases in locally grown food has fostered the growth of local produce auctions, expansion of farmers' markets, and roadside stands in many locations in western Wisconsin. This has provided Amish and some small acreage, non-Amish farmers in the area an opportunity to diversify their farms and enhance farm income by adding vegetable enterprises. Several farms use a significant portion of their land for raising fresh market vegetables. This has presented two primary challenges; first, they have limited experience in growing vegetables commercially, creating the need for training on cultural and pest management practices on a variety of vegetable crops. Secondly, they need to make sure they have enough quality production from their field crops to meet the needs of rapidly emerging markets driven by the regional food sourcing initiatives. These farmers have been seeking information to help with these two concerns from several sources including Agribusinesses, Wis. Cooperative Extension, and other producers.

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Among the range of production issues faced by this clientele group, cucumber beetles and the bacterial pathogen *Erwinia tracheiphila*, continue to rank high among limiting factors annually recurring in many areas. The overwintering adult insect causes feeding damage on young, emerging plants as well as blossoms and fruit. In addition to direct damage on plants, cucumber beetles are vectors of the bacterial wilt pathogen. The transmission of bacterial wilt disease is even more serious than direct damage because the disease will kill the plant. Because grower access to IPM strategies for management of this insidious pest complex has been limited, insecticides have been commonly used in conventional cucurbit production for control of cucumber beetles especially in melons and summer squash. Very often, the insecticide options used have been inappropriate formulations applied at inappropriate times leading to direct impacts on native and domestic pollinators and ultimately poor fruit set. IPM practices crucial for successfully improving our management of these beetles and the bacterial wilt pathogen they transmit are the focus of this project.

Research Objectives / Performance Targets.

The primary goal of this research project has been focused on the development of a comprehensive set of IPM-based tools to manage the cucumber beetle – bacterial wilt pathosystem and document reductions in total pesticide use and avoidance of risk associated with adoption of IPM.

Associated Research Goals:

1. Participating growers will grow a field of highly-susceptible, cucurbit crops with greater than a 50% reduction in the use of high risk insecticides required to produce a non-resistant variety.
2. Participating growers will achieve a > 75% reduction in disease incidence by layering multiple management tactics with minimal adverse effects on fruit yield or quality.
3. The long-term persistence of cucumber beetle populations and incidence of bacterial wilt inoculum will be reduced by greater than 50% through sanitation and source reduction efforts.
4. Assessing the seasonal host utilization and foraging patterns of native and domestic pollinators in vine crop production with the following sub-goals:
   a. Determine what bee species we find in cucurbit fields in Wisconsin.
   b. Evaluate if field size affects bee visits.
   c. Determine if there are differences in bee visits between field edges and field centers.
   d. Characterize the impact(s) of insecticide inputs that affect pollinator effectiveness.
   e. Determine if different bee species and the number of bee visits affect crop yield.

Research Approach and Outcomes to Date.

Site Selection(s):

A total of 5 experimental farms were identified on which the proposed research was conducted in 2008. Field locations 1-3 were located approximately 8.8 km southwest of Cashton, WI in both Monroe and Vernon counties. Field Site 1 is operated by Mr. Joseph Kauffman and located at S805 Irish Ridge Rd., Cashton, WI. The principal agricultural outputs of the operation include manufactured wood products, greenhouse bedding plants, and field grown fruiting vegetables and cucurbit vine crops occupying approximately 8.5 acres. Both greenhouse and field grown vegetable produce are sold locally at the Cashton, WI produce auction. Field Site 2 is operated by Mr. Christ Hershberger, S2185 County Highway D, Westby, WI. Here again, agricultural outputs of the farm operation include cucurbit vine crops, fruiting vegetables, and greenhouse bedding plants and hanging baskets produced on approximately 4.5 acres and also retail sold at the Cashton WI produce auction. Field Site 3 is operated by Mr. James Yoder, S3718 County Highway D, Westby, WI and is operated as a certified organic produce operation occupying approximately 12.5 acres. Similar to the other local farm operations, the range of vegetable offerings are similar in kind but sold as wholesale raw product to Organic Valley's, Organic Produce Pool, LaFarge, WI. Experimental Site 4 is operated by Mr. Jerry Schneider and Ms. Lisa Riniker, 1103 Habhegger Ave., Sparta, WI and consisted of 12 acres of retail pumpkin. Finally, Field Site 5 is operated by Mr. Grant Murphy, S1028 90 Meter Dr., Westby, WI and consisted of approximately 2.5 acres of cucurbit vine crops as well as a minor component of fruit crops including apples and rapsberries. These sites were co-selected to monitor for both native and domestic pollinator species foraging within vine crop production acres.

Briefly, Field Sites 1, 2, and 4 were included as conventional grower locations which adopted the comprehensive program of IPM-based tactics to limit insect and disease pressure, which included reduced-risk insecticides. Experimental Site 3 was included as the 'organically managed, comparatively standard location which included all non-chemical approaches to management of the insect pathosystem. Field Site 5 was managed by the grower/operator consistent with their past management practices. This site served as the conventional standard location as many broad spectrum insecticides were used for insect and disease control with very little adoption of IPM-based practices.

The methods used for documenting pollinators were designed to be simple, repeatable, and easily incorporated into other concurrent research objectives and were modeled after past research protocols. It provides consistency among locations and years to effectively track population trends and evaluate species richness across different landscapes, and finally to begin to make comparisons across treatments in the total project. To minimize captures of bees from other habitat types, sample plots were located away from the edge of adjacent habitat types and were generally placed centrally in the crop area. Plots were generally no less than 0.75 acre in size and generally consisted of crop that met minimums of 100 m in length and 100 m in width. Detailed records for each plot were kept including surrounding habitat, aspect, slope, latitude, longitude (degrees, minutes, seconds) and elevation. Specifically, vegetation landuse coverage (NASS Landcover Data) was recorded for each site. A list of species that were in bloom for each date is also recorded at each sample site twice through the sample interval.

Plots were sampled on a monthly basis from mid-June to the end of August in 2008. In each plot, pan traps were placed prior to 9:00 am and picked up from the plot after 5:00 pm of the same day by each cooperating grower. As well, two 50-m transects were established in each plot and the pan traps were placed on each transect. Transects were arranged to form an 'X' pattern reaching the corners of the plot. Pan trap colors (white, yellow, and blue) were randomly assigned each time the pan traps are placed out at each sample position in the fields. The start and finish of transects were marked to ensure that the same transects were used in subsequent samples.

Pan traps used were small, white Solo brand dishes holding approximately 6 fl oz of liquid. The pans were subdivided into thirds and 1/3 of the pan traps were painted fluorescent blue, 1/3 painted fluorescent yellow and 1/3 left white. Pans were then filled with a solution made up of 1 teaspoon per gallon of dishwashing soap and pans were placed at level ground during the sample interval. After placement in the field for 6-8 hours, we strained all bees in the field and placed these in 75% alcohol. Prior to identifications, the contents of each sample were dumped through a sieve, rinsed with water, and patted dry on a towel to remove excess water. All bees were placed on a paper towel and rubbed gently to remove all excess water and alcohol. We have begub to compile a reference collection through assistance from Ms Hannah Gaines, Department of Entomology, University of Wisconsin, how has greatly assisted with preliminary identifications, pinning and labeling of specimens.

Grower Cooperator Acknowledgements:
● Mr. Jerry Schneider and Ms. Lisa Riniker, 1103 Habhegger Avenue, Sparta, WI 54656
● Michael and David Warzynski, Paradise Farms, 9950 County Road AA South, Almond, WI 54909

First year project accomplishments to be recorded through this interval include:

(A) During monthly field visits, a 10-minute interval of time during the early morning was spent monitoring / recording pollinator services in the main crop and the portion of the crop under row cover. Specifically, the frequency and duration of visits to flowers by domestic honeybees (*Apis mellifera*), wild bumblebees (*Bombus* spp.), and other wild pollinators such as the squash bee (*Peponapis pruinosa*) were evaluated through visual counts.

(B) A total of 11 predominant bee species were recorded from fields:

Family	Species	Common name
Apidae	*Peponapis pruinosa*	Squash bee
	Apis mellifera	Honey bee
	Bombus impatiens	Bumble bee
	Melissodes bimaculata	Two-spotted miner bee
	Doeringiella remigatus	Cuckoo bee
Halictidae	*Agapostemon sericeus*	Green sweat bee
	Augochloropsis metallica	Metallic green sweat bee
	Lasioglossum leucozonium	Black sweat bee
	L. zonulum	Black sweat bee
	Halictus sp.	Black sweat bee
Megachilidae	*Megachile sculpturalis*	Giant resin bee

(C) We recorded a total of 3,672 total bee visits; 94% of all bee visits were by honey bees, bumble bees, and squash bees. The remaining bees constituted the remaining 6% of total visits to cucurbit flowers over 4 vine crop species (pumpkin, muskmelon, cucumber, and summer squash).

(D) Squash bee and bumble bee visits were higher in smaller fields, but decreased with increasing field size. Honey bee visits increased with increasing field size and were likely supplemented by nearby bee yards.

(E) There were more squash bee visits at field edges than in field centers. No difference between honey bee visits or bumble bee visits and field location.

(F) There were significant differences among pollination treatments in fruit weight. Trends reported in increasing fruit weight with additional bee visits. Honey bees and bumble bees were both effective pollinators of pumpkins, cucumbers, and muskmelons. More than four bee visits required for maximum fruit weight, especially with pumpkin fruit set.

Taken together, the proposed management program continues to enhance the close cooperation that has developed between direct market produce growers, wholesale produce buyers, county agricultural extension agents, and extension specialists at the University of Wisconsin. The collaboration team is very much on course towards the development of sustainable, culturally-based, pest management recommendations to limit the damage caused by cucumber beetles and bacterial wilt with an emphasis on reduced pesticide inputs targeted as high risk by FQPA. Field scale trials in the coming year have again been focused on confirming the effectiveness of different strategies within local production systems towards verification that these multiple tactics do not interfere with native and domestic pollinators.

PROPOSED NATIONAL SUSTAINABILITY STANDARDS: IMPLICATIONS FOR THE AGRICHEMICAL AND FERTILIZER INDUSTRIES

Jed Colquhoun [1]

From environmentally-concerned groups to buyers, retailers and consumers, "sustainability" is certainly the current buzzword in many industries, including agriculture. Several retailers and agricultural industries are independently developing sustainability standards, indices, and certification programs for their businesses and others throughout the supply chain. Additionally, national sustainability standards, which would ultimately encompass all agricultural crops, have been proposed or are in development by multiple groups. The intent of this presentation is to give an overview and update on national sustainability standards, and to outline potential implications on Wisconsin's agricultural industries.

While the concept of sustainable agriculture has been a point of discussion for several years, the desire to use it as a marketing tool or to add value to products in the marketplace is a relatively recent development. Individual retailers and suppliers, such as Walmart, are developing sustainability scorecards and standards. For example, McDonald's recently agreed to comply with a shareholder request to look at ways to reduce pesticide use in potatoes and document such progress. As a result, growers may be required to fill out several surveys to sell to multiple buyers, in addition to current requirements for good agricultural practice (GAP) surveys.

In response, multiple entities are developing national standards that would be applicable to agriculture in general and could be used to certify agricultural production with a single survey, thus reducing the duplicative efforts required to satisfy multiple buyers. Three national sustainability standard efforts are now taking place: the Field to Market efforts led by the Keystone Center, the Stewardship Index for Specialty Crops, and the American National Standards Institute efforts organized by Scientific Certification Systems.

Scientific Certification Systems developed the "Draft American National Standard for Trial Use for Sustainable Agriculture." This standard was proposed to the American National Standards Institute (ANSI) in 2007, an organization that develops and implements voluntary standards for a variety of industries. The Leonardo Academy, a Madison-based organization accredited by ANSI, is leading the standard development process. After an initial meeting of the Standards Committee in September 2008, the initial draft standard will be re-tooled. Those critical of the initial draft standard have cited two primary issues: (1) the standard set organic production as the highest level of sustainability, and may in fact be duplicative of current organic standards in many areas, and (2) the initial standard prohibited the use of genetically modified crops. The groups involved in this standard development are in the process of developing a new draft standard.

The Keystone Center Field to Market group consists of entities with varying interests, including several food and fiber national commodity groups, environmental organizations, end-users and retailers, and academia. The goal of this group is not to develop a certification system, but to develop a grower tool that can be used to gauge production and sustainability metrics relative to neighbors, regional and national producers of a given crop. The proposed tool would allow growers to identify potential areas of improvement as well as to follow sustainability trends through time in terms of production efficiency per unit of production area. The Keystone Center

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participants are currently investigating methodology and feasibility of quantifying sustainability parameters, such as water quality and energy use, at the grower level. The focus of this group is on major agronomic crops, such as cotton, corn, soybeans and wheat.

The Stewardship Index for Specialty Crops has taken an approach analogous to the Keystone Center, but with a focus on specialty food crops. The approach is outcome-based and not practice-based, and has focused on self-evaluation instead of certification. This group has organized several well-attended webinars and educational venues on parameters that would be included in the people, planet and profit parameters of sustainability.

While these efforts and others are currently very active, quantifying agricultural sustainability poses many challenges:

1. Agriculture is a complex biological system overlaid with an equally complex management system. Therefore, an inclusive standard across regions and crops is logistically challenging.
2. Quantifying sustainability could be costly, particularly with parameters such as water quality, where there is no substitute for expensive laboratory analyses.
3. At some point, participants or leaders may need to weight parameters in order to make difficult choices. This will raise questions of differing values systems. For example, which is more important: preserving rural farmland or preserving water?

Many involved have indicated that, ultimately, consumers will determine the success of such programs. So, will consumers pay for sustainability? The Healthy Grown potato program in Wisconsin provides an interesting case study. The Healthy Grown potato program is a unique collaboration among growers, academics and environmentally-oriented NGOs. The research-based program was built with over 20 grants totaling $2.7 million, about $200,000 per year in research support directly from growers, and about 15 to 20 researchers involved through time. In terms of documenting and improving “sustainability” parameters, Healthy Grown has been a great success. Between 2001 and 2005, IPM adoption increased 30 to 40% while pesticide toxicity scores decreased. The program is third-party certified by Protected Harvest and is rigorous. In 2006, only 35% of participants passed the minimum level for certification. In market surveys, 70% of consumers said that they were likely to purchase Healthy Grown potatoes, and of those, 88% indicated that they would pay $0.25 more than standard potatoes. However, in 2004 and 2005, only 1% of the certified crop was sold as Healthy Grown. It appears that there is a strong disconnect between what consumers say they will buy and what is actually riding around in their grocery carts.

The measurement of “sustainability” parameters, such as the carbon footprint, has been successfully adopted in industrial processes; however, there are a couple of key differences between these efforts in industry versus agricultural production. First, the parameters often surveyed in industrial processes can be and are currently quantified with something as simple as a meter, such as electricity, natural gas and water usage, whereas those proposed for measurement in agriculture are much more nebulous, such as fair labor, rural community value and biodiversity. Second, the outcome of measuring these parameters in industry is often an implementation of efficiencies that slow the meter down - i.e. quantifying sustainability saves money. We have not yet been able to demonstrate a similar relationship in agriculture.

ROUNDUP-READY, LOW LIGNIN AND OTHER NEW TRAITS ALFALFA'S FUTURE

Dan Undersander[1]

Abstract

The benefits of using new breeding techniques for alfalfa improvement are just being developed. These GMO alfalfa varieties will revolutionize the using and management of alfalfa. This paper presents information on the development of two GMO alfalfa traits (Roundup Ready and Low Lignin Alfalfa) that will provide new tools for many farmers. It will mention some other research/development being conducted.

Roundup Ready Alfalfa

Forage Genetics International began developing Roundup Ready alfalfa in 1994. The inserted gene produced the same protein as found in other roundup ready crops on the market. In conventional plants, glyphosate binds to an enzyme, blocking the biosynthesis of aromatic amino acids and depriving the plant of essential components (Haslam, 1993; Steinrucken and Amrheim, 1980). The RR plants are similar to non GMO plants but has a greatly reduced affinity for glyphosate (Padgette et al., 1995).

Commercialized RR alfalfa varieties use two independent events (J101 and J163) combined through a commercial breeding process (Samac et al., 2004). Alfalfa varieties are heterogeneous populations with individual plants being phenotypically and genotypically unique. The populations of alfalfa plants in commercial Roundup Ready varieties consist of individual plants with zero to eight copies of the *cp4 epsps* gene insert, contributed by either event J101 or J163. The Roundup Ready phenotype is exhibited if one or more copies of the RR gene are present in the plant.

While useful to all farmers, RR alfalfa provides great benefit to the grower where weed control has been an issue in the production of alfalfa. First, glyphosate does not injure alfalfa as the most commonly used pre- and post-planting herbicides do. Further, imazethapyr has risk of yield loss with the crop following alfalfa when flax, corn, meadow bromegrass, oriental mustard, sunflower, timothy and wheat were seeded 1 year after herbicide application to the alfalfa, canola seeded up to 2 years later, and sugarbeet and potato seeded up to 3 years later (Moyer and Easu, 1996). Glyphosate can be used on RR alfalfa at very high rates with no detectible crop injury. Multiple studies by the senior author have shown an average yield reduction of 0.2 t/a for the cutting following imazethapyr or imazamox application to alfalfa compared to glyphosate.

Another advantage of RR alfalfa is that glyphosate can be applied over a wider time window for effective weed control so that weather delays are less of an issue. Most other post emergent herbicides need to be applied when weeds are small, requiring greater rates and being less effective on larger weeds.

Glyphosate controls a wider range of weeds than most other herbicides for alfalfa. One of the benefits of RR alfalfa will be the ability to use glyphosate to get much better control of

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winter annuals such as chickweed, wild garlic, wild onion, perennials such as dandelion, difficult weeds such as nutsedge and dodder, and poisonous weeds such as groundsel. All have been difficult to control, in some cases, limited to dormant herbicide applications so that control was not an option when the problem was visible. Further dormant herbicides are discriminated against in northern regions because, if winterkill occurs, no crop can be planted in the field during the following growing season.

Another advantage of the RR alfalfa system is safety. Glyphosate is among the safest pesticide used on farms. It has an extremely low acute toxicity (the oral LD50 in the rat of pure glyphosate is 4,230 mg/kg, or 5,600 mg/). In fact, some of the surfactants mixed with glyphosate are more toxic than the herbicide. Glyphosate is inactivated when it comes into contact with soil since it is adsorbed onto soil particles in the same way as inorganic phosphates. Unbound glyphosate is rapidly degraded by microbial activity to carbon dioxide. Because of its adsorption to soil, glyphosate is not easily leached and is unlikely to contaminate ground water (Giesy et al., 2000) unlike certain other herbicides used on alfalfa (e.g., Velpar).

Lastly there is a significant ease of use factor with glyphosate on RR crops since is not a restricted pesticide so growers do not need pesticide applicator certification to apply this compound. Also, many farmers growing corn or soybeans will already be using glyphosate. Therefore, they will not need separate herbicide storage or record keeping; they will not need to clean the sprayer or change nozzles when moving from one crop to another. There will also be less risk of drift onto a susceptible crop or the potential for spraying the wrong herbicide onto a susceptible crop.

Glyphosate resistance has been reported in approximately a dozen weeds (Boerboom and Owen, 2006; http://www.weedscience.org/In.asp). Some have been concerned that alfalfa as the third crop in the corn-soybean-alfalfa rotation of many dairy farmers would increase the rate of resistance development in weeds. However, including a forage crop in rotation with row crops will generally enhance weed control because some weeds cannot tolerate the frequent defoliation of a forage crop (Martin et al., 1967). It is believed that inclusion of alfalfa in corn-soybean rotations will be another tool to slow development of weed resistance to glyphosate. Thus the key to minimizing development of resistant weed populations and weed shifts will be the recommended stewardship of using multiple herbicides in rotational systems combined multiple mechanical controls such as preplant tillage and frequent mowing of alfalfa.

Low Lignin Alfalfa

Lignin provides strength to plants and allows the plant vascular system to transport water in the plant without leakage. Lignin increases with advanced maturity in alfalfa. However lignin is indigestible and reduces fiber digestibility in ruminants. Thus reducing lignin content should increase fiber digestibility at any maturity stage.

1
2
3

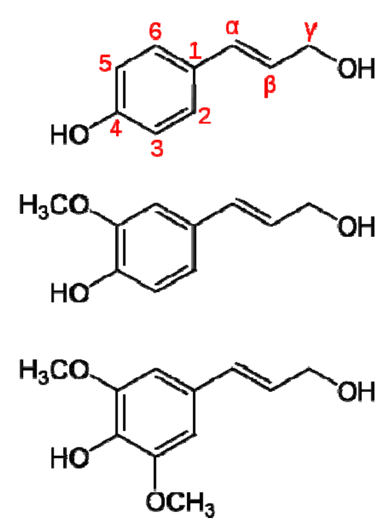


Fig 1. Three Lignin Precursors

Lignin is composed of three monomers, each a carbon ring with differing methoxy group configuration and a 3-carbon tail (Fig. 1). These subunits polymerize into lignin. This lignin molecule fills the spaces between cellulose, hemi-cellulose and pectins as the plant ages and binds with the hemicellulose. Lignin coating the cellulose allows water to move up the plant stem without leakage but also reduces digestion of the cellulose in the rumen. Thus some lignin is necessary but lignin above the minimum reduced fiber digestibility without additional benefit to the plant.

We have tested transgenic alfalfa lines down-regulated for two lignin biosynthetic genes (COMT and CCOMT). Alfalfa populations for this study consisted of transgenic alfalfa lines down-regulated for one of two lignin biosynthetic genes, their null isogenic lines, and a check variety (LegenDairy 5.0). Replicated studies were conducted at Becker, MN; Arlington, WI; West Salem, WI and Davis, CA and Tulelake, CA. Plants were started in the greenhouse and then transplanted into the field in spring 2008 into rows spaced 30 cm apart with 30 cm between rows. Each plot consisted of three rows of 9 plants. The middle 7 plants of the middle row were harvested for yield and quality in summer 2008. Harvests were taken beginning at late vegetative stage and continued at 5 day intervals for 5 total harvests.

Forage samples were analyzed for crude protein (CP), neutral detergent fiber (NDF), acid detergent lignin (ADL), and neutral detergent fiber digestibility (NDFD) (in vitro 48 hr) and Relative Forage Quality (RFQ) was calculated.

Proof of concept trials were conducted (separately from this study) where lignin transgenic alfalfa hay fed to rapidly growing lambs (Table 1) or in total mixed diets with corn silage to lactating dairy cows measured increased fiber digestibility and (Table 2). In the lamb trial, while NDF was not significantly different, both intake and NDFD of the COMT line was increased over its null (active) control. CCOMT did not show any significant responses. In the study with dairy cattle, digestible dry matter of COMT alfalfa increased 3.5% fat corrected milk over it's null (active) line by 2.6 lb/hd/day (Table 2).

Table 1. Digestibility of low lignin alfalfa types and controls fed to lambs, diet was 100% alfalfa hay fed ad libitum.

100% alfalfa hay diet	aNDF % DM	ADL % DM	NDFD % NDF	DMD % DM
COMT Inactive	38.2	5.3	57.5*	67.5*
COMT Active (Control)	39.0	5.8	49.1	64.5
CCOMT Inactive	39.4	5.2	50.1	65.3
CCOMT Active (Control)	39.4	5.9	46.4	63.7

*Significant, P < 0.05

SOURCE: Mertens et al. 2008. J. Dairy Sci. Supple. 1

Table 2. Lactating cow responses to alfalfa hays with down-regulated lignin biosynthesis

Alfalfa hay type[1]	CP % DM	NDF % DM	NDFD %NDF	Milk lb/day
COMT Inactive	18.1	31.1	53.5**	84.7*
COMT Active (Control)	18.4	29.3	42.5	82.1
CCOMT Inactive	18.1	42.5	48.6**	84.5
CCOMT Active (Control)	18.3	31.1	44.5	86.7

[1]TMR diets - 50 % alfalfa hay, 10 % corn silage, 40 % concentrate

*Significant, P < 0.10; ** significant P <0.01 (different from control)

SOURCE: Weakley et al. 2008. J. Dairy Sci. Supple. 1

Alfalfa stems from reduced lignin genotypes increased sugar yield which potentially could increase ethanol > 50% compared to standard alfalfa.

Fig 2

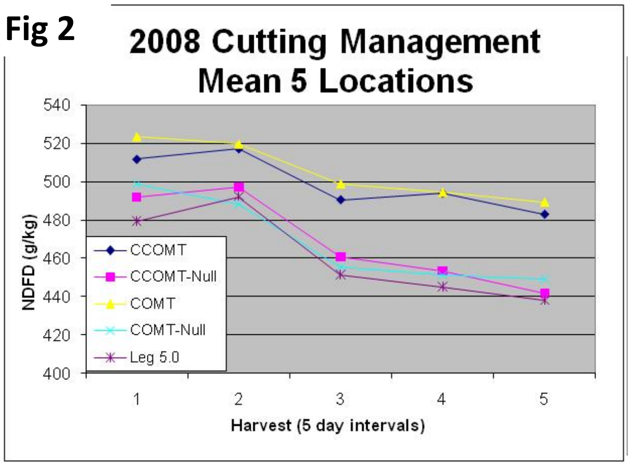
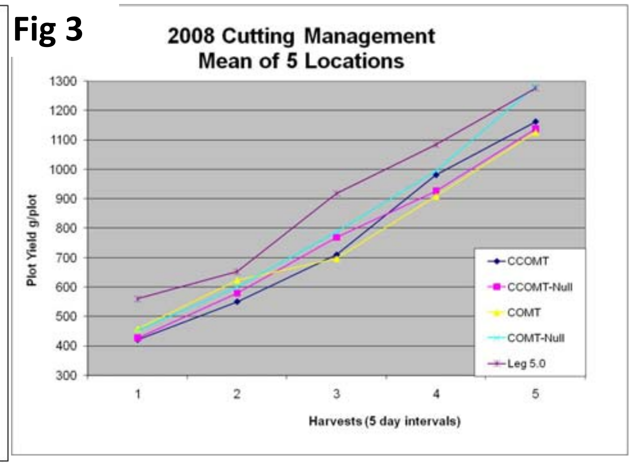


Fig 3



In the current study, the null lines and the check variety (LegenDairy 5.0) had similar fiber digestibility which gradually declined as maturity advanced (later harvest date). Both low lignin lines had consistently higher fiber digestibility at each harvest date (Fig. 3). The CCOMT line averaged 12 percentage units less ADL than the null and had 10.2 percentage units more NDFD. The COMT line averaged 3.7 percentage units less ADL than the null and 14.0 percentage units more NDFD. A change in lignin composition in the COMT population is a likely explanation for the increased fiber digestibility relative to lignin content. Thus it will be possible to harvest higher quality with either of the transgenic alfalfa lines down-regulated for lignin synthesis when harvesting occurs on a similar schedule as for non-transgenic lines.

Another way to view this data is that COMT and CCOMT lines harvested 8 to 12 days later than the nulls or commercial check had the same forage quality. Later harvesting will allow for higher yield per cutting (Fig. 3). When alfalfa begins to regrow after being cut, the growth per acre is low (perhaps less than 50 lb/acre/day) but as the crop matures the growth per day increases (to 200 lb/acre/day or more at harvest). Thus, in alfalfa harvest systems where we took 3 vs 4 cuttings within the same time period, alfalfa yield was 20 to 30% greater (with the labor of one less cutting) for the 3-cut system. In the past the quality of the 3-cut system was much lower; now it may be possible to delay harvest to get the higher yield with the same forage quality as from standard alfalfa varieties cut earlier. I believe that this will be the most important aspect of this transgenic reduced lignin alfalfa, rather than higher quality forage harvested at the same date.

The CCOMT line stood (lack of lodging) as well in space plantings at the commercial alfalfa line. COMT is an artificially created mutation for the same gene as bm3 which is a naturally occurring reduced lignin gene in corn. We did see some standability issues with this line. However, further breeding efforts may be able to solve this problem.

Other Alfalfa Traits Being Tested/Developed

In addition, several other GMO traits in alfalfa are available and being evaluated some of which will be extremely beneficial to farmers:

1) Increased by pass protein of alfalfa. Alfalfa has a high protein content but most of it is soluble (degraded in the rumen), especially when alfalfa is made into silage. As such the protein may need to be supplemented with bypass protein in dairy rations, resulting in extra expense to the dairyman and increased methane loss to the atmosphere. Sullivan and Hatfield (2006) showed that red clover red clover (*Trifolium pratense* L.) has up to 90% less proteolysis during ensiling. They found that the combination of polyphenol oxidase (PPO) and *o*-diphenol PPO substrates, both abundantly present in red clover, is responsible for postharvest proteolytic inhibition in this forage crop. This gene has been transferred to from red clover to reduce the bypass protein of alfalfa. It may also reduce bloat problems. Another approach has been Similar attempts shave been made to identify genes that regulate the expression of sulfur amino acid-rich, ruminal degradation- resistant proteins and to transfer these genes into alfalfa.

2) A GMO trait is available that enhances leaf retention through the later stages of growth and the harvesting process. Since the bulk of the nutrients are in the leaves such a trait could have significant economic benefit to farmers.

3) Several GMO traits have been identified for drought resistant in alfalfa. These traits could be of great benefit in drought or where water is limiting. Some traits may also increase the dry matter produced per unit of water used (water use efficiency).

4) A GMO trait for with delayed flowering has been identified that may allow alfalfa to be harvested later resulting in higher total season yield and possible reducing the number of cuttings taken per season.

Summary

Thus the potential for alfalfa is exciting if breeding techniques currently available to other crops can continue to be used for alfalfa development. However, the development and use of GMO alfalfa was stopped by a court decision in 2007. The court required an EIS be issued from APHIS. This has been drafted and is available for public comment. If any of the above traits are ever to be available to farmers, it is crucial that the first trait (Roundup Ready alfalfa) be approved since this contains much information on seed production and management of GMO traits that would not need to be repeated in future applications for GMO traits in alfalfa. It is crucial that you register a public comment to preserve this breeding technology for the betterment of alfalfa. Comments can be made by either of the following methods:

- Federal eRulemaking Portal: Go to http://www.regulations.gov/search/Regs/home.html#documentDetail?R=0900006480a6b7a1 to submit or view comments and to view supporting and related materials available electronically.
- Postal Mail/Commercial Delivery: please send two copies of your comment to Docket No. APHIS-2007-0044, Regulatory Analysis and Development, PPD, APHIS, Station 3A-03.8, 4700 River Road, Unit 118, Riverdale, MD 20737-1238. Please state that your comment refers to Docket No. APHIS-2007-0044

Public comment ends Feb 16, 2010

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BREAKING THROUGH THE SOYBEAN YIELD PLATEAU AND COMPARISON OF CONVENTIONAL VS. TRAITED SOYBEANS

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

It is commonly stated as fact that soybean is experiencing a yield plateau. However, multiple sources of information from plant breeders, to yield trials, to the USDA suggest that soybean yield is increasing as a modest rate of 0.4 to 0.5 bu/a per year. Soybean yield can be explained by genetic potential, agronomic management, and environment. If growers are experiencing a yield plateau then it is critical to identify the source of this yield loss. For the purposes of this discussion, we will focus on the factors that growers and managers can control; genetic potential and management.

Genetic Potential

Variety selection is the most important factor in maximizing grain yield and profitability in both corn and soybean. The difficult year we experienced in 2009, coupled with the launch of Roundup Ready 2 Yield® (RR2Y) soybean, and increased interest in LibertyLink® (LL) and conventional soybean varieties makes the selection decision even more important.

When selecting a soybean variety remember you can never have too much information. When we were students we were taught to compare grain yields over years and locations before a seed purchasing decision was made. In today's competitive environment however, the life span of a soybean variety is often limited to 2-3 years. To make the best variety decision today, collect yield data from several sources including the University of Wisconsin Soybean Variety Test program (http://www.coolbean.info) as well as from several seed company representatives. Compare yields from a wide range of locations and environments. A common mistake that we often make is only looking at local data (your farm, neighbor, county, etc.). Though interesting, local data will only tell you how well that soybean variety performed in a narrow area last year. Comparing variety performance over many different environments will offer growers that best "predictive ability" for next year's environment.

Once you have selected a group of high yielding soybean varieties, choose those that have the disease resistance/tolerance characteristics that meet your specific field needs. In Wisconsin, soybean cyst nematode (SCN), brown stem rot, and Sclerotinia stem rot (aka, white mold) are considered the largest annual concerns. The Wisconsin Soybean Variety Test Program conducts variety trials targeted specifically at SCN and white mold. We also take extensive field notes at all of our locations to quantify the incidence (percentage of plants infected) of white mold and brown stem rot among the varieties entered. In 2009, our White

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Mold Variety Test showed a wide range of differences in susceptibility of entered varieties. Incidence levels at the plot level in our trials ranged from <5% to 100% infection.

Agronomic Management

New technology is continuously being developed and implemented to increase soybean yield. The return on investment (ROI) for these innovations and management practices are often difficult to quantity. Therefore in 2008, we initiated an experiment to quantify the ROI of implementing different management strategies. Using small, replicated plots, we compared soybeans grown in rain-fed versus irrigated environments at the Arlington Agricultural Research Station. Within each of these environments, we imposed 4 management levels starting with a low input system and ending with a very high input system. The inputs for each management level are shown in Table 1.

Table 1. Inputs, yields, costs, and net return for high yield soybean study. Arlington, WI. 2008.

	Management Level			
Input	**Low**	**Standard**	**High**	**Very High**
Seeding rate	175,000	175,000	260,000	260,000
Inoculant		Optimize	Optimize	Optimize
Seed treatment		CruiserMaxx	CruiserMaxx	CruiserMaxx
Fertigation (Irrigated only)	28% N	28% N	28% N	28% N
Soil applied biocide			Contans	Contans
P and K			40P + 80K	40P + 80K
Foliar nutrients			Micros (2x)	Micros (4x)
Other fertilizer			Chicken litter	Chicken litter
Foliar fungicides		Headline (1x)	Headline/Quilt (3x)	Headline/Quilt (2x)
Foliar insecticide		Warrior	Warrior	Warrior
Ethephon				Yes
	Yield (bu/a)			
Irrigated	67.1	74.3	76.1	78.1
Rainfed	66.8	64.2	69.5	69.4
	Cost of inputs ($/a) (those shown above only)			
Irrigated	110	142	369	407
Rainfed	45	78	304	342
	Partial net return/a based on $9.00/bu soybean			
Irrigated	$494	$526	$316	$296
Rainfed	$556	$500	$321	$283

Yields in the irrigated environment were significantly higher with the “very high” level of management compared to the “standard” and the “low” input levels. Input costs were also much higher due to additional product and application costs. These input costs, however, were not justified when an economic analysis is performed on the results. As shown in Table 1, the highest net return ($/a) in the irrigated environment was from the “standard” management level. And in the rainfed environment, the “low” input level provided the highest net return. We do not intend to imply a complete economic analysis with these results. Other fixed and variable costs that could be applied here include land, interest, machinery, and return to management. Since these costs would be applied to all management levels, the "very high" management level could easily see negative returns if these costs were factored in.

Based on the results from 2008, it was apparent in this study that even higher yields would have needed to offset the expensive inputs. We were however, able to increase yield with higher inputs. So in 2009, we adjusted our experimental design to focus on the maximum yield potential in WI using variety selection as our treatment factor and to apply high inputs across all varieties. To facilitate the variety selection objective, we asked five seed companies to send us their "best" soybean variety to include in this study. These five varieties were planted in replicated plots, all under irrigation, and using inputs shown in Table 2.

Table 2. Inputs and yields for high yield soybean study at Arlington, WI in 2009.

Input	
Irrigation	4 acre inches
Seeding rate	260000 seeds/a
Inoculant	Optimize and Soil Implant
Seed treatment	CruiserMaxx
Fertigation	28% N
Soil applied biocide	Contans
P and K	40 lb/a P + 80 lb/a K
Foliar nutrients	Micros (4x)
Foliar fungicides	Headline/Quilt (3x)
Foliar insecticide	Warrior (2x)

		High input	**RR variety trial**
Brand	**Variety**	**Yield (bu/a)**	
Asgrow	DKB27-52	79	
Dairyland	DSR-2560/RR	81	60
Kruger	K-249RR/SCN	79	72
NK Brand	NK S21-N6	81	72
Nu-Tech	6244	79	65
Pioneer	93M11	75	

Irrigated yields in 2009 were similar to the high yield obtained in 2008 irrigated plots. There was no significant yield difference between the varieties in 2009 (Table 2). Combining the highest yielding varieties seed companies offered with the high input management levels, we can produce higher yields compared to state average yields. By comparison, the highest yield in our RR variety test at the same station (in a different field) was 74 bu/a in 2009. Though a statistical comparison cannot be conducted we did list the yield of those varieties that were entered into our 2009 RR Performance Trial that we also used in the high yield study (Table 2). Yield levels in the high input trials were higher most likely due to irrigation and/or combinations of certain inputs. Results from 2008 and 2009 suggest that we can increase yield levels with higher input levels and we can expect higher yields by selecting high yielding varieties. The remaining question is "if a grower is using the highest yielding varieties available, what level of management is most economical to maximize profits?"

Comparison of Conventional vs. Traited Soybeans

Seed price will be a large driver of seed sales in 2010. Preliminary quotes on base seed price (quoted prices before discounts and programs) have ranged from the high $30's (conventional) to the mid-$70's (RR2Y®) on a per bag basis. Such a huge discrepancy in price has growers struggling over their 2010 variety selection decision. Since 2003, we have seen a divergence in yield potential between conventional and Roundup Ready (RR®) soybean varieties across our trials. To further characterize these yield differences and test the yield potential of LL® soybean, we added several high yielding RR® and LL® soybean varieties as checks into our conventional trials in 2009. This information will provide growers with an accurate yield comparison among LL®, RR®, and conventional soybean varieties to aid in their decision process. Our RR® trials also had several RR2Y® varieties entered in 2009 to allow for this new trait comparison.

In our southern conventional and traited herbicide soybean test, we found high yielding varieties across the LL®, RR®, and conventional soybean varieties entered (Table 3). In contrast at our North Central conventional and traited herbicide soybean test, only three conventional soybean varieties produced the highest yield (Table 4). These results, though preliminary, suggest that growers have several conventional soybean variety choices which can yield equal to or greater than some RR or LL varieties.

Due to the lateness of harvest, we were unable to provide a direct comparison of RR® vs. RR2Y® across our Southern, Central, and North Central locations in time to be added to this document. This information will be provided at the WCMC.

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

Table 3. Southern conventional and traited herbicide soybean test.
Performance of Public and Commercial Entries at Two Wisconsin Locations. ARL = Arlington, LAN = Lancaster

				2009 2-Test Average			2009		
		Maturity	Herb.[1]	**Yield**	Lodging	Maturity	ARL		LAN[3]
Originator/Brand	Entry	Group	Toler.				Yield	WM[2]	
				bu/a	1-5	date	bu/a	%	bu/a
Public	MN 0302	0.3	CN	**38**	1.5	9-Sep	60	0	16
Public	Hamlin	0.9	CN	**46**	1.8	19-Sep	63	4	29
Public	Surge	0.9	CN	**46**	2.3	15-Sep	62	13	29
Public	MN 1005	1.0	CN	**43**	3.0	19-Sep	54	6	31
Public	SD 02-833	1.1	CN	**46**	3.0	19-Sep	56	9	35
Public	MN 1410	1.4	CN	*** 50**	2.3	23-Sep	* 66	9	34
Public	IA 1006	1.6	CN	**45**	2.6	26-Sep	58	15	32
Public	MN 1701 CN	1.7	CN	*** 48**	2.5	28-Sep	58	14	38
Public	IA 1008 BC	1.9	CN	**45**	1.4	25-Sep	61	6	28
Public	IA 1022	1.9	CN	**47**	2.0	24-Sep	59	8	35
Public	IA 2076	2.0	CN	*** 54**	2.4	30-Sep	65	14	42
Public	SD 02-22	2.2	CN	*** 51**	2.1	27-Sep	60	25	42
Asgrow	AG 2108	2.1	RR	*** 58**	2.0	1-Oct	65	15	50
Blue River	2A12	2.1	CN	*** 53**	2.3	24-Sep	64	5	41
Blue River	2A71	2.7	CN	*** 55**	2.9	9-Oct	52	5	* 57
Dairyland	DSR-2118	2.1	CN	*** 50**	1.4	1-Oct	58	4	41
Dairyland	DSR-2200/RR	2.2	RR	*** 56**	2.0	6-Oct	58	5	* 53
Dairyland	DSR-2215	2.2	CN	*** 50**	1.8	4-Oct	60	14	39
FS HiSOY	L 09-23	2.3	LL	*** 58**	1.6	7-Oct	* 66	14	50
FS HiSOY	HS 25L80	2.6	LL	*** 59**	2.3	7-Oct	62	5	* 56
NK Brand	S21-N6 Brand	2.1	RR	*** 56**	1.6	28-Sep	* 72	4	39
O'Brien	O'Soy 108C	1.8	CN	**46**	2.3	24-Sep	59	10	33
O'Brien	O'Soy 183LL	1.8	LL	**46**	1.8	25-Sep	61	10	30

-- Continued --

Renk	RS 230NLL	2.3	LL	* 60	1.8	7-Oct	* 69	9	51
Viking	O.1692	1.6	CN	* 51	1.9	22-Sep	* 68	10	34
Viking	O.1706N	1.7	CN	* 55	1.5	19-Sep	* 66	19	43
Viking	2020N	2.0	CN	46	2.4	22-Sep	59	18	32
Viking	O.2078N	2.0	CN	* 51	1.4	25-Sep	57	16	44
Viking	O.2265	2.2	CN	* 54	2.0	29-Sep	* 67	11	40
Mean				50	2.1	26-Sep	62	10	39
LSD(0.10)				12	1.1	7	6	ns	5

* Yields preceded by a '*' are not significantly different (0.10 level) than the highest yielding cultivar.
[1] Herb. Toler. ; Herbicide Tolerance : CN = Conventional herbicide , LL = = Tolerance to Ignite herbicide, RR = Tolerance to glyphosate herbicide. [2] WM = White Mold data is expressed as a percent of diseased plants.
Results that are shaded provide the best estimate of relative variety performance.

Table 4. North central conventional and traited herbicide soybean test.

Performance of Public and Commercial Entries at Marshfield WI.

				2009			
Originator/Brand	Entry	Maturity Group	Herb.[1] Toler.	Yield	Maturity	Protein	Oil
				bu/a	date	%	%
Public	MN 0302	0.3	CN	34	17-Sep	34.6	18.5
Public	MN 1005	1.0	CN	47	27-Sep	34.0	18.6
Public	Surge	0.9	CN	49	24-Sep	36.2	17.9
Public	Hamlin	0.9	CN	45	24-Sep	37.2	17.3
Public	MN 1410	1.4	CN	* 57	29-Sep	35.2	18.5
Public	MN 1701 CN	1.7	CN	* 54	6-Oct	35.5	17.5
Public	SD 02-833	1.1	CN	53	30-Sep	35.2	17.5
Public	IA 1006	1.6	CN	* 58	3-Oct	34.2	17.9
Public	IA 1022	1.9	CN	50	4-Oct	32.5	18.9

-- Continued --

Asgrow	AG 1506	1.5	RR	**50**	3-Oct	33.3	18.5
Blue River	10F8	1.0	CN	**42**	27-Sep	34.5	18.6
Blue River	1A24	1.2	CN	**46**	13-Oct	35.4	16.7
Blue River	15K9	1.5	CN	**44**	6-Oct	36.4	17.6
Blue River	16A7	1.6	CN	**45**	27-Sep	34.1	17.5
Dairyland	DSR-1302/RRSTS	1.3	RR/STS	**50**	4-Oct	34.6	17.2
NK Brand	S12-P4 Brand	1.2	RR	**51**	3-Oct	34.8	17.4
O'Brien	O'Soy 183LL	1.8	LL	**47**	18-Oct	34.2	17.7
O'Brien	O'Soy 108C	1.8	CN	**51**	5-Oct	32.8	19.0
Renk	RS 170LL	1.7	LL	**52**	17-Oct	35.7	16.8
Mean				**49**	2-Oct	34.7	17.9
LSD(0.10)				**4**		0.4	0.3

* Yields preceded by a '*' are not significantly different (0.10 level) than the highest yielding cultivar.

[1] Herb. Toler. ; Herbicide Tolerance : CN = Conventional herbicide , LL = = Tolerance to Ignite herbicide, STS = Tolerance to Sulfonylurea herbicides, RR = Tolerance to glyphosate herbicide.

Results that are shaded provide the best estimate of relative variety performance.

PICKING THE TOP CORN HYBRIDS: FIVE KEYS TO SUCCESSFUL SELECTION

Joe Lauer, Kent Kohn, and Thierno Diallo [1]

One of the most important decisions corn producers make is the selection of high performing, adapted hybrids. Selecting the correct hybrid can often mean the difference between profit and loss. Plant breeders and agronomists test thousands of commercial and experimental hybrids for several years at many locations over a range of plant populations and other management practices. These corn hybrid performance trials determine which hybrids have yielding ability superior to current hybrids and estimate disease resistance and other important characteristics.

What is G x E ?

The reason for conducting hybrid performance trials is to understand Genotype by Environment (GxE) interactions. If GxE did not exist we could conduct one trial at one location and use the best hybrid to plant across the entire state. Hybrids (genotypes) often respond (or interact) differently in different environments due to soils, diseases, insects, fertility, and especially weather! GxE is called different things by seed companies: "Fix / Flex," "Offensive / Defensive," and "Racehorse / Workhorse" hyrbids. Seed companies benefit greatly from on-farm hybrid trials that producers establish. They get hundreds of test plots per year, hundreds of weather patterns per year, and hundreds of disease situations per year.

Identifying high yielding hybrids with low G x E requires lots of data. It takes many years of hybrid testing to determine stability to weather patterns at a location. This is difficult because of hybrid turnover. The solution is to substitute multiple locations for multiple years to assess stability.

What you are looking for are hybrids that yield consistently well across a diverse set of conditions, especially weather and disease. You are looking for hybrids with high yield and low GxE. If you concentrate on your farm's results, you miss the benefits of multi-location testing! Do not place a HIGH priority on hybrid trials grown on your farm. Performance in one environment does not predict the future accurately. Think outside the box by looking at data from other states. Links to other university variety testing programs can be found at: http://www.ksu.edu/kscpt/nccec/ (University Crop Testing Alliance).

Hybrid Selection Strategies

Your challenge is to obtain hybrid performance data from multi- locations. Especially large groups of common hybrids grown across many locations. Emphasize locations within your latitude or hybrid 'adaptation zone.' Don't hesitate to use data outside of your 'zone'.

Identify consistent performers. There are several selection criteria to consider. Hybrids should be consistently within the upper group of hybrids as determined by a trial's Least Significant Difference (LSD) value. They should be consistently within 5 to 10% of the

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maximum yield in a trial. They should be consistently greater than 5% above the average yield of a trial.

After identifying hybrids eliminate hybrids with weaknesses for specific traits important to your farming operation, e.g., disease resistance, root and stalk strength, etc. Info about hybrid characteristics can be found on many seed company web sites.

Avoid single location-single year trials because there is not enough data to predict stability of hybrid performance across a range of growing conditions. This is why you should not place a lot of faith in the ability of your own on-farm testing to predict a hybrid's yielding ability in the future. Also, avoid side-by-side comparisons, unless they are between pairs of hybrids you've already identified as being top yielders. In other words, just because my hybrid out yields your hybrid in 752 side-by-side comparisons across 10 states, does not mean that either hybrid is the best performer in the marketplace! Also, avoid hybrids without documented comparative yield performance data over multiple locations. Don't buy on advertising or price alone! Also avoid, "Percent wins against the competition." The "competition" can be a "bunch" of unidentified hybrids that could be "dogs" for all you know. What you need to know is the "percent wins" against the best of the competition!

Use Multi-location Data and Evaluate Consistency

As farm managers we need to be able to predict next year's performance of the corn hybrids we buy. The best way to predict next year's performance is to use multi-location data of a large set of hybrids. Figure 1 provides an example of multi-location average data from the University of Wisconsin Corn Hybrid Evaluation program. Asterisks (stars) indicate that the hybrid was not statistically different from the highest yielding hybrid in the trial. Hybrids A-E represent examples of typical hybrid performance. For example, hybrid A was similar to the yield average for the zone and was starred at one location. Hybrid B was one of the top hybrids in the zone and was not significantly different from the top hybrid at two locations. Hybrid C was an average hybrid in the zone and at all three locations. Hybrid D was the top hybrid in a zone and at all three location for two years. Finally, hybrid E yielded below the trial average for the zone and all locations.

Example: South Central Zone - Early Maturity Grain Trial (page 1 of 3)

100 DAY RELATIVE MATURITY OR EARLIER, BASED ON COMPANY RATING (FOND DU LAC = FON, GALESVILLE = GAL, HANCOCK = HAN)

	2009								2008					6 Test
	AVERAGE					FON	GAL	HAN	AVERAGE		FON	GAL	HAN	AVE
	Yield	P.I.	Moist	Test	Lodged	Yield	Yield	Yield	Yield	P.I.	Yield	Yield	Yield	Yield
HYBRID	bu/A	#	%	Wt.	%	bu/A	bu/A	bu/A	bu/A	#	bu/A	bu/A	bu/A	bu/A
A 1 Loc *	229	101	18.8	55	0	207	214	265 *						
B Zone *, 2 Loc *	248 *	105 *	19.4	56	0	223 *	244	279 *						
C Average	229	100	19.7	56	1	211	249	229						
D Zone *, 3 Loc *, 2 Yrs	261 *	107 *	20.4	54	0	229 *	274 *	279 *	219 *	106 *	173 *	232 *	248 *	239 *
E Bottom 10%	178	88	20.6	56	0	156	146	232						
MEAN	227	100	19.6	56	0	205	230	248	195	101	160	206	213	216
LSD(0.10)	17	4	0.8	1	1	13	16	20	22	7	28	20	19	12

Figure 1. An example of multi-location average data from the Univ. of Wisconsin Corn Hybrid Performance Trials. The shaded areas provide the best predictor for performance.

If we grew hybrids A-E next year, what would be their likely performance? We have been able to simulate how well we can predict performance next year using the UW hybrid trials. These trials have been conducted since 1973, and we have numerous examples of hybrids selected using various strategies. We have simulated 64 different strategies using zone averages, location performance, maturity groups, trial rank (top 1 versus top 3), and starred hybrids. Figure 2 describes the results of some selection strategies.

The basic idea is that the more stars (trials where the hybrid is not significantly different from the top hybrid in a trial) a hybrid has the more likely we can predict that it will perform higher than the trial average. For example, a randomly selected hybrid has a 50:50 (above:below the trial average) chance of beating the trial average next year. A hybrid that was starred at a location and planted back to that location next year (similar to an on-farm hybrid trial) has a 72:28 percent chance of beating the trial average the next year. Likewise a hybrid that was starred for the zone, regardless of its performance at specific locations will beat the trial average 71:29 percent of the time next year. A hybrid that is starred using multi-location data (zone) and consistently performs well increases their chances of beating the trial average from 77:23, 83:17 and 87:13 as consistency increases from one location to three locations to two-years and three locations.

If a hybrid is ever average at one location it has 48:52 odds of beating the trial average the next year. If it finishes in the bottom 10% of the hybrids at one location, it has 29:71 odds of finishing above the trial average. The strategy you use makes all the difference in predicting and picking high performing hybrids for next year.

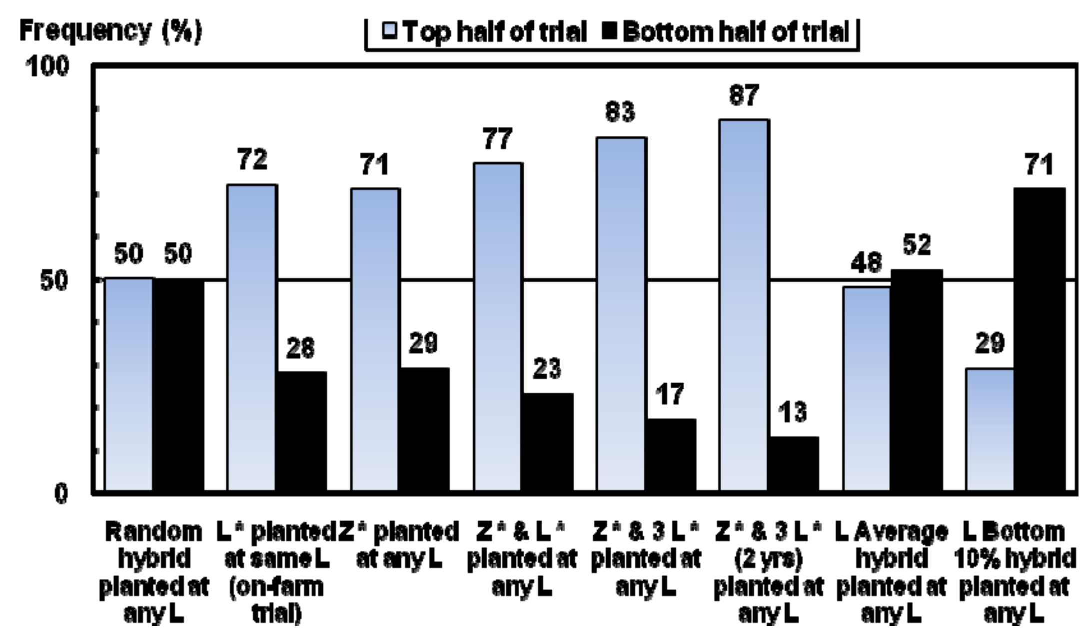

Figure 2. Next year's performance of a hybrid using various selection strategies. Simulated using UW Hybrid Trial Results 1973-2009.

Table 1. Agronomic and economic consequences of various hybrid selection strategies.

Selection scheme	N	Relative yield	Grain yield difference	Grower return difference
		%	bu/A	$/A
1 L* (on-farm)	2816	105	7	21
Z*	2405	104	7	21
Z* & 1L*	1122	106	10	28
Z* & ≥ 3L*	515	107	13	36
Z* & ≥ 3L* (2 yrs)	261	109	16	45
1 L average	4205	100	0	0
1 L bottom 10%	1122	94	-8	-22

Grower return difference ($3.50 per bushel) = grower return - trial average

The amount of yield gain ranges from -6 to 9 percent depending upon the selection strategy (Table 1). Yield gains range from -8 to 16 bu/A which is economically significant ($-22 to $45 per acre.

Not only does the way you pick hybrids influence next year's performance, but also the decision influences the economics for a number of years into the future. Table 2. describes the economic consequences of hybrid selection strategies into the future. Picking hybrids that have been starred in a zone and across 3 or more locations is better even four years into the future than using your own on-farm results.

Table 2. Economic consequences of corn hybrid selection strategies.

	Previous years		Selected year	Future years			
Selection scheme	-2	-1	0	1	2	3	4
	dollars per acre difference						
1 L* (on-farm)	31	30	68	21	15	14	11
Z*	34	31	51	21	17	15	10
Z* & 1L*	37	37	76	28	20	18	16
Z* & ≥ 3L*	52	48	63	36	30	25	17
Z* & ≥ 3L* (2 yrs)	58	57	65	45	37	31	23
1 L average	17	13	2	0	-1	-3	-5
1 L bottom 10%	-2	-10	-78	-23	-22	-19	-24

Dollars per acre difference ($3.50 per bushel) = grower return - trial average

In 1985, the approach of using zones (multi-location) average data was started within the University of Wisconsin corn hybrid evaluation program. A total of 1122 GxE hybrids have been starred within a zone and starred at least one location (Table 3). During five year increments predicted relative yield has increased using this strategy about 6% providing 9 to 11 bu/A more yield. The most recent five-year period has seen fewer examples of hybrids with this strategy and less relative and actual gain in yield. This is somewhat related to the fact that hybrids are changing so fast now, that they rarely are tested in the program more than one year. Also, we still have one more year for this five year period.

Table 3. Economic consequences of one hybrid selection strategy over time.

Z* & 1L*	N	Relative yield	Grain yield difference	Grower return difference
		Percent	bu/A	$/A
1985-1990	213	106	9	25
1990-1995	255	106	9	25
1995-2000	286	106	11	30
2000-2005	255	106	11	34
2005-2009	113	104	7	20

Grower return difference ($3.50 per bushel) = grower return - trial average

Within the hybrid trial results there are two tables (the index and the history) which users get a handle on consistency. The general principle of "the more stars, the better" applies to individual hybrids.

Every Hybrid Must Stand on Its Own

Evaluating transgenic hybrids is often more complex than normal hybrids. First you need to know the performance of a hybrid compared to other hybrids with similar traits, if others exist. Evaluate grain yield, output trait "yield" or quality, and other important characteristics. Finding comparative data in public or private trial reports may be difficult.

Second, you need to compare specialty hybrids to "normals." Compare the best specialty hybrids in a trial with the best normal hybrids. University trials work well for this, assuming that companies enter the best hybrids of these traits in the trials. This strategy is useful for comparing Bt vs. non-Bt hybrids, RR vs. non-RR hybrids, waxy vs. normal starch hybrids.

Third, you need to compare the best performance compared to the best "normal" hybrids in the marketplace (yield versus economics). Comparison to "normal" version of same hybrid is not important because you have access to all hybrids sold in the marketplace.

Table 4 describes the performance of six hybrid "families" where transgenic trait(s) were inserted into a common isoline or family of genetics. Hybrid performance was statistically significantly different between hybrids.

"Bottom line: Each hybrid must stand on its own for performance." Do not select hybrids based on family (sister) performance.

Buy the Traits You Need

Not all fields require transgenic traits. We need to remember that **transgenic traits do not add to yield, they protect yield.** If you do not need transgenic traits then do not buy them. This is more difficult than it sounds, especially for smaller seed companies and inventory control. It is easier for some seed companies to limit their inventory and carry hybrid products with more rather than fewer traits. For most producers in Wisconsin rotations involving alfalfa do not require traits for corn rootworm control. Likewise corn has a number of good herbicide treatments available, so Roundup Ready™ and Liberty Link™ traits may not be needed.

Table 4. Relative performance among "Families" compared to the trial average.

Family	Specialty Trait	N	Grain yield
			Bu/A
A12	DBT418	12	5 [b]
	Mon810	3	27 [a]
	MonGA21	23	4 [b]
	Normal	88	5 [b]
C216	Mon810	30	13 [a]
	Mon810+Mon863+Nk603	5	-2 [b]
	Normal	9	6 [ab]
E424	Bt11+Mon863+T25	4	6 [a]
	MonGA21	4	-15 [b]
B441	Mon810	23	2 [a]
	Mon810+Mon863+Nk603	6	-10 [b]
	Nk603	13	-7 [b]
	Normal	2	-2 [ab]
D340	Mon810	6	11 [ab]
	Mon810+Mon863+Nk603	5	-3 [b]
	Normal	9	13 [a]
F393	Mon810	18	7 [a]
	Mon810+Mon863+Nk603	8	-5 [b]

Pay Attention to Seed Prices

Before the commercialization of transgenic hybrids, it was rare that seed price had a dramatic influence on a hybrid selection decision. Often premium hybrids would cost more because they were consistently better performing. So even though cost was greater, they were worth it and usually more than offset the premium price.

Today, the price difference between non-transgenic and transgenic hybrids is so great that growers must factor into their decision seed price. A good performing non-transgenic hybrid will cost $100 to $150 per bag, while high performing transgenic hybrids easily run $225 to $300 per bag. Some of the new SmartStax™ are projected to be above $350 per bag. Remember from Table 1 that we can at best predict a 16 bu/A gain over an average hybrid. The yield gain is likely lower. USDA data indicates average yield gains of 1.5 to 2.0 bu/A per year with some of the best counties at ~4 bu/A per year. Your annual yield gain is how premium seed will be paid for.

A seed price calculator was developed to help producers with this decision. It is located at http://corn.agronomy.wisc.edu/Season/DSS.aspx. The spreadsheet can be used for any crop. Users can input various costs for herbicides, insecticides, etc.

Conclusions

Hybrid selection requires a lot of research and homework of the data to make sense out of it. It can be challenging because multiple location performance data are often difficult to obtain. It can be challenging because performance data often require further analysis and scrutiny. But the payoff is that it can improve net profits due to higher and more consistent hybrid yields on your farm.

NEW INVASIVE SPECIES AND THE NR 40 RULE

Kelly Kearns [1]

Invasive species are those plants, animals and disease organisms that are not native to a region, yet when introduced, can cause significant harm. The term is generally used for those species that cause ecological harm to our native fish, wildlife, plants, lakes, forests and other natural areas. Many species are weedy or pests in agricultural areas, but not in wild lands. Conversely, many of the invasive plants and animals affect only wild areas species, and do not harm crops or livestock. However, there are a number of species such as Canada thistle that do double duty. It is important for persons involved with agriculture to know about invasive species, as they can be both the victims of this harm, and may unwittingly introduce or spread invasive species.

There are a number of factors that are causing a rapid increase in the number of species invading Wisconsin. These include rapidly growing global trade, the public's insatiable desire for new landscaping plants and global climate change. In addition, those invaders already in the area are accidentally moved around by roadside mowing, logging and farm equipment, tourists and outdoor recreationalists. The majority of people introducing or spreading these harmful species around are unaware of the harm they are causing. Many efforts have been underway for a number of years to raise the public's awareness of the species of concern and what they can do to minimize their spread. Outreach efforts alone have not been sufficient to stem the tide of these invaders. Over the last few years groups of foresters, right-of-way managers, recreation enthusiasts and landscape industry members have been working together to create a series of voluntary Best Management Practices to help people in their fields to minimize the accidental spread of invasives. Agriculture is another large area of the economy that may benefit from developing similar voluntary practices.

Until recently, the laws in the state relating to various types of invasive species were piecemeal, and inconsistent from one group of organisms to another. In 2002, the state legislature authorized the Department of Natural Resources to write rules to classify, identify and control invasive species. After extensive input from stakeholders and the public, a comprehensive set of rules went into effect September 1, 2009 to minimize the intentional introduction and accidental spread of certain species listed in the rule.

NR 40 lists 73 plants as 'Restricted' or 'Prohibited'. Most of the 'restricted' species are too widespread to expect anyone to completely control them, so the goal is to minimize the spread. Therefore landowners are not required to control restricted species, but must take reasonable precautions to avoid transporting them from an infested area. Keeping these weeds contained will protect our pastures, farmland and natural areas from further infestations. Several of the restricted species are commonly found in perennial grass fields or on roadsides or the borders of ag fields. These widespread invasive weeds include: Canada, musk and plumeless thistle, leafy and cypress spurge, spotted knapweed, teasel, Japanese knotweed and purple loosestrife.

The prohibited species are those not yet in the state, or only in limited populations, but known to be troublesome in nearby states. These species have been listed as 'prohibited' in an effort to try to stop them before they become established, regardless of where they may appear in the state. The prohibited plants are species that most people in Wisconsin, even farmers, are not familiar with.

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However, one of the reasons for the rule is to ask people who are on the land frequently to learn to recognize these species before they become widespread. When these plants are sighted, we are asking that they be reported so they can be controlled quickly before they produce seed and get established. A few of the species listed as prohibited are especially important for farmers, crop consultants and others in agriculture to become aware of now, as they have the potential to cause significant damage on farms. Some of those species are described here.

Poison hemlock (*Conium maculatum*) is a biennial weed that closely resembles the common Queen Anne's lace, or wild carrot. This plant is common in Illinois and is being rapidly spread along a few Wisconsin roadsides by mowing. From these roadsides it moves into pastures, hay fields and CRP fields. This plant is highly toxic to cattle and could cause illness and death in livestock if allowed to spread freely.

Hill mustard (*Bunias orientalis*) looks like the common yellow rocket from a distant, but has larger basal leaves and bumps on the stem. This mustard was discovered in a few townships in Green County just a few years ago and has already expanded into many pastures in the area, eliminating forage crops.

Giant hogweed (*Heracleum mantegazzianum*) looks like a Queen Anne's lace on steroids. It can reach fifteen feet in height with leaves that can be three feet across. The sap of this plant can cause serious burns on the skin.

Yellow star thistle (*Centaurea solstitialis*) has made millions of acres of grazing lands in the western states unusable for forage. This perennial knapweed has flower and seed heads with long stiff spikes that get caught in the fur and mouths of livestock causing skin and facial irritations.

Kudzu (*Pueria Montana*) is commonly known as the "vine that ate the South." It is less well known that this southern weed has been found within a few miles of Wisconsin, north of Chicago. This vine was originally introduced as a forage crop and very rapidly spread, climbing and toppling trees, covering buildings and making forests impassable.

Photographs and detailed control information for these and other invasives can be found at the DNR website at www.dnr.state.wi.us/invasives. In order to help people learn about these and other invasive plants in Wisconsin, the WI DNR has created a pocket size field guide with photos, identification and control information for over sixty invasive plants. This guide can also be accessed on the WI DNR website.

For more details on NR 40 go to http://dnr.wi.gov/invasives/classification/. For questions, contact Kelly.Kearns@wisconsin.gov or 608-267-5066.

DEALING WITH LISTED INVASIVE PLANTS BY THE BOOK

Mark J. Renz[1]

The Wisconsin Department of Natural Resources Invasive species law (NR40) established a classification and regulatory system for invasive species restricting actions such as sales, transportation, planting, or releasing listed species to the wild without a permit. While none of these plants classified by the rule have any direct agronomic value as a crop, producers will need to ensure that they are not transporting viable propagules (seeds or perennial tissue that can resprout) of prohibited and restricted species as this is illegal (unless a permit is obtained). While the rule exempts people who incidentally or unknowingly transport, possess, transfer or introduce a listed invasive species, knowledgeable producers must demonstrate that they took reasonable precautions to prevent movement of listed species. An example of this situation would be haying a field filled with listed plants like spotted knapweed or Canada thistle and transporting the bales to another location off farm. Producers can transport plant tissue of these species, but they must be incapable of reproducing/propagating. So harvesting these fields before any viable seeds are produced would be considered an adequate practice to prevent spread by DNR as the producer took steps to prevent movement of propagules of known listed plants.

This presentation will discuss common ways agricultural producer could be out of compliance and provide management options a producer can implement to remain in compliance.

To see additional information about NR40, go to http://dnr.wi.gov/invasives/classification/

DEFINITIONS OF LISTED SPECIES

Prohibited species are not yet in the state or only exist as small populations, but have the potential to cause significant damage if they are allowed to spread and become established. It is illegal for people to transport, import, possess, transfer, sell and introduce these species without a permit. Landowners will be expected to control prohibited species found on their property.

Restricted species are invasive species that are already too widespread to expect statewide eradication. For this classification it is illegal for people to transport, import, transfer, sell and introduce these species, but people may possess plants.

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PREDICTED YIELD LOSSES WITH POSTEMERGENCE HERBICIDES

Nathanael D. Fickett, David E. Stoltenberg, Chris M. Boerboom, and Clarissa M. Hammond[1]

Introduction

In a postemergence herbicide program, the application of the herbicide can easily be delayed by weather, time constraints, equipment availability, and other such causes. However, if weeds are not controlled early enough, there is potential for yield loss from early season weed competition. This is true even when herbicides provide high levels of efficacy.

It has been observed that a large number of corn and soybean fields in Wisconsin are currently being managed with postemergence programs. Thus, the potential for significant yield loss due to early-season weed competition exists. This became more evident after an initial survey of grower's fields was taken in 2008. In this survey, weeds were controlled at an average height of 2 inches taller than the recommended critical heights for weed removal (4-inch weed height in corn and 6-inch weed height in soybean).

In order to better understand the potential for yield loss from early season weed competition in Wisconsin corn and soybean fields managed with postemergence herbicide programs, in-field surveys of weed populations were conducted in 2008 and 2009. Individual field data from these surveys was used to estimate yield loss using a computer program called WeedSOFT®. A possible solution in soybean was also evaluated using on-farm trials comparing a single pass glyphosate program with a half rate of a preemergence broadleaf herbicide followed by glyphosate.

Methods

Field Surveys. In the summers of 2008 and 2009, surveys were conducted every 3 to 4 days until postemergence herbicide applications in 48 and 45 corn fields and 30 and 40 soybean fields, respectively. The fields were selected randomly from fields likely to be managed postemergence without a preemergence treatment. Approximately five fields per crop were surveyed per county per year, and surveyed fields were spaced at least 3 miles apart to increase the likelihood that the fields were managed by different growers.

For each field, a surveyor walked a horseshoe pattern through the field starting and ending at the field's edge. Heights and densities of predominant weed species in the field were estimated in 10 1-m^2 quadrats per field spaced at intervals of 30 paces. Weed heights were recorded in 2-inch increments ranging from less than 2 inches tall to less than 12 inches tall. Estimated heights of any weeds over 12 inches tall were also recorded. Weed densities were recorded within ranges of 1-5, 6-10, 11-50, 51-100, 101-500, and greater than 500 plants/m^2. Estimations were used to speed the survey procedure in order to increase the number of fields sampled. The average crop height, crop growth stage, and row spacing were recorded for each field. Also, leaf samples were taken from each field and were tested for the glyphosate-resistant trait using an Elisa-test.

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In summarizing the weed population data, the average of a given density range was used as the weed density. The average height of a weed species within a field was calculated using its height within a quadrat weighted by the respective densities in the different quadrats. This helped to account for the variance between height and density in the different quadrats. The data are summarized in tables listing the minimum and maximum values for individual fields, the median (value where 50% of fields have more than this number), and the overall average among fields.

Yield Loss Estimates. Yield loss estimates were based on the weed population characteristics and calculated using a modified version of WeedSOFT®. The modification was adding weed species to WeedSOFT®, which were not already in its database. For calculations, WeedSOFT® first estimates a competitive load for each weed species based on the species competitive index and is modified by weed height, weed density, crop growth stage, and crop row spacing. These characteristics had been collected in the field survey. Yield loss is then estimated with a crop specific yield loss function based on the total competitive load, which is a summation of the individual competitive loads from each weed. The data are summarized in tables listing the minimum and maximum values for individual fields, the median (value where 50% of fields have more than this number), and the overall average among fields.

On-Farm Trials. In 2009, 12 on-farm trials were coordinated through the help of Richard Proost and UW Extension county agents. Growers split about 15 acres of a soybean field into 6 strips with two treatments. On three of the strips the growers applied preemergence FirstRate or Sonic (both contain the same premix of sulfentrazone plus cloransulam) at 3 oz/a, which is a half rate intended for early season weed suppression prior to a glyphosate application. Later, the entire field was sprayed with glyphosate. Right before the glyphosate treatment, three quadrats per strip were surveyed in the same fashion as the field survey. This was done to test the efficacy of the half rate of the preemergence broadleaf herbicide.

The weed populations were summarized similar to the field survey. The average density within a given range was used as the weed density. The average height of a weed species within a field was calculated using the weed's height in a quadrat weighted by their respective densities. The data is summarized by broadleaf and grass species separately because a broadleaf herbicide was used.

Results and Discussion

Field Surveys. The field survey gave interesting results characterizing weed populations in Wisconsin corn and soybean fields managed with postemergence programs. The average density was fairly similar across both years and crops at about 100 plants/m^2. In 2008 and 2009, the average density in corn was 102 and 93 plants/m^2 and the average density in soybean was 107 and 98 plants/m^2, respectively (Table 1). Some individual fields had high weed densities. The maximum density in corn was 582 and 460 plants/m^2 and the maximum density in soybean was 526 and 551 plants/m^2 in 2008 and 2009, respectively (Table 1).

Table 1. The minimum, maximum, median, and average weed density and weed height across 48 and 45 corn fields and 30 and 40 soybean fields in 2008 and 2009.

	Year	Crop	Minimum	Median	Average	Maximum
			Number per m^2			
Weed density	2008	Corn	8	47	102	582
		Soybean	3	33	107	526
	2009	Corn	4	70	93	460
		Soybean	5	46	98	551
			Inches			
Weed height	2008	Corn	2.0	5.6	5.9	11.6
		Soybean	3.0	7.5	8.5	26.7
	2009	Corn	2.0	5.0	5.5	14.0
		Soybean	2.1	5.8	7.0	23.9

The weed heights were taller than would be desired to avoid the risk of yield loss from weed competition. Across both year and crop, the average weed height was about 2 inches taller than the critical height when weeds start to affect crop yield. Based on research across the upper Midwest, corn should typically be managed before weeds reach 4 inches tall. In both 2008 and 2009, 75% of the corn fields were managed after weeds exceeded this height (data not shown). The average weed height in corn fields was 5.9 and 5.5 inches in 2008 and 2009, respectively (Table 1). Extension specialists typically recommend that soybean should be managed before weeds reach 6 inches tall. In 2008 and 2009, respectively, 75% and 50% of the soybean fields were managed after weeds exceeded this height (data not all shown). The average weed height in soybean fields was 8.5 and 7.0 inches in 2008 and 2009, respectively (Table 1).

With reasonably high densities and weeds more often than not being sprayed after their critical heights, the field survey found there was a significant potential for yield loss to be occurring in Wisconsin corn and soybean fields managed with postemergence programs. Consequently, we wanted to estimate the yield loss using the software program WeedSOFT®.

Yield Loss Estimates. WeedSOFT® is good in estimating average yield loss across multiple fields, and satisfactory in estimating average yield loss in individual fields. In this study, WeedSOFT® was primarily used for estimates across multiple fields, so results are expect to be reasonably accurate. As expected from the field surveys, yield loss was predicted in most of the fields. The average estimated yield loss across all corn fields was 4.4 and 4.8% in 2008 and 2009, respectively (Table 2). The average estimated yield loss across all soybean fields was 9.3 and 3.1% in 2008 and 2009, respectively (Table 2). Also, in corn in both years and soybean in 2008, about 50% of the fields had estimated yield losses greater than 4% (Table 2). Some fields had substantial estimated losses with one soybean field in 2008 reaching 54% (Table 2).

Table 2. The minimum, maximum, median, and average estimated yield loss across 48 and 45 corn fields and 30 and 40 soybean fields in 2008 and 2009.

	Year	Crop	Minimum	Median	Average	Maximum
			Percent of total yield			
Estimated yield loss	2008	Corn	0.6	3.7	4.4	13.4
		Soybean	0.3	4.4	9.3	53.9
	2009	Corn	0.3	4.0	4.8	26.2
		Soybean	0.2	1.4	3.1	20.8

Yield loss at this rate can cause significant economic loss. For example, in 2008 corn sold for $4.59 per bushel on average and soybean sold for $11.15 per bushel on average. The average corn grower produced 137 bushels per acre and the average soybean grower produced 35 bushels per acre. If estimates of 4.6 and 6.2% yield losses in corn and soybean are used, the total economic loss average $28.93 per acre in corn and $24.20 per acre in soybean, respectively. Fields with higher yields would expect even higher losses.

Expected yield losses were fairly high in corn and soybean in both 2008 and 2009. To study one possible solution in soybean, on-farm trials were conducted comparing a postemergence glyphosate program with a half rate of a preemergence broadleaf herbicide followed by postemergence glyphosate program.

On-Farm Trials. Results from the on-farm trials showed a reduction in both weed density and weed height with the use of a half rate of a preemergence broadleaf herbicide. Overall, the average density of broadleaf and grass weeds was reduced by 66 and 50% and heights were reduced by 20 and 30%, respectively. The reduction in density means there would be a reduction in early-season weed competition. The reduction in height means the weeds would not reach their critical height as quickly, giving the grower more time to spray their field.

Recommendations

This research shows there was a significant predicted yield loss in many Wisconsin corn and soybean fields that are managed with postemergence herbicide programs. The field surveys showed that fields were being sprayed about 2 inches after the critical height. This resulted in estimated yield losses on averaged of 4.4 and 4.8% in corn and 9.3 and 3.1% in soybean in 2008 and 2009, respectively. A further study showed a half rate of preemergence herbicide can successfully reduce both weed density and height. Based on this information, it would be suggested that growers whose fields are at risk of yield loss from high weed densities or delayed application should consider using a preemergence herbicide even at a half rate. In a burndown situation, this can often be combined with the burndown herbicide to reduce application costs.

OPTIMIZING PERENNIAL WEED MANAGEMENT

Mark J. Renz[1]

Herbaceous perennial weeds are common pests in agricultural production systems. Plants with this life history have proven to be especially competitive as they have the ability to regenerate from perennial organs that persist belowground. This trait allows plants to tolerate management methods, compete with other plants, and survive stressful growing conditions. These traits can cause significant reductions in crop yield and may account for why herbaceous perennial weed species are increasing in frequency throughout Canada, the Midwestern United States and Wisconsin.

Herbicides, mowing, tillage, burning, seeding competitive plants, and biological control have been effective in managing perennial weeds if applied correctly. Management methods typically target reducing stored resources in perennial storage organs and shading of shoots. Often combining techniques that integrate both strategies work the best. Due to the range of species biology and phenology, no recommendations are effective across all weed species. Often, it is useful to determine if perennial weeds are simple or creeping perennial weeds as biology and spread have subtle, but important differences for each life history. Correct identification of this type of life history is also useful in selecting the appropriate management methods. Below is a summary of biology, spread, and general management recommendations for simple and creeping perennial weeds along with a table of common perennial weeds found in Wisconsin. This presentation will provide an overview of the biology of perennial weeds and important factors to consider when using a range of management methods for these weed species.

Table 1. Common perennial weeds found in Wisconsin.

Common name	Scientific name	Type of perennial
hemp dogbane	*Apocynum cannabinum*	Creeping
common milkweed	*Asclepias syriaca*	Creeping
yellow rocket	*Barbarea vulgaris*	Simple
hoary alyssum	*Berteroa incana*	Simple
Canada thistle	*Cirsium arvense*	Creeping
field bindweed	*Convolvulus arvensis*	Creeping
yellow nutsedge	*Cyperus esculentus*	Creeping/Simple
quackgrass	*Elytrigia repens*	Creeping
field horsetail	*Equisetum arvense*	Creeping
leafy spurge	*Euphorbia esula*	Creeping
wirestem muhly	*Muhlenbergia frondosa*	Creeping
blackseed plantain	*Plantago rugelli*	Simple
curly dock	*Rumex crispus*	Simple
white cockle	*Silene latifolia*	Simple
perennial sowthistle	*Sonchus arvensis*	Creeping
dandelion	*Taraxacum officinale*	Simple

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Biology and Spread of Perennial Weeds

Simple perennial weeds typically establish from seeds that can germinate anytime when appropriate conditions exist. After germination, plants quickly develop a tap root and a group of leaves, called a rosette, clustered around the base of the root at the soil surface. Plants can be found as rosettes in the fall and spring, but will produce stems and flowers in the late spring to summer. After flowering, shoots die back, but lower leaves often resprout in the fall and remain green until winter. The following spring, shoots resprout from perennial organs. Organs can last for several years and often increases both in size and its ability to tolerate management. Simple perennials spread throughout fields by seed. While plants can resprout from perennial taproots, this rarely results in spread unless equipment spreads roots into uninfested areas. Therefore, management should focus on identifying and eliminating seed production as well as nearby sources of seed.

Creeping perennial weeds can also establish from seeds or perennial vegetative organs. Often, seedlings initially devote resources to developing a root system and perennial organs; therefore, plants may not flower during the establishment year. Creeping perennial weeds have organs, including rhizomes, tubers, stolons, bulbs, corms, or creeping roots, that enable plants to expand by growing or "creeping" away from the parent plant, producing additional shoots along the way. This growth is often visible as discrete circular patches within fields. Like simple perennials these structures can last for several years and often increase in size and stored resources, making management more difficult. Creeping perennial weeds spread throughout fields by seed movement and by creeping stems or roots. They must be managed carefully, as inappropriate methods can lead to further spread. Long-term management plans should be developed for these species, focusing on preventing seed spread, controlling plants while they are seedlings, and managing the resprouts of older plants without spreading perennial organs to uninfested areas.

Management Methods for Perennial Weeds

Prevention

Preventing the introduction and establishment of any weed is the most cost-effective management strategy. This can be achieved by maintaining a healthy stand of desirable vegetation which can resist weed invasion, and by monitoring sites to detect and remove new weed invaders. Perennial crops like alfalfa and pasture grasses are an excellent tool to prevent invasion as they are good competitors with these weed species and can prevent establishment. Edges of fields are often vulnerable to invasion, so pay attention to these areas to prevent new invasions from getting established. If equipment is to be used within the field, remove all dirt and debris which may contain seeds or other vegetative tissue as these are additional sources for new invasions.

Physical/Mechanical

Mechanical or physical methods that sever roots below the soil surface (cultivation) can be effective in suppressing perennial weeds, but once cut the belowground organs typically resprout and compete. Therefore, these methods have to be repeated several times to be effective each season. The best results are seen several weeks after new regrowth has emerged, but before plants have begun to flower. The benefits of these methods are alleviation of above ground competition and if repeated enough (multiple times per year for multiple years), populations can be reduced significantly in size. Deep plowing is much more effective than cultivation, but if belowground perennial organs are large enough, particularly with creeping perennials, they can often survive. Some perennial organs are sensitive to cold temperatures and/or dry conditions and tillage conducted prior to extended periods of either of these environmental factors can lead to extensive mortality. Severed roots/rhizomes from this type of management can spread to previously uninfested areas of the field. Therefore this management method is not recommended if only a small portion of the field is infested.

Mowing/Grazing

Mowing/grazing perennial weeds repeatedly over the growing season and over multiple years can suppress perennial weed growth, especially if conducted in conjunction with competitive plant species (e.g. alfalfa). Mowing can prevent the production of seeds if it is carried out prior to the opening of flower buds. This method will not kill the plant and repeating it more than once per season is typically required to eliminate seed production similar to physical and mechanical methods. If possible, mow plants before they produce flower buds as this will reduce the most stored energy in perennial tissue. Some plants low growth form, prevent this method from being effective as most plant tissue avoids any mowing, but often grazing animals will select for these species.

Biological Control

Natural or introduced insects or diseases can also be used to manage invasive weeds. If biological control agents are released and established, they can help suppress weed populations. However, success of agents is typically specific to the weed species, and due to the interdependency of the agent and the host populations are only reduced, not eliminated. Results may not be visible for several years with this technique as populations released need to increase in size to see a visible effect on populations. Biological control is recommended for common weeds that are extensively found in fields and surrounding areas, but not on species that are new and just establishing as eradication of populations will likely not occur from biological control.

Herbicides

Several herbicides are effective at controlling these weedy species, but results are species and timing specific. A wide range of selective herbicides are available for use in a range of crops in Wisconsin. For specific information in a crop of interest please consult Pest Management in Wisconsin Field Crops (A3646). The timing of herbicide application is also very important as it can affect the level of control. With systemic herbicides like glyphosate results are best when applied in the just prior to flowering or in the fall to actively growing green tissue as these timings maximize the herbicide movement into perennial organs. Plant growth can be suppressed with spring applications, but often plants resprout later in the year. Fall-applied herbicides should be applied prior to a killing frost to avoid reductions in herbicide absorption from damaged/senesced leaf tissue.

Additional Considerations

While perennial weeds can be managed with a range of options, often an integrated approach that uses multiple methods works best. Use of competitive perennial crops in the rotation of the infested fields will provide additional suppression and should be considered. Realize that even when utilizing all of these techniques fields that have large infestations will take many years to reduce population sizes to a level that will require minimal management, and eradication may never occur. Of all the management methods considered, early detection of perennial weeds followed by intensive management before they become extensive is the most cost effective approach at controlling these weed species.

DISAPPEARING LAKES: GROUNDWATER LEVELS IN CENTRAL WISCONSIN

Amber Radatz[1/], Birl Lowery[2/], William Bland[2/], Mack Naber[2/], and Dwight Weisenberger[2/]

Introduction

Significant decline in depth to the water table in the Wisconsin Central Sand Plain (WCSP), especially Portage and Waushara counties, has caused concern over the increase in land area devoted to irrigated agricultural crop production. The decrease in groundwater elevation, lake levels, and stream flows, has significant impacts on aquatic ecosystems, recreational uses of streams and lakes, and property values of riparian lands (Fig. 1). Since 2002, water table levels in parts of the WCSP have dropped over 30 cm per year. Thus, we conducted a study to investigate the interactions between vegetation (irrigated agricultural crops, prairie, and forest) and depth to groundwater in the WCSP. The purpose of this study is to understand the degree to which these groundwater fluctuations are driven by climate changes or increasing irrigated agriculture. After collecting over 18 months of continuous water table elevation data under several vegetation types, we can see effects of vegetation cover and irrigation practices on fluctuation patterns in the water table. The data show clear differences in recharge and discharge behavior of the water table under irrigated crops and natural vegetations. The groundwater monitoring site location within the groundwatershed also influenced recharge characteristics. The impact of seasonal changes on the water table is also apparent. We will continue to expand our current database of groundwater elevations to further understand vegetation and irrigation impacts on groundwater levels.

A variety of vegetation types are present in WCSP including dryland agricultural crops, irrigated agricultural crops, and several natural vegetation covers. For this study, shallow groundwater monitoring wells were installed and implemented with groundwater level monitoring equipment, a rain gauge, and a soil moisture sensor. The eight sites are located in several different vegetation types including a pine plantation, irrigated sweet corn, irrigated soybeans (two sites), irrigated oats, irrigated potato, a mixed prairie including mature trees and grasses, and a native grassland. At each of these sites, groundwater table elevation and precipitation data are recorded every 15 minutes. Our data show that groundwater recharge patterns varied by vegetation type, seasonally, and according to location within the groundwatershed.

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Fig. 1. Long Lake near Plainfield, WI in May 2008.

Groundwater Fluctuations and Vegetation Cover

After snowmelt events in winter 2008-2009, prairie vegetation resulted in a 7.5 cm greater rise in the water table than agricultural fields (Fig. 2). The lack of plant residue cover on agricultural fields leads to a continuous layer of frost in the soil profile that extended to a depth of about one meter. Cemented frost in the soil profile reduced snowmelt water from infiltrating and recharging the groundwater. Increased residue on the surface of agricultural fields may enhance recharge to the water table in this region.

In a pine forest site, precipitation events from July 2008 to February 2009 yielded little to no recharge to the water table (Fig. 3). In areas where groundwater is close to the soil surface, vegetative characteristics become important to recharge trends of the water table. Interception by tree canopies and decomposing vegetative layers on the soil surface can hinder infiltration of precipitation into the soil and eventually water drainage to the water table. Precipitation intercepted by canopies and duff layers then evaporates from those surfaces instead of infiltrating into the soil profile.

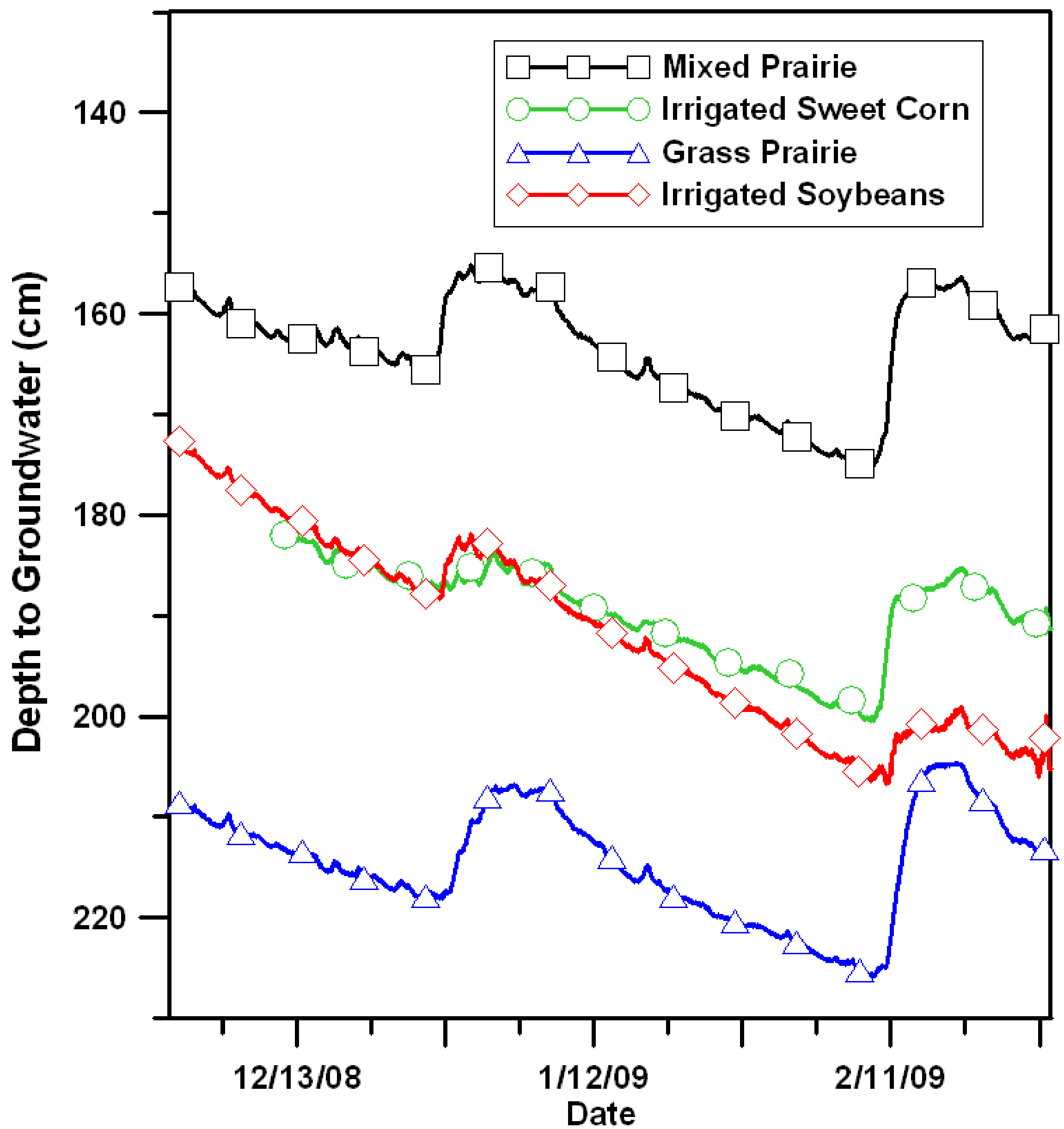

Fig. 2. Depth to groundwater under natural vegetation and agricultural land for December 1, 2008-March 1, 2009.

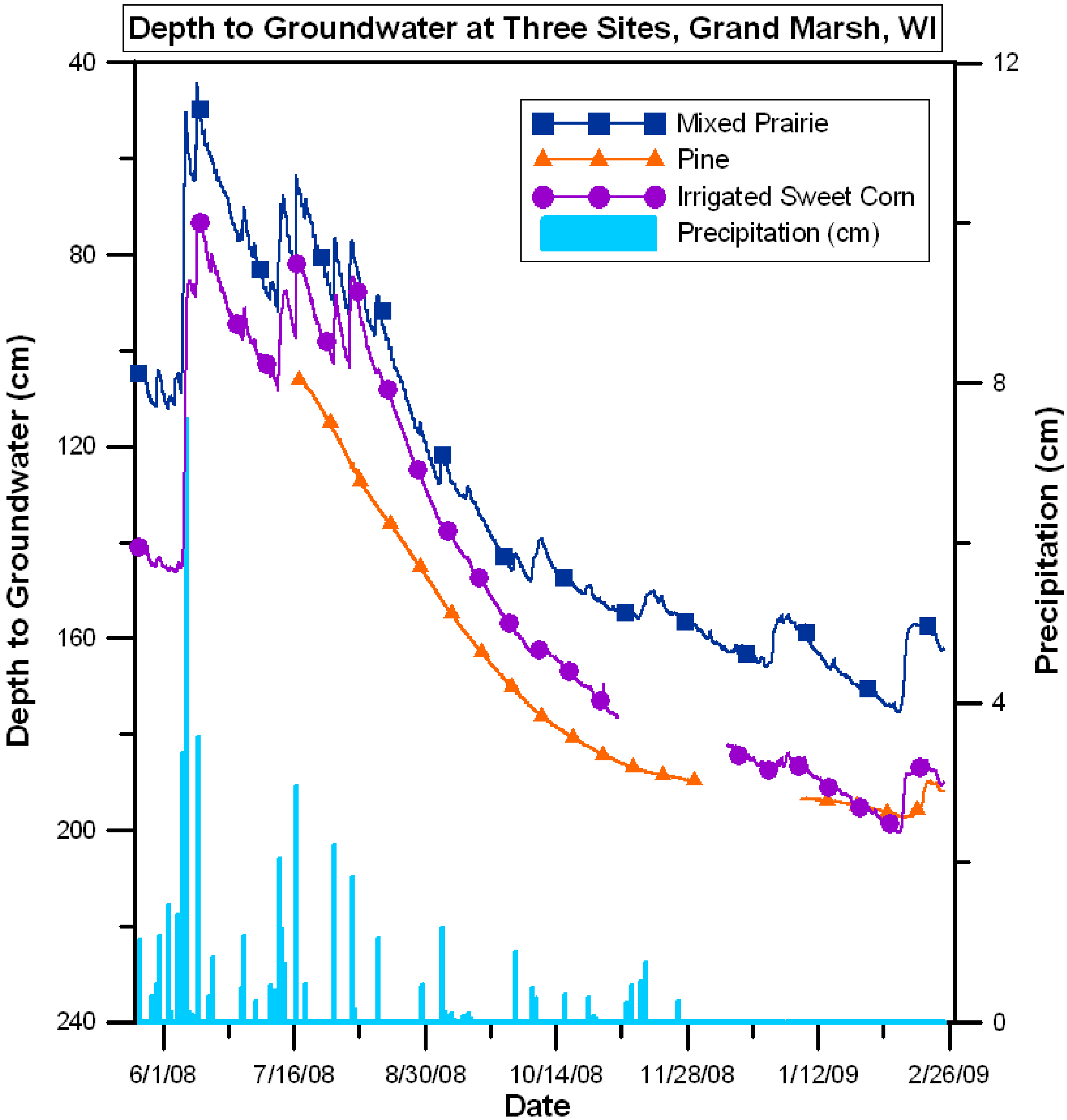

Fig. 3. Depth to groundwater at three sites near Westfield, WI.

Site Location and Groundwater Recharge Patterns

Monitoring sites in the discharge area of the groundwatershed responded quickly to precipitation events and the amount of rise in the water table increased linearly with precipitation. While agricultural crops used groundwater through irrigation, natural vegetation relied on the water table for daily transpiration needs in shallow groundwater areas (Fig. 4).

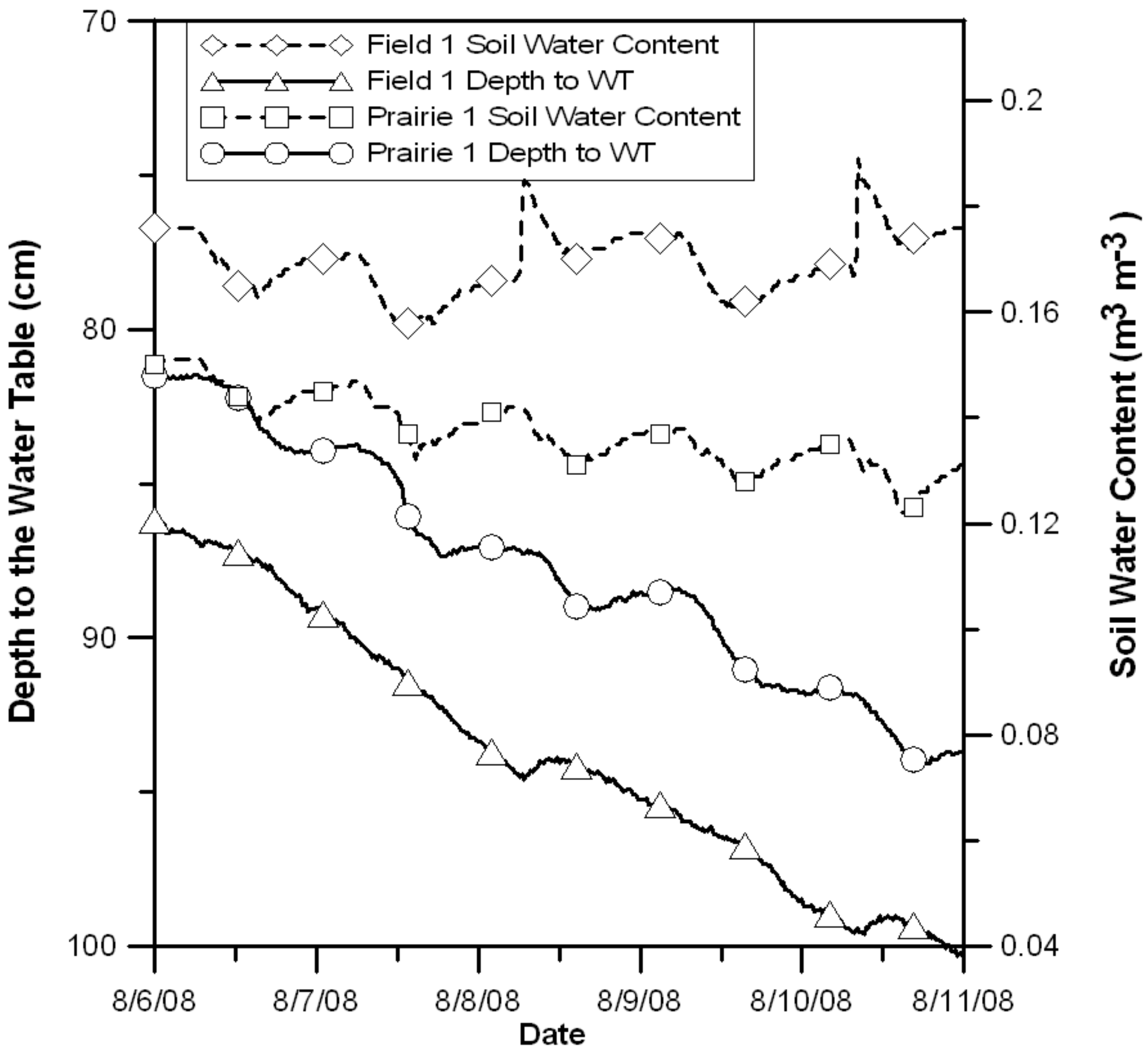

Fig. 4. Depth to groundwater and soil water content at two sites (irrigated agricultural and natural vegetation) near Westfield, WI.

Where groundwater was further from the surface, in the recharge area of the groundwatershed, responses to precipitation events were buffered by the greater depth of soil above the water table. There were limited noticeable responses of the water table to rain events less than 0.4 cm and we do not anticipate that natural vegetation will use water directly from groundwater.

Natural vegetation in the groundwater discharge area of the groundwatershed likely uses the same or similar amounts of groundwater as an irrigated crop. In the groundwater recharge area, however, where groundwater is further from the surface, irrigated agricultural crops have the potential to use a larger amount of water than dryland agricultural crops or natural vegetation would. The natural vegetation at these sites will eventually stop transpiring during very dry periods to minimize stress on the plant. However, during the same periods irrigated agricultural crops will still receive enough water to continue transpiring at potential rates. The depths to water table differences are fundamental to the way each site responds to irrigation, precipitation, and vegetation type.

IS VERTICAL TILLAGE A PRACTICE FOR WISCONSIN SOILS?

Richard P. Wolkowski [1/]

Introduction

The interest in "vertical tillage" management has increased throughout the grain production region of the US in the past several years. The perception exists that certain traditional tillage practices create compacted layers and may reduce soil quality relative to crop production. These layers basically restrict root development into the soil; whereas vertical tillage systems "open up" the soil to better root growth down into the soil. Many companies now promote their tillage equipment as vertical tillage implements. However, it is likely that the practice means different things to different people. It has been suggested that vertical tillage could be conducted shallow, at a depth of 3 to 4 inches using tools that are equipped with specialized disks or harrow attachments or deep to depths well beyond 12 inches using subsoiling-like knives that create slots and do not invert the soil.

Perhaps it is easier to describe what is understood to not be vertical tillage (i.e., horizontal tillage). Such practices are those that shear the soil horizontally using a moldboard plow, field cultivator, or similar tools designed to cut and lift the soil often across the full tillage width. A chisel plow equipped with sweeps could be considered a horizontal tillage tool, while the same implement with straight points would provide vertical tillage. The principal effect is that there is a downward force associated with their operation that compresses the soil underneath as it cuts and lifts the soil, thereby creating a tillage pan. According to Dr. Randall Reeder, an agricultural engineer at The Ohio State University, negative factors associated with horizontal tillage practices include surface soil compaction, poorer root growth, increased erosion potential, and greater energy requirement to prepare a seedbed.

An abstract from a patent application for a vertical tillage tool by a prominent US company provides the following description. *"A vertical tilling implement to be pulled behind an agricultural vehicle having a number of gangs of fluted-concave disc blades, rolling baskets, and wheels connected to a main frame. As the vertical tilling implement is pulled, the fluted-concave disc blades move the soil in a direction lateral to the side of the blades as well as up. Meanwhile, the rolling bars aid in leveling the seedbed and crushing the remaining large pieces of soil. The vertical tilling implement reduces the amount of subsoil compaction and cuts through heavy residue making it ideal for use in the fall or in the spring."*

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The University of Delaware Extension has described vertical tillage as an intermediate tillage method between no-till and full-width tillage with a chisel plow. Note that they consider chisel plowing to be a conventional tillage practice, while others consider it vertical tillage. The interpretation is likely related to the type of point used on the chisel plow. They summarized the benefits of vertical tillage to include:

1. The preservation of a large percentage of crop residue on the surface.
2. The creation of tilled slots that encourages downward root growth leading to better rooting.
3. A method to break up surface compaction without plowing.
4. Promote the drying out and warming the surface in the spring allowing for earlier planting than full no-till.
5. Control slug problems.
6. Shallow incorporation of fertilizers, soil amendments, and cover crop seedings.
7. Incorporation of surface-applied manures to conserve the ammonia fraction of the manure.

Research

A relatively small number of studies have been published that purposely compare crop response between defined vertical tillage systems and other practices; however tillage studies have been conducted that essentially provide such a comparison of these systems. No publications were found in the refereed literature. A study was conducted by the author that compared fall chisel plow and strip-till, spring field cultivator, and no-till at Lancaster, Wis. in first-year corn after soybean. The original objective of the research was not to evaluate vertical tillage with other systems. The fall chisel and strip-till treatments could be considered vertical tillage; one pass in the spring with a field cultivator a horizontal tillage method; and a no-till treatment (with row cleaners). Although the chisel and strip-till treatments produced higher yields than the field cultivator, the resulting silage and grain yields were not significantly affected by tillage type. Of course other considerations may favor the tillage selection on specific soils, including the effect on total cost or production, equipment availability, and addressing soil conservation issues. A more detailed report can be found in the 2006 proceedings of this conference.

A second tillage study conducted by the author compared what would be considered two vertical tillage methods and a horizontal tillage practice in both corn and soybean at the Arlington Agricultural Research Station in 1998 and 1999. The site had a very low initial soil test K level of about 60 ppm K and included K fertilizer treatments, however for the purposes of this paper only the results of the highest K treatment were considered. More information on the project can be found in the 2000 Proceedings of this conference. The tillage treatments were fall subsoiling to a depth of about 16 inches with a straight shanked tool, fall twisted-shovel chisel plowing, and no fall tillage, but a single pass with a field cultivator, that was also run over the fall-tilled plots. The yield results for these two years are shown in Table 2. Yield of corn or soybean was not affected by any of the tillage treatments in either year.

Table 1. Effect of tillage on corn silage and grain yield, Lancaster, WI, 2004 and 2005.†

Tillage	Silage yield (ton DM/a)		Grain yield (bu/a)	
	2004	2005	2004	2005
Fall chisel	9.6	10.1	203	195
Field cultivator	9.0	10.2	198	183
Fall strip-till	9.5	10.1	200	187
No-till	9.1	9.6	195	186
Pr>F	0.25	0.55	0.52	0.62
LSD	NS ‡	NS	NS	NS

† Wolkowski (2006). ‡ NS = not significant.

Table 2. Effect of tillage on corn and soybean yield, Arlington, WI, 1998 and 1999.†

Tillage	Corn yield (bu/a)		Soybean yield (bu/a)	
	1998	1999	1998	1999
Fall chisel	223	206	57	47
Fall subsoil	218	201	54	51
Spring field cultivator	223	204	53	45
Pr>F	0.15	0.44	0.38	0.31
LSD	NS	NS	NS	NS

† Adapted from Wolkowski (2000). ‡ NS = not significant.

A study evaluating deep subsoil tillage with a straight-shanked tool to a depth of 20 in. was conducted in southern Minnesota by Jodi DeJong-Hughes, a University of Minnesota Regional Extension Soils Specialist and Jane Johnson, a NRCS Soil Scientist in 2003 and 2004. This study examined the use of the practice in an on-farm strip trial that was replicated eight times in a ridge-till system on a loam soil. The deep tillage was conducted on alternate sets of rows in the fall and then the ridge-till practice was applied over the entire field the following year. Yield measurements were taken from both upland and depressional areas in the field. This study did not show a yield response to deep vertical tillage and as a result they concluded that there would be considerable profit loss because of the added expense of the deep tillage (Table 3).

Table 3. Effect of deep tillage on corn and soybean yield, Elrosa, MN 2003 and 2004.†

Tillage	2003 corn yield (bu/a)		2004 soybean yield (bu/a)	
	Upland	Depression	Upland	Depression
Ridge-till	183	156	32	14
Ridge-till with deep tillage	185	155	33	17
Significance	NS	NS	NS	NS

† Jodi DeJong-Hughes, personal communication. NS= Probability of significant exceeds 5%.

Another Midwestern study conducted at the Iowa State University Southeast Research and Demonstration Farm examined shallow vertical tillage in 2004 on corn. This one-year study was reported by Superintendent Kevin Van Dee. Tillage systems included what was termed conventional (spring disking followed by a field cultivator), no-till, and spring vertical tillage using a Phoenix harrow; a tool with a rolling set of tines. The results of this evaluation are shown in Table 4. The reported values are the average of four measurements; however statistical analysis was not reported and it is therefore not possible to conclude much from the study.

Table 4. Effect of tillage on corn stand and yield, Crawfordsville, IA, 2004. †

Tillage	Stand (x 1000)	Yield (bu/a)
No-till	32.2	193
Disk/field cultivator	32.6	192
Phoenix harrow	32.2	196

† ISU SE Research and Demonstration Farm, Pub. ISRF04-34.

Summary

Clearly every producer wants to create a seedbed that promotes rapid and uniform crop emergence, while having a soil condition that permits deep and extensive rooting. Poor, uneven stands with limited root development are a recipe for disaster. Producers should be encouraged to carefully evaluate the purpose and reasoning for selecting tillage practices. If not doing so they stand to lose operational efficiency, increase their cost of production, and potentially increase soil loss from their land. They may find that no one system will work in every part of the rotation, or for that matter on every field. Vertical tillage describes a practice that should offer a good seedbed and root zone and still maintain adequate crop residue for soil conservation purposes. Many producers are likely unknowingly using vertical tillage methods already and most will continue to fine-tune their practices over time. One could argue that a well-managed no-till system offers some of the same benefits as vertical tillage if traffic is managed to reduce compaction and the soil is allowed to naturally develop vertical pores from earthworm activity, root traces, and voids between soil aggregates. Whether using a modern vertical tillage tool with concave or other specialized coulters, strip-tillage, or a chisel system it is still important that producers strive to avoid compaction by staying off wet soils, limiting load, and controlling traffic.

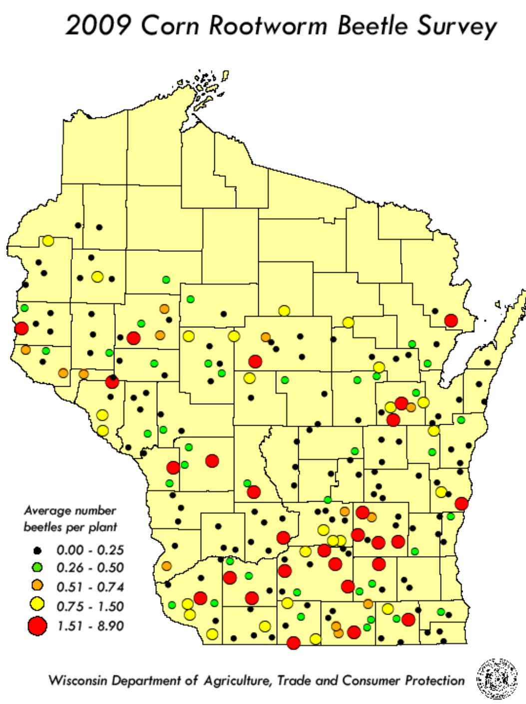
WISCONSIN INSECT SURVEY RESULTS 2009 AND OUTLOOK FOR 2010

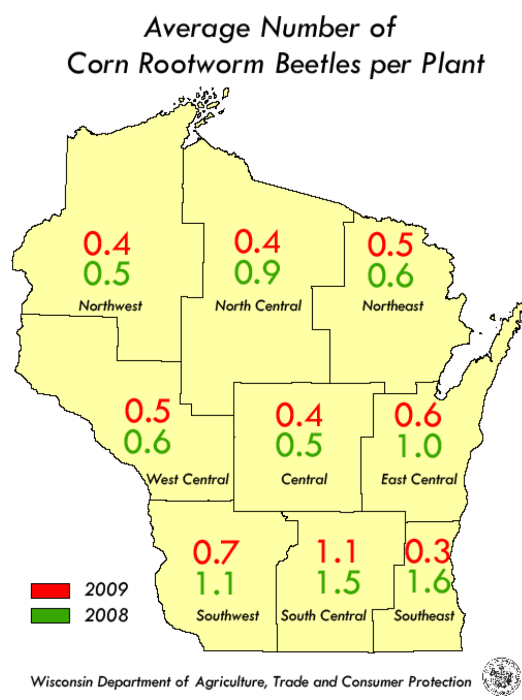
Krista L. Hamilton [1/]

Corn Rootworm

The annual survey in August documented a decrease in the state average number of beetles per plant for the first time in five years. Population declines were charted in every district, with the largest reductions occurring in the southeast, east-central and north-central areas. The state average of 0.6 beetle per plant compares to 1.0 last season and a 5-year average of 1.1 per plant. District counts were as follows: northwest 0.4, north-central 0.4, northeast 0.5, west-central 0.5, central 0.4, east-central 0.6, southwest 0.7, south-central 1.1, and southeast 0.3. Populations in 77% of surveyed fields were below the 0.75 beetle per plant level which indicates root injury potential in 2010 if some form of control is not used.

The causes of the decline in beetle numbers are not certain. It is presumed that widespread use of stacked Bt hybrids is a major contributing factor, both in Wisconsin and across the Midwest where populations of the western species were greatly reduced this season. Wet soil conditions last spring also may have caused some degree of larval mortality, thus lowering adult numbers. The map below shows the locations of 229 fields sampled in August. Areas with an elevated risk of root injury to non-Bt, continuous corn are represented by red and yellow circles.





European Corn Borer

Examination of 229 corn fields between September 1 and October 31 found the second lowest population since the survey began in 1942. The state average of 0.06 borer per plant (6 per 100 plants) represents a decline from last year's very low average of 0.09 per plant, and is well

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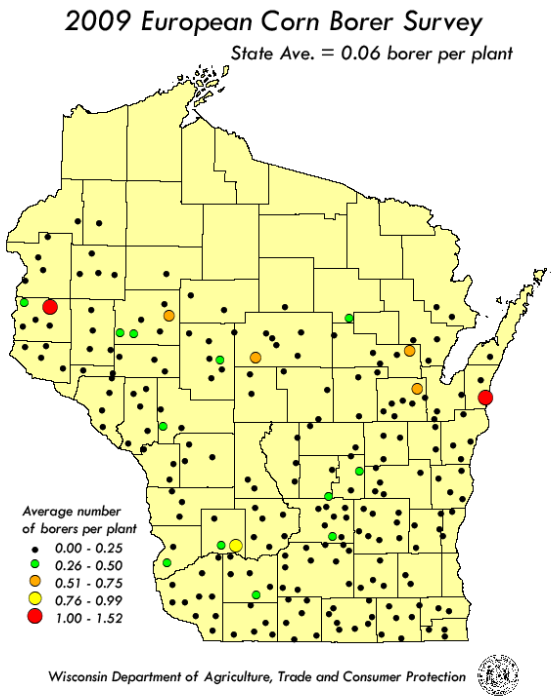
below both the 10 and 50-year averages. Populations this fall exceeded 2008 levels only in the southwest and west-central districts (see table below). Less than 1% of the fields sampled had populations that met the treatment criteria of 1.0 or more borer per plant, and 75% had no detectable larval population. Survey data from 2009 and the previous several years continue to suggest that transgenic Bt-corn has become a major mortality factor among the European corn borer population.



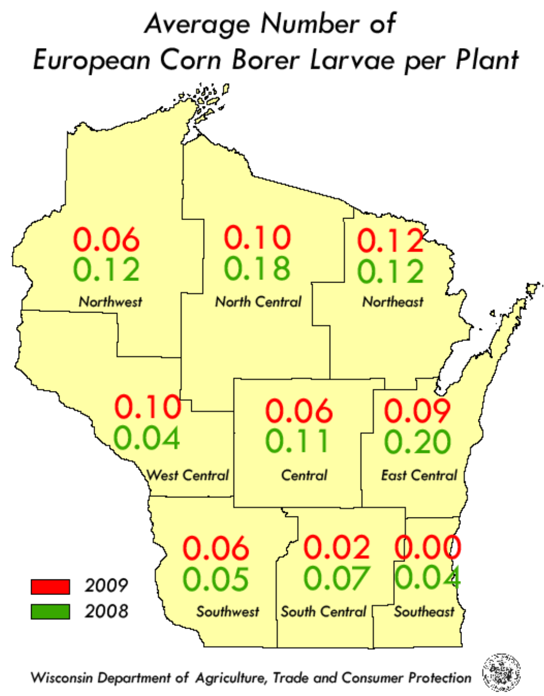


Table 1. European corn borer fall abundance survey results 2000-2009 (average no. borers per plant).

District	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	10-Yr Ave
NW	0.24	0.33	0.44	0.20	0.13	0.01	0.27	0.24	0.12	0.06	0.20
NC	0.04	0.05	0.26	0.14	0.20	0.36	0.16	0.35	0.18	0.10	0.18
NE	0.03	0.07	0.75	0.23	0.22	0.33	0.23	0.07	0.12	0.12	0.22
WC	0.31	0.67	0.71	0.16	0.05	0.24	0.42	0.52	0.04	0.10	0.32
C	0.41	0.48	1.21	0.44	0.06	0.44	0.51	0.42	0.11	0.06	0.41
EC	0.19	0.33	0.44	0.20	0.22	0.25	0.11	0.21	0.20	0.09	0.22
SW	0.39	0.87	0.65	0.34	0.10	0.49	0.20	0.28	0.05	0.06	0.34
SC	0.33	0.48	0.86	0.51	0.05	0.67	0.38	0.33	0.07	0.02	0.37
SE	0.16	0.36	0.61	0.21	0.02	0.35	0.16	0.12	0.04	0.00	0.20
State Ave.	**0.24**	**0.40**	**0.66**	**0.30**	**0.10**	**0.40**	**0.29**	**0.31**	**0.09**	**0.06**	**0.29**

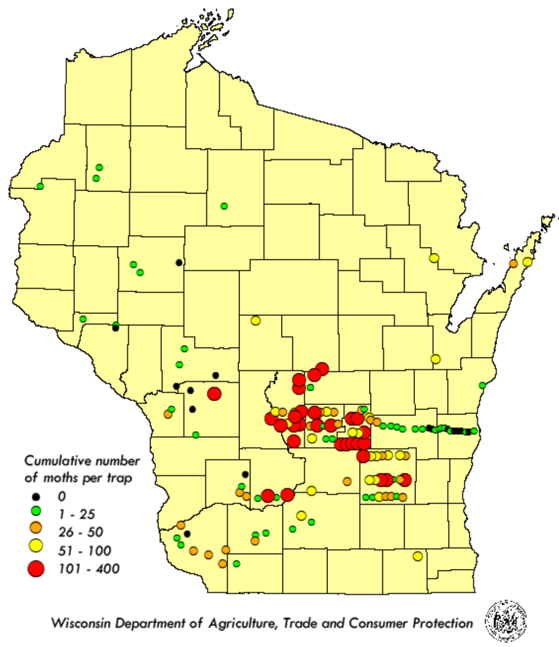
Corn Earworm

Significant flights of moths did not materialize this season at the majority of pheromone trap locations. Despite favorable migrating conditions and large source populations in the south-central U.S., adult dispersal was suppressed throughout much of August by low nightly temperatures. Moderate counts were registered in Dane County from August 14-21 and numbers escalated to 60-160 moths per trap by August 31, but the flight was considered to have been too minor to produce substantial larval infestations. Larvae were very scarce in corn fields examined during fall surveys. If pheromone trap counts are indicative, the flight was almost six times smaller than that of 2008. The cumulative seasonal capture was 990 moths in 2009, compared to 5,624 moths in 2008 and 8,055 moths in 2007.

Western Bean Cutworm

The adult flight period was delayed by record low temperatures in July and most moths did not appear in trap collections until July 27-August 14. Egg deposition was noted by July 18. Although larval populations were found in corn throughout the state in August and September, the heaviest infestations were concentrated on sandy soils in the central district. Pheromone trap counts coincided closely with field observations, documenting the largest moth numbers in the central counties of Adams, Green Lake, Juneau, Marquette, Monroe and Waushara. High cumulative counts for the season were 339 moths in a pheromone trap and 350 moths in a black light trap, both located near Grand Marsh in Adams County. Larvae persisted in some corn fields past October 16.

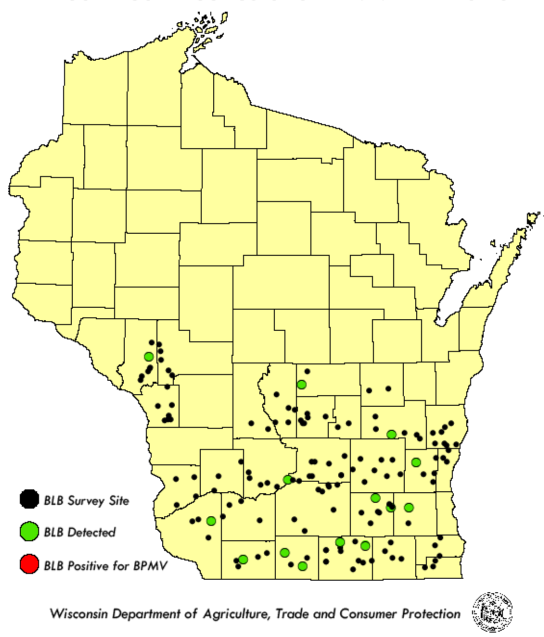
2009 Western Bean Cutworm Trap Counts



Bean Leaf Beetle

The spring survey of 152 first growth alfalfa fields conducted from May 18-June 10 yielded just 24 overwintered adults. This figure is comparable to the 21 beetles collected during a similar survey last season, but considerably lower than the numbers found during annual surveys in the years 2003-2007 when several hundred specimens were collected. Beetles were swept from only 14 fields in Columbia, Fond du Lac, Grant, Green, Jefferson, Lafayette, Rock, Trempealeau, Waukesha, Waushara and Washington counties, with no apparent pattern to their distribution (see map). Laboratory testing of the 24 specimens showed all were negative for bean pod mottle virus (BPMV). Based on the low population of overwintered beetles detected last spring, a minimal risk of early-season defoliation and virus transmission was predicted for emerging soybeans.

2009 Spring Survey for Overwintered Bean Leaf Beetles and BPMV in Alfalfa



Soybean Aphid

According to the results of the annual survey, the vast majority of Wisconsin soybean fields did not develop economically significant populations during the R2-R4 growth stages. Of the 247 fields examined in late July and early August, 94% had non-economic densities below 250 aphids per plant. Economic populations were observed at scattered locations in Columbia, Dunn, Eau Claire, Marquette, Pepin, Pierce, Taylor, St. Croix and Wood counties, but these were exceptional. The survey found the state average density to be 53 aphids per plant, which compares to 72 in 2008, 164 in 2007, 69 in 2006, 118 in 2005, 11 in 2004, and 758 in 2003.

By mid-August the situation changed considerably. Densities surged above treatment thresholds and remained extremely high for the balance of the season. Swarms of winged aphids descended on urban areas across the Midwest during an unprecedented fall migration to buckthorn, causing great annoyance to humans. Despite the magnitude of the flight, a fungal disease apparently decimated populations by late October and substantially reduced egg counts on buckthorn.

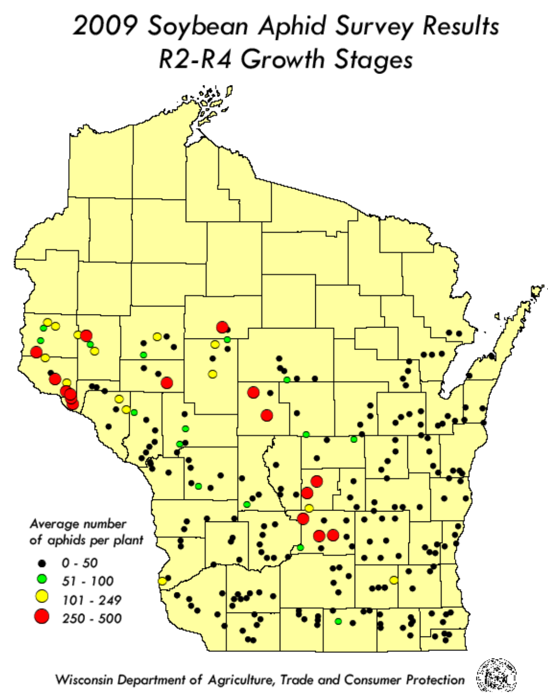


Table 2. Soybean aphid survey results 2003-2009 (average no. aphids per plant, R2-R4 stages).

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

WHAT IS BITING ME? – DELUSIONS OF INSECTS

Phil Pellitteri [1]

Whether you work as a consultant, agronomist, landscaper or co-op, people ask questions about all kinds of things . We all have the sensation from time to time of something biting us. Sometimes you look down and see a critter sometimes there seems to be nothing there. What about when you wake up and find bites all over you and you wonder who did that? Have you ever had a person that believed they were infested with some type of bug or worm and were looking to you for help?

The first question is – are their visible bites? This is a starting point. In Wisconsin most of the things that bite will be active during the late spring to early fall. It is very difficult to diagnose the cause of the bite without looking at the history and circumstances surrounding the problem. Were has the person been in the last 48 hr? Where are the bites located and how long have they had them? Do they have pests?

The next step is to ask to see a sample of the possible creature. Some of the more common causes to look for include:

Assassin bugs- Normally feed on insects- gives painful bite if handled
Bird mites in summer- bites show up anywhere on body. Mites look like walking pepper grains- will find bird nest near windows, vents; most common in June.
Chiggers a mite that attacks insects, - oozing welts found where clothing is restricted- sock and belt line, etc- History of being outside in last 48 hrs. Bites take at least 12 hr. to show – mites already gone but body reacts. Bites can last for days.
Fleas from pets – group of bites often around ankles find small jumping insects.
Fur mites of pets- Blister like bites on forearms and body – pet often shows more of a dry skin symptom. May need to take pet to a veterinarian for confirmation
Bed bugs if you are traveling or purchased used furniture, Most bites on arms and body. Not all people react- Look like big mosquito bites. Spots on sheets
Black Flies- small gnat that bites around neck and hair line- bites often bleed and swell up but you do no feel them at first- mostly in late May and June when work outdoors.
Straw itch mite – Bites or blisters all over body. History of working around grain, feed or hay that is infested with grain beetles or moths- These mites are parasites of the grain insects.
Scabies – “human mange”- Can only be diagnosed with a skin scraping- more of a rash – do not feel bites. Need to come into close contact with infested person.
Spider bites- most of what people call spider bites are not- single bite with bruising- in rare cases an open sore- - can be misdiagnosed bacterial infection (MRSA)

What about you feel like you are getting bite but no creatures can be found?

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If there are visible reactions it could be allergies, medication reactions, symptoms of underlying medical issues, irritation from fiberglass or other fibers or even a reaction to a new soap or body cream. You need to be a detective and look at possibilities other than insects or mites.

At times people will have imaginary problems. This is given the medial diagnosis of delusions of parasitosis – It is a persistent unshakable belief held in the face of strong contradictory evidence. People are convinced there are insects or worms on or inside them that are biting them , but no insects can be found and the stories often do not make biological sense or match any of the know problems

The "classic case" is a person who has been infested for weeks or months. They cannot find real insects but often will bring in samples with numerous pieces of lint, fibers and hair. They believe creatures are living inside them and are concerned they are contagious. Often there has been recent major stress in their lives and believe they became infested from some object or animal. If it is a medical problem it must be dealt with by a health professional. We can help by eliminating insects or mites as the source. Do not assume that the person does not have real symptoms. It is important to separate the sensation of being bitten vs. finding a real bite. If you need help with samples or want to talk about the case send it to the Insect Diagnostic Lab. – 1630 Linden Dr., Madison Wisconsin – 53706. Support the person–do not doubt they have the sensations–but suggest they look in other directions other than an insect or mite cause.

Unfortunately there is information on the internet that will support the delusions. One of the more common ones is Morgellons disease or syndrome. People submit samples with fibers and lint that they are sure are infesting their skin. There are web sites that support this "scientifically undiscovered "problem. No credible medical or public health association has verified the existence or diagnosis of Morgellons disease. There are physicians who are both dermatologist/psychiatrist that specialize in helping people find a cause for their sensations or skin problems. The bottom line is these are medical issues that should be handled by medical people. We never recommend spraying homes or using pesticides on people without knowing what the problem is.

WHY INCLUDE COVER CROPS IN WISCONSIN CROP ROTATIONS?

Kevin Shelley and Jim Stute[1]

What Is A Cover Crop?

A cover crop is a crop grown to benefit the soil and other crops in the rotation and is usually not intended for harvest. The term cover crop is really a catchall phrase for numerous uses ranging from soil conservation, nutrient retention and environmental protection, improving soil quality and reducing use of purchased inputs. As such, a cover crop is usually planted to provide soil cover during otherwise idle intervals, or fallow periods, in a given crop rotation – that is, between harvest and planting of commodity or feed crops. In some cases, "living covers" may be inter-planted to grow with the commodity crop.

Cover crops are widely recognized as an integral component of organic production systems but also have great potential in conventional agriculture where several cover crops systems have been successfully implemented by producers. The right cover crop can provide multiple benefits while other uses and benefits are mutually exclusive. For example, a green manure crop grown to provide nitrogen (N) will not increase soil organic matter because it's biomass must rapidly decompose to release N to the following crop.

Examples of Cover Crops for Use in Wisconsin

Legumes

- Hairy vetch
- Chickling vetch
- Sweet clover
- Red clover
- Berseem clover
- Crimson clover
- Field pea

Non-legumes

- Oats or barley
- Annual ryegrass
- Winter (cereal) rye
- Buckwheat
- Tillage/Forage radish

Fast growing legumes, such as annual clovers or vetches, can be planted after short season crops such as small grains or peas. With adequate top and root growth, and associated root nodulation, legume species will fix atmospheric nitrogen into their biomass for microbial release to a following N-demanding crop such as corn, potatoes or snap bean. This is in addition to protecting the soil against erosion and suppressing weeds that may otherwise grow and produce seed, following harvest of these commodity crops.

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In Wisconsin, some producers have found success planting relatively fast establishing species such as berseem clover, chickling or hairy vetch following small grains in late July to mid August. But the soil moisture required for acceptable growth can be less predictable at this time. Medium red clover has shown better consistency in biomass and N yield, but must be planted in early spring with spring seeded small grains or frost seeded into winter grains.

While legume covers are primarily used as biological N producers, non-legume species have slightly different niches. Small grain species such as winter rye, barley, oats or winter wheat tend to be used more for soil conservation, field runoff prevention and soil nutrient retention. In southern Wisconsin, annual small grain species probably need to be planted by September 1 for significant growth and soil protection going into winter (Stute, 2000). Winter (cereal) rye or winter wheat are popular choices to follow corn harvested as silage or early maturity soybeans. Both crops leave relatively little crop residue after harvest and manure is often applied following corn silage. The winter annual grass crops can provide some soil cover, slowing runoff, and have fibrous root systems that help to recycle N and P for next year's crop reducing runoff and leaching losses.

Other non-legumes, such as buckwheat or sorghum-sudan grass hybrids, planted in mid-summer after peas or early snap beans, can be used primarily as weed suppressors and/or soil builders. Their ability to grow quickly at this time, producing several tons of biomass per-acre, can smother, by competition, persistent perennial and other weeds and add recalcitrant organic matter to aid soil conditioning (structure and quality). Sorghum-sudan and winter (cereal) rye, produce allelochemicals (sorgeleone and diboa, respectively) that function as natural herbicides for some following crops if managed accordingly. Another non-legume cover growing in popularity is forage (or tillage) radish which potentially produces a very long taproot selected to penetrate sub-surface soil compaction, thus providing a so-called "bio-tillage." The UW-Extension (*UWEX*) Cover Crops workgroup is beginning to evaluate this species in on-farm and research station trials.

Cover crops work by capturing unused solar energy and storing it as carbon and fixed N (if the cover is a legume) in their biomass along with associated soil derived nutrients. This energy is released to the soil by microbial decomposition of the residue. The amount of unused or wasted energy in some cropping sequences can be substantial. Figure 1 shows growing degree day (GDD) accumulation in Southern Wisconsin from July 1 through October, a period often fallowed after harvest of short season crops. Fully one-half of GDD accumulation occurs during this time.

Purposes and Functions of Cover Crops

Soil Conservation

This use is where the term cover crop is derived. Rapid growing species with spreading stature provide cover on soil with low residue cover, preventing soil and nutrient movement and maintaining soil productivity. By reducing erosion, they can help maintain conservation program eligibility and cropping flexibility on highly erodible land (HEL).

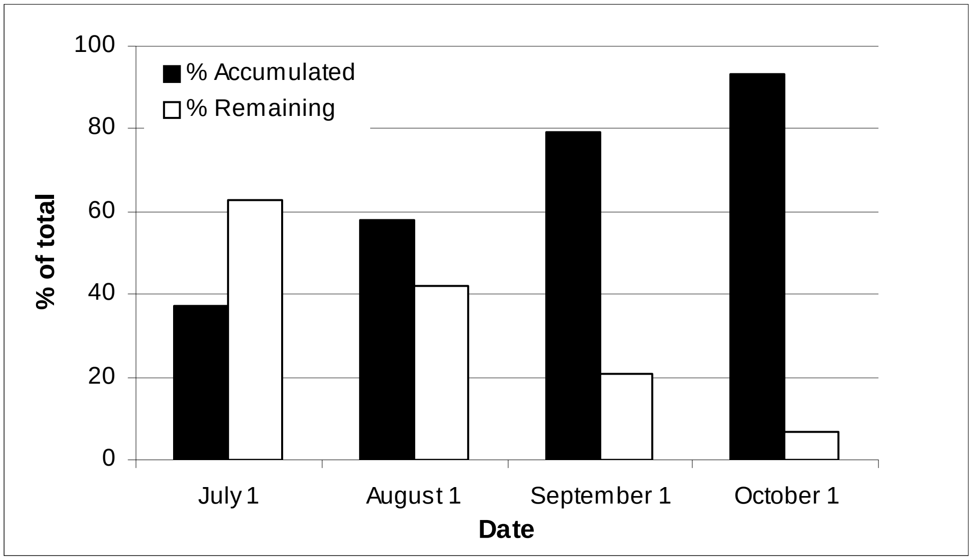

Figure 1. Mean growing degree-day accumulation in Southern Wisconsin, Arlington, (30 year average, AWON).

Some of the more common cover crop systems have been built into the RUSLE2 module of the SNAP Plus nutrient management planning software. This allows a planner to assess the impact of cover crop scenarios on a producer's current conservation plan. Table 1 shows the impact of a red clover cover crop on predicted soil erosion on several soil types and tillage systems.

Soil Building by Adding Organic Matter and Improving Structure

Cover crops can help maintain or increase soil organic matter levels by adding more residue than would be produced by the cropping system alone. To contribute more stable OM, the species selected must produce significant dry matter which is also recalcitrant. In general, grass species have higher C:N ratios than broadleaves (and especially legumes) so they are more resistant to complete decomposition. Lignin content is also important because it resists decay.

Soil quality can be improved by an increase in aggregation and reduced compaction. Since cover crops are often terminated at a vegetative stage of growth, their tissues provide a highly suitable substrate for microbial growth, resulting in greater populations and a more diverse species mix. The resulting increase of biological activity produces microbial gums which glue soil particles together, resulting in better aggregation. Legume cover crops also stimulate mycorrhizal fungi that produce glomalin, a water insoluble glyco-protein that produces more stable aggregates. Even though legumes don't contribute to OM levels, these two aggregate forming processes are important for soil structure.

Root penetration can relieve plow layer and deep compaction and create macro-pores for improved gas exchange and water infiltration. This is important in no-till systems which have no other option, especially when soils are damaged by wheel traffic during wet conditions. Many cover crops are planted at densities which greatly exceed those of routinely grown field crops, increasing the total volume of soil influenced by roots. Species with deep taproots can influence compaction deeper in the soil profile.

Table 1. `Effect of red clover on estimated soil loss (SNAP Plus RUSLE2) based on tillage for corn and soybean (no-till or fall chiseled). Clover seeded into winter wheat as part of a soybean-wheat-corn sequence. Yield levels: 46-55, 81-100, 151-170 bu/a respectively.

			Soybean tillage system			
			No-till		Fall chisel	
			Corn	Corn	Corn	Corn
Soil type	"T"	Clover	NT	CT	NT	CT
			Annual soil loss (ton/acre/year)			
Fox	4					
		-	0.5	2.4	2.0	3.1
		+	0.3	1.9	1.6	2.5
		reduction(%)	40	21	20	19
Kidder	5					
		-	0.5	2.7	2.3	3.5
		+	0.3	2.2	1.8	2.9
		reduction(%)	40	19	22	17
Ogle	5					
		-	0.4	2.1	1.8	2.7
		+	0.2	1.4	1.3	2.2
		reduction(%)	50	33	28	19

6% slope, 500 ft length

Nutrient Management

Adapted cover crops can play a significant role in nutrient management, adding biologically fixed N in the case of legumes, retaining readily lost nutrients or managing soil test levels, especially phosphorus.

Green manure crops fix atmospheric N that can be used to meet a significant portion of the requirements of high N demand crops such as corn. Nitrogen credit information for various legumes can be found in UWEX publication A2809, Nutrient Application Guidelines for field, vegetable, and Fruit Crops in Wisconsin. The amount of credit is based on total biomass which is related to length of growing season and above-ground herbage management.

Nutrient retention includes excess nitrate-N which could otherwise leach and phosphorus which could be lost with run-off. Rapid growing species reduce losses by accumulating these nutrients in their biomass, by increasing infiltration and reducing soil movement. Winter rye planted after corn silage is a good example of a cover crop which can accomplish both of these functions. Data from Wisconsin shows a 50% reduction of nitrate-N the spring after manure application when winter rye was grown (Stute et al., 2007). Winter rye is also capable of removing large amounts of soil P if the biomass is harvested for forage (Shelley and Stute, 2008). This research showed that P removal is maximized at N rates which optimized forage yield and confirmed rye is a luxury consumer of P under Wisconsin conditions, meaning that P removal increases with increasing soil test levels. See Shelley and Stute (2008) for a discussion of nutrient management planning implications.

Weed Management

There are three main mechanisms whereby cover crops can provide a weed controlling function:

1. Smothering and competition
2. Allelopathy
3. Enhanced crop competitiveness

Research trials and on-farm experience show that these mechanisms can be effective components of an integrated weed management program, but none are likely to provide consistently acceptable control on their own in agronomic or horticultural crop rotations.

(1) Smothering and competition

Some cover crops can provide a "smother crop" function whereby the cover grows more aggressively than most of the weed species present, and out-compete weeds for water, light and nutrients. Thus, many of the weeds that would otherwise grow are prevented, for this time, from growing and producing seed that would be added to existing soil seed banks. Suppression of some weed species MAY last longer than the duration of the cover crops and into the following production crop. This could be the result of an induced dormancy of weed seeds or from the cover crop's allelopathy. Examples may include buckwheat, sorghum-sudangrass, rye, barley or other small grains, hairy vetch or sweet clover.

(2) Allelopathy

Allelopathy is the ability of some plant species to reduce the growth and development of others via chemical inhibitors. Thus, these plants are producing and releasing their own bio-herbicide as a competitive mechanism. Chemical compounds are released either as root exudates from a living, growing plant, or are released from dead, decomposing plant tissue after the crop is killed with herbicide or tillage. The phytotoxic allelochemicals function to inhibit seed germination or stem elongation of other plants.

The inhibitory effect is usually reduced substantially if the allelopathic cover crop is incorporated into the soil. The dying, decomposing plants need to remain on or very near the soil surface for the compounds to be effective on germinating seeds and seedlings. Also, killing the cover crop at the right stage of growth is important, usually near or after flowering and pollination. This is when the allelochemicals are often at their highest concentration and when the cover crop is less likely to re-grow and become a weed itself. Winter (cereal) rye has been shown in SOME field and laboratory research to be the most effective of the small grains in production of allelochemicals and inhibition of weed seed germination and stem elongation. Sorghum-sudangrass produces sorgeleone, a relatively potent allelochemical as well.

The primary biochemicals involved include:

- Phenolic compounds such as ferulic acid and coumaric acid
- Amine alkaloids (grammines)
- Hydroxamic acids: DIBOA (dihydroxy benzoxazin) and BOA (Benzoxazolin)

Field studies suggest suppression of small seeded annual weeds (and crops) more than larger seeded. Corn, soybeans and wheat have generally been shown as not affected by allelopathic chemicals. Control efficacy is not complete on its own, reported in the range of 20-90% (season long) compared with untreated controls of no cover crop or other controls. Some of the weeds shown to be suppressed by small grains, hairy vetch and sorghum-sudangrass include barnyardgrass, bristly foxtrail, crabgrass, wild proso millet; jimsonweed, velvetleaf and redroot pigweed.

While weed control resulting from allelopathic cover crops is usually not complete, it can be an effective component of either an organic or conventional system. In an organic system, allelopathy can help control early developing weeds, but mechanical cultivation will usually be required to supplement later. In a conventional no-till or reduced till systems, allelopathy can often be used to reduce herbicide requirements by replacing one application in what may otherwise be a two pass herbicide program.

For example, research was conducted at Arlington, WI in 1989 and 1990 by Jerry Doll and Tom Bauer with soybeans no-till planted into rye just after it was killed, either by mowing (sickle bar) or by Glyphosate application (Doll and Bauer, 1991). Results showed that rye killed in early May, when rye was in the tillering stage (10-12"), did not provide season-long weed control, and that a 2nd post emerge application was required. But, when they waited until boot or heading stages to kill the rye, season-long weed control was adequate and yields were competitive with one Glyphosate application for burn-down of the rye (before soybean planting). In treatments where the initial kill was by mowing, weed control and soybean yield were generally comparable (some favorable) when the mowing was at boot or heading stages and followed by one post emerge application of Glyphosate. Soybean yields were, however, maximized in a no-till, 2-pass system without rye in 1990.

However, more recent trials at Arlington by Dwight Mueller and Jerry Doll (2003-05) showed season-long weed control and acceptable soybean yields by no-till planting soybeans into growing rye in the jointing stage (8-12") with Glyphosate applied shortly after (Stute et al., 2008). Soybeans developed as the rye died and no additional herbicide applications were required. Soybean yields were equal to soybeans planted without rye. Corn yields were reduced in the no-till rye system. This was interpreted as due, not to allelopathy, but, to competition from the rye residue, cooler soil temperatures and delayed planting compared to a no-rye comparison. Nitrogen immobilization from the decomposing rye residue also likely contributed to reduced corn yield. These are all factors soybeans seem to tolerate better than corn.

(3) Enhanced crop competitiveness

As discussed previously, soil quality and nutrient cycling benefits associated with cover crops will serve to enhance the competitive abilities of the crops against weeds as well as other pests.

<u>Supplemental Feed Production</u>

Productive cover crops can be harvested for forage and still accrue many of the conservation benefits they were planted for. Herbage can be harvested either as a planned management practice or in years when forage inventories are reduced by less than optimal growing conditions.

Winter rye is again a good example and is discussed in the NPM publication: Planting Winter Rye after Corn Silage: Managing for Forage. Other options include small grains after short season crops (Oplinger et al., 1997) or red clover interseeded with winter wheat. In on-going research, two years of red clover forage harvest data shows an average DM yield of 2.23 t/a (harvested in early

November) with quality measurement of: 134 RFQ; 16.8% CP; 32.6% ADF and 41.2% NDF (Stute, 2009).

Carbon Sequestration

Because cover crops capture unused solar energy and store it as carbon in their biomass, they have potential to sequester C, especially if their residues resist decay. Little is known about this potential use because it's emerging area of research, but ultimately successful systems may provide an additional revenue source in carbon cap and trade systems.

Risk and Incentive

While cover crops can provide several benefits, their use also has potential risks which need to be considered. These risks include cover crop failure or poor performance and negative impact on the subsequent crop. Failure of the cover crop results in additional costs without the intended benefits. If the cover is intended to reduce input use, for example growing a legume for nitrogen credits, then the added cost is combined with the cost of full rate nitrogen needed to optimize production of the following crop. Potential negative impacts also include soil moisture relations, either depletion or slower drying in spring caused by increased surface residue, potential disease and insect interactions, N immobilization by high C:N residues, allelopathy, competition from escapes or volunteers and crop insurance ineligibility. Any of these has the potential to reduce income by yield reduction or added costs.

Short and long-term economic benefit should be weighed against the risk when deciding to implement the practice of cover cropping. The *UWEX* Cover Crop workgroup has conducted several trials related to successful systems which have identified best management practices to minimize risk and optimize income. Examples include winter rye after corn silage and interseeding red clover in winter wheat. Factsheets outlining these systems and their best management practices are available at: http://ipcm.wisc.edu/Publications/tabid/54/Default.aspx

Cost-share programs may be available, either locally or through the NRCS Environmental Quality Incentive Program (EQIP) to offer short-term financial incentive for using cover crops.

The long-term benefit of cover crop use is improved soil quality which should translate into higher crop yield. Long-term cover crop use is also a performance criterion for the NRCS Conservation Stewardship Program which provides financial reward for using environmentally sound farming practices.

Success with Cover Crops

Cover crops require the same management attention as other crops to be productive This includes selecting the right species, using quality seed and inoculant, making sure soil conditions are right for establishment, calibrated seeding equipment and using the right termination method and timing. Also, look for efficiencies to combine operations for reducing costs such as broadcasting seed with fertilizer. Finally, start with a small area to experiment with before implementing the practice on a large scale.

Information Resources for Cover Crops

Publications

Managing Cover Crops Profitably, Third Edition
http://www.sare.org/publications/covercrops.htm

Cover Crops on the Intensive Market farm, June 2009
http://www.cias.wisc.edu/wp-content/uploads/2003/09/covercrop09final.pdf

Websites

Midwest Cover Crops Council
http://www.mccc.msu.edu/index.htm
Website provides links to a variety of state level publications, resources and expertise.

ATTRA, National Sustainable Agriculture Information Service
http://attra.ncat.org/attra-pub/covercrop.html
This is a national level information clearinghouse.

Seed Sources

Welter Seed and Honey, Onslow IA.
http://www.welterseed.com/default.aspx

Albert Lea Seed House
http://www.alseed.com/

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ORGANIC NO-TILLAGE WINTER RYE-SOYBEAN SYSTEMS: AGRONOMIC, ECONOMIC, AND ENVIRONMENTAL ASSESSMENT

Emily Bernstein[1], Josh Posner[2], Dave Stoltenberg[2], and Janet Hedtcke[3]

Organic soybean and corn production in Wisconsin has rapidly increased to meet demand of the expanding organic dairy industry (USDA-ERS, 2006). A major challenge that organic row crop growers face is the intensive tillage needed for successful weed management (Posner et al., 2008), spurring interest by growers in improving weed management techniques (Walz, 1999). The use of a rye cover crop to facilitate no-till organic soybean production may improve weed management for organic growers, and provide additional ecosystem services including reduced soil erosion and runoff, increased soil organic matter and water infiltration, and trapping of excess nitrogen. This organic no-till rye mulch system has been limited in part due to uncertainty regarding the reliability of mechanical methods of terminating the cover crop, difficulty in establishing soybeans in the rye residue (Williams et al., 2000; Reddy et al., 2003), and the potential risk of competition between the rye cover crop and soybeans for soil moisture and nutrients resulting in reduced yields and economic returns (De Bruin et al., 2005; Westgate, 2005).

We conducted research to determine some of the agronomic, economic, and environmental risks associated with the use of winter rye cover crop in no-till organic soybean production systems. Our objectives were to determine the effect of rye management (plowing, crimping, and mowing), and soybean planting date (mid-May or early June) on soil moisture availability, soybean stand establishment, weed suppression, and soybean yield. Treatment effects on economic gross margins, soil loss, and soil quality were also predicted.

Materials and Methods

Research was conducted at the Univ. of Wisconsin Arlington Agricultural Research Station (UWAARS) near Arlington, WI in 2008 and 2009. The soil type was a Plano silt loam (fine-silty mesic Typic Argiudoll) with 4.7% organic matter and pH 6.7 in 2008 and 3.6% organic matter and pH 6.0 in 2009. Research sites changed each year to place the study following corn silage. The experimental design was a randomized complete block with four replications of six treatments (Table 1). The tilled treatment represented a typical organic soybean production system, while the other five treatments were no-till rye cover crop treatments with varying factors of rye management, soybean planting date, and row spacing (seeding rate). Plot size was 30-ft wide by 180-ft long in 2008 (0.12 acre) and 30-ft wide by 165-ft long (0.11 acre) in 2009.

Winter rye variety ‘Rymin’ was planted in early-October (Oct. 5, 2007 and Oct. 10, 2008) at a rate of 160 lb acre^{-1}. Rye in the tilled treatment was disk-chiseled in mid-April at the second node growth stage (Feekes growth stage 7; Apr. 23, 2008) and at tillering (Feekes growth stage 4; Apr. 17, 2009) (Zadoks et al., 1974). The subsequent stale seedbed was lightly disked (two passes) and field cultivated (two passes) for weed management and seedbed preparation prior to soybean planting. Feed-grade soybean varieties (Maturity Group I) ‘Viking 0.1832’ in 2008 and 'Blue River 16A7' in 2009 (due to unavailability of 'Viking 0.1832' in 2009) were planted with a conservation corn planter (30-inch row spacing) or no-till drill (7.5-inch row spacing). In the mowed, crimped drilled, and mowed drilled treatments, soybeans were planted/drilled approximately two weeks prior

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to crimping (crimped drilled) or mowing (mowed and mowed drilled) the rye, on the same date soybeans were planted in the tilled treatment. Rye in no-till treatments was roller-crimped or sickle-bar mowed in early June after the rye reached late anthesis (Feekes stage 10.5.1) (Ashford and Reeves, 2003; De Bruin et al., 2005). Soybeans were planted in the crimped drilled late and mowed drilled late treatments in early-June immediately after the rye was crimped or mowed. In the tilled treatment, flex-tine weeding, rotary hoeing, and inter-row cultivation were used for weed management as needed, typically 2-3 passes each, spaced a week apart from mid-May until soybean canopy closure in July.

Table 1. Treatments for experiments conducted at the UW-Arlington Agricultural Research Station in 2008 and 2009.

Treatment	Rye management	Soybean planting date	Soybean row spacing	Soybean viable seeding rate
	(month)	month	inches	seeds acre^{-1}
Tilled	Plowed (April)	Mid-May	30	225,000
Mowed	Mowed (June)	Mid-May	30	225,000
Crimped Drilled	Crimped (June)	Mid-May	7.5	275,000
Mowed Drilled	Mowed (June)	Mid-May	7.5	275,000
Crimped Drilled Late	Crimped (June)	Early June	7.5	275,000
Mowed Drilled Late	Mowed (June)	Early June	7.5	275,000

Rye shoot mass was harvested immediately prior to rye management in April (tilled treatment) or June (no-till treatments). Volumetric soil moisture was measured in tilled and crimped drilled late treatments at 0- to 2-, 6- to 8-, 15- to 17- and 20- to 22-inch depths in late May. Soybean plant density was measured in mid-July. Weed shoot mass was harvested in late August. Soybean grain was harvested by machine from the center 15 ft of each plot in late October, weighed, and adjusted to 13% moisture. The number and type of field operations, inputs, and the local November price for organic feed grade soybean were used to estimate gross margins using the Agricultural Budget Calculation Software (Frank and Gregory, 2000). The Revised Universal Soil Loss Equation 2 (USDA 2005) model was used to predict treatment effects on soil loss and organic matter (soil conditioning index, SCI) based on a run of 200 feet, contours of 0.5%, and 1 and 4.5% slopes.

Data were pooled across the two site-years and analysis of variance was conducted using the MIXED procedure in SAS/STAT (SAS Institute 2007) to test the effect of treatments on early-season soil moisture, soybean establishment, yield, and profitability. Treatment comparisons were made using Fisher's Protected LSD method ($\alpha = 0.05$). Pre-planned contrasts were made to compare rye and soybean management effects within no-till treatments, and between tilled and no-till treatments.

Results

At the time of rye management (plowing, crimping, or mowing), rye mass was 7 to 10-fold greater in no-till than tilled systems in each year (Table 2). In no-till systems, rye mass exceeded the minimum (1.5 ton acre^{-1}) considered necessary for effective weed suppression (Doll and

Mueller, 2005). Greater rye mass in 2008 was likely due to more timely precipitation and warmer spring temperatures as well as greater soil fertility than in 2009 (data not shown).

Table 2. Rye cover crop dry shoot mass at the time of plowing (4/23/08 and 4/17/09) and mowing or crimping (6/11/08 and 5/29/2009).

	Rye dry shoot mass	
Rye management	2008	2009
	——— tons $acre^{-1}$ ———	
Tilled (mid-April)	0.7	0.2
No-till (June)	4.8	1.9

At soybean planting, soil moisture was the same at the surface in no-till rye and tilled systems (Figure 1), indicating that a reduction in soybean germination due to soil moisture use by rye would not be expected in no-till rye systems relative to the tilled system. However, at deeper depths, soil moisture was less in no-till rye than tilled systems. This reduction in available soil water at deeper depths was likely due to the growing rye cover crop, which in years of inadequate rainfall could pose a risk to early-season soybean growth in no-till rye systems.

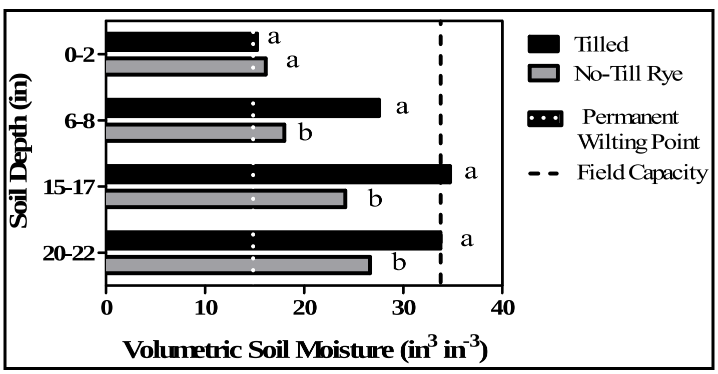

Figure 1. Mean early-season (5/28/08 and 6/1/09) volumetric soil moisture content at 0- to 22-inch depths for tilled and no-till (crimped drilled late) systems. Values within depth followed by the same letter do not differ at $p<0.05$ (Fishers protected LSD test).

Soybean establishment (stand density as a percent of viable seeding rate) did not differ between tilled and no-till systems, suggesting that rye had little effect on soybean germination and emergence ($p=0.3822$; data not shown). However, within the no-till drilled treatments, contrasts indicated that soybean establishment was affected by planting date. Establishment in treatments planted prior to rye crimping or mowing (crimped drilled and mowed drilled) was 80%, greater than the 60% establishment in treatments in which planting was delayed until after crimping or mowing (crimped drilled late and mowed drilled late) ($p = 0.0406$; data not shown). Lower stand density was likely due to poor seed placement through the rye mulch, particularly in 2008. Soybean establishment was not affected by rye management (crimped or mowed, p=0.5423) or row spacing (30 or 7.5 inches, p=0.9317) (data not shown).

Weed mass across years was several-fold greater in the tilled system than in no-till systems (p = 0.0058) (Figure 2). Contrasts indicated that weed mass among no-till systems was less for early- than late-planted soybean (p = 0.0612) and less for narrow- than wide-row spacing (p = 0.0991). Weed mass did not differ between crimped and mowed rye treatments (p = 0.9566).

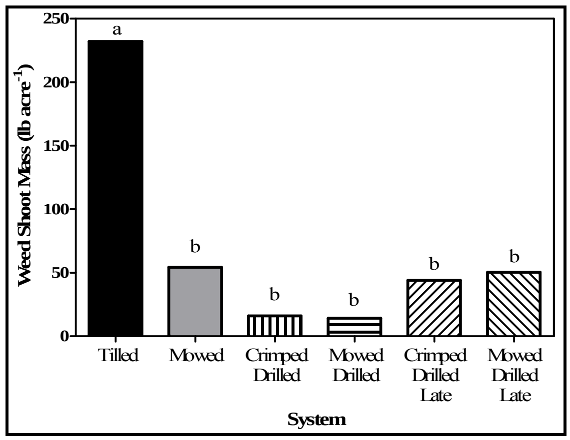

Figure 2. Mean late-season (late August) weed shoot mass in 2008 and 2009. Values designated by the same letter do not differ at p<0.05 (Fishers protected LSD test).

Soybean yield across years was greater for the tilled system than no-till systems (p = 0.0041) (Figure 3). Contrasts indicated that among no-till systems, yield was greater for narrow- than wide-row spacing (p = 0.0883), but yield was not affected by planting date (p = 0.1636) or rye management (p = 0.7667). Tilled rye was more profitable than no-till rye treatments (p = 0.0054) (Figure 4). However, profitability was not affected by rye or soybean management among no-till systems.

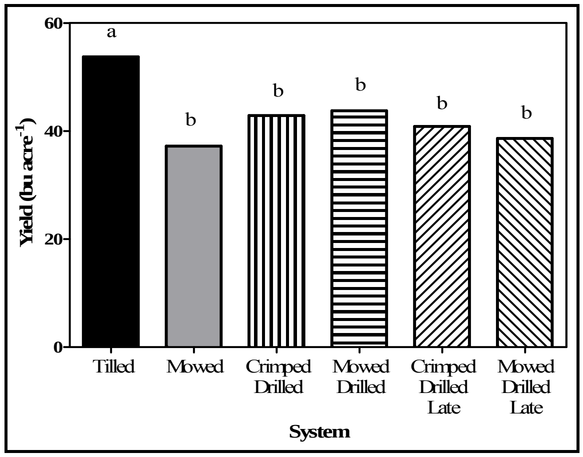

Figure 3. Mean soybean grain yield adjusted to 13% moisture in 2008 and 2009. Values designated by the same letter do not differ at p<0.05 (Fishers protected LSD test).

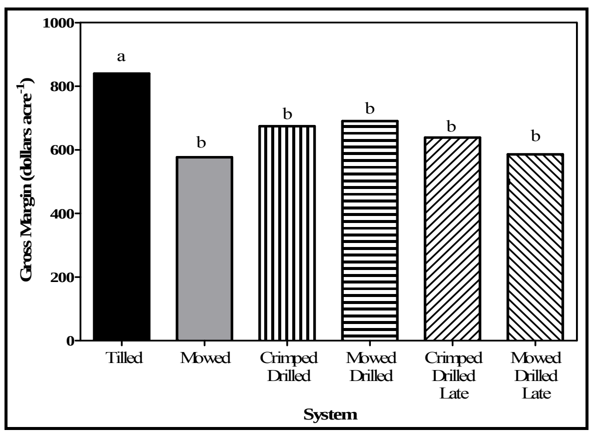

Figure 4. Mean estimated economic gross margins in 2008 and 2009. Values designated by the same letter do not differ at p<0.05 (Fishers protected LSD test).

Predicted soil loss was several-fold greater in tilled rye than in no-till rye systems for both 1 and 4.5% slopes (Figures 5A and 5B). Soil loss in no-till rye was less than T (5 tons $acre^{-1}$ $year^{-1}$) in each scenario. Predicted changes in soil organic matter (soil conditioning index, SCI) were positive in no-till rye systems and negative in the tilled rye system for both 1 and 4.5% slopes; SCI was highly negative for plowed rye on a 4.5% slope (Figures 5C and 5D).

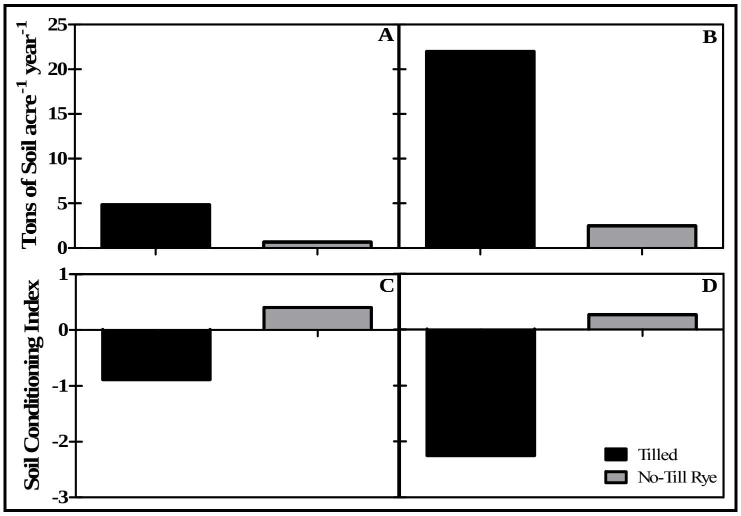

Figure 5. Predicted soil loss on (A) 1% slope and (B) 4.5% slope, and soil conditioning index on (C) 1% slope and (D) 4.5% slope for tilled and no-till rye systems.

Conclusions

Early-season soil moisture availability did not appear to be an important risk factor affecting soybean stand establishment in no-till rye systems, although rye depleted moisture deeper in the soil profile. While rye depleted available soil water at depths of 6-22 inches, adequate rainfall replenished the soil moisture in each year (data not shown). Soybean stand establishment was not affected by the rye cover crop between no-till and tilled systems.

Within no-till systems, soybean stand establishment was greater when planted into standing rye two weeks prior to crimping or mowing (crimped drilled and mowed drilled treatments) than when planted after crimping or mowing at rye anthesis (crimped drilled late and mowed drilled late treatments). Earlier planting was also associated with greater weed suppression, as was narrow-row spacing. Soybean grain yield was greater in narrow- than wide-row spacing. However, neither row spacing nor planting date affected economic returns. Soybean stand establishment, grain yield and economic returns were similar between crimped and mowed rye, although the sickle-bar mower may be preferable to growers since it cost half as much as the roller-crimper.

Organic no-till rye-soybean systems were associated with greater weed suppression, less soil loss and greater soil organic matter. However, these potentially long-term benefits were offset by 24% less soybean yield and 25% less economic return (due largely to high prices for organically-grown, feed-grade soybeans). Even so, the no-tillage systems were highly profitable and represent economically viable alternatives to a tillage-intensive approach. These systems are particularly attractive to organic growers due to the reduction in required labor.

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