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Program Co-Chairs:

Matthew D. Ruark
Department of Soil Science

Shawn P. Conley
Department of Agronomy

Cooperative Extension
University of Wisconsin-Extension
and
College of Agricultural and Life Sciences
University of Wisconsin-Madison

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2012 Wisconsin Crop Production Association Distinguished Service Awards

Distinguished Organization Award
Vita Plus Coop
{For Exemplary Industry Professionalism}

Education Award
Larry Fiene, WinField
{For Leadership & Commitment
to Educational Excellence}

Outstanding Service to Industry
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{For Dedication & Support to WABA and Its Members}

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John Every, Vita Plus Corp.
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Scott Rabe, Quality Roasting, Inc.
{For Full-Term Board of Director Service}

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Stan McGraw, Dodgeville Agri-Service
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{For Dedication, Service, & Leadership}

2012 – 2013
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Haily Henderson
UW-River Falls

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Laura Schulz
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Leo Walsh Distinguished Fellowship

Erica Anderson
UW-Madison

Ronald E. Doersch Scholarship

Gregory Vogel
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WITH VISION, THERE IS HOPE

Bruce Vincent [1/]

{This page provided for note taking}

[1/] Bruce Vincent Speaking.

WAS 2012 A TASTE OF GROWING SEASONS TO COME?

W. L. Bland[1]

Southern Wisconsin suffered through a drought during the 2012 growing season that rivaled that of 1988. Affected areas were at the northern fringe of a devastating drought that engulfed over half of the contiguous United States. The 2012 drought joins about 15 previous ones, some of them multi-year, that Wisconsin has endured since 1900. For the practicing agronomist it will be one of two or three profound droughts of a career. As with most droughts it was associated with warmer-than-average summer temperatures. Of the ten driest summers (June, July, and August - JJA) since 1895 in Southcentral Wisconsin, 2012 was the hottest, followed by 1988. In this same region 2012 JJA was essentially tied with 1948 as the driest since 1895 (at 6.2”) (Figure 1).

The large area, intensity, duration, and high temperatures of the 2012 drought, following on that of the Texas drought of 2011, leads to speculation on the role human-caused climate change in such extreme weather. We are in the midst of the biggest experiment ever, anywhere: how Earth’s climate will change as a result of releasing enough stored C from soil, coal, and oil to significantly alter the chemical composition of the atmosphere. From theory and observation we now know that this will raise the average temperature of Earth and cause substantial and expensive increases in sea level (World Bank 2012). But what will this mean for Wisconsin growing seasons, and particularly the frequency, duration, and severity of drought?

Understanding and predicting the temperature and sea level impacts of this huge experiment are somewhat further advanced than for precipitation. We do know that as the atmosphere warms it will hold more water vapor - here again theory and observations are in complete agreement. More water in the atmosphere does appear to lead to greater rainfall over much of Earth, but there is also more energy available for evaporation and longer growing seasons to extract soil moisture. There is continuing debate in the scientific literature over whether or not the area of drought has increased worldwide. The difficulty of quantifying drought is making this a challenging question to resolve.

Our best chance of knowing what the future holds is revealed by global climate models. These huge computer programs simulate Earth’s climate system to give us insight into the possible effects of our C experiment. The model results are in general agreement about increasing temperatures, but less clear from them is how patterns of precipitation will change. Most likely for Wisconsin is that we will see slight increases in precipitation, and that more of this will come in large (say > 2” in 24 hours) storms. There seems little reason to think that droughts like 2012 or 1988 will become more common in the state over the coming decades (IPCC 2012).

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[1] Professor, Department of Soil Science, 1525 Observatory Dr., University of Wisconsin-Madison, Madison, WI, 53706.

Climate change will affect Wisconsin agriculture and life, however. There is widespread agreement that temperatures will increase in all seasons. Perhaps most worrisome for agriculture will be summer heat extremes, experienced as heat waves that reduce crop growth, reduce cow productivity and reproduction, and stress people. For example, the maximum summer daily temperature that we experienced but once every 20 years in recent decades will occur every 2-4 years by 2100 (IPCC 2012). Studies of Wisconsin crop yields have revealed that exceptionally hot summer temperatures depress corn and soybean yields. For 1976 to 2006, climate change reduced the technologically-driven increase in yields by 5-10%. As temperatures like that of 2012 and higher become more common in coming decades, the positive benefits of longer growing seasons and more precipitation may not be enough to prevent reductions in yield (WICCI 2011). Beyond Wisconsin the effects of higher temperature will combine with decreased rainfall to more dramatically impact grain yields (World Bank 2012).

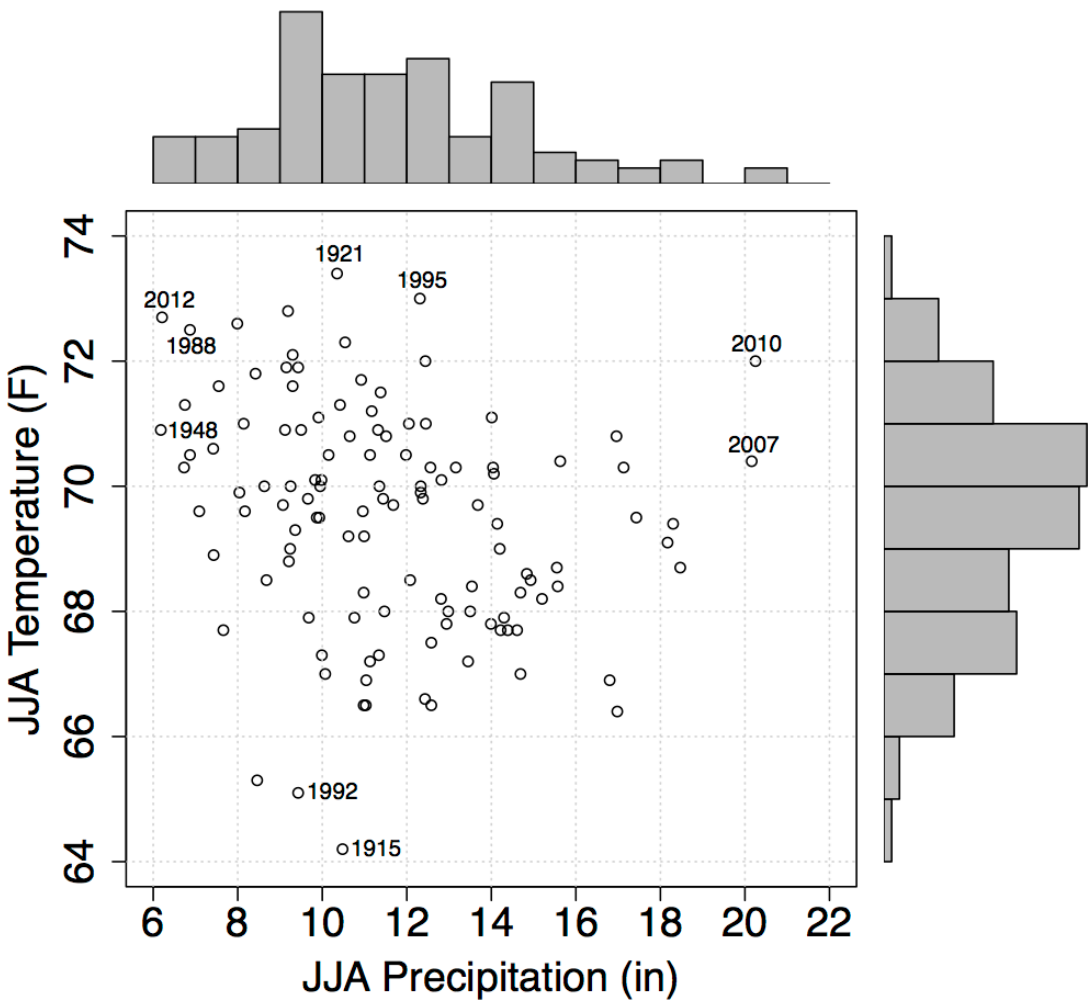

Figure 1. Summer (June-July-August) average air temperature and precipitation for Wisconsin climate district 8, 1895-2012.

References

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MANAGING NUTRIENTS AFTER A DROUGHT

Carrie A.M. Laboski[1]

Introduction

There is a strong possibility that there will excess (carryover or residual) N in the soil profile after the 2012 corn crop is harvested because the corn was too affected by drought to use all of the applied N. If soybean is the previous crop, there is a low likelihood of excess N remaining in the soil profile. Regardless of previous crop, some of the P and K applied last year will be available for the 2013 crop if the field was impacted by drought.

Nitrogen

Profitability of the 2013 crop may be improved by adjusting N application rates on fields where there is residual nitrate left over from the 2012 crop. Situations where there may be residual nitrate in drought impacted fields include: corn grown in 2012, manure applied after 2011 harvest, 2011 crop was a forage legume, and if fall and winter precipitation is below normal. Residual nitrate is not likely where the 2012 crop was soybean.

To adjust corn N applications in 2013 in fields where residual nitrate is likely, a preplant nitrate test (PPNT) can be taken prior to planting corn in the spring. The PPNT value should then be subtracted from the top end of the corn MRTN rate guidelines. For more information on the PPNT consult UWEX Publication A2809 *Nutrient application rates for field, vegetable, and fruit crops in Wisconsin*. Where a PPNT is not taken, but residual nitrate is expected, growers can adjust corn N rates by using the low end of the corn MRTN range. Another method that can be used to adjust 2013 N application rates is to take a N credit based on the formula below.

$$\text{2013 N credit} = (\text{total N applied in 2012} - \text{2012 yield in bu/a}) \div 2$$

The decision to adjust 2013 N application rates should be based on the potential for residual N. In an effort to assess residual soil nitrate following the 2012 corn crop, a soil nitrate monitoring network was developed. Soil samples were collected from 0 to 1, 1 to 2, and in some cases, 2 to 3 feet deep in fields throughout the state after corn was harvested and after adequate rainfall occurred to allow sampling with depth. Table 1 provides a summary of residual nitrate amounts and field history. The amount of nitrate remaining in the soil profile is highly variable. For a spring PPNT, a background of 50 lb N/a is normal. Thus profile nitrate concentrations greater than 50 lb/a represent amounts of N that could potentially be credited to the 2013 crop. Coarser textured soils typically had lower amounts of residual N. Fields with higher N application rates and/or manure application tended to have higher residual N. These results suggest that growers should strongly consider taking soil samples for PPNT in the spring to adjust N applications to improve profitability.

Soil samples will also be collected from these fields in spring 2013. Information collected by the soil nitrate monitoring network can be found at: http://uwlab.soils.wisc.edu/soilnitratemonitoring/

[1] Associate Professor, Dept. of Soil Science, 1525 Observatory Dr., Univ. of Wisconsin-Madison, Madison, WI 53706.

Phosphorus and Potassium

In some fields, it is likely that not all of the P and K fertilizer applied this past spring was used by the 2012 crop and will be available for the 2013 crop. Thus, recommended P and K applications may be reduced. Take credit for unused P and K using the following formula.

Nutrient credit =

2012 fertilizer applied – {2012 fertilizer applied x (yield achieved ÷ expected yield)}

Example K_2O credit:

- The expected corn yield used to determine 2012 fertilizer application rates was 200 bu/a
- The actual corn yield was 120 bu/a
- The K fertilizer application rate was 250 lb K_2O/a
- K_2O credit = 250 – {250 x (120 ÷ 200)} = 100 lb K_2O/a

Issues with Fall 2012 Soil Sampling

Agronomists and growers have some concern about the effects of drought on soil test results. Sampling very dry soil may provide erroneous soil test results for several reasons:

1. It is difficult to sample to the desired depth consistently.
2. The soil core does not stay intact, particularly very dry surface soil, and some of the soil is lost between taking the probe out of the ground and placing the sample in the bucket.
3. Soil test P and K may be lower with smaller differences for P and larger differences for K.
4. pH may be slightly lower because of salt build up with lack of rain.

Once rainfall has occurred, soils will begin to re-equilibrate and the effects of dry conditions on soil test P, K and pH will diminish. It is hard to provide an exact amount of rainfall that is needed to alleviate the effects of dry conditions on soil test results because it depends upon how dry the soil was, soil mineralogy, and likely other site specific conditions. However, if the soil is moist enough to push a probe into the ground to the desired sampling depth consistently, it is likely that the soil has re-equilibrated. Given all of the above, soil test results, particularly K, might be different than expected.

Summary

There is a possibility for excess nitrate to carryover into spring. Consider adjusting N application rates using a preplant nitrate test (PPNT) for corn if growing corn in 2013 and the 2012 crop was corn. In addition, consider moisture levels in the soil profile and the long-range precipitation outlook before selecting a N fertilizer rate. If soil moisture levels are low and less than average precipitation is predicted, consider using lower N application rates because lack of water will impact the corn yield more than somewhat lower N application rates.

If 2012 yield levels were substantially different than expected at planting, consider taking P & K credits. If fall 2012 soil test results are quite different than expected, consider sampling again in spring to make adjustments for 2013 or next fall to better plan for 2014.

Acknowledgments

Many thanks to the following people for assisting with soil sampling and collecting field history: Todd Andraski, Ted Bay, Jerry Clark, Don Genrick, Richard Halpoka, Max Hart, Ken Hubbard, Kevin Klingberg, Geroge Koepp, Dan Marzu, Kim Meyer, Steve Okonek, Richard Proost, Nick Schneider, Laura Schulz, Kevin Shelley, Trisha Wagner. Appreciation is also extended to Bonner Karger and the UW Soil & Forage Analysis Lab.

References

Laboski, C.A.M., and J.B. Peters. 2012. Nutrient application guidelines for field, vegetable, and fruit crops in Wisconsin. UWEX Publication A2809. p 88.

Table 1. Field information and amount of nitrates in the soil profile at various locations in Wisconsin after corn harvest in 2012.

Location ID	4	5	26	27	60	58	59	9
Town	Coloma	Grand Marsh	Strongs Prairie	Strongs Prairie	Delmar	Wheaton	Wheaton	Dorchester
County	Adams	Adams	Adams	Adams	Chippewa	Chippewa	Chippewa	Clark
Soil Series	Billett	Richford	Delton	Plainfield	Withee	Seaton	Meridian	Withee
Surface texture	sandy loam	loamy sand	sand	sand	silt loam	silt loam	loam	silt loam
2012 Corn Yield, bu/a	236	268	105	35	180	190	97	115
Total Fertilizer N rate applied, lb N/a	216	209	182	136	0	0	163	115
Manure applied	None	None	None	None	Dairy	Dairy	None	None
Rate of Manure	.	.	.	.	12000 gal/a	15 T/a	.	.
Precipitation†	22.6	25.8	.	.	15.4	15.4	15.4	19.25
Irrigation	11.6	12.7	.	.	.	.	.	.
Fall Sampling Date	11/16/12	11/16/12	11/1/12	11/1/12	11/19/12	11/19/12	11/19/12	11/1/12
Soil Nitrate								68
0-1', lb N/a	0	2	12.4	9.2	40.8	44.4	24.4	35.2
1-2', lb N/a	15	0	24.8	7.2	22	22.4	8.8	.
2-3', lb N/a	3	2	.	.	.	.	.	103
0-2', lb N/a	15	2	37	16	63	67	33	.
0-3', lb N/a	18	3	.	.	.	.	.	9

Continued on next page.

† Amount of precipitation from the time soil thawed in spring until the fall soil sampling.

Table 1 (continued). Field information and amount of nitrates in the soil profile at various locations in Wisconsin after corn harvest in 2012.

Location ID	7	8	1	53	54	46	66	37
Town	Neillsville	Owen	Arlington	Arlington	Lewiston	Portage	Steuben	Cottage Grove
County	Clark	Clark	Columbia	Columbia	Columbia	Columbia	Crawford	Dane
Soil Series	Loyal	Withee	Plano	Plano	Yahara	Ossian	.	Plano
Surface texture	silt loam	silt loam	silt loam	silt loam	fine sandy loam	silt loam	.	silt loam
2012 Corn Yield, bu/a	160	150	133	168	135	150	.	198
Total Fertilizer N rate applied, lb N/a	165	136	209	166	144	96	.	140
Manure applied	None	None	None	None	None	Beef	.	None
Rate of Manure	.	.	.	.	.	20 T/a	.	.
Precipitation†	23.25	21.25	19.5	21.5	21.5	20.5	.	19
Irrigation	.	.	.	.	.	.	.	.
Fall Sampling Date	11/1/12	11/1/12	11/13/12	11/14/12	11/14/12	11/1/12	11/23/12	11/18/12
Soil Nitrate								
0-1', lb N/a	15.6	95.2	83	23.2	28.8	169.6	33.6	58.4
1-2', lb N/a	3.2	50.4	86	26.4	27.6	34.8	18.4	64
2-3', lb N/a	.	.	5	.	.	.	7.6	.
0-2', lb N/a	19	146	169	50	56	204	52	122
0-3', lb N/a	.	.	174	.	.	.	60	.

† Amount of precipitation from the time soil thawed in spring until the fall soil sampling.

Continued on next page.

Table 1 (continued). Field information and amount of nitrates in the soil profile at various locations in Wisconsin after corn harvest in 2012.

Location ID	38	55	2	3	57	34	33	61
Town	Cottage Grove	Roxbury	Sun Prairie	Waterloo	Clear Creek	Fairchild	Otter Creek	Lancaster
County	Dane	Dane	Dane	Dodge	Eau Claire	Eau Claire	Eau Claire	Grant
Soil Series	Salter	Seaton	Ringwood	Pella	Eleva	Seaton	Arenzville	.
Surface texture	silt loam	silt loam	silt loam	silty clay loam	Sandy loam	Silt loam	Silt loam	.
2012 Corn Yield, bu/a	135	4 T DM/a	96	184	80	135	202	.
Total Fertilizer N rate applied, lb N/a	170	163	200	205	70	128	92	.
Manure applied	None	None	None	None	None	None	Dairy	.
Rate of Manure	.	.	.	.	.	.	5000 gal/a	.
Precipitation†	19	11.6	21.3	21.3	15.4	15.4	15.4	.
Irrigation	.	.	.	.	.	.	.	.
Fall Sampling Date	11/18/12	11/18/12	11/13/12	11/13/12	11/14/12	11/14/12	11/14/12	11/16/12
Soil Nitrate								
0-1', lb N/a	48	65.6	17	148	43.6	9.6	28.8	31.6
1-2', lb N/a	56	52.8	128	74	21.6	0.4	16.4	5.6
2-3', lb N/a	.	.	40	20	.	.	.	.
0-2', lb N/a	104	118	144	221	65	10	45	37
0-3', lb N/a	.	.	184	242	.	.	.	.

Continued on next page.

† Amount of precipitation from the time soil thawed in spring until the fall soil sampling.

Table 1 (continued). Field information and amount of nitrates in the soil profile at various locations in Wisconsin after corn harvest in 2012.

Location ID	28	56	11	10	12	64	65	62
Town	Marquette	Moscow	Black River Falls	Hixton	Melrose	Darlington	Darlington	Shullsburg
County	Green Lake	Iowa	Jackson	Jackson	Jackson	Lafayette	Lafayette	Lafayette
Soil Series	Granky	Richwood	Sebbo	Merit	Seaton	.	.	.
Surface texture	loamy fine sand	silt loam	loam	silt loam	silt loam	.	.	.
2012 Corn Yield, bu/a	12 T/a	70	125	130	200	.	.	.
Total Fertilizer N rate applied, lb N/a	18	177	138	.	164	.	.	.
Manure applied	Dairy	None	None	None	None	.	.	.
Rate of Manure	45 T/a	.	.	.	.	.	.	.
Precipitation†	.	14.5	22.59	22.59	22.59	.	.	.
Irrigation	.	.	.	.	.	.	.	.
Fall Sampling Date	11/6/12	11/20/12	10/30/12	10/25/12	11/2/12	11/20/12	11/20/12	11/20/12
Soil Nitrate								
0-1', lb N/a	32.8	71.2	47.6	46	30	24	33.2	46.4
1-2', lb N/a	17.6	79.6	9.6	53.6	58	5.6	14.4	25.2
2-3', lb N/a	.	.	.	.	.	0	0.8	2.8
0-2', lb N/a	50	151	57	100	88	30	48	72
0-3', lb N/a	.	.	.	.	.	30	48	74

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† Amount of precipitation from the time soil thawed in spring until the fall soil sampling.

Table 1 (continued). Field information and amount of nitrates in the soil profile at various locations in Wisconsin after corn harvest in 2012.

Location ID	63	17	16	18	20	19	36	35
Town	Shullsburg	Gleason	Merrill	Abbots-ford	Birnam-wood	Mosinee	Durand	Pepin
County	Lafayette	Lincoln	Lincoln	Marathon	Marathon	Marathon	Pepin	Pepin
Soil Series	.	Padus	Magroc	Loyal	Kennan	Mosinee	Dramen	Bear Pen
Surface texture	.	loam	silt loam	silt loam	sandy loam	sandy loam	loamy sand	silt loam
2012 Corn Yield, bu/a	.	.	150	.	15 T DM/a	.	60	220
Total Fertilizer N rate applied, lb N/a	.	45	3	.	.	95	122	180
Manure applied	.	Paper Mill Fiber Cake	Liquid	.	Liquid	.	None	None
Rate of Manure	.	unknown	5200 gal/a	.	6000 gal/a	.	.	.
Precipitation†	.	20	18	18	16	16	20	20
Irrigation	.	.	.	.	.	.	.	.
Fall Sampling Date	11/20/12	10/5/12	10/5/12	10/17/12	10/18/12	10/18/12	10/29/12	10/29/12
Soil Nitrate								
0-1', lb N/a	19.6	64	47.6	162.8	4.8	14.8	39.2	49.2
1-2', lb N/a	7.6	68.4	31.2	162.4	4.8	37.6	18.8	7.2
2-3', lb N/a	0.8	.	.	.	.	.	.	.
0-2', lb N/a	27	132	79	325	10	52	58	56
0-3', lb N/a	28	.	.	.	.	.	.	.

Continued on next page.

† Amount of precipitation from the time soil thawed in spring until the fall soil sampling.

Table 1 (continued). Field information and amount of nitrates in the soil profile at various locations in Wisconsin after corn harvest in 2012.

Location ID	24	45	44	40	41	39	52	47-A
Town	Amherst	Emerald	Erin Prairie	Arcadia	Eleva	Galesville	Kewaskum	West Bend
County	Portage	St. Croix	St. Croix	Trempea-leau	Trempea-leau	Trempea-leau	Washing-ton	Washing-ton
Soil Series	Rosholt	Santiago	Sattre	Seaton	Gale	Downs	Lamartine	Mayville
Surface texture	sandy loam	silt loam	silt loam	silt loam	silt loam	silt loam	silt loam	silt loam
2012 Corn Yield, bu/a	10	8.4 T DM/a	197	140	105	170	120	123
Total Fertilizer N rate applied, lb N/a	30	0	64	0	100	111	138	112
Manure applied	Dairy	Dairy	Turkey	Broiler	None	None	None	Dairy
Rate of Manure	8000 gal/a	18000 gal/a	3 T/a	5 T/a	.	.	.	4000 gal/a
Precipitation†	.	24	28	16.6	18.5	16.6	20.3	20.3
Irrigation	.	.	.	.	.	.	.	.
Fall Sampling Date	10/26/12	11/16/12	11/16/12	10/29/12	11/21/12	10/29/12	11/13/12	11/7/12
Soil Nitrate								
0-1', lb N/a	27.6	113.6	29.2	45.2	56	15.2	51.6	42
1-2', lb N/a	52.8	123.2	14	15.6	62.8	5.2	21.6	56
2-3', lb N/a	.	.	.	.	.	.	.	.
0-2', lb N/a	80	237	43	61	119	20	73	98
0-3', lb N/a	.	.	.	.	.	.	.	.

Continued on next page.

† Amount of precipitation from the time soil thawed in spring until the fall soil sampling.

Table 1 (continued). Field information and amount of nitrates in the soil profile at various locations in Wisconsin after corn harvest in 2012.

Location ID	47-B	48	49	50	25	51	21	23
Town	West Bend	West Bend	Fremont	Fremont	Wautoma	Fremont	Cary	Hansen
County	Washing-ton	Washingt-on	Waupaca	Waupaca	Waushara	Winne-bago	Wood	Wood
Soil Series	Mayville	Theresa	Tutsin	Borth	Richfield	Nebago	Kent	Elkmound
Surface texture	silt loam	silt loam	Loamy Sand	Sandy Loam	Loamy Sand	Fine Sand	silt loam	Sandy Loam
2012 Corn Yield, bu/a	123	90	160	220	15	100	26 T/a	12 T/a
Total Fertilizer N rate applied, lb N/a	112	151	218	218	146	94	0	0
Manure applied	Dairy	Dairy	None	None	None	Dairy	Dairy	Dairy
Rate of Manure	4000 gal/a	2000 gal/a	.	.	.	20 T/a	12000 gal/a	12000 gal/a
Precipitation†	20.3	20.3	21	21	.	19	.	.
Irrigation	.	.	.	.	.	.	.	.
Fall Sampling Date	11/7/12	11/7/12	11/7/12	11/7/201	10/26/12	11/7/12	10/22/12	10/22/12
Soil Nitrate								
0-1', lb N/a	247.2	54.4	14	114	10.4	78.4	54.4	61.2
1-2', lb N/a	68.8	64.4	0	50.8	5.2	46.4	4	56
2-3', lb N/a	.	.	0	16.8	.	35.6	.	.
0-2', lb N/a	316	119	14	165	16	125	58	117
0-3', lb N/a	.	.	14	182	.	160	.	.

Continued on next page.

† Amount of precipitation from the time soil thawed in spring until the fall soil sampling.

Table 1 (continued). Field information and amount of nitrates in the soil profile at various locations in Wisconsin after corn harvest in 2012.

Location ID	6	22
Town	Marshfield	Richfield
County	Wood	Wood
Soil Series	Withee	Hiles
Surface texture	silt loam	silt loam
2012 Corn Yield, bu/a	157	51 T/a
Total Fertilizer N rate applied, lb N/a	159	165
Manure applied	None	None
Rate of Manure	.	.
Precipitation†	23.8	.
Irrigation	.	.
Fall Sampling Date	11/16/12	10/22/12
Soil Nitrate		
0-1', lb N/a	19	134
1-2', lb N/a	15	34
2-3', lb N/a	3	.
0-2', lb N/a	34	168
0-3', lb N/a	36	.

† Amount of precipitation from the time soil thawed in spring until the fall soil sampling.

HERBICIDE CARRYOVER AFTER A DROUGHT: THINGS TO CONSIDER AND WHAT TO EXPECT

Scott Senseman [1/]

{This page provided for note taking}

[1/] Professor, Texas A&M University, College Station, TX.

WORKING WITH CUSTOM MANURE APPLICATORS TO IMPROVE NUTRIENT MANAGEMENT PLAN IMPLEMENTATION AND QUALITY

Kevin Erb, Brent Cook, Dave Eisentraut, and Chad Tasch [1/]

The dairy industry in Wisconsin produces the equivalent of 12 Billion gallons of liquid dairy manure annually. That's enough to cover Lambeau field (including the endzones) to a depth of just over 5 miles. Wisconsin's 134 for-hire manure applicators apply ~ 6 billion gallons of liquid manure and ~800,000 tons annually. This is a 50% increase in liquid manure application by for-hire applicators since 2006, and >300% increase in solid manure handling.

Management of solid manure has become a much larger part of the industry, with the number of solid spreaders in operation nearing 100 in 2012, compared to less than 30 six years ago. Other areas where the industry has added significant capacity in the same timeframe includes >140 semis for long-distance manure transport and the recent innovation of floating boats for storage agitation.

Given the volume of manure applied and handled by the custom manure applicators, they are the critical partners in implementing the nutrient management plans developed both by professionals and by farmers. Yet less than one of every three farmers served by a custom manure applicator (30.6%) are showing that applicator their Nutrient Management Plan (NMP), according to the every 5 year survey of the industry conducted in late 2011 by UW Extension, in partnership with the Professional Nutrient Applicators Association of Wisconsin (PNAAW). This is an increase over 2001, when 22% of their clients were sharing a NMP with the applicator.

The survey also showed that 72.8% of the manure applied (4.3 billion gallons/560,000 tons) was spread in accordance with the written plan presented to the applicator, and that the industry injects or incorporates 51.5% of the manure they apply. The farmer or their agronomist makes 79% of the rate decisions, while the farmer asks the applicator for a rate recommendation only 15% of the time. Survey respondents noted that only 2.9% of their annual volume is applied to either frozen or snow covered ground.

In terms of rates, 54% of fields receive between 6,000 and 12,000 gallons/acre, while 8% receive more than 16,000 gallons/acre. Interestingly, the percentages in all categories are very similar to where they were in 2001.

[1/] Conservation Professional Development and Training Coordinator, Univ. of Wisconsin-Extension, Green Bay, WI; Co-owner, Cook's Countryside Trucking, North Freedom, WI; Owner, Eisentraut Ag Services, Waldo, WI; Owner, Tasch Custom LLC, Malone, WI.

When asked in the same survey what nutrient management plan writers could do to make the task of implementing the plan easier, several themes emerged:

- Communication: Put your cell phone number on the pages of the plan I get, send me the plan before the hauling season starts. Better yet, talk to me when developing the plan.
- Maps: Keep them simple, consistent—rate, field id and setbacks, tell customers to show them to me!
- Field Planning: With the farmer, plan an early harvested crop in a field that needs manure so we have somewhere to go very early in fall. Plan applications in the same direction – not one field south, one north and the other 3 miles east.

When asked what farmers could do to make their job easier, several similar areas were identified, including:

- Have everything ready to go when we arrive – the plan, the pit, and the tractors, but especially the maps.
- Plan crop rotations to allow for off-peak application
- Don't pre-work the entire field
- Have a back-up plan if some fields are too wet to spread in

Many of the medium and larger sized farms in the state are now inviting their manure applicator to the planning/strategy sessions with the agronomists, nutritionists and other key farm advisors to feed needs/quality, crop rotation, neighbor concerns and manure application. This type of approach pays large dividends, as problems later in the year can be avoided if the farm's advisors are all working from the same playbook.

Keeping in mind the following facts and suggestions will make the nutrient management implementation process easier for the farmer, the crop consultant and the custom applicator.

1. **A single sheet and a map**: Provide each of your clients with multiple copies of a summary sheet that lists ONLY the fields to receive manure, acreage, manure rate, and if incorporation/injection is included as part of the nutrient management plan. A map showing the entire farm with those fields highlighted makes the applicator's job easier. The CCA should also put their phone number on the field listing so that if the applicator needs clarification, he can do it quickly and effectively.

2. **Maps and Marking:** A sign at each field entrance with the field name helps eliminate errors. Many applicators now have GPS, and may be able to preload your maps or provide you with as-applied data files.

3. **Go north in odd-numbered years.** Well, not really. But if you can group fields by location (north this year, west next year), it may reduce costs by eliminating the down time of tearing down and setting up equipment. Consider as well the equipment – semis dumping into transfer stations usually dump only on the right, so think about the routing of equipment and what equipment will be used.

4. **The rule of 2's**: Do not plan a unique rate for each field. If you can group fields by rate (high fields at 15,000 gal/acre, low rate fields at 9,000 gal/acre), mistakes are less likely to happen. Larger farms may have 3 rates.

5. **How low can you go?** Call the farmer's manure applicator in the dead of winter. Find out not only what rates they prefer to use, but also what is the lowest they normally go and how low they actually can apply. It does no good to recommend 4,000 gallons/acre if their equipment can't go below 8,000. Lower rates increase wear and tear and take longer, so they will drive the cost up for the farmer.

6. **Remember the road:** Those low phosphorus fields are prime targets for manure. But if the tanker can't get there easily (low weight limit bridge, field access through neighbor's yard), hold that field until a year when a dragline is available.

7. **A manure sample in the bottle is worth two on the dashboard**. Find out from your client when the applicator is pumping. Make sure a sample is taken, or better yet, do it yourself. A sample taken from the dragline after it's being wound up at the end of the job is worse than no sample at all.

8. **Use the off season:** Manure applicators are available during the summer, and making an application before hay or winter wheat can buy your clients much needed fall flexibility, esp. in wet falls. This means thinking about the crops and crop rotation (topdressing alfalfa, adding wheat into the rotation, etc.)

9. **Encourage your client to hire a certified applicator.** A trained applicator is more likely to understand the regulations and helps insure that the 590 is implemented more effectively. More than half of Wisconsin's applicators are trained, tested and certified by their professional organization.

10. **Consider a partnership**. Many manure applicators are looking for qualified drivers in the fall season. Creating an employee sharing arrangement with a local manure applicator may help you keep some of your more valued pesticide applicators by providing off-season employment.

More information is available at the PNAAW website at http://fyi.uwex.edu/wimanuremgt/about/

DAIRY MANURE APPLICATION METHODS: N CREDITS, GASEOUS N LOSSES, AND CORN YIELD

Carrie A.M. Laboski[1], William Jokela[2], and T.W. Andraski[3]

Introduction

Ammonia (NH_3) nitrogen (N) losses from surface-applied manure can be large, reducing the amount of N available to the crop and, therefore, the economic value as a fertilizer N credit. Ammonia emission into the atmosphere can also contribute to environmental problems. Ammonia emission can contribute to eutrophication of surface waters (especially marine and estuarine) via atmospheric deposition. The decreased amount of available N in manure reduces the N:P ratio and leads to a more rapid build-up of P in the soil for a given amount available N. And ammonia in the atmosphere can combine with fine particulates to lower air quality.

The most common approach to controlling ammonia volatilization from manure is to incorporate it into the soil with tillage or subsurface injection. Losses can be reduced by 50 to over 90% compared to surface application (Thompson and Meisinger, 2002; Powell et al., 2011). Timing of manure application can also affect N losses and availability to the crop. Injecting into a growing corn crop at sidedress time offers another window of time for manure application, allows use of the pre-sidedress nitrate test to adjust rates, and can be an effective way to meet corn N needs (Ball-Coelho et al., 2006). While ammonia has been shown to be the greatest volatile N loss from applied manure in most situations, nitrous oxide (N_2O) is another form of gaseous N loss. While amounts lost are often too small to be of economic importance, even low emissions can contribute to the greenhouse effect because N_2O is about 300 times as potent as carbon dioxide in its effect on global warming (USEPA, 2010).

We carried out a 4-year field experiment to evaluate the effect of dairy manure application method and timing and time of incorporation on a) corn yield, b) fertilizer N credits, c) ammonia losses, and) nitrous oxide emissions.

Methods

This field research was conducted at the UW Agricultural Research Station in Marshfield, WI on fields where the previous crop was corn. To avoid residual manure N effects a new site was selected each year, but all sites were predominantly Withee silt loam (Aquic glossudalf), a somewhat poorly drained soil with 0 to 2% slope. The Withee silt loam is considered a medium yield potential soil because productivity is limited by heat units. Soil test P (average 47 ppm) and K (average 133 ppm) levels were interpreted as excessively high for P and high for K based on

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[1] Associate Professor, Dept. of Soil Science, 1525 Observatory Dr., Univ. of Wisconsin-Madison, Madison, WI 53706
[2]Research Soil Scientist, USDA-ARS, Dairy Forage Research Center-IEIDM, 8396 Yellowstone Dr., Marshfield, WI 54449.
[3]Researcher, Dept. of Soil Science, 1525 Observatory Dr., Univ. of Wisconsin-Madison, Madison, WI 53706

the Wisconsin nutrient guidelines (Laboski and Peters, 2012). Soil pH and organic matter values averaged 6.7 and 3.0%, respectively.

Dairy manure was applied either at pre-plant (mid- to late May) or sidedress time (5-6-leaf stage). Pre-plant treatments were either injected or incorporated with a tandem disk immediately after manure application (< 1 hour), 1-day later, or 3 days later. Injection was with an S-tine (KongsgildeVibro-flex) injector with 15-inch spacing at a 4- to 6-inch depth (Figure 1). All plots were chisel plowed 3 to 5 days after application. Sidedress manure applications were either injected with an S-tine injector (30-inch spacing) equipped with shields or surface applied (2010-2012) (Fig. 1). Fertilizer N was applied at pre-plant at rates of 0, 40, 80, 120, 160, and 200 lb/acre as urea and incorporated with a disk. Each treatment was replicated four times in a randomized complete block design. Ammonia and N_2O measurements were made in three of the replications in 2009 to 2011. Plot size was 15 by 50 feet.

Liquid dairy manure was applied at a target rate of 6,500 gal/acre, a rate designed to supply less than optimum N so as to be more sensitive to application method differences. Manure averaged 14% solids and 158 lb total N and 62 lb/acre NH_4-N per 1000 gallons (for 2009 to 2011, the years ammonia N was measured) but varied across years and application times (Table 1). The amount of total N and ammonium N applied in each year with each application timing is provided in Table 1.

Ammonia emission was measured following pre-plant (injection, immediate and 3-day disk incorporation) and sidedress (injection and, in 2011 only, surface) manure applications in the first three years of the study (2009-2011). We used the dynamic chamber/equilibrium concentration technique (Svensson, 1994; Misselbrook and Hansen, 2001) with two 12 by 15-inch chambers and an ambient meter per plot. Measurement started immediately after manure application and continued for six separate periods through the third day. Ammonia measurement ended just before disking of the 3-day incorporation treatment, so the 3-day treatment represents surface-applied manure.

Nitrous oxide (N_2O) was measured using the static, vented chamber technique following the GRACEnet protocol (Parkin and Venterea, 2010). Measurement began two days after pre-plant manure application and continued approximately weekly (more frequently after manure or rain, less frequently late in the season) into October. Each measurement consisted of removal of three gas samples from each chamber with a syringe over a 60-minute period for later analysis in the lab.

Corn (P38N88; 92-day RM; HX, LL, RR2) was planted in May in 30-inch rows at 35,000 seeds/acre with 100 lb/a of 9-11-30-6S-1Zn starter fertilizer in a 2 x 2 configuration. Conventional herbicides were used to control weeds. Corn biomass (silage) yield was determined by hand harvesting six plants at physiological maturity. Corn grain yield was determined by harvesting all ears from the middle two rows from each plot using a plot combine in late October or early November. Corn grain yields are reported 15.5% moisture.

All yield data were analyzed using PROC MIXED for the appropriate experimental design (SAS Institute, 2002). Significant mean treatment differences were evaluated using Fisher's protected LSD test at the 0.10 probability level. Plateau N rate (PNR) and the economic optimum N rate (EONR) were determined for both silage and grain yield using regression analysis (PROC REG or PROC NLIN).

Results and Discussion

Ammonia losses and nitrous oxide emissions

The 3-year average ammonia emission rate from surface applied (3-day incorporation) manure was relatively high immediately following application but declined rapidly after the first several hours to quite low levels (Figure 2A). This pattern is similar to those observed in other studies in Wisconsin (Powel et al., 2011), Pennsylvania (Dell et al., 2012), Maryland (Thompson and Meisinger, 2004), and Vermont (Jokela and Meisinger, 2008). [Measurement of ammonia emission from surface-applied manure at sidedress time (2011 only; not shown) showed losses similar to those from pre-plant surface-applied manure.] Ammonia emission was greatly reduced by prompt incorporation by disking or injection. Cumulative NH_3 loss over the full measurement period was over 40 lb/acre from surface application but was reduced by 75% by immediate disking and over 90% by injection (Figure 2B). Ammonia losses varied somewhat by year, but patterns over time and reductions by incorporation were similar. The pattern of ammonia loss, 75% of the total loss in the first 6 to 8 hours, emphasizes the importance of prompt incorporation to reduce losses and conserve N for crop use.

Nitrous oxide (N_2O) flux was quite low for most manure treatments during most of the May to October period in both years (Figure 3). However, some increase in N_2O flux occurred after the 2010 pre-plant application, and there were pronounced peaks of N_2O emission from the injection treatment at either pre-plant (2010) or sidedress (2011) time. A smaller increase following the pre-plant application in 2011, greater from injection, can also be observed from the expanded scale shown in Figure 3C. The greater emission from injection compared to other treatments can be explained by examining the process that causes N_2O flux. Nitrous oxide is produced by denitrification, a microbial process that is facilitated by anaerobic (lacking in oxygen) conditions. Also, typical of most microbial activity, it is enhanced by a readily available carbon energy source and by warm temperatures. Injection of liquid manure places manure in a relatively concentrated band below the surface, creating anaerobic conditions (because of water from manure and the lack of exposure to the atmosphere) and providing available carbon from manure. Reasons for the difference between 2010 and 2011 are not readily obvious, but it is probably a result of different soil moisture and temperature conditions. A 5-inch rainfall event shortly after the 2011 sidedressed manure application increased soil moisture content (data not shown) and likely created optimum conditions for denitrification at that time.

Based on these results, injection of liquid dairy manure resulted in opposite effects on NH_3 and N_2O emission, suggesting a trade-off between the two gaseous N loss pathways. However, the total annual N losses from N_2O emissions (1 lb/acre or less; Figure 4) were only a fraction of those by ammonia volatilization, so under the conditions of this study N_2O emission is not an economically important loss. As noted earlier, however, N_2O is a potent greenhouse gas, so even small amounts can contribute to the potential for global climate change. The dramatic reduction in NH_3 loss from injection, though, may at least partially balance out the increased N_2O because 1% of volatilized N is assumed to be converted to N_2O (IPCC, 2010).

Immediate disk incorporation was almost as effective as injection for controlling NH_3 loss, and on average resulted in less N_2O emission than injection. A drawback is that it requires another field operation, and to be effective it must be done promptly after manure application. A possible alternative is to use sweep injectors or other direct incorporation methods that deposit manure over a larger volume of soil and/or create more mixing with soil, thus creating conditions less conducive to denitrification and N_2O loss.

Corn yield and manure N credits

In each year, agronomic optimum N rate (AONR, the N rate where yield was maximized) and the economic optimum N rate (EONR, 0.10 N:corn price ratio for grain and 0.005 N:corn price ratio for silage) were determined for both grain and silage (Tables 2 and 3). The AONR for grain ranged from 94 to 182lb N/a while the EONR ranged from 94 to 149 lb N/a. For silage, AONR ranged from 92 to 195 lb N/a and EONR ranged from 92 to 124 lb N/a. In 2010, 2011, and 2012 for both grain and silage, the EONR and AONR were identical because a linear plateau model was the best fit for the N response data.

Manure application timing and method/time to incorporation significantly affected grain yield in 2009, 2010, and 2012 (Table 4) and silage yield in 2012 (Table 5). Preplant injection produced greater yields than one or more of the broadcast treatments in 2009 (grain) and 2012 (grain and silage). Sidedress injected manure produced yields that were not significantly different than preplant injected manure except for grain yield in 2010, perhaps because of differences in manure N applied. Manure that was broadcast prior to planting and incorporated after 3 days had yields that were not significantly different from manure incorporated within 1 hour or 1 day. One might expect that yield would be lower as time to incorporation increased because ammonia loss was greater where manure was not incorporated for 3 days (Figure 2). An explanation may be that the difference in NH_3 loss was not great enough to be reflected in yield differences. At sidedress, injecting manure resulted in greater yield compared to surface banding without incorporation though the results were only significant in 2012.

The N fertilizer equivalence value (NFEV) of manure at each timing and method/time to incorporation was calculated by inputting the yield achieved in each treatment to the N response function fitted to the urea yield data. The NFEV in lb/a are provided in Table 6 and appear to be quite variable with year. However, it is important to remember that the total N application rate applied varied for each time manure was applied. Thus, the NFEV was normalized by dividing it by the total amount of manure N applied, resulting in a percent of total N applied that was available to the crop (Table 7). Annually the manure N availability varied within a treatment. The four year average N availability for each treatment is also given in Table 7. Injecting manure resulted in 51 and 53 % of total N applied being available for the preplant and sidedress treatments respectively. Preplant broadcasting with incorporation within 1 hour or 1 day of application resulted in 36 and 37 %, respectively, of total N being available. Thirty-four percent of manure N was available when broadcast prior to planting and incorporated after 3 days; while 32% was available when surface banded (no incorporation) at sidedressing. When expressed as a percent of total N applied, in general N availability decreased as time to incorporation increased which reflects the amount of ammonia lost in these treatments (Figure 2).

Conclusions

Ammonia volatilization losses increase as the time to incorporation of manure increases. Injection of manure results in the lowest amount of ammonia volatilization but the higher N_2O emissions. In this study, reducing the large ammonia losses by injection provided more environmental benefit compared to the small increase in N_2O emissions. In addition to environmental benefits, injection or immediate incorporation of manure resulted on average in a greater percentage of total manure N applied being available to corn. This means that a smaller amount of commercial fertilizer N would need to be supplied to maximize yield resulting in greater profitability and a smaller carbon footprint.

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Table 1. Manure dry matter (solids), total N, and ammonium-N concentration and the total application rate applied preplant and sidedress at 6500 gal/acre at Marshfield, 2009 to 2012.

Year	Time of application	Concentration			Total application rate	
		Dry matter	Total N	NH_4-N	Total N	NH_4-N
		--------------------- % --------------------- -			----------- lb/a -----------	
2009	Preplant	17	1.9	0.74	185	74
	Sidedress	12	4.6	1.99	293	127
2010	Preplant	24	1.3	0.47	171	61
	Sidedress	13	1.5	0.54	107	38
2011	Preplant	13	1.5	0.58	107	40
	Sidedress	16	1.0	0.38	86	32
2012	Preplant	8	2.9	1.23	121	51
	Sidedress	5	3.3	1.37	96	40

Table 2. Effect of N rate (preplant urea incorporated) on corn grain yield at Marshfield, 2009 to 2012.

N rate	Grain yield			
	2009	2010	2011	2012
lb/a	------------------------------------ bu/a ------------------------------------			
0	120	89	88	143
40	139	85	108	164
80	144	121	136	186
120	145	151	150	186
160	155	157	152	197
200	151	154	157	183
AONR: †				
N rate, lb/a	182	149	133	94
Yield, bu/a	151	156	155	189
EONR: ‡				
N rate, lb/a	126	149	133	94
Yield, bu/a	149	156	155	189

† AONR, agronomic optimum N rate. N rate where yield is maximized as determined by regression analysis including starter N (9 lb/a).
‡ EONR, economic optimum N rate at a N:corn price ratio of 0.10,determined by regression analysis including starter N (9 lb/a).

Table 3. Effect of N rate (preplant urea incorporated) on corn silage yield and the economic optimum N rate (EONR) at Marshfield, 2009 to 2012.

	Silage yield			
N rate	2009	2010	2011	2012
lb/a	ton/a			
0	5.5	4.2	4.3	10.3
40	6.4	3.9	5.0	11.3
80	6.5	5.4	6.3	12.9
120	6.6	6.6	6.9	12.6
160	7.2	6.8	6.9	13.5
200	6.9	6.7	7.1	12.6
Plateau: †				
N rate, lb/a	195	149	118	92
Yield, bu/a	7.0	6.8	7.0	12.9
EONR: ‡				
N rate, lb/a	124	149	118	92
Yield, bu/a	6.8	6.8	7.0	12.9

† AONR, agronomic optimum N rate. N rate where yield is maximized as determined by regression analysis including starter N (9 lb/a).
‡ EONR, economic optimum N rate at a N:corn price ratio of 0.0005,determined by regression analysis including starter N (9 lb/a).

Table 4. Effect of manure timing and method of application (6,500 gal/acre) on corn grain yield at Marshfield, 2009 to 2012.

		Grain yield			
Timing	Method and days to incorporation	2009	2010	2011	2012
		bu/a			
Preplant	Injected	144 ab	123 a	107	179 a
	Surface broadcast (< 1 hour)	134 bc	124 a	110	158 bc
	Surface broadcast (1 day)	133 c	122 a	112	159 bc
	Surface broadcast (3 days)	137 bc	105 ab	103	166 ab
Sidedress	Injected	147 a	98 b	114	175 a
	Surface band (no incorporation)	-	89 b	108	150 c
	p	0.09	0.07	0.75	0.02
	LSD(0.10)	10	23	NS	14

NS, not significant at the 0.10 probability level.

Table 5. Effect of manure timing and method of application (6,500 gal/acre) on corn silage yield at Marshfield, 2009 to 2012.

		Silage yield			
Timing	Method and days to incorporation	2009	2010	2011	2012
		---------------------- ton/a ----------------------			
Preplant	Injected	6.5	5.2	5.0	12.5 a
	Surface broadcast (< 1 hour)	6.0	5.5	5.3	11.1 bc
	Surface broadcast (1 day)	5.9	5.3	5.2	11.1 bc
	Surface broadcast (3 days)	6.3	4.8	4.7	11.4 b
Sidedress	Injected	6.7	4.2	5.2	11.8 ab
	Surface band (no incorporation)	-	4.0	5.0	10.4 c
	p	0.12	0.19	0.27	0.02
	LSD(0.10)	NS	NS	NS	0.9

NS, not significant at the 0.10 probability level.

Table 6. Nitrogen fertilizer equivalence value (NFEV) of manure based on corn grain yield for several timing and application methods at Marshfield, 2009 to 2012.

		NFEV†				
Timing	Method and days to incorporation	2009	2010	2011	2012	Mean‡
		----------------------- lb N/a -----------------------				
Preplant	Injected	88	90	44	76	75
	Surface broadcast (< 1 hour)	40	86	49	37	53
	Surface broadcast (1 day)	36	88	53	39	54
	Surface broadcast (3 days)	56	57	36	52	50
	Total N content of manure applied preplant:	185	171	107	121	146
Sidedress	Injected	115	45	57	69	(57)
	Surface band (no incorporation)	-	28	46	22	(32)
	Total N content of manure applied sidedress:	293	107	86	96	(96)

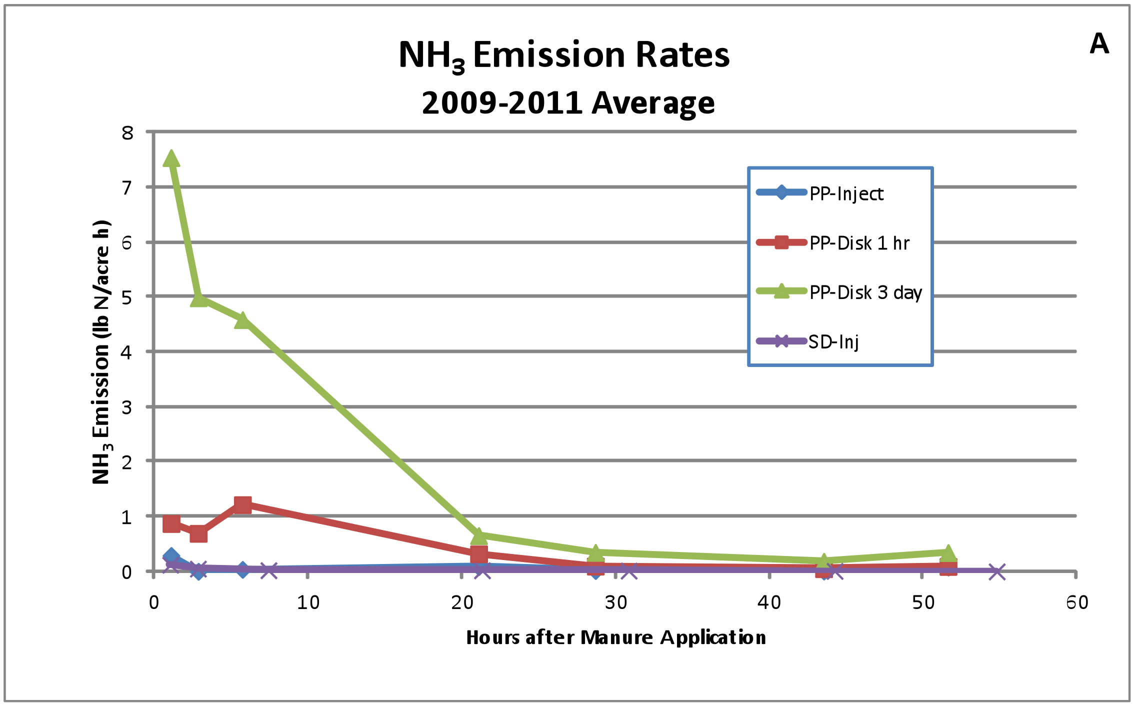
† Yield values from the manure treatments were entered into the regression model equation for the relationship between N rate (urea plus starter N rate) and grain yield. The N fertilizer rate (including starter) that would have produced the same yield as the manure treatment was determined and reported as NFEV.
‡ Numbers in parentheses are the three-year mean values from 2010 to 2012.

Table 7. First-year manure N availability to corn based on corn grain yield for several timing and application methods (6500 gal/acre) at Marshfield, 2009 to 2012.

Timing	Method and days to incorporation	Manure N availability†				
		2009	2010	2011	2012	Mean‡
		-------- % of total N applied in manure -------				
Preplant	Injected	48	53	38	63	51
	Surface broadcast (< 1 hour)	22	50	42	31	36
	Surface broadcast (1 day)	19	51	46	32	37
	Surface broadcast (3 days)	30	33	31	43	34
Sidedress	Injected	39	42	60	72	53 (58)
	Surface band (no incorporation)	-	26	48	23	(32)

† Manure N availability = (NFEV / total N rate applied in manure and starter) x 100.
‡ Numbers in parentheses are the three-year mean values from 2010 to 2012.

Figure 1. Injection equipment used for pre-plant application (top) and sidedress application (bottom) of liquid dairy manure.



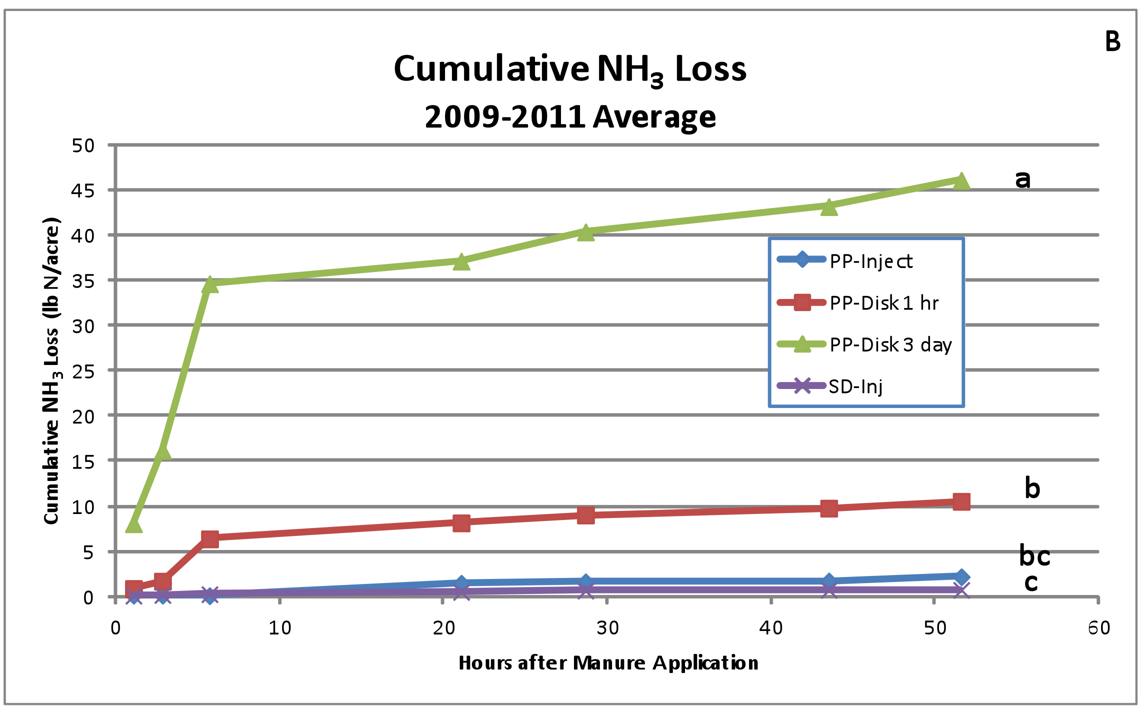


Figure 2. Average (2009-2011) ammonia emission rates (top) and cumulative NH_3-N losses (bottom) as affected by method and timing of manure application.

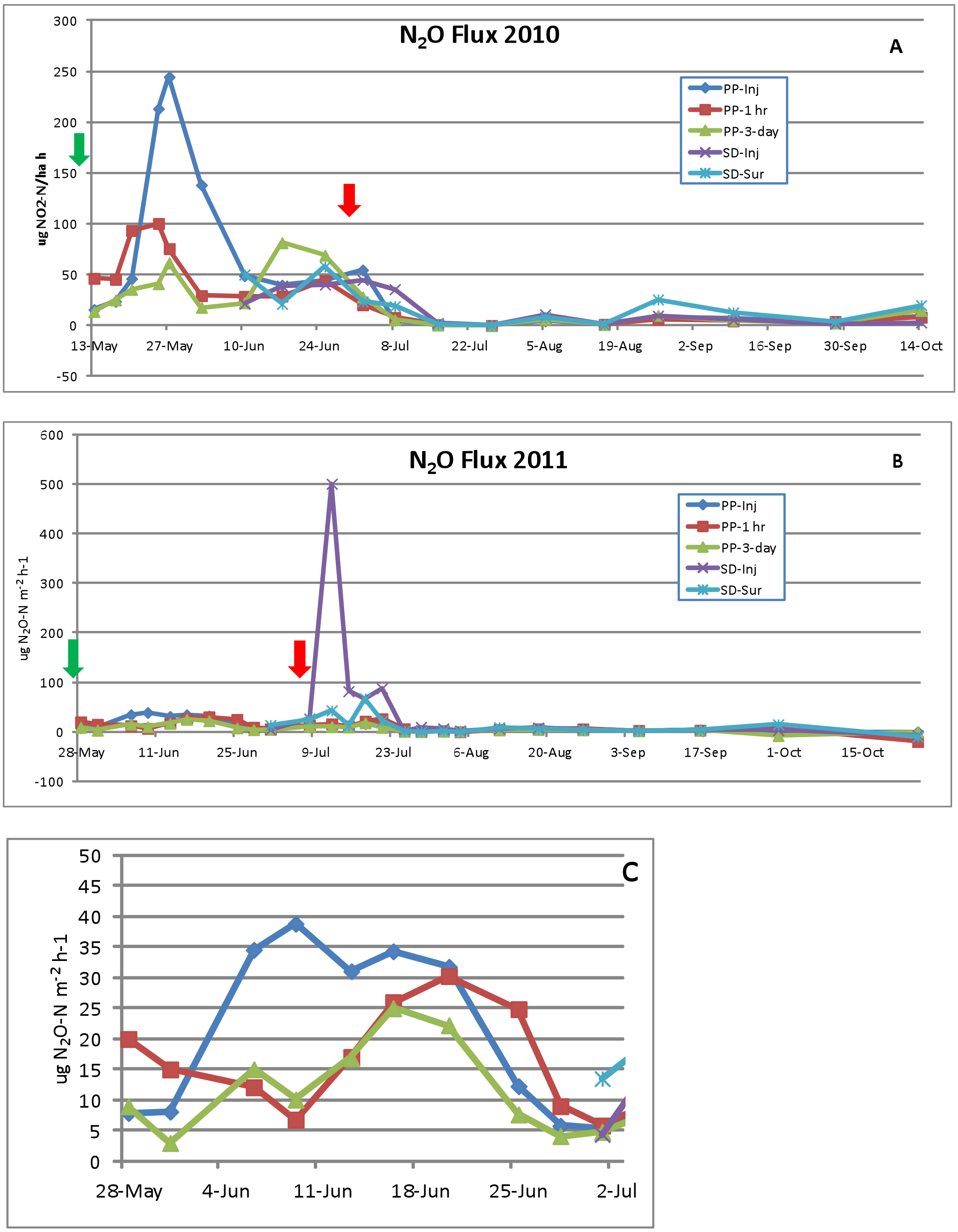


Figure 3. Nitrous oxide (N_2O) flux as affected by method and timing of dairy manure application from May to October of 2010 (A) and 2011 (B), and for May-June of 2011 (expanded scale).

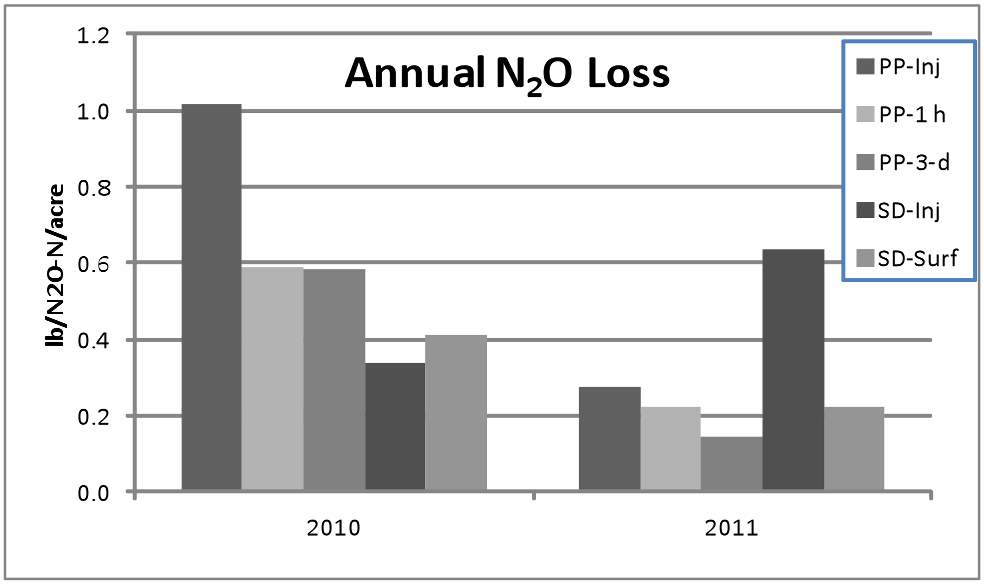


Figure 4. Annual (May-Oct.) loss of N_2O as affected by method and timing of liquid dairy manure application. 2010 and 2011.

COVER CROP CONSIDERATIONS FOR 2013

Paul Mitchell, Vince Davis, Francisco Arriaga, and Matt Ruark [1/]

In response to the increase in interest in cover crop use and cover crop management, we have written several extension articles on economics, weed and herbicide management, soil erosion control, and nitrogen management. This paper is intended as review and a resource for those interested in cover crop management. The accompanying presentation at the 2013 Wisconsin Crop Management Conference will be conducted as a Question and Answer session on all aspects of cover crop management, with a particular focus on addressing concerns for the 2013 growing season.

Economics (http://www.aae.wisc.edu/pdmitchell/extension.htm)

The drought this summer not only had many Wisconsin farmers concerned about crop yields and their crop insurance coverage, but also emergency and extra forage production. Various crop insurance rules exist regarding cover crops and some of these rules were relaxed this year to help farmers looking for extra forage. To help inform Wisconsin farmers about these and other issues related to the drought, I wrote several short fact sheets that will serve as the basis for my panel comments and discussion. Titles and links are below:

1. Drought 2012: Crop Insurance Rules to Consider When Growing Emergency Forage or Cover Crops: http://www.aae.wisc.edu/pdmitchell/CropInsurance/EmergencyForage.pdf
2. Drought 2012: USDA Changes Crop Insurance Rules for Cover Crop Harvesting in Spring 2013: http://www.aae.wisc.edu/pdmitchell/CropInsurance/RuleChange.pdf
3. Drought and Crop Insurance: Patience Please!: http://www.aae.wisc.edu/pdmitchell/CropInsurance/DroughtInsurance2012.pdf
4. Cover Crops and Crop Insurance: http://www.aae.wisc.edu/pdmitchell/CropInsurance/CoverCrops.pdf
5. Drought 2012: Moldy Corn and Crop Insurance: http://www.aae.wisc.edu/pdmitchell/CropInsurance/MoldyCorn.pdf
6. Drought 2012: Forward Contracts & Crop Insurance: http://www.aae.wisc.edu/pdmitchell/CropInsurance/ForwardContractsAndInsurance.pdf

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[1/] Associate Professor, Agricultural and Applied Economics; Assistant Professor, Dept. of Agronomy; Assistant Professor, Dept. of Soil Science; Assistant Professor, Dept. of Soil Science, respectively, Univ. of Wisconsin-Madison.

7. Crop Insurance Implications of Planting Crops Early: http://www.aae.wisc.edu/pdmitchell/CropInsurance/PlantingEarly.pdf

Weed and Herbicide Management

In theory and practice it seems like a great idea to establish winter annual 'cover crops' with the dual purpose of producing extra forage. In fact, the future of cover crops in annual cropping systems probably hinges on the ability to add an economic value to cover crops so their adoption is driven by more economic incentive than government program subsidies. Of course, there may be long-term environmental benefits and that is the base of much interest, but nonetheless growers must generate economic income for business survival which is 1/3 of the sustainability equation. With that said, crops or crop parts that enter the food or feed system are regulated in many different ways to importantly protect food quality and safety. It is important to continue to steward pesticide products in a legal manner to ensure food safety and ensure consumer confidence. Consumers want to know they will get a safe product free from harmful levels of pesticide residue even when conventionally grown. To highlight and clarify the rules to consider during cropping system design and planning, I produced this extension piece to clarify rules regarding this practice.

- Is it legal to use a cover crop as a forage crop? Maybe NOT…:

  http://ipcm.wisc.edu/download/pubsPM/9-19-12-Cover-Crops-used-for-forages.pdf

Erosion Control

The drought experienced during the 2012 growing season in most of Central and Southern Wisconsin significantly reduced grain availability for feed use. Grain production in the Midwest in general was also severely affected by the drought. Given the pressing need for feed, a significant number of acres that were originally seeded for corn grain were harvested for silage. This situation left a considerable amount of agricultural land bare and susceptible to erosion this fall and spring. Cover crops can be useful in these conditions by protecting the soil surface from raindrop impact and holding soil particles together with their root systems. An extension article was written to bring attention to the increased erosion risk after the drought and highlight the benefits of cover crops.

- Soil erosion concerns after silage harvest (New Horizons in Soil Science, Issue 12-03)

http://www.soils.wisc.edu/extension/nhss/2012/12_03_Arriaga_soil_erosion.pdf

Nitrogen Management

With a growing season like we are having in 2012, it is likely that residual nitrate concentrations in the soil will be high, especially if corn was harvested early as silage or if yields are well below expected. One benefit of planting cover crops after corn silage, small grain, or a processing vegetable crop, or after a manure application is that the cover crop can take up residual nitrate and reduce the risk of nitrate leaching between harvest and planting. Other benefits of cover crops include reduction in soil erosion and weed suppression. This article focuses on using cover crops for nutrient conservation benefits rather than growing cover crops for forage. For tips on growing cover crops for forage see Winnebago County Agricultural Agent Nick Schneider's article on Emergency Forage Cover Crop Tips (http://go.wisc.edu/xvmh3a).

There are many nitrogen related issues surrounding cover crops. The following link is a summary that highlights issues related to cover crops and the nitrogen cycle, specifically regarding why some cover crops are associated with a nitrogen credit and some are not. http://www.soils.wisc.edu/extension/nhss/2012/12_02_ruark_consider_cover_crops_2012.pdf

INDUSTRY TRAIT PIPELINE: DROUGHT MITIGATION OFFERINGS FOR 2013 AND BEYOND – PANEL

Nicholas Goeser, Jeff Krumm, and Mike Johnston [1/]

{This page provided for note taking}

[1/] Monsanto, Syngenta, and Pioneer, respectively.

STRATEGIES FOR MANAGING CORN PRODUCTION DURING DROUGHT YEARS: WHAT WORKS AND WHAT DOESN'T

Joe Lauer [1]

Due to warmer than normal conditions during March, planting started quickly and then was delayed by wet conditions around May 1. Over the entire growing season, growing degree-day accumulation was above the 30-year normal. During May, June and July, precipitation was significantly below average in southern Wisconsin, while northern Wisconsin had above average precipitation. Drought conditions continued through August and September in the southern half of Wisconsin and were also observed in the northern half of the state. Due to a dry and warm September and October, good grain drying occurred with harvest grain moisture lower than normal in all trials.

Crop productivity is an indicator of drought intensity. Most grain crops have specific stages of development when their yields are most sensitive to drought stress, so timing of stress also influences the amount of yield loss. Stress during mid-vegetative stages may reduce ear size by reducing the number of flowers on the ear and may reduce plant height and leaf size. Usually, drought stress during early vegetative stages has little effect on grain yield, but nodal root growth can be impacted by dry soil during stages V2 to V5. Greatest yield reductions usually occur with sustained drought stress during late vegetative stages and throughout the reproductive stages. Corn's most sensitive stage is a three week period centered on R1 (silking). Stress during this period reduces the number of flowers that are successfully fertilized. Stress after silking will result in increased kernel abortion, and if the stress is not been relieved, reduced seed size.

Like 1988 (Table 1), the impact of the 2012 drought was significant as shown in Table 2. Grain yield in the University of Wisconsin hybrid performance trials was significantly lower at all southern locations.

Table 1. 1988 Wisconsin Corn Performance Trials - Grain Summary

	1978-1987		1988		Percent
Location	N	Yield	N	Yield	change
Arlington	756	185	166	131	-29
Janesville	706	184	166	151	-18
Lancaster	706	146	166	71	-51
Fond du Lac	718	138	151	114	-17
Galesville	718	157	151	162	3
Hancock	719	170	151	198	16
Chippewa Falls	510	141	*	*	---
Marshfield	510	125	126	99	-21
New London/Waupaca	514	152	126	172	13
White Lake	54	135	58	94	-30
Spooner	534	115	116	87	-24

* Chippewa Falls was not harvested in 1988.

Table 2. 2012 Wisconsin Corn Performance Trials - Grain Summary

	2002-2011		2012		Percent
Location	N	Yield	N	Yield	change
Arlington	758	222	160	203	-9
Janesville	702	232	147	183	-21
Lancaster	658	219	147	146	-33
Fond du Lac	631	196	132	189	-4
Galesville	615	214	132	215	0
Hancock	626	207	132	243	17
Chippewa Falls	607	194	162	138	-29
Marshfield	756	170	232	167	-2
Seymour	607	170	162	179	5
Valders	606	180	162	213	18
Coleman/Rhinelander	175	183	70	202	10
Spooner	690	156	210	131	-16

[1] Corn Agronomist, University of Wisconsin, Department of Agronomy, 1575 Linden Drive, Madison, WI 53706.

USDA-NASS preliminary data confirm these findings (Figures 1 and 2). Corn grain yields are forecasted at 124 bu/A. Projected production has been reduced by 20% causing a spike in corn price. Many acres that were planted for grain production ended up being harvested for silage production, especially in the southern two tiers of counties in Wisconsin.

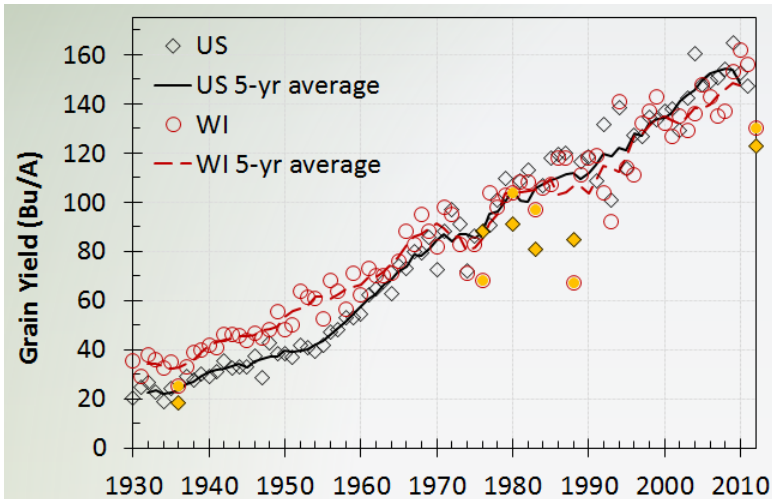

Figure 1. Corn grain yield (Bu/A) in the United States and Wisconsin over time. Filled symbols indicate drought years.

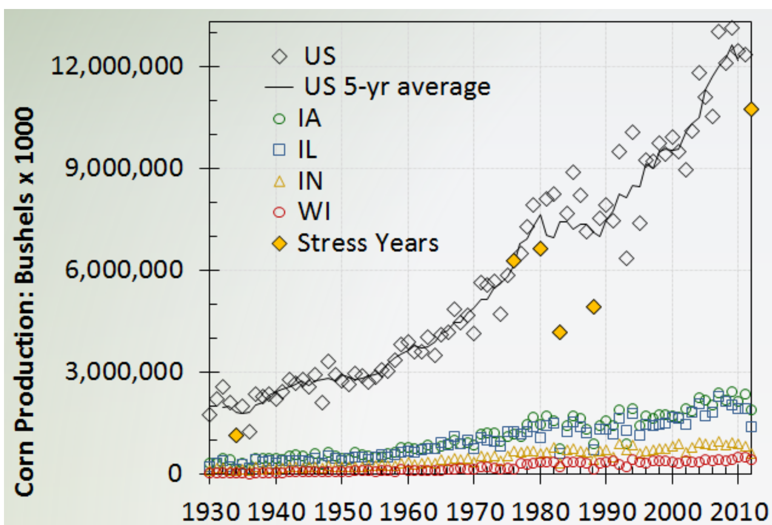

Figure 2. Corn production (Bushels x 1000) in the United States, Iowa, Illinois, Indiana and Wisconsin over time. Filled symbols indicate drought years.

What Happens Within The Corn Plant When Drought Occurs?

In nearly every year, drought affects corn growth and development somewhere in Wisconsin. It will often progress to the point where farmers feel that the dry weather is reducing yield potential.

To begin talking about water influences on corn growth and development and yield we must begin with the concept of evapotranspiration. **Evapotranspiration** is both the water lost from the soil surface through **evaporation** and the water used by a plant during **transpiration**. Soil evaporation is the major loss of water from the soil during early stages of growth. As corn leaf area increases, transpiration gradually becomes the major pathway through which water moves from the soil through the plant to the atmosphere.

Yield is reduced when evapotranspiration demand exceeds water supply from the soil at any time during the corn life cycle. Nutrient availability, uptake, and transport are impaired without sufficient water. Plants weakened by stress are also more susceptible to disease and insect damage. Corn responds to water stress by leaf rolling. Highly stressed plants will begin leaf rolling early in the day. Evapotranspiration demand of corn varies during its life cycle (Table 3). Evapotranspiration peaks around canopy closure. Estimates of peak evapotranspiration in corn range between 0.20 and 0.39 inches per day. Corn yield is most sensitive to water stress during flowering and pollination, followed by grain-filling, and finally vegetative growth stages.

Vegetative development

Water stress during vegetative development reduces stem and leaf cell expansion resulting in reduced plant height and less leaf area. Leaf number is generally not affected by water stress. Corn roots can grow between 5 and 8 feet deep, and soil can hold 1.5 to 2.5 inches of available soil water per foot of soil, depending upon soil texture. Ear size may be smaller. Kernel number (rows) is reduced. Early drought stress does not usually affect yield in Wisconsin through the V10-V12 stages. Beyond these stages water stress begins to have an increasing effect on corn yield.

Table 3. Estimated corn evapotranspiration and yield loss per stress day during various stages of growth.

Growth stage	Evapo-transpiration	Percent yield loss per day of stress (min-ave-max)
	inches per day	%
1 to 4 leaf	0.06	---
4 to 8 leaf	0.10	---
8 to 12 leaf	0.18	---
12 to 16 leaf	0.21	2.1 - 3.0 - 3.7
16 leaf to VT	0.33	2.5 - 3.2 - 4.0
Silking (R1)	0.33	3.0 - 6.8 - 8.0
Blister (R2)	0.33	3.0 - 4.2 - 6.0
Milk (R3)	0.26	3.0 - 4.2 - 5.8
Dough (R4)	0.26	3.0 - 4.0 - 5.0
Dent (R5)	0.26	2.5 - 3.0 - 4.0
Maturity (R6)	0.23	0.0

derived from Rhoads and Bennett (1990) and Shaw (1988)

Pollination

Water stress around flowering and pollination delays silking, reduces silk elongation, and inhibits embryo development after pollination. Moisture stress during this time reduces corn grain yield 3-8% for each day of stress (Table 3). Moisture or heat stress interferes with synchronization between pollen shed and silk emergence. Drought stress may delay silk emergence until pollen shed is nearly or completely finished. During periods of high temperatures, low relative humidity, and inadequate soil moisture level, exposed silks may desiccate and become non-receptive to pollen germination.

Silk elongation begins near the butt of the ear and progresses up toward the tip. The tip silks are typically the last to emerge from the husk leaves. If ears are unusually long (many kernels per row), the final silks from the tip of the ear may emerge after all the pollen has been shed. Another cause of incomplete kernel set is abortion of fertilized ovules. Aborted kernels are distinguished from unfertilized ovules in that aborted kernels had actually begun development. Aborted kernels will be shrunken and mostly white.

Kernel development (grain-filling)

Water stress during grain-filling increases leaf dying, shortens the grain-filling period, increases lodging, and lowers kernel weight. Water stress during grain-filling reduces yield 2.5 to 5.8% with each day of stress (Table 3). Kernels are most susceptible to abortion during the first 2 weeks following pollination, particularly kernels near the tip of the ear. Tip kernels are generally last to be fertilized, less vigorous than the rest, and are most susceptible to abortion. Once kernels have reached the dough stage of development, further yield losses will occur mainly from reductions in kernel dry weight accumulation.

Severe drought stress that continues into the early stages of kernel development (blister and milk stages) can easily abort developing kernels. Severe stress during dough and dent stages of grain fill decreases grain yield primarily due to decreased kernel weights and is often caused by premature black layer formation in the kernels. Once grain has reached physiological maturity, stress will have no further physiological effect on final yield (Table 3). Stalk and ear rots, however, can continue to develop after corn has reached physiological maturity and indirectly reduce grain yield through plant lodging. Stalk rots are seen more often when ears have high kernel numbers and have been predisposed to stress, especially drought stress.

Premature Plant Death

Premature death of leaves results in yield losses because the photosynthetic 'factory' output is greatly reduced. The plant may remobilize stored carbohydrates from the leaves or stalk tissue to the developing ears, but yield potential will still be lost. Death of all plant tissue prevents any further remobilization of stored carbohydrates to the developing ear. Whole plant death that occurs before normal black layer formation will cause premature black layer development, resulting in incomplete grain fill and lightweight, chaffy grain. Grain moisture will be greater than 35%, requiring substantial field dry-down before harvest.

Yield Components and When They Are Determined During the Corn Life Cycle

With the onset of tasseling the corn crop is in a critical growth and development stage for grain yield. The tasseling, silking, and pollination stages of corn development are extremely critical because the yield components of ear and kernel number can no longer be increased by the plant and the potential size of the kernel is being determined.

For example, the potential number of ears per unit area is largely determined by number of seeds planted, how many germinate, and eventually emerge. Attrition of plants through disease, unfurling underground, insects, mammal, bird damage, chemical damage, mechanical damage, and lodging all will decrease the actual number of ears that are eventually harvested. The plant often can compensate for early losses by producing a second or third ear, but the capacity to compensate ear number is largely lost by R1 and from then on no new ears can be formed.

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

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

Management Decisions Will Depend Upon Success of Corn Pollination

By the end of July, the key plant indicator to observe and base future management decisions upon is the success of pollination. Each ovule (potential kernel) has a silk attached to it. When a pollen grain falls on a silk, it germinates, produces a pollen tube that grows the length of the silk which fertilizes the ovule in 12 to 28 hours. If fertilization of the ovule is successful, within 1 to 3 days the silk will detach from the developing kernel. Silks will remain attached to unfertilized ovules and be receptive to pollen up to 7 days after emergence. Silks eventually turn brown and dry up after pollination is over.

Two techniques are commonly used to assess pollination success or failure. The most rapid technique to determine pollination success is the "shake test." Carefully unwrap the ear husk leaves and then gently shake the ear. The silks from fertilized ovules will drop off. The proportion (%) of silks dropping off the ear indicates the proportion of future kernels on an ear. Randomly sample several ears in a field to estimate the success of pollination.

The second technique is to wait until 10 days after fertilization of the ovules. The developing ovules (kernels) will appear as watery blisters (the "blister" R2 stage of kernel development).

Management Guidelines for Handling Cornfields with Poor Pollination

Typical management options and uses are available for corn that has successfully pollinated. If pollination is unsuccessful, we are usually trying to make the best of a bad situation.

If **pollination is good**, harvest in a normal fashion for either grain or forage use. If **pollination is poor** yet some kernels are developing, the plant can gain dry matter and farmers should wait with harvest. In Wisconsin, many farmers have the option of harvesting poorly pollinated fields for silage use. If there is **no pollination**, then the best quality forage will be as found as close to flowering as possible. Quality decreases after flowering. The challenge is to make sure that no potential pollination occurs and that the forage moisture is correct for the storage structure.

Drought-stressed corn can be grazed or used for forage, either as green chop or silage. Because of the potential for nitrate toxicity, grazing or green chopping should be done only when emergency feed is needed. The decision to chop corn for silage should be made when:

i. You are sure pollination and fertilization of kernels will not or did not occur and that whole-plant moisture is in the proper range for the storage structure so that fermentation can occur without seepage or spoilage losses. If there is no grain now, florets on the ear were either not pollinated or have not started to grow due to moisture stress, and the plant will continue to be barren. If the plant is dead, harvest should occur when whole plant moisture is appropriate for preservation and storage.

ii. If pollination and fertilization of kernels did occur but it was poor, do not chop until you are sure that there is no further potential to increase grain dry matter and whole plant moisture is in the proper range for the storage structure. These kernels may grow some now, if the plant is not dead and in those fields receiving rain. If kernels are growing dry matter is accumulating and yield and quality of the forage is improving.

Green, barren stalks will contain 75-90% water. If weather remains hot and dry, moisture content drops, but if rain occurs before plants lose green color, plants can remain green until frost. Drought stressed corn has increased sugar content, higher crude protein, higher crude fiber and more digestible fiber than normal corn silage. Drought generally reduces yield and grain content resulting in increased fiber content, but this is often accompanied by lower lignin production that increases fiber digestibility.

Forage quality of normally pollinated corn

Corn has two peaks in forage quality: one at pollination and one at harvest maturity (Figure 3). The early peak in forage quality at pollination is high in quality but too wet for ensiling. The later peak is more familiar, and is the one we typically manage for when producing corn silage.

Forage quality of poorly pollinated corn

Coors et al. (1997) evaluated the forage quality of corn with 0, 50 and 100% pollination of the kernels on an ear during 1992 and 1993. These years were not considered “drought” stress years, but they can give us an idea as to quality changes occurring due to poor pollination. These plots were harvested in September.

A typical response of corn to stress is to reduce grain yield. Bareness reduced whole-plant yield by 19% (Table 4). Kernels on ears of 50% ear fill treatments were larger and tended to more than make up for reduced numbers (Albrecht, personal communication). With the exception of protein, as ear fill increased, whole-plant forage quality increased.

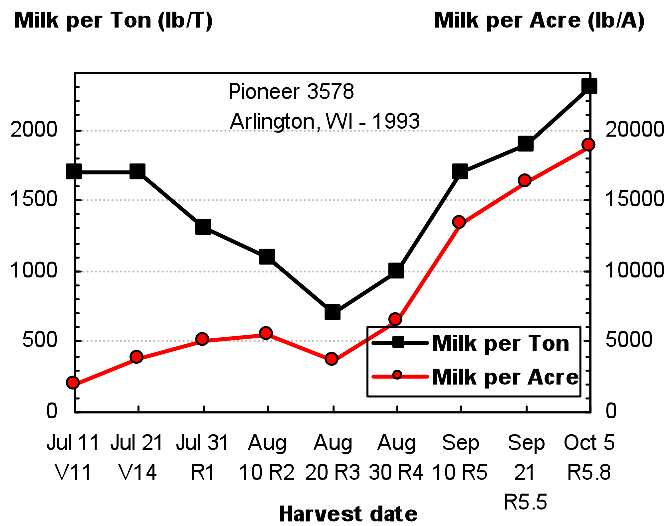

Figure 3. Corn silage yield and quality changes during development.

Table 4. Forage yield (% of control) and quality of corn with differing amounts of pollination grown at Madison in 1992 and 1993 (n= 24).

Ear fill	Forage yield	Crude protein	NDF	ADF	IVTD	NDFD
%	%	%	%	%	%	%
0	81	8.5	57	30	74	52
54	93	8.0	54	28	76	52
100 (control)	100	7.5	49	26	77	54
LSD (0.05)	6	0.3	1	1	1	1

derived from Coors et al., 1997

Forage moisture

If the decision is made to harvest the crop for ensiling, the main consideration will be proper moisture for storage and fermentation. The crop will look drier than it really is, so moisture testing will be critical. Be sure to test whole-plant moisture of chopped corn to assure yourself that acceptable fermentation will occur. Use a forced air dryer (i.e. Koster), oven, microwave, electronic forage tester, NIR, or the rapid "Grab-Test" method for your determination. With the "Grab-Test" method (as described by Hicks, Minnesota), a handful of finely cut plant material is squeezed as tightly as possible for 90 seconds. Release the grip and note the condition of the ball of plant material in the hand.

- If juice runs freely or shows between the fingers, the crop contains 75 to 85% moisture.
- If the ball holds its shape and the hand is moist, the material contains 70 to 75% moisture.
- If the ball expands slowly and no dampness appears on the hand, the material contains 60 to 70% moisture.
- If the ball springs out in the opening hand, the crop contains less than 60% moisture.

The proper harvest moisture content depends upon the storage structure, but is the same for drought stressed and normal corn. Harvesting should be done at the moisture content that ensures good preservation and storage (Table 5).

Table 5. Recommended moisture content (%) for corn stored in various types of storage structures.

Horizontal bunker silos	70-65
Bag silos	70-60
Upright concrete stave silos	65-60
Upright oxygen limiting silos	60-50

derived from Roth et al., 1995

Raising the bar

Depending upon farm forage needs, raising the cutter-bar on the silage chopper reduces yield but increases quality. For example, raising cutting height reduced yield by 15%, but improved quality so that Milk per acre of corn silage was only reduced 3-4% (Lauer, Wisconsin). In addition the plant parts with highest nitrate concentrations remain in the field (Table 6).

Table 6. Nitrate nitrogen of corn plant parts harvested for silage.

Plant part	NO3N
	ppm
Leaves	64
Ears	17
Upper 1/3 of stalk	153
Middle 1/3 of stalk	803
Lower 1/3 of stalk	5524
Whole plant	978

derived from Hicks, Minnesota

Nitrate problems

If drought-stressed corn is ensiled at the proper moisture content and other steps are followed to provide good quality silage, nitrate testing should not be necessary. The risk of nitrate poisoning increases as pollination becomes poorer. Nitrate problems are often related to concentration (i.e. the greater the yield the less chance of high nitrate concentration in the forage). If pollination is poor only about 50 to 75% of the dry matter will be produced compared to normal corn forage.

It is prudent to follow precautions regarding dangers of nitrate toxicity to livestock (especially with grazing and green-chopping) and silo-gasses to humans when dealing with drought-stressed corn. Nitrates absorbed from the soil by plant roots are normally incorporated into plant tissue as amino acids, proteins, and other nitrogenous compounds. Thus, the concentration of nitrate in the plant is usually low. The primary site for converting nitrates to these products is in growing green leaves. Under unfavorable growing conditions, especially drought, this conversion process is slowed, causing nitrate to accumulate in the stalks, stems, and other conductive tissue. The highest concentration of nitrates is in the lower part of the stalk or stem. If moisture conditions improve, the conversion process accelerates and within a few days nitrate levels in the plant returns to normal.

Nitrate concentration usually decreases during silage fermentation by one-third to one-half, therefore sampling one or two weeks after filling will be more accurate than sampling during filling. If the plants contain nitrates, a brown cloud may develop around your silo. This cloud contains highly toxic gases and people and livestock should stay out of the area. The resulting energy value of drought-stressed corn silage is usually lower than good silage but not as low as it appears based on grain content. The only way to know the actual composition of drought-stressed corn silage is to have it tested by a good analysis lab.

Marshfield Plant and Soil Analysis Laboratory
8396 Yellowstone Dr.
Marshfield, WI 54449-8401
Phone: (715) 387-2523

Estimating Yield

Growers need to carefully monitor, inspect, and dissect plants in their own fields as to plant survival potential, kernel stages, and plant moisture contents in determining when to begin silage harvest. Fields and corn hybrids within fields vary greatly in stress condition and maturity. Often questions arise as to the value of drought-stressed corn. In order to estimate pre-harvest silage yields, the National Corn Handbook publication "Utilizing Drought-Damaged Corn" describes methods based on either corn grain yields or plant height (if little or no grain yield is expected). Below is a summary of this publication.

Grain yield method for estimating silage yield

For moisture-stressed corn, about 1 ton of silage per acre can be obtained for each 5 bushels of grain per acre. For example, if you expect a grain yield of 50 bushels per acre, you will get about 10 tons/acre of 30% dry matter silage (3 tons/acre dry matter yield). For corn yielding more than 100 bushels per acre, about 1 ton of silage per acre can be expected for each 6 to 7 bushels of grain per acre. For example, corn yielding 125 bushels of grain per acre, corn silage yields will be 18 to 20 tons per acre at 30% dry matter (5 to 6 tons per acre dry matter yield). See also Table 2 in A1178 "Corn silage for the dairy ration."

Plant height method for estimating silage yield

If little or no grain is expected, a rough estimate of yield can be made assuming that 1 ton of 30% dry matter silage can be obtained for each foot of plant height (excluding the tassel). For example, corn at 3 to 4 feet will produce about 3 to 4 tons per acre of silage at 30% dry matter (about 1 ton per acre of dry matter).

How do our management decisions work during a drought

As we begin to evaluate the success of corn pollination during the 2012 drought, it might be useful to also evaluate which management decisions were most beneficial during this growing season. Although a season like 2012 is rare and extreme, it will likely happen again. Taking some time now to evaluate your management decisions might help during a future growing season.

Our last major drought year was 1988. There were numerous experiments established around the state by Dr. Paul Carter. Below I summarize his results for a number of management decisions that were important at the time including hybrid selection, plant density, date of planting, tillage and rotation decisions. The question is, "How do these decisions affect grain yield during a drought growing season?"

Plant density

The plant density which produces maximum yield has been increasing over time, but what happens during a growing season with drought? During 1988, a plant density experiment was established at nine locations with target densities of 18,000; 24,000; 30,000 and 36,000 plants per acre. At 7 of 9 locations, grain yield either increased or was not affected as plant density increased (Table 7). At Lancaster, grain yield decreased 16 bu/A from low to high plant density, while at Spooner grain yield decreased 27 bu/A. So even during drought years when a response to plant density is not expected, higher plant densities were only detrimental at two locations. The best recommendation would be to manage for potential yield with higher plant density because the only risk for return on investment is minor seed costs.

Table 7. Grain yield (bu/A) of corn planted at target plant densities of 18000, 24000, 30000 and 36000 plants/A at various locations in Wisconsin during 1988.

	Actual Harvest Plant Density (plants/A)				
Location	18100-20500	22500-24100	28600-29900	33300-36800	LSD(0.10)
	Grain yield (bushels/A)				
Janesville	125	133	137	139	7
Lancaster	64	62	50	48	9
Fond du Lac	109	112	118	108	NS
Hancock	160	175	193	188	9
Galesville	133	163	172	174	9
Chippewa Falls	39	34	32	20	NS
Marshfield	88	87	89	85	NS
New London	109	112	118	108	NS
Spooner *	78	71	66	51	11

* At Spooner target plant density was lower and resulted in harvest densities of 15900, 18600, 22000, and 24500.

Date of planting

Earlier planting dates are typically recommended for avoiding drought growing conditions. However, during 1988 the planting dates of May 13 and May 18 were higher yielding than earlier planting dates (Table 8). Some of the better performance of later planting dates has to do with timing of when drought (heat and water stress) occurs during the life cycle of the corn plant. Another interaction is the distribution of rainfall during the growing season.

Table 8. Grain yield (bu/A) response to planting date during 1988 at Arlington, WI.

Experiment 1		Experiment 2	
Planting date	Grain yield (bu/A)	Planting date	Grain yield (bu/A)
April 18	59	April 27	67
May 13	63	May 26	84
LSD(0.10)	NS	LSD(0.10)	8

Tillage

During the 1980s, no tillage was becoming popular as a management practice. Usually due to cool, wet soils corn often experience "slow growth syndrome" and yielded lower than conventionally tilled fields. During 1988, there were no differences between no-till and conventional-till in six experiments conducted at Janesville and Arlington (Table 9).

Table 9. Corn grain yield (bu/A) response to tillage during 1988 at Arlington and Janesville, WI.

Location	Conventional tillage	No tillage	LSD(0.10)
Arlington-Experiment 1	62	64	NS
Arlington-Experiment 2	83	69	NS
Arlington-CS rotation	75	77	NS
Arlington-CSW rotation	70	72	NS
Janesville-Experiment 1	117	112	NS
Janesville-Experiment 2	117	109	NS

Rotation

Rotation is probably the easiest management decision we have available to get "free" yield. During drought (stress) years it is even more important (Table 10). Rotated corn increased grain yield 16 to 36 bu/A (29 to 59%) over continuous corn grain yield.

Table 10. Corn grain yield (bu/A) response to crop rotation during 1988 at Arlington, WI.

Rotation	Grain yield (bu/A)	
Continuous corn	61	56
Corn-Soybean	97	82
Corn-Soybean-Wheat	--	72
LSD(0.10)	16	15

The presentation will cover the effect of management during 2012.

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STRATEGIES FOR MANAGING SOYBEAN PRODUCTION DURING DROUGHT YEARS: WHAT WORKS AND WHAT DOESN'T

Shawn P. Conley [1/]

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[1/] Associate Professor, Dept. of Agronomy, Univ. of Wisconsin-Madison, Madison, WI 53706.

HERBICIDE PERSISTENCE AND THE UTILITY OF BIOASSAYS

Scott Senseman [1/]

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[1/] Professor, Texas A&M University, College Station, TX.

THE UTILITY OF PREEMERGENCE HERBICIDES WITHOUT ADEQUATE RAINFALL IN SPRING 2012

Vince M. Davis[1]

Introduction

Herbicide resistance in weeds, especially glyphosate resistance, has generated many recommendations from University Extension over the last several years to include more preemergence herbicides with residual weed control activity as a greater part of an Integrated Weed Management approach. Unfortunately, over the last many years the economics have favored the sole reliance on a postemergence glyphosate system. It is apparent that constantly 'beating the drum' to include residual herbicides as a way to prevent resistance falls on deaf ears unless economics favor the approach. Moreover, residual herbicides applied at the preemergence timing do not come without potential drawbacks. These drawbacks can include injury on young crop seedlings under adverse weather conditions, poor performance when rainfall does not occur to 'activate' the herbicide into soil-water solution, and potential carryover under prolonged dry soil conditions adversely affecting a sensitive rotational crop. Unfortunately, we experienced both of the latter of those three statements in 2012, even though the extent to the problems of carryover will not be clear until we're into the 2013 season. So, in a dry year like 2012, it may easily leave some to question whether the risk of preemergence herbicides is worth the reward. With this background in mind, it is important to constantly evaluate the value of using preemergence herbicides with residual weed control activity for protecting crop yield, and ultimately producing greater economic returns. At the UW-Madison Arlington Agriculture Research station, we annually conduct several herbicide evaluation trials. This year we also conducted several trials that evaluated the impact of several other pest management treatments on the yield of corn and soybean. Several trials revealed the impact of early-season weed control through the use of residual herbicides this year, but to stay concise, I will summarize one corn trial and one soybean trial which demonstrated the effect of early-season weed control in a dry year (2012).

Materials and Methods

These trials were grown at the University of Wisconsin-Madison Arlington Agriculture Research Station near Arlington, WI in 2012. The corn trial was planted on 5/11/2012, and the soybean trial was planted on 5/14/2012. At the farm there were 2.4 inches of rainfall between May 1 and May 10, 2012 (before planting). Rainfall during the remaining May and June timeframe was 0.2 inches on May 24th, 0.4 inches on May 26th, and 0.2 inches on May 28th, 0.1 inches on June 12th, and 0.1 inches on June 21st. This equated to only 1 inch of rainfall during the first 48 to 51 days of crop growth. Moreover, rainfall did not occur for 10 to 13 days after the preemergence herbicide applications, which limited efficacy.

Because these trials focused on yield, plot dimensions were larger than normal efficacy plots. The corn trial plots were 10' wide by 65' long, and they were replicated six times. Corn was planted at 32,000 seeds/a. The trial design was a split-plot with nitrogen as a main plot effect

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[1] Assistant Professor, Dept. of Agronomy, 1575 Linden Dr., Univ. of Wisconsin-Madison, Madison, WI, 53706.

where N was applied at either 135 or 185 lb/a. There were six subplot treatments based on increasing pest control inputs. The first three subplot treatments were increases in herbicide program ‘intensity’. Those three treatments included 1) No PRE 2) Outlook® at 20 fl oz/a PRE 3) Verdict® at 15 fl oz/a PRE. All three treatments were followed by 0.77 lb ae/a glyphosate at V7.

The soybean study was planted at 143,000 seeds/a. Plots in the soybean study were 10’ wide by 100’ long and replicated four times. The soybean study was also a split-plot where main plots were split with a PRE herbicide treatment of 1.5 pt/a Boundary®, or no PRE herbicide treatment. The six subplots were treatments of increasing pest management intensity. In this trial the residual herbicide was followed by one pass of glyphosate (Touchdown Total at 24 fl oz/a) at the V3 soybean stage, and the NO PRE plots were followed by two passes of glyphosate at the same rate; the first pass at V2, and the second at V7.

Summary of 2012 results

Corn study: In brevity, averaged over the main plot effect of N rate, the NO PRE treatment yielded 175 bu/a, the Outlook treatment yield 182 bu/a, and the Verdict treatment yielded 191 bu/a.

Soybean study: In brevity, the whole plot effect of the PRE Boundary treatment, averaged over all six subplot treatments, was 4.1 bu/a where the NO PRE yielded an average of 45.3 bu/a and the PRE Boundary yielded 49.4 bu/a.

Given the yield difference in both corn and soybean trials at Arlington, WI this year, the return on investment (ROI) for preemergence residual herbicides was very favorable despite low rainfall. Reduced efficacy was observed from these soil-applied residual herbicides compared to expectations in a ‘normal’ year because of low rainfall for activation, however, the disadvantage of weed competition on corn and soybean from the loss of early-season soil moisture was equally more important than in a ‘normal’ year. However, the advantage of a weed control system with a diverse approach to controlling weeds, versus reliance on glyphosate alone, is a very valuable benefit for protecting against the development of glyphosate resistance.

Acknowledgments

Much credit for these trials is due to Mr. Tim Trower for his dedication of generating valuable research trial results, and several graduate and undergraduate research assistants that also helped with these trials. Moreover, I thank BASF and Syngenta for providing funding for these trials.

UPDATE ON HERBICIDE RESISTANCE IN WISCONSIN AND PROACTIVE LATE-SEASON WEED ESCAPE SURVEY EFFORTS[1]

Ross A. Recker and Vince M. Davis[2]

Introduction

The potential increase of glyphosate-resistant weeds is a major threat to corn and soybean production across the nation and in Wisconsin. There are 14 glyphosate-resistant weeds confirmed in the United States, five of which occur in states that border Wisconsin (Heap 2012). A southern Wisconsin population of giant ragweed (*Ambrosia trifida* L.) was confirmed to be glyphosate-resistant and announced at this conference one year ago (Stoltenberg et al. 2012). Additionally, a different Wisconsin population of giant ragweed was also recently confirmed as resistant to cloransulam-methyl[3]. Integrated weed management tactics, including the use of multiple effective modes-of-action (MOA) against troublesome weeds are important to delay the onset of glyphosate resistance (Norsworthy et al. 2012). Identifying geographies that may be most vulnerable to glyphosate resistance development could help direct attention and pro-active resistance management tactics before wide-scale control failures occur (Davis et al. 2008). The objective of the late-season weed escape survey is to identify areas of Wisconsin for potential shifts to weeds that are more difficult to control with glyphosate and areas where glyphosate resistant weeds may first appear.

Materials and Methods

An on-line survey was distributed to Wisconsin producers in June 2012 to generate sample locations with known crop history, herbicide use, tillage practices, and problematic weeds. The on-line survey was followed with an in-field survey of late-season weed escapes in corn and soybean fields throughout Wisconsin during late-July through early-September. The fields sampled were chosen from on-line survey participants that provided their contact information and agreed to participate. In-field sampling procedures were similar to methods previously described by Thomas (1985). The surveyor walked 100 paces along the edge of the field and then 100 paces into the field. From there, an inverted W pattern was followed, and individual weeds were counted at five, one m^2 quadrants evenly spaced along each arm of the W for a total of 20 quadrants per field. The spacing and angles were achieved by the surveyor walking 14 meters parallel to a row, followed by 14 meters perpendicular to a row, resulting in quadrants spaced approximately 20 m apart. Frequency data were calculated for each weed species according to Equation 1.

Equation [1] $$\text{Frequency} = \frac{\text{number of fields where species occurred}}{\text{number of fields sampled}} \times 100$$

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[1] Funded by Wisconsin Corn Promotion Board
[2] Graduate Research Assistant and Assistant Professor, Dept. of Agronomy, 1575 Linden Dr., Univ. of Wisconsin-Madison, Madison, WI, 53706.
[3] Dave Stoltenberg. 2012. Personal communications. Professor. Dept. of Agronomy, Univ. of Wisconsin-Madison, Madison, WI, 53706.

Data are grouped separately by crop (corn or soybean), tillage (full, reduced, or no-till), and region based on National Agricultural Statistics Service (NASS) reporting districts described in Table 1. The tillage categories used are defined by the Conservation Technology Information Center (CTIC) [http://www.ctic.purdue.edu/CTIC%20HOME/]. The differences in frequency were subject to either a chi-square test or Fisher's exact test. Fisher's exact test was used when the expected weed species frequency was less than 5, and therefore chi-square may not have been a valid test.

Table 1. Region definitions based on NASS reporting districts.

Region	NASS District
North Central (NC)	20
West (W)	40 & 70
Central (C)	50
South Central (SC)	80
East (E)	60 & 90

Results and Discussion

There were responses describing 167 fields from the on-line survey. Problematic weeds as indicated by the survey respondents are presented in Table 2. Only weeds that were reported as the most problematic for five or more fields are shown for brevity. The problematic weeds reported most often were common lambsquarters, foxtail species (primarily giant and yellow), velvetleaf, giant ragweed, and pigweed species (primarily redroot pigweed and waterhemp).

Table 2. Problematic weeds as indicated by on-line survey respondents.

Common Name	Number of responses	Percentage of fields
Common lambsquarters	127	76.0%
Foxtails	90	53.9%
Velvetleaf	72	43.1%
Giant ragweed	57	34.1%
Pigweeds	51	30.5%
Yellow nutsedge	49	29.3%
Common ragweed	45	26.9%
Dandelion	23	13.8%
Crabgrass	19	11.4%
Quackgrass	18	10.8%
Woolly cupgrass	15	9.0%
Thistles	13	7.8%
Wild proso millet	13	7.8%
Common chickweed	12	7.2%
White cockle	9	5.4%
Fall panicum	7	4.2%
Curly dock	6	3.6%

The in-field survey consisted of sampling 151 fields. The number of fields in each categorical variable is displayed in Table 3. Sixty-four different weed species were documented in total, of which, 43 were broadleaf species and 21 were grass species or plants resembling grass species. The weeds that had the highest frequency in all fields sampled were common lambsquarters (58.3%), dandelion (57.6%), velvetleaf (32.5%), giant foxtail (24.5%), and yellow foxtail (22.5%). The frequencies of weed species found are summarized by crop, tillage practice, and region in Tables 4, 5, and 6, respectively. To be concise, only weeds that occurred in five or more fields of the total number of sampled fields are shown in Tables 4 to 6.

Table 3. The number of fields surveyed by crop, tillage practice, and region.

	--------Crop--------		---------Tillage Practice[1]---------			-----------------Region------------------				
	Corn	Soybean	Full[2]	Reduced[3]	No-till[4]	NC	W	C	E	SC
Fields Surveyed	88	63	77	25	43	22	38	28	29	34

[1] Fields in which tillage was undetermined were not included
[2] Full: < 15% residue at planting
[3] Reduced: 15% to 30% residue at planting
[4] No-till: > 30% residue at planting

Crop: Weed species which were correlated with crop type (α = .1) were found more often in corn with the exception of volunteer corn found in soybean. Seven of those nine species associated most often with corn were grass weed species. Interestingly, giant ragweed was the 11th most often found weed in soybean fields, but it was only the 25th most frequently found weed species in corn fields.

Tillage: Six of the ten weed species which were correlated with tillage type (α = .1) were more often found in fields where reduced tillage practices were used. On the contrary, giant ragweed frequency was dependent on tillage practice and occurred in 9.1%, 0%, and 16.3% of full, reduced, and no-till fields, respectively.

Region: Velvetleaf frequency was correlated to region and was highly variable ranging from 55.2% in the east region to 7.1% in the central region. Common ragweed was found least often in the west region (2.6%), and most often in the central (32.1%) and east regions (27.6 %). Redroot pigweed occurred in 31.8% of fields sampled in the north central region. Giant ragweed escapes were only found in the west and south central regions with 26.3 and 14.7 %, respectively.

Summary of 2012 results

It is likely that late-season weed escapes were present in 2012 Wisconsin corn and soybean fields for a variety of reasons. Several of those reasons may be attributed to droughty weather conditions. A lack of rainfall in 2012 resulted in poor herbicide performance in many systems. This includes inadequate soil moisture for soil applied herbicide activity, inadequate vegetative crop growth causing slow canopy closure to aid weed suppression, and a deficient in postemergence herbicide translocation of systemic herbicides like glyphosate created by low moisture conditions. These results will be further analyzed for correlation to herbicide resistance indication factors, and these late-season weed survey efforts will continue in the late-summer of 2013. If you did not participate in 2012 but would be willing to participate in 2013, please contact us at rrecker@wisc.edu or vmdavis@wisc.edu.

Table 4. Frequency of weeds that occurred in five or more fields displayed by crop. The statistics indicate whether weed presence was correlated with crop type.

Common Name	Type[1]	Total	Corn	Soybean	Chi-square test[2]
		Weed frequency by crop			
		------------------- % -------------------			P-Value[3]
Common lambsquarters	B	58.3	61.4	54.0	0.3635
Dandelion	B	57.6	61.4	52.4	0.2707
Velvetleaf	B	32.5	34.1	30.2	0.6108
Giant foxtail	G	24.5	30.7	15.9	**0.0370** **
Yellow foxtail	G	23.2	29.6	14.3	**0.0284** **
Yellow nutsedge	G	22.5	22.7	22.2	0.9416
Fall panicum	G	21.2	33.0	3.0	**<0.0001** ****
Common ragweed	B	17.9	15.9	20.6	0.4549
Black nightshade	B	17.9	18.2	17.5	0.9092
Volunteer corn	G	15.2	8.0	25.4	**0.0033** ***
Large crabgrass	B	13.3	19.3	4.8	**0.0093** ***
Quackgrass	G	13.3	21.6	1.6	**0.0003** ****
Barnyardgrass	G	11.9	14.8	7.9	0.2011
Wild proso millet	G	11.9	15.9	6.4	**0.0738** *
Lady's thumb smartweed	B	11.3	8.0	15.9	0.1290
Green foxtail	G	11.3	13.6	7.9	0.2745
Redroot pigweed	B	9.9	11.4	7.9	0.4875
Giant ragweed	B	9.9	6.8	14.3	0.1303
Shepherd's-purse	B	9.3	12.5	4.8	0.1060
Common waterhemp	B	8.6	5.7	5.3	0.1296
Woolly cupgrass	G	8.6	11.4	4.8	0.1538
Smooth crabgrass	G	8.0	9.1	6.4	0.5391
Yellow woodsorrel	B	8.0	9.1	6.4	0.5391
					Fisher's exact test[2]
Broadleaf plantain	B	7.3	10.2	3.2	0.1221
Prostrate knotweed	B	6.6	6.8	6.4	1.0000
Wild buckwheat	B	6.0	3.4	9.5	0.1651
Smooth pigweed	B	5.3	8.0	1.6	0.1399
White clover	B	4.6	3.4	6.4	0.4517
Field bindweed	B	4.6	8.0	0.0	**0.0418** **
White cockle	B	4.0	4.6	3.2	1.0000
Eastern black nightshade	B	4.0	4.6	3.2	1.0000
Common chickweed	B	3.3	4.6	1.6	0.4013
Common milkweed	B	3.3	2.3	4.8	0.6497
Common burdock	B	3.3	5.7	0.0	**0.0755** *
All weeds		95.4	96.6	93.7	0.4517

[1] Type of weed: B=broadleaf species, G= grass species or plants resembling grass species
[2] P-Value Significance: 0 to 0.001 = '****'; 0.001 to 0.01 = '***'; 0.01 to 0.05 = '**'; 0.05 to 0.1 = '*'
[3] A significant p-value indicates a correlation between weed species frequency and crop type.

Table 5. Frequency of weeds that occurred in five or more fields, separated by tillage. The statistics indicate whether weed presence was correlated with tillage.

Common Name	Type[1]	Full	Reduced	No-till	Chi-square test[2]
		Weed frequency by tillage			
		------------------- % ------------------			P-Value[3]
Common lambsquarters	B	53.3	76.0	53.5	0.1140
Dandelion	B	59.7	52.0	51.2	0.6047
Velvetleaf	B	35.1	28.0	25.6	0.5248
Giant foxtail	G	22.1	24.0	30.2	0.6083
Yellow foxtail	G	16.9	36.0	27.9	0.1044
Yellow nutsedge	G	28.6	8.0	23.3	0.1080
Fall panicum	G	26.0	12.0	20.9	0.3347
Common ragweed	B	16.9	24.0	16.3	0.6829
Black nightshade	B	13.0	32.0	16.3	**0.0898** *
Volunteer corn	G	14.3	8.0	23.3	0.2163
Large crabgrass	B	11.7	28.0	9.3	**0.0721** *
Quackgrass	G	16.9	12.0	9.3	0.4928
Barnyardgrass	G	16.9	12.0	4.7	0.1494
Wild proso millet	G	7.8	24.0	14.0	**0.0957** *
					Fisher's exact test[2]
Lady's thumb smartweed	B	11.7	16.0	4.7	0.2783
Green foxtail	G	6.5	16.0	14.0	0.2071
Redroot pigweed	B	13.0	0.0	9.3	0.1743
Giant ragweed	B	9.1	0.0	16.3	**0.0754** *
Shepherd's-purse	B	16.9	4.0	0.0	**0.0035** ***
Common waterhemp	B	6.5	8.0	14.0	0.3842
Woolly cupgrass	G	3.9	24.0	9.3	**0.0126** **
Smooth crabgrass	G	5.2	24.0	2.3	**0.0055** ***
Yellow woodsorrel	B	6.5	16.0	2.3	**0.1000** *
Broadleaf plantain	B	11.7	4.0	2.3	0.1647
Prostrate knotweed	B	7.8	0.0	7.0	0.5208
Wild buckwheat	B	9.1	0.0	0.0	**0.0504** *
Smooth pigweed	B	6.5	8.0	2.3	0.6230
White clover	B	5.2	4.0	4.7	1.0000
Field bindweed	B	3.9	4.0	7.0	0.8676
White cockle	B	5.2	4.0	2.3	0.8579
Eastern black nightshade	B	6.5	0.0	2.3	0.3912
Common chickweed	B	2.6	4.0	4.7	0.8422
Common milkweed	B	0.0	0.0	11.6	**0.0031** ***
Common burdock	B	2.6	0.0	7.0	0.3844
All weeds		96.1	100.0	90.7	0.2756

[1] Type of weed: B=broadleaf species, G= grass species or plants resembling grass species
[2] P-Value Significance: 0 to 0.001 = '****'; 0.001 to 0.01 = '***'; 0.01 to 0.05 = '**'; 0.05 to 0.1 = '*'
[3] A significant p-value indicates a correlation between weed species frequency and tillage.

Table 6. Frequency of weeds that occurred in five or more fields, separated by region. The statistics indicate whether weed presence was correlated with region.

Common Name	Type[1]	Weed frequency by region					Chi-square test[2]
		NC	W	C	E	SC	
		--------------------	--------------------	%	--------------------	--------------------	P-value[3]
Common lambsquarters	B	63.6	55.3	60.7	55.2	58.8	0.9642
Dandelion	B	77.3	55.3	53.6	58.6	50.0	0.3338
Velvetleaf	B	31.8	26.3	7.1	55.2	41.2	**0.0021** ***
Giant foxtail	G	13.6	29.0	10.7	37.9	26.5	0.1080
Yellow foxtail	G	18.2	21.1	28.6	20.7	26.5	0.8830
Yellow nutsedge	G	27.3	26.3	17.9	13.8	26.5	0.6415
Fall panicum	G	22.7	23.7	14.3	14.3	26.5	0.7706
Common ragweed	B	13.6	2.6	32.1	27.6	17.7	**0.0171** **
Black nightshade	B	4.6	15.8	32.1	27.6	8.8	**0.0340** **
							Fisher's exact test[2]
Volunteer corn	G	4.6	18.4	7.1	31.0	11.8	**0.0669** *
Large crabgrass	B	9.1	15.8	28.6	3.5	8.8	**0.0718** *
Quackgrass	G	31.8	13.2	10.7	3.5	11.8	**0.0776** *
Barnyardgrass	G	22.7	2.6	14.3	6.9	17.7	**0.0853** *
Wild proso millet	G	4.6	5.3	17.9	10.3	20.6	0.2020
Lady's thumb smartweed	B	13.6	5.3	14.3	20.7	5.9	0.2541
Green foxtail	G	0.0	2.6	3.6	24.1	23.5	**0.0011** ***
Redroot pigweed	B	31.8	10.5	3.6	3.6	8.8	**0.0041** ***
Giant ragweed	B	0.0	26.3	0.0	0.0	14.7	**0.0001** ****
Shepherd's-purse	B	22.7	2.6	3.6	10.3	11.8	**0.0944** *
Common waterhemp	B	4.6	10.5	0.0	10.3	14.7	0.2545
Woolly cupgrass	G	0.0	5.3	10.7	17.2	8.8	0.2529
Smooth crabgrass	G	18.2	2.6	21.4	3.5	0.0	**0.0022** ***
Yellow woodsorrel	B	9.1	7.9	14.3	3.5	5.9	0.6619
Broadleaf plantain	B	31.8	0.0	0.0	10.3	2.9	**<0.0001** ****
Prostrate knotweed	B	4.6	5.3	3.6	10.3	8.8	0.8486
Wild buckwheat	B	13.6	0.0	14.3	6.9	0.0	**0.0104** **
Smooth pigweed	B	0.0	2.6	3.6	13.8	5.9	0.2678
White clover	B	9.1	5.3	7.1	0.0	2.9	0.5466
Field bindweed	B	0.0	0.0	0.0	6.9	14.7	**0.0104** **
White cockle	B	0.0	2.6	3.6	6.9	5.9	0.8125
Eastern black nightshade	B	13.6	2.6	0.0	3.5	2.9	0.2011
Common chickweed	B	4.6	7.9	0.0	0.0	2.9	0.3774
Common milkweed	B	0.0	2.6	0.0	3.5	8.8	0.4194
Common burdock	B	4.6	5.3	0.0	0.0	5.9	0.5912
All weeds		95.5	92.1	100.0	93.1	97.1	0.6232

[1] Type of weed: B=broadleaf species, G= grass species or plants resembling grass species
[2] P-Value Significance: 0 to 0.001 = '****'; 0.001 to 0.01 = '***'; 0.01 to 0.05 = '**'; 0.05 to 0.1 = '*'
[3] A significant p-value indicates a correlation between weed species frequency and region.

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GIANT RAGWEED EFFICACY IN 2012 CORN AND SOYBEAN TRIALS

Vince M. Davis[1]

Introduction

Giant ragweed is becoming an increasingly problematic weed to control in both corn and soybean fields in Wisconsin. In an on-line survey conducted between June and September of this past year (2012), respondents indicated that giant ragweed was the fourth most problematic weed to control in their corn and soybean fields. Moreover, in Wisconsin there has been a giant ragweed population confirmed resistant to glyphosate, and recently one population confirmed resistant to cloransulam-methyl. In total, there are now eleven states in the U.S. and one province in Canada (Ontario) with reported populations of glyphosate-resistant giant ragweed (Heap 2012; Stoltenberg et al. 2012). The populations confirmed resistant to glyphosate were collected in Ohio (2004), Arkansas (2005), Indiana (2005), Kansas (2006), Minnesota (2006), Tennessee (2007), Ontario, CA (2008), Iowa (2009), Missouri (2009), Mississippi (2010), Nebraska (2010), and Wisconsin (2010). Additionally, there are five other states in the U.S. with giant ragweed populations resistant to cloransulam-methyl including Illinois (1998), Indiana (1998), Ohio (1998), Iowa (2000), and Minnesota (2008). Most concerning is that Ohio (2006) and Minnesota (2008) have both reported populations that are multiple resistant to both glyphosate and cloransulam meaning tank-mixtures of these two herbicide mode-of-actions (MOAs) are not effective. There is a very high level of importance to find and evaluate control strategies for giant ragweed in corn and soybean for Wisconsin crop producers.

Materials and Methods

In 2012 we conducted standard herbicide efficacy field trials in both corn and soybean to evaluate giant ragweed control. Plots were 10’ wide by 25’ long in both crops, and all treatments were replicated three times in corn and four times in soybean. Two corn trials were located near Prairie Du Sac, WI. One soybean trial was located near Janesville, WI. The two corn trials evaluated many herbicide treatment combinations including one-pass and two-pass programs. These trials were located in a field where glyphosate resistance was suspected prior to the 2012 growing season, but later preliminary greenhouse studies did not indicate resistance was evident (Dr. Dave Stoltenberg, personal communication). In the soybean trial, we did not expect giant ragweed to be resistant to glyphosate or cloransulam. However, the objectives of the soybean study were to evaluate control options in a situation where resistance to ALS-inhibiting herbicides (i.e. cloransulam) was expected, AND, poor efficacy of glyphosate was observed indicating fear that glyphosate resistance was developing in the population. Therefore, the focus of this study was to evaluate ‘rescue’ scenarios, not including ALS-inhibiting herbicides, where efficacy of an initial application of postemergence glyphosate was not adequate. Our treatment structure was such that we investigated many combinations and timing strategies of PPO inhibitors, primarily lactofen and fomesafen, along with glyphosate.

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[1] Assistant Professor, Dept. of Agronomy, 1575 Linden Dr., Univ. of Wisconsin-Madison, Madison, WI, 53706.

Summary of 2012 results

Despite greenhouse studies that indicated a giant ragweed population susceptible to glyphosate in the two corn trials, sole reliance on postemergence glyphosate in the field was not an entirely acceptable treatment even with good spray coverage and applications on appropriate size weeds. It was, however, unusually hot and dry in 2012, and that may have reduced postemergence glyphosate performance, nonetheless, a diverse herbicide approach was needed. The efficacy of many herbicide treatments will be revealed, but in short, numerous two-pass, diverse herbicide programs that utilized residual products were effective. If herbicide programs are chosen wisely, and applied at appropriate timings, there are still a number of effective herbicide programs to control giant ragweed in corn. These programs will be discussed.

In contrast, our soybean trial was located in Janesville and focused on 'rescue' treatments following poor performance of postemergence glyphosate. In this trial complete control of giant ragweed was not achieved by treatments in our study. Unfortunately, we did not find any combinations or timings for 'rescue' of poor glyphosate performance to clearly provide better control compared to glyphosate alone. These results indicate a major concern about the future of giant ragweed control in soybean if we do not prevent glyphosate and ALS resistance from developing!

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HOW MUCH IS CANADA THISTLE COSTING ME IN MY PASTURES?

Mark J. Renz[1]

Canada thistle (*Cirsium arvense*) has been identified as a weed of concern in Wisconsin pastures. It can reduce forage yield and utilization, both of which can have a negative impact on animal performance (Undersander et al., 2002). Control typically involves the use of herbicides, an effective control that has been well-researched and documented. Though effective in controlling Canada thistle, herbicides also kill clovers, which are highly desired in Wisconsin pastures. Thus graziers are often left wondering if they should manage Canada thistle infestations in pastures with an herbicide, knowing it will remove the clovers, or if they should allow this problem weed to persist. To answer this question it is important to understand how much forage is being lost due to direct competition with Canada thistle and how much forage utilization is reduced by this spiny weed.

Forage quantity reductions from Canada thistle. Several studies have estimated losses in forage quantity from Canada thistle. Research has documented losses in forage from as few as 1 shoot/ft^2 with losses ranging from 0-96 % forage loss depending on the level of infestation and other site-specific variables (Grekul and Bork, 2004). It is important to realize that these values do not include Canada thistle biomass in the forage calculation. Canada thistle is eaten in pastures, and does have high forage quality, but its spiny nature decreases its palability. This needs to be considered.

Forage utilization of Canada thistle and adjacent forage. Few studies have evaluated the utilization rates of Canada thistle and forage adjacent to infestations. Work out of Alberta, Canada suggests that Canada thistle utilization is between 0-40% in pastures, depending on the time of grazing, other forage present, and grazing method utilized deBruin and Bork (2006). While others have shown that utilization of weeds can be increased by training animals, this is an uncommon practice rarely seen in the upper Midwest (Undersander et al. 2002). In addition to the reduced utilization of the Canada thistle, forage adjacent to this spiny plant is not heavily utilized. Research indicates utilization of other forage ranges between 47-88% (deBruin and Bork, 2006).

Thus Canada thistle has the potential to reduce the amount of desirable forage as well as the use of that forage, but no information is available from Wisconsin or similar areas in the upper Midwestern United States. This presentation will discuss results from trials at three locations across Wisconsin in 2012 that utilized Management Intensive Rotational Grazing with and without an herbicide application. Results will summarize the costs and benefits of an herbicide application and also compare results to a mob grazing.

[1] Extension Weed Scientist. Department of Agronomy, 1575 Linden Drive, University of Wisconsin-Madison. mrenz@wisc.edu

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FERTILIZER INDUSTRY UPDATE

Joe Dillier [1/]

{This page provided for note taking}

[1/] Director of Plant Food, Growmark, 1701 Towanda Ave, Bloomington, IL 61701..

NUTRIENT MANAGEMENT PANEL

Pat Murphy, Sara Walling, and Andrew Craig [1/]

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

HISTORICAL PERSPECTIVES ON SOIL LOSS

Francisco J. Arriaga[1] and Greg Andrews[2]

Erosion is older than human kind. It has helped shape and form numerous landscapes on the planet. However, erosion is detrimental to agriculture, the environment, and the economy. In the 1930s the damaging effects of soil erosion were felt in Washington DC, bringing the attention of government officials to this problem. This awareness of soil erosion's negative impacts, both on- and off-farm, was key for establishing new programs to address the issue. Wisconsin played a crucial role in the fight against soil erosion in the United States. In 1933, the Coon Valley Watershed Project became the first watershed conservation project in the nation. The site was selected due to the interest of many local farmers in stopping rills and gullies from ravaging their fields. Many conservation practices, such as contour planting and strip cropping, were established and implemented for the first time in multiple farms in a single watershed. Not only was progress monitored at the field and farm level, but benefits to local streams and wildlife were also studied. This watershed project was so successful that it led to the establishment of the Soil Conservation Service (currently Natural Resources Conservation Service). Awareness of soil and other natural resources gained significant attention during this period and the decades that followed. Although great advances have been made in the area of soil and water conservation, the need for this work continues. Many fields still have erosional losses well above soil tolerable loss values, and these are much greater than soil formation rates. Recent changes in climatic patterns, including droughts and severe rainfall events, have created more stress on soil resources. Further, high grain prices have placed incentives on farming marginal and fragile lands. All of these factors have generated greater risks for soil erosion. Can we learn any lessons from history to protect one of our most precious and important resources?

1/ Assistant Professor and Extension Soils Specialist, Dept. of Soil Science, Univ. of Wisconsin-Madison.
2/ Professor, Agriculture Agent and Department Head, UW-Extension Pierce County.

AFTER TMDL APPROVAL: THE NEXT STEPS IN THE LOWER FOX RIVER WATERSHED

Keith Marquardt 1/

Introduction

Green Bay is the largest freshwater estuary in the world. All the waters within the Lower Fox River Basin drain to Green Bay. However, there are waters within the Lower Fox River Basin that are impaired due to high levels of sediment and phosphorus entering the waters. Impaired waters need to be corrected - - restored to fishable, swimmable, and designated use conditions as required by the U.S. EPA in the Clean Water Act.

All land uses within the Lower Fox River Basin, whether urban or rural, contribute a source of sediment and phosphorus to the waters within the basin to some extent, but in varying amounts. To determine the amounts of sediment and phosphorus being delivered to the waters, total maximum daily loads (TMDLs) were developed and subsequently approved by EPA in May 2012 (http://dnr.wi.gov/topic/tmdls/). By knowing the amounts of sediment and phosphorus being delivered to a waterbody, and which areas or land uses contribute the most pollutants, resource managers can focus their restoration efforts in the watershed in order to achieve improved water quality.

TMDL Implementation Discussion

Within the Lower Fox River Basin, point sources (industrial, municipal, CAFOs, and stormwater) and nonpoint sources will be required to address their sediment and phosphorus loading to the Lower Fox River Basin. The TMDL will be implemented through existing regulations, financial incentives, and various pollution control programs. In addition, relatively new pollution control programs, including water quality trading and adaptive management, may be utilized by the permit holders and landowners within the Lower Fox River Basin to achieve these goals.

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1/ Water Resource Management Specialist, Wisconsin Department of Natural Resources, 625 E. County Road Y, Suite 700, Oshkosh, WI 54901

THE STATE OF THE ALFALFA ADDRESS

Mike Rankin [1/]

Introduction

Alfalfa has been a primary forage crop on Wisconsin dairy farms for many years. As we enter 2013 it is readily apparent that today's alfalfa varieties are much different than those planted 15-20 years ago. Further, alfalfa is managed more intensively from a cutting frequency standpoint in an attempt to harvest forage of higher quality. In 2012 Wisconsin alfalfa was subject to a multitude of stresses, the consequences of which have yet to be seen. As we enter 2013 it seems appropriate to take inventory of the current state of alfalfa, looking both at factors that have been changing over the past 20 years and those that have impacted the crop and its management recently.

Long-term Trends and Impacts

Changes that occur over many years often are not often noticed because they occur in small increments. Several of the changes that have impacted alfalfa in the past 20 years fall into this category, while others have been readily apparent. Here are seven significant trends and conditions that have shaped the current status of alfalfa:

1. Consolidation of alfalfa breeding programs
2. Characteristics of alfalfa varieties
3. Alfalfa yield enhancement
4. Increase in alfalfa persistence and winter survival
5. Increase in harvested forage quality
6. Changes in soil fertility status
7. Introduction of transgenic traits

<u>Consolidation of alfalfa breeding programs:</u>

In October 2012 Dow AgroSciences LLC acquired Cal/West Seeds. The company had previously purchased Wisconsin-based Dairyland Seeds in 2008. The merging of these two previously independent entities continues a long-term consolidation trend and now means that effectively all dormant alfalfa varieties will come from one of three breeding programs---Dairyland-Cal/West, DuPont Pioneer, or Forage Genetics International.

<u>Characteristics of alfalfa varieties:</u>

Alfalfa varieties today "look" very different than those of the 1990s. Table 1 compares the fall dormancy (FD) ratings of alfalfa varieties tested in the University of Wisconsin performance

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[1/] Crops and Soils Agent, Univ. of Wisconsin-Extension, Fond du Lac County
michael.rankin@uwex.edu

trials in 1995 and 2012. In 1995 over 60% of the varieties were FD 2 or 3. Today, over 80% are FD 4 or 5. In the past 20 years we have also seen a large proliferation of alfalfa varieties with specialized traits. Included are traits for higher forage quality, standability, potato leafhopper resistance, defined soil conditions (wet, salt, etc.), and glyphosate resistance. Hybrid alfalfas have also been made available.

Table 1. Fall dormancy ratings of alfalfa varieties tested in the UW performance trials – 1995 vs. 2012

FD Rating	1995	2012
	% of total	
2	19	4
3	42	12
4	38	71
5	1	13
# varieties	103	52

Alfalfa yield enhancement:

Gains in alfalfa yield were shown to be on a small decline from 1978 through the mid-1990's (Wiersma et al., 1997). Although varieties showed improvements in disease resistance, it came at the expense of winter survival and persistence under more intensive cutting systems. In the past 20 years, alfalfa yields have been on a slow, but steady increase. Since 1989, mean alfalfa yield of varieties entered in the UW performance trials at the Arlington site have increased by an average of 0.1 tons/acre/year for 1st and 2nd production year stands (Figure 1). Mean trial yields now are routinely near 7 tons/acre. Individual varieties have recently yielded over 10 tons/acre.

Persistence and winter survival:

The extreme alfalfa winterkill years of the early 1990's in the upper Midwest shifted the focus of alfalfa breeding programs. Cultivar selections started to be made under intense cutting regimes, while still putting an emphasis on yield potential. This has resulted in the breaking of the long-standing fall dormancy x winter survival/persistence relationship (Table 2). Fall dormancy 4 and 5 varieties with fast regrowth and yield potential now also possess exceptional winter survival and persistence characteristics.

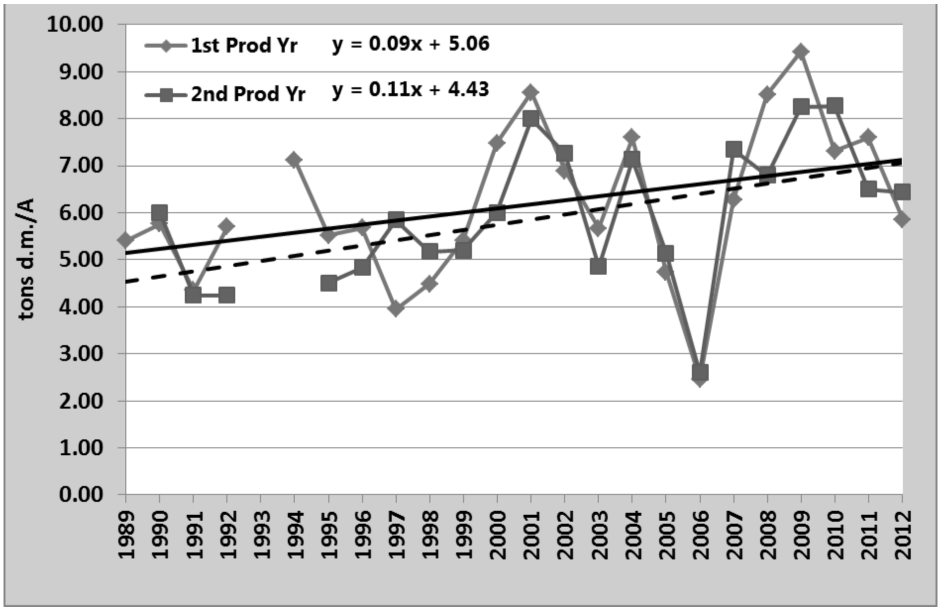

Figure 1. UW variety performance trial mean alfalfa yield at Arlington, WI (1989-2012).

Forage quality:

Alfalfa producers are now harvesting much higher quality forage than was the case 20 years ago. Many factors have contributed to this change, but alfalfa scissors-cut programs, pressure from nutrition consultants, and improved varieties have been major factors. Data from the Wisconsin Agricultural Statistics Service clearly shows that the state's alfalfa growers are harvesting 1st-cut hay much earlier in recent years compared to before the mid-1990s (Figure 2). The average percent of hay harvested by June 1st in Wisconsin has been 8, 14, and 21 for the years 1980-89, 1990-99, and 2000-10, respectively.

Changes in soil fertility status:

Two well-documented trends in soil fertility have taken place in the past ten years; both have consequences to alfalfa production. First, the state's soils have seen an overall decline in potassium (K) fertility. Visual deficiency symptoms are becoming more commonplace. The increase in corn silage acres and a corresponding increase in fertilizer price are likely major contributing factors to declining soil K levels.

A second trend has been a long-term decline in available soil sulfur (S) caused by a reduction in the amount of atmospheric S deposition. Like K, both plant tissue tests and visual field observations help to confirm the increase in deficient situations. Where K and/or S are limiting, alfalfa production can be significantly impacted.

Transgenics:

For alfalfa, the road to transgenic traits has lagged behind other grain and oilseed crops, but the availability of glyphosate resistant alfalfa varieties has now made it possible for future traits to be offered. Currently, plant breeders are developing cultivars with low lignin, drought tolerance, enhanced yield genes, pest resistance (both insect and disease), and improved animal protein utilization.

Table 2. Comparison of fall dormancy, winter survival (1=best), and persistence (10=best) between typical 1990s and current alfalfa varieties

Typical "1990s" alfalfa varieties **Low FD = best winter survival, low yield, poor under intensive cutting management** **High FD = faster regrowth, higher initial yield, poor winter survival/persistence**		
	Winter Survival Score (1-6)	3rd-Yr. Persistence Index (10-1)
FD2	2.6	3.2
FD4	4.7	2.3
New generation alfalfa (means of several varieties) **No relationship of FD to winter survival** **High yielding and persistent**		
	Winter Survival Score (1-6)	3rd-Yr. Persistence Index (10-1)
FD4	1.7	7.9
FD5	1.6	7.9

Data provided by M. McCaslin, Forage Genetics Int.

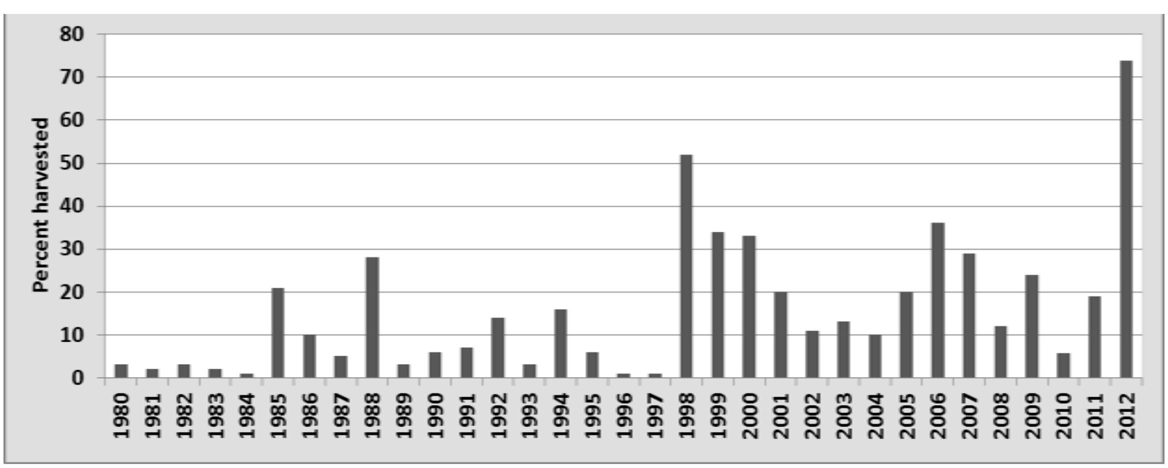

Figure 2. Percent of 1st-crop hay harvested by June 1 in Wisconsin, 1980-2012 (NASS)

Current Short-term Factors

In addition to long-term impacts and trends, there are also some significant short-term factors having immediate consequence to Wisconsin alfalfa production. These include:

1. Stresses induced by the 2012 growing season
   a. Drought
   b. Short or more frequent cutting intervals
   c. Insects
2. Seed supplies
3. Hay price
4. Fungicides
5. Forage inventory

Stresses--drought:

The degree of drought during the 2012 growing season ranged from severe to non-existent, but most areas experienced some degree of moisture deficit. Though drought has a significant impact on productivity, it is mostly a temporary condition and one that is overcome when normal moisture conditions return. For some areas this has already occurred and for the rest it is reasonable to assume that 2013 won't be a continuation of 2012; or at least that is the hope.

Stresses--frequent cutting:

Perhaps of greater consequence than drought alone were the multiple factors in 2012 that contributed to more frequent cutting of alfalfa stands. These factors included: drought (fewer days to flower), an early spring (longer growing season), and an above average number of growing degree days (fewer days to flower). The long, warm, and dry growing season resulted in some alfalfa stands being harvest as many as 5 or 6 times.

Stresses--insect pressure:

Though insect pressure on alfalfa is a problem in many years, coupled with drought-stress it can be especially detrimental. Variegated cutworms reached rock star status about the time 1st-cutting was ready to be made and many stands needed to be treated with insecticide. Reports of alfalfa weevils also were above average in 2012. Potato leafhoppers reached economic threshold levels in many fields and damage was significant where control measures weren't implemented.

Stresses--combined:

There's an old saying along the lines of "you can cut an alfalfa field ten times in one year or one time per year for ten years." The numbers are arguable, but the underlying principle is sound ---multiple stresses shorten stand life. The good news is that this is less true today than it was 20 years ago because of improved genetics.

Under moisture stress, alfalfa begins flowering in fewer days than normal. This doesn't necessarily need to, but often does prompt a more frequent cutting regime. Add into the mix potato leafhopper pressure that goes uncontrolled, yet an additional late-fall cutting to fill forage voids, and soon the situation develops into an all-out stress-fest. It's these fields that will demand the most attention and evaluation in 2013. Conversely, fields that experienced only moderate or short-term drought conditions, were allowed longer cutting intervals, had low or controlled insect pressure, or were not cut in the fall should bounce back to full production in 2013 given favorable winter and spring weather.

Seed situation:

Alfalfa seed availability looks to be adequate in 2013. Of course the best varieties will be in the shortest supply. Growers should also be cognizant that more and more seed is being sold with a seed coating that can comprise up to one-third of the seed bag weight.

Alfalfa hay price:

Since 2003, the US marketing year hay price has only had one year-to-year decrease (Figure 3). Current 2012-13 hay prices are at an all-time high with upper Midwest hay auction prices in the $250-$350 per ton range for premium quality.

Fungicides:

Alfalfa is last frontier for exploring the use of fungicides as a routine management practice. In the past couple of years many on-farm and research station plot trials have been initiated to quantify the economic consequences of fungicide use. To date, results have been variable. One thing that has been reinforced from these trials is the positive economic benefit of insecticide applications to control potato leafhoppers; many of the fungicide trials included insecticide treatments mixed with the fungicide or applied alone.

Forage inventory:

Although most farms will have enough forage to get them through the spring, typical carryover supplies will be depleted in drought areas. Alfalfa feed reserves will likely need to be replenished in 2013. This might mean seeding down more alfalfa acres than normal, especially if production in multi-stressed fields is reduced. Perhaps there are opportunities to lease established stands of alfalfa from neighboring operations or to produce alternative feeds. Planning now, using reasonable 2013 yield expectations and evaluating stands early and often in spring will help to avoid a crisis mode later in 2013.

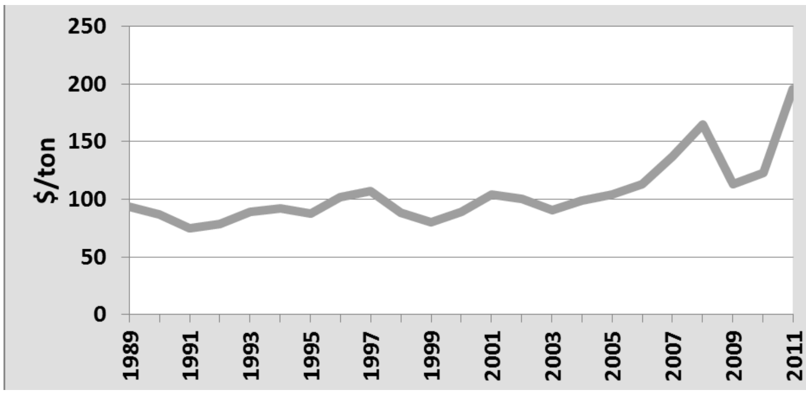

Figure 3. US marketing year hay price, 1989-2011 (Source: NASS).

Conclusion

Even with some short-term concerns following a stressful 2012 growing season, there is a bright future for alfalfa in Wisconsin. Some of the long-term improvements made to alfalfa in the past 20 years will help the crop withstand many of the stresses encountered in 2012. Even so, a high level management will still be needed to achieve the potential yields possible with current and future alfalfa varieties.

EFFECT OF 2012 DROUGHT ON ALFALFA AND MANAGING FOR 2013

Dan Undersander [1/]

The 2012 drought reduced alfalfa yield by significantly across Wisconsin. It appears, that while some regions (especially northeast Wisconsin) had better yield than others, the overall average yield was down about 25% and (since haylage is made first and the rest baled) hay production may be down by as much as 50%.

In the Southern part of the Wisconsin yield of first cutting was reduced due to a dry March. Alfalfa root systems die back to some extent over winter. The root system requires good soil moisture in the early spring to regrow. If a strong root system forms then high yields will occur on first cutting. If the root system growth is restricted by dry soil, then the top growth will be reduced, even if good rain occurs in the later part of the first cutting growth period (during April and May) as occurred this past year.

Dry periods during summer, reduced alfalfa growth across much of western and southern Wisconsin. Most of this drought-stressed field areas of very short alfalfa with some areas of better growth due to subsoils with higher water hold capacity. Our recommendation is to harvest what is economic and to leave very short field or short portions of fields.

Moisture stress has the following effects on the alfalfa plant:

- Cell enlargement is inhibited.
- The number of basal buds and the number of shoots or stems/plant is reduced when moisture stress occurs in the first 14 days after a harvest.
- The stem internode length is reduced; thus the flowering is seen at reduced plant height.
- Leaf area/leaf size and leaf growth rate is reduced, although to a lesser degree than stem growth. Therefore leaf to stem ratio is higher under moisture stress.
- Stem nitrogen percentage is increased while leaf nitrogen percentage is decreased, therefore whole plant nitrogen (CP) may be reduced though effect varies with severity/timing of moisture stress.
- NDF is generally decreased, though effect varies with severity/timing of moisture stress.
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Thus forage from drought stress fields is often lower yielding but of higher forage quality. This is the opposite of drought stressed grass fields.

Recommendations for managing drought stress alfalfa during growing season:

1. **Established stands**
   a. **If stand is over 10 inches tall and flowering, harvest if economic to do so.** Moisture stressed alfalfa should be mowed at the normal cutting height. There is no advantage to raising the cutting height. Alfalfa can regrow from axillary buds on the stubble but these shoots are smaller and produce lower yield than stems growing from the crown buds. Since quality is not declining as rapidly with advancing maturity as under normal growing conditions, let the plants approach 100% bloom before harvest to allow the plant to build nonstructural carbohydrate reserves. You can harvest only the taller portion of disuniform fields.

[1/] Professor, Department of Agronomy, Univ. of Wisconsin-Madison.

b. **If stand is 10 inches or less tall and flowering, do not cut.** Let regrowth come through existing growth. Mowing will not increase regrowth.
c. Make sure that soil fertility is at optimum levels.
d. Scout and control potato leaf hopper, army worm and other insects.

2. **New seedings should not be harvested during the season** but an early cutting, when moisture was adequate could have been taken. New seedings may also be harvested in late fall if adequate growth is present to harvest. The key is to time fall harvests so that alfalfa either has no regrowth or more than 8 inches of regrowth at frost.

New seedings may have had poorer stands if a dry period followed seeding. Further, these plants may not have developed as extensive root systems as fields that were seeded and dad adequate moisture. The result of the reduced root systems will be reduced yield from these new seeding in 2013.

The higher than average temperatures resulted in increased water need, earlier flowering and lower than average fiber digestibility. In addition, fields with Aphanomyces which reduced root growth, suffered more yield loss due to the drought than healthy stands.

The drought in late summer and early fall certainly reduced the carbohydrates stored in the roots for winter survival and spring growth. Whether or not this will be significant will depend on the winter – if the stands encounter warm periods so that they begin to green up and are frozen back – this pattern will be more detrimental than if the greenup occurs to healthy plants. Thus good snow cover will minimize the weak stand effects and a warm, open winter will exacerbate the weakness of the stands.

As of mid-December we are still in a drought in much of Wisconsin. Dry soils going into the winter enhance alfalfa survival, since dry soils insulate the crown better from air temperatures and result in less disease in the alfalfa roots.

One the other hand we need to hope that soil moisture increases by March so that good root growth and high yields can occur for 2013.

Many farmers will need forage early in 2013. The best recommendations to get both early season yield and high total season yield are:

- Evaluate alfalfa stands and replant if necessary for top yield
- Plant alfalfa with oat or ryegrass cover crop to increase early season yield
- Prepare to fertilize alfalfa after first cutting (in early spring if potassium and sulfur are low).
- Maximize pasture use.
  - Fertilize
  - Allocate forage (small paddocks).

EMERGENCY FORAGES: TARGETING GAPS IN THE GROWING SEASON

Nick Schneider [1/]

Introduction

Drought experienced through much of Wisconsin during the summer has reduced the states dry alfalfa inventory by 32% and other dry forage by 1% as of the 2012 USDA October Crop Production summary. Forage shortages are of great concern to livestock producers. The high cost of many forms of feed caused unexpected financial challenges for livestock producers. New forage production strategies will help rebuild the low forage inventories across the state.

One such strategy is the potential to raise double crop forages after winter wheat harvest. Farms scattered across Wisconsin tried growing emergency forages and double crop soybeans after winter wheat during the 2012 drought with mixed results. Rather than growing emergency forages during the wheat fallow gap in the growing season, planned double crop forage can increase the likelihood of success.

Discussion

Winter Wheat Growing Season Gap in Wisconsin

From 2006 to 2010, Wisconsin averaged 282,000 acres of harvested wheat (USDA-NASS, 2007-2011). After harvest some of these fields are planted with late summer alfalfa and a few more receiving manure, but many sit idle for the rest of the growing season. Fields that are tilled late summer for weed control are left vulnerable to erosion. If growers take action shortly after harvesting wheat and straw, they can use the 30% of growing season precipitation and 40% of total Growing Degree Units (GDUs) that remain. This 30 to 40% rule of thumb applies throughout the state. Data from the National Oceanic and Atmospheric Administration (1971-2000) across Wisconsin demonstrate a similar rate of GDU and precipitation increase through the growing season (NOAA, 2004). On average between the end of July to the end of October, Wisconsin receives 975 to 1,300 GDUs (corn base) (Fig. 1) and 9 to 11 inches of precipitation (Fig. 2). This amount of heat and precipitation has the potential to grow more forage.

Growing Double Crop Forages

Double crop forages such as brassicas, annual small grains, legumes, sorghums and millets, and even corn silage can be sources of late season forage with the potential to provide erosion protection, suppress weeds, and cycle nutrients. Double cropping after wheat is a value added forage opportunity. Many studies have been conducted on emergency forages and fall small grain forage. Yield results vary from 0.5 tons/dry matter/acre to 4.0 tons/dry matter/acre or more (Undersander, 2008). Planting timing is important because 20% of GDUs accumulate in August. Variety selection is also important for maximizing yield and quality. For example, Forage Plus oats is a good fit for yield and quality reasons because this variety should not develop into the boot stage as quickly as others thereby allowing time to work around corn and soybean harvest.

[1/] Winnebago County Agricultural Agent, Univ. of Wisconsin Extension, 625 E. County Road Y, Oshkosh, WI, 54901

Earlier maturing oat varieties can yield well but forage quality may decrease as heading stage is reached. If fall planting is delayed, then earlier maturing varieties should be considered (Coblentz and Bertram, 2012).

The decision process for growing double crop forages requires both planning and flexibility. Look back at the field's herbicide history. There may have been soil applied residual herbicides sprayed within past years that can create herbicide injury from persistence plus feeding the forage from fields with these residues may be an off-label use (Davis, 2012). UW Extension Publication A3646 ("Pest Management in Wisconsin Field Crops") has a table that provides planting intervals for rotational crops. Since some of the double crop forage species are not commonly found on herbicide labels, the field may need to follow the longest rotation interval provided. Producers and agronomists planning to integrate double crop forages into the crop rotation should review planting intervals of herbicides to select products that will allow for the necessary flexibility.

Plan seed acquisition early, yet have flexibility. Some producers that planted double crop forages in the summer of 2012 had difficulty obtaining seed. Because of the limited use of double crop forages in the past, local agricultural retailers and suppliers did not have all seed immediately available in local warehouses. Early conversations between seed buyers and sellers can help alleviate these problems in the future. While it is important to plan seed purchases early, variability of summer weather may change planting decisions. For example, during a summer that has above normal temperatures and wheat is harvested during early July, planting sorghum, sudangrass, or millet may be preferred. Conversely, during a cool summer with late harvested wheat, forage oats w/o peas could be preferred.

Double cropping can put crop insurance coverage in jeopardy. Insurance coverage concern has been a problem in the winter rye – corn silage rotation because delays in planting the insured crop have a greater potential to reduce yields. In response to the 2012 drought, the USDA has temporarily changed the crop insurance rules for cover crop harvesting in spring of 2013. In the spring of 2013, a farmer may harvest a forage/cover crop planted the previous summer/fall/winter, and then insure the following grain crop. Follow up with the insurance provider (Mitchell, 2012).

Fertilizer can help push the growth of forage cover crops. Nitrogen will increase yield of non-legume double crop forages when applied before precipitation. Nitrogen rate should be adjusted to the needs of the plant species. UW Extension Publication A2809 ("Nutrient Application Guidelines for Field, Vegetable, and Fruit Crops in Wisconsin") provides nutrient application guidance.

<u>Double Crop Forage Options</u>

Old standbys such as oat, oats/peas, or even barley (if oats are unavailable) are viable options for growing another 1 to 3 tons/acre dry matter. Oat variety matters. There is a planting date interaction indicating value to selecting a forage type oat or at least a late maturing oat when the forage double crop is planted during late summer. Research summaries by Coblentz and Bertram (2012) can be found online at: http://www.uwex.edu/ces/crops/uwforage/FocusonForage.htm

Timing and heat are important for planting millet, sorghum, sudangrass, sorghum-sudangrass, and corn silage fields. A few farmers planted these earlier in 2012. They are a better fit when planting in early July and forecasts call for above normal temperatures. These plants grow slowly once temperatures drop in the fall. This group of plants has specific feeding precautions for nitrates and prussic acid, especially when killed by frost. A Focus on Forage tip sheet by Undersander (2003) can be found online at: http://www.uwex.edu/ces/crops/uwforage/SorghumsFOF.htm

Planting corn silage after winter wheat is another option that had some success in 2012. Studies from 2005-2006 found yield of corn silage planted at the Arlington Research Station on July 15 at 5.3, 4.7, and 3.8 T/A dry matter for 108 day, 94 day, and 102/112 day BMR RM hybrids, respectively (Lauer, 2008). When corn silage planting was delayed until August 1, yield dropped to 2.1, 1.9, and 1.4 T/A, respectively. Corn silages planted on July 15 or August 1 had low starch content at 8% or less.

Forage radish and forage turnips are options for grazing livestock and heifers. There is enough time for establishment of the *Brassica* forages in August. Top growth and root size becomes smaller as these are planted later. Forage radish has grown very well planted after winter wheat; however, it struggles to develop a large taproot when planted after corn silage harvest. These cover crops show considerable potential but this note is meant to remind growers to have realistic expectations about growth as planting is delayed after corn silage harvest. A tip sheet by Undersander (1996) can be found online at: http://www.uwex.edu/ces/forage/pubs/brassica.html

Summer is too late for red clover seeding, rather it should be spring frost seeded into winter wheat. Red clover can be alternative late season forage after wheat is harvested with the bonus of nitrogen fixation. A research summary by Stute and Shelly can be found online at: http://ipcm.wisc.edu/download/pubsNM/RedClover_0109.pdf

If feed supply will be tight coming out of winter, growers can plant winter rye after corn or soybeans for early harvest next spring. If winter rye seed is unavailable, then winter triticale and winter wheat are forage options. This practice can cause delays in spring planting which has the potential to lead to yield reduction in the following crop. A research summary by Stute et al. can be found online at: http://ipcm.wisc.edu/download/pubsNM/Rye_090507_final.pdf

Legumes including soybeans, chickling vetch, hairy vetch, crimson clover, berseem clover, Austrian winter field pea, and Sunn hemp have not been thoroughly researched as double crop forage in Wisconsin. Late planted soybeans are the best understood with data supporting high quality but low yield. Large amounts of feed tonnage are unlikely to accumulate from these plants after wheat. If new legumes are tried, please be sure to inoculate them with the correct *Rhizobium* inoculant.

Double crop forages planted after winter wheat have the potential to add more money per acre to a crop rotation. Wisconsin has low feed inventories after the 2012 drought; as a result, forage is more valuable than past years. The wide range of double crop forage species can help fill gaps in the growing season, provide ground cover and recover low feed inventories.

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Figure 1: Growing Degree Unit (GDU) accumulation selected from southern (Beloit) and northern (Ashland) Wisconsin. Two GDU formulas, the corn base and 45° F, demonstrate a similar rate of GDU accumulation across the state.

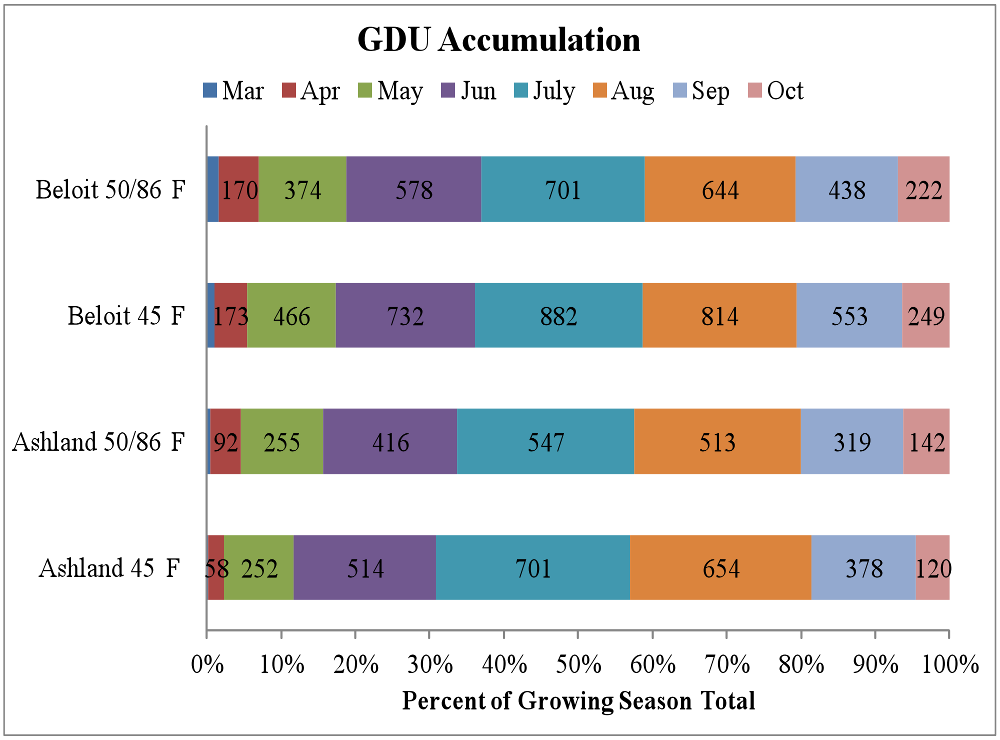
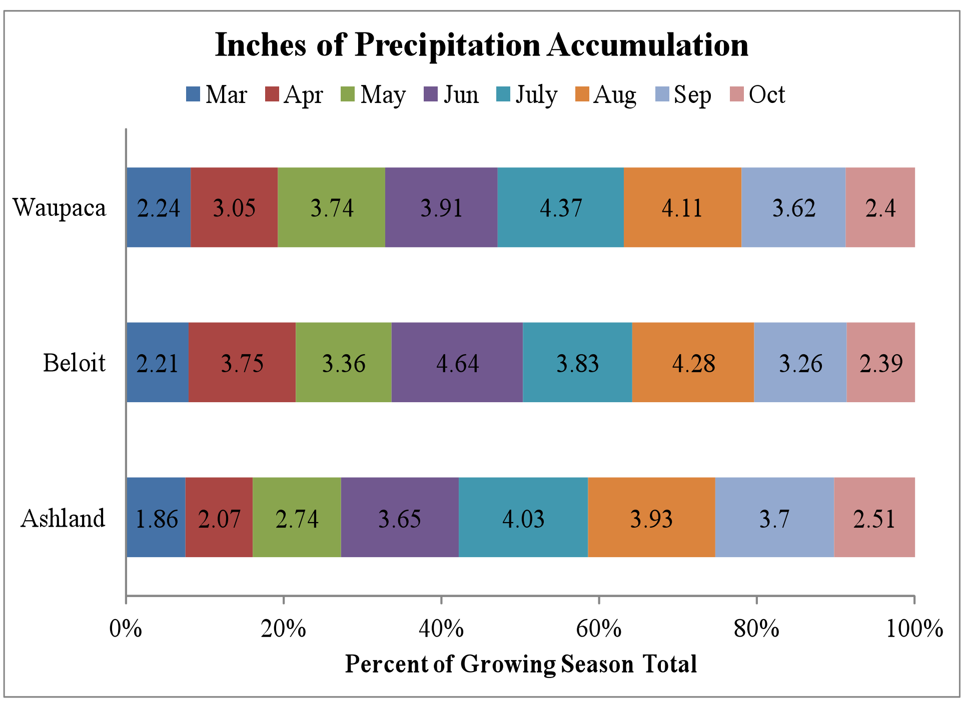


Figure 2: Precipitation accumulation (in inches) selected from southern (Beloit), central (Waupaca) and northern (Ashland) Wisconsin.



2012 DROUGHT: A DAIRY CATTLE NUTRITION PERSPECTIVE

Randy Shaver and Pat Hoffman [1/]

The 2012 drought generated many dairy cattle feeding related questions, especially in southern Wisconsin. Harvest and storage issues emerged and disappeared as the cropping year progressed, while feeding issues linger through feed out. The situation has been exacerbated by very high corn, soybean meal, forage, and byproduct feedstuff prices for those needing to purchase more feed unexpectedly due to the drought. Below is a list of sub-topics for discussion from a dairy cattle nutrition perspective at the conference.

- Feed inventory
- Harvest of immature drought-stressed corn as silage
- Pricing drought-stressed corn silage
- FeedVal 2012
- Nitrates
- Corn smut
- Emergency cover crops for forage
- Feeding wheat grain
- Feeding potatoes
- Variation corn silage NDF and starch contents within silos
- Minimizing feed shrink
- Feeding minimum-forage diets to milking cows
- Feeding reduced-starch diets to milking cows
- Byproduct feed usage
- Controlling feed use and cost in replacement heifer diets
- Chemically treated corn stover
- Aflatoxin
- Starch digestibility

[1/] Professor Dept. of Dairy Science, 1675 Observatory Dr., Univ. of Wisconsin-Madison and Outreach Program Manager, ARS Marshfield Lab., Univ. of Wisconsin-Extension.

FOLIAR FUNGICIDES ON ALFALFA: IS IT WORTH IT?

Bill Halfman, Greg Blonde, Bryan Jensen, Deborah Samac, Lisa Behnken, and Fritz Breitenbach [1/]

Introduction

Current trends in agronomic field crop production (corn and soybean) have been towards the use of foliar fungicides to promote "plant health" and increase yield in the absence of disease. Trials to examine this trend have been conducted across the upper Midwest and have resulted in very inconsistent results. Headline (pyraclostrobin, BASF, Research Triangle Park, NC) was approved for use in alfalfa beginning in 2011. We received numerous questions from growers and university researchers regarding the benefits of foliar fungicide use in alfalfa grown for forage. Many of these questions were focused on the use of a fungicide in a tank-mix with an insecticide, with the intent of providing a positive synergistic yield response. Thus, the objective of this study was to conduct field research trials in Wisconsin and Minnesota to examine the benefit of using a foliar fungicide, alone or in combination with foliar insecticide on alfalfa.

Methods

Trials were conducted at three locations in Wisconsin (Arlington, Tomah and Waupaca) and two locations in Minnesota (Waseca and Rosemount) in 2012. Arlington, Waseca and Rosemount locations were conducted on University Research Stations, Tomah and Waupaca were conducted in grower fields.

At each location, a randomized complete block experimental design was used with four replicates. Treatments were: Headline® (9 fl oz/a), Headline® (9 fl oz/a) + Warrior II® (1.2 fl oz/a), Warrior II® (1.2 fl oz/a), and an untreated check (UTC). All plots measured 20 ft wide x a minimum of 30 ft long. Total application volumes ranged from 23.7 to 24.7gallons per acre depending on the equipment used at the location. Application timing was between 6 and 9 inches of growth. Trials were conducted on first, second, and the last cutting before September 1st, except at Tomah, which did not have a last cutting due to drought conditions. Plots in Wisconsin were harvested on a cutting schedule to maximize alfalfa quality for use in dairy forage. The Minnesota plots were harvested on a schedule to mimic good quality heifer and beef cattle forage.

Yields were taken using small plot harvesters. Subsamples for quality analysis were whole plants harvested separately from yield measurements and sent to the University of Wisconsin-Madison, Department of Agronomy for near infrared (NIR) analysis. The following data were collected from each site: yield (T/a), forage quality, insect sweep counts, and stem heights. Individual plant samples were sent to Dr. Samac at the University of Minnesota for foliar disease rating and subsequent pathogen isolation

A procedure was developed with Dr. Victor Cabrera, UW Extension Dairy Management Specialist and Dr. Randy Shaver, UW Extension Dairy Nutrition Specialist, utilizing the UW developed Milk 2006 and the FeedVal 2012 spreadsheet tools to determine dollar values of the alfalfa harvested from the plots when feed value differences (α=0.10) were measured between treatments at

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[1/] UW Extension Monroe County; UW Extension Waupaca County; UW IPM Program; USDA-ARS; University of Minnesota Extension; University of Minnesota IPM Program respectively

locations. The FeedVal 2012 spreadsheet uses benchmark feeds of known quality and prices to make economic comparisons with feeds of known nutritional values. Milk 2006 was used to calculate net energy of lactation values (neL) for the alfalfa samples. FeedVal 2012 was then used for calculating economic values of the alfalfa samples using crude protein and neL. Annual average prices for corn grain, soybean meal, good quality alfalfa hay, poor quality alfalfa hay and corn silage were used as benchmark prices. Alfalfa hay prices were obtained from records of actual sales of known quality tested hay from Ken Barnett, UW Extension Center for Dairy Profitability.

If there were yield and/or quality differences (α=0.10) these values were then used to calculate the total value of the forage harvested in that cutting between treatments and then adjusted for the cost difference of the treatments based on average costs obtained from area agronomy dealers.

Results

Fourteen unique comparisons of treatments were possible across locations and cuttings. Response to the application of Headline fungicide either alone or in combination with Warrior II was inconsistent for both yield and quality.

A positive yield response (α=0.10) was observed in five out of 14 observations when using Headline® alone compared to the untreated check. When evaluating the addition of Headline® to an application of Warrior II®, a positive yield response (α=0.10) was observed in four out of 14 observations. A negative yield difference (α=0.10) was observed at one of the locations when comparing Headline® + Warrior II® with Warrior II® alone.

When evaluating forage quality between Headline and the untreated check, Headline positively influenced (α=0.10) crude protein in three out of 14 observations, and had a negative influence on crude protein (α=0.10) in three of 14 comparisons. Observations of neL were influenced positively by Headline® (α=0.10) in three of 14 observations and negatively (α=0.10) in four of 14 observations.

When evaluating forage quality between the Headline® + Warrior II® and Warrior II® alone, Headline® + Warrior II® positively influenced (α=0.10) crude protein in three out of 14 observations, but also had a negative influence on protein (α=0.10) in two of 14 comparisons. Observations of neL were affected positively (α=0.10) by the Headline® + Warrior® treatments in four of 14 observations and a negative influence (α=0.10) in two of 14 observations.

Headline® treatment significantly (P<0.05) reduced defoliation and infected leaf area in 12 of 14 observations and Headline® + Warrior® reduced disease significantly in 10 of 14 observations compared to the untreated control. Warrior® reduced disease significantly (P<0.05) in 1 of 14 observations. The greatest effect on foliar diseases was in the first forage harvest at all locations.

Return on investment was calculated for all treatment observations, using average feed prices from Jan 2012 through November 2012 for the benchmark feeds. Treatment costs were obtained from a survey of agronomy dealers requesting the costs of Headline® (9 fl. oz/A) and applications fees. A treatment cost of $35/A was assigned to the Headline® treatment and included the application fee ($8/A). It reflects the average cost of applying only the fungicide. A treatment cost of $27 was assigned to the Headline® + Warrior® treatment. It excludes the application fee and the cost of

Warrior®. This figure reflects the cost of adding Headline® to an already planned application of Warrior®. For all treatment observations (positive or negative) the economic gain or loss was determined from using the Milk 2006 and FeedVal 2012 spreadsheets. In cases where there were statistically significant yield or quality responses the return on investment ranged from -$104 per acre to $93.91 per acre.

Conclusion

Additional trial data are needed before economical recommendations can be made regarding foliar fungicide use in alfalfa.

COSTS AND BENEFITS OF ROUNDUP READY® ALFALFA IN THE ESTABLISHMENT YEAR

Mark J. Renz[1]

Weed suppression can be important during alfalfa establishment as weeds can reduce stand life, alfalfa biomass, and forage quality. To reduce these impacts producers commonly apply herbi-cides to establishing alfalfa. A range of options exist, but the most common applications include imazamox (Raptor) or imazethapyr (Pursuit). These compounds have traditionally given the best control of common weeds (e.g., lambsquarter & foxtail species) and can be applied post emer-gent. With the introduction of Roundup Ready® alfalfa, producers now have an additional choice for weed management.

Weed management with glyphosate has benefits compared to imazamox and imazethapyr. Imazamox and imazethapyr can cause injury to seedling alfalfa resulting in biomass reductions up to 20% in the 1st cutting of the establishment year. In contrast, no injury or yield reduction has been observed with glyphosate in Roundup Ready® alfalfa. Additionally, to avoid reduced efficacy, it is recommended that imazamox and imazethapyr be applied to small weeds that are less than or equal to 3 inches tall or in diameter. It can be difficult for producers to make applications to weeds at this stage as imazamox and imazethapyr cannot be applied until the alfalfa seedlings have at least two trifoliate leaves. Alfalfa plants often do not reach this stage until weeds are larger than 3 inches. Due to this, applications are typically made 2 to 3 weeks after the weeds were at the 3 inch stage, resulting in reduced control. This lower level of control can also result in reductions in alfalfa biomass and decreased forage quality. Glyphosate use in Roundup Ready® alfalfa is not restricted with respect to the stage of alfalfa and glyphosate's effectiveness has been demonstrated on larger weeds. Thus, the Roundup Ready® alfalfa establishment system offers many benefits to producers. However, these benefits are expensive as every bag of Roundup Ready® alfalfa seed has an additional fee of $125. Information is needed to help producers make an informed decision on when the benefits of Roundup Ready® alfalfa outweigh the additional costs in direct seeded establishment methods. I will present research results that will compare establishment systems at a field scale at seven sites across Wisconsin.

METHODS

We established seven fields with Roundup Ready® alfalfa. One field was established in each of the following Wisconsin counties: Brown, Clark, Dane, Door, Fond du Lac, Jackson, and Washburn. At each site we used a randomized complete block design with three replications. Each plot was 10-20' wide and 50-125' long depending on the site. Treatments consisted of glyphosate + AMS applied at 0.75 lbs ae/A or imazamox + MSO applied at 0.04 lbs ae/a (Raptor at 5 fl oz/A). Applications of either glyphosate or imazamox were made to weeds 1 to 3" in height/diameter or 4 to 8" height/diameter (2 to 3 weeks after 1st treatment) in addition to an untreated control (5 treatments per site). Visual estimates of control of major weed species and percent injury and growth reduction of alfalfa were taken prior to each harvest. Plots were harvested by randomly placing three 0.5 m^2 quadrats in each plot. Samples were separated into weeds and alfalfa, dried, and weighed. Due to drought, only four sites were harvested for the 2nd cut (Clark, Dane, Fond du Lac, and Jackson counties).

[1] Extension Weed Scientist. 1575 Linden Drive, University of Wisconsin-Madison. mrenz@wisc.edu

RESULTS

Weed control and alfalfa injury: Weed pressure varied between sites with low weed pressure at Dane (<15% weed biomass in 1st cut of untreated control); moderate weed pressure at Brown, Fond du Lac, and Jackson (40-50% weed biomass in 1st cut of untreated control); and high weed pressure at Clark, Door, and Washburn (> 60% weed biomass in 1st cut of untreated control). Lambsquarter control, summarized across locations, was best (94%) when glyphosate applications were made to small plants compared to all other treatments. When sites were analyzed separately, Imazamox applied to small weeds gave similar control as glyphosate applied at the same timing at three sites, but across locations did not control lambsquarter as well (75%). This suggests that environmental and physical factors affect control with imazamox more than glyphosate. While variable among sites, visual injury and growth reduction was greater with imazamox treatments at the later timing (13 and 5%, respectively) when analyzed across sites.

Forage yield: Total forage yield was greatest in the untreated areas in the 1st cut, but consisted of 54% weeds when analyzed across sites. Glyphosate applied early provided the highest percentage of alfalfa (96%) compared to other herbicide treatments (71-79%). However, when locations are analyzed separately no benefit in percent of alfalfa was found in the low weed pressure site (Dane), percentage of alfalfa was similar between all herbicide treatments but higher than untreated plots at moderate weed pressure sites (Brown, Fond du Lac, Jackson), and glyphosate applied to small weeds performed the best at the high weed pressure locations (Clark, Door, and Washburn). Due to drought conditions, only four locations were cut a 2nd time. In three of the four locations percent alfalfa was similar among herbicide treatments, with two sites having higher alfalfa percentages compared to untreated plots. In Clark county alfalfa percentage was similar across all treatments.

Forage quality: Samples are currently being analyzed for forage quality.

Alfalfa plant density: Alfalfa density was variable within and among sites. Analysis across sites found that glyphosate applied to small weeds resulted in higher alfalfa densities compared to late applications of imazamox or the untreated control. Differences in alfalfa plant density, however, were only observed at one location (Dane), in which early applications of glyphosate and late applications of imazamox resulted in more alfalfa plants compared to other treatments. This location was under severe drought stress in the spring and early summer, which likely contributed in the difference compared to other locations.

CONCLUSIONS

Glyphosate provided equivalent or superior control of lambsquarter and other weed species (data not presented) with less crop injury across the seven locations in 2012. Analyzed across sites, resulting forage biomass had the highest percentage alfalfa when glyphosate was applied to small weeds. However, analysis of sites separately indicate the percentage of alfalfa is similar in fields with low weed pressure, greater with any herbicide treatment in fields with moderate weed pressure, and consistently greatest with glyphosate applied to small weeds in fields with high weed pressure. Alfalfa plant density across sites was highest with glyphosate applications to small weeds. However within each site densities were highly variable, but similar among treatments at five out of the six locations. This suggests environmental and physical factors control stand density to a greater degree than weed management methods. While it remains difficult to predict weed pressure of a field for a given year, benefit in the seeding year was only evident in these areas. Determination of the forage quality of samples will be critical in assessing the economic value of these various management methods.

UNDERSTANDING WESTERN CORN ROOTWORM FIELD-EVOLVED RESISTANCE TO BT CORN AND BEST MANAGEMENT PRACTICES

Eileen Cullen [1/]

Transgenic Bt corn hybrids that produce insecticidal proteins from the soil bacterium *Bacillus thuringiensis* (Bt) have become the standard insect management tactic across the U.S. Corn Belt. In 2012, 67 percent of 96.4 million acres of corn planted in the U.S. contained a Bt trait (USDA ERS, 2012; USDA NASS, 2012). Widespread planting of Bt corn creates intense selection pressure for target insects to develop resistance. Evolution of resistance diminishes the efficacy and benefits of Bt corn technology.

Because Bt traits are pesticidal substances produced by plants, the U.S. Environmental Protection Agency (EPA) registers Bt crops through the Federal Insecticide Fungicide and Rodenticide Act (EPA, 2012). Recognizing the threat of evolution of insect resistance, the EPA requires registrants (seed companies) to include an insect resistance management (IRM) plan when applying to register a Bt crop. The goal of the IRM plan is to reduce selection pressure associated with Bt crops and prevent, or at least delay, development of resistance in the target insect population. Growers are required to implement the IRM plan on-farm by planting a refuge. The refuge provides a corn crop habitat that allows target pest insects to develop without exposure to the Bt trait. Mating between susceptible insects from the refuge and potential resistant insects from the Bt corn minimizes the chance of resistance developing in the population.

Thus far, field-evolved resistance has not been detected for the European corn borer even though this species has been exposed to Bt proteins since 1996. The primary reason relates to the use of hybrids that offer a high dose of Bt protein expression for European corn borer. The refuge (historically 20%) and high-dose Bt expression have worked in tandem very well to prevent resistance development in the European corn borer population (Tabashnik, 1994; Gould, 1998).

The IRM situation is unfolding differently for Bt corn and western corn rootworm (*Diabrotica virgifera virgifera*; WCR). The evolution of WCR resistance to all Bt rootworm proteins currently registered has been demonstrated in artificial laboratory and greenhouse selection experiments (Meihls et al., 2008; Oswald et al., 2008; Meihls et al., 2001; Lefko et al., 2008). To date, field-evolved resistance to Bt Cry3Bb1 has been confirmed for 11 populations of WCR in Iowa. In each of these cases (adult WCR collected from one field constitute a population), the problem fields had been planted to the same single Bt rootworm trait for at least three consecutive years, and as many as seven consecutive years (Gassmann et al., 2011; Gassmann et al., 2012).

Despite the requirement that growers plant a refuge to delay or prevent resistance development, the evolution of WCR field resistance to the Cry3Bb1 protein occurred in a relatively short period of time. Why? Insufficient planting of refuges and non-recessive inheritance of resistance for WCR may have contributed to resistance (Gassmann et al., 2011).

[1/] Associate Professor and Extension Specialist, Department of Entomology, 1630 Linden Drive, University of Wisconsin-Madison, Madison, WI 53706.

Additionally, all of the Bt hybrids registered for corn rootworm are low- to moderate-dose events, ensuring some corn rootworm survivors in every field (EPA, 2002; Storer et al., 2006; Hibbard et al. 2010).

When enough heterozygotes (individuals with a resistant and a susceptible allele) survive and mate, a Bt-resistant population can begin to increase rapidly (assuming fitness costs are not extreme). In fact, fitness costs of WCR resistance to Bt Cry3Bb1 may be low (Meihls et al., 2008; Gassmann et al., 2011). Additionally, there is evidence of nonrandom mating for WCR and initial resistance allele frequencies in the WCR population may be much higher than initially assumed (Kang and Krupke, 2009; Onstad and Meinke 2010).

In March 2012, 22 corn entomologists from land-grant universities and USDA sent a letter to the U.S. EPA expressing concern over the development of WCR resistance to the Cry3Bb1 protein and providing integrated pest management (IPM) recommendations to sustain the effective use of Bt corn in the U.S. (Porter et al., 2012). In particular, these public sector scientists indicated that the durability of the Cry34/35Ab1 protein, used in conjunction with the Cry3Bb1 protein in pyramided Bt corn hybrids, could be compromised in areas where a resistant population of WCR is present. This concern is heightened because the refuge size has been reduced from 20% to 5% for these pyramided products. Additional concerns mentioned in the letter include the "insurance-based approach" to insect management – the standard practice across the U.S. Corn Belt.

Authors of the letter acknowledge challenges faced by U.S. corn growers in a high value corn commodity market. For example, Bt rootworm traits are incorporated into elite germplasm lines with highest yield potential, and growers report increasing difficulty obtaining non-transgenic seed with equally high yield potential. This can result in Bt rootworm hybrids planted prophylactically in areas or crop rotation sequence with little or no rootworm pressure. Moreover, widespread adoption of Bt technology has left many growers without the equipment necessary to apply soil insecticides to non-Bt corn at planting if necessary. The authors state that many growers have utilized a single-tactic approach for too many years and now unfortunate consequences are beginning to emerge. The letter provides specific integrated pest management (IPM) recommendations to help corn growers delay further corn rootworm resistance and conserve WCR susceptibility to Bt corn technology:

- Consider rotation to soybean or another non-host crop.
- Consider the use of a corn rootworm soil insecticide at-planting with a non-Bt hybrid.
- Consider the use of a Bt hybrid that expresses a different corn rootworm Cry protein than one which may have performed poorly in the past on a particular farm.
- Consider the use of a pyramided Bt hybrid that expresses multiple Cry proteins targeted against corn rootworms.
- Most importantly, implement a long term integrated approach to corn rootworm management that includes multiple tactics such as rotation of Bt hybrids that express different Cry proteins for corn rootworm, use of soil insecticides at-planting with a non-Bt hybrid, rotation to a non-host crop, adult suppression programs where appropriate, and field scouting information and knowledge of corn rootworm densities.

On-farm planting and other rootworm management decisions will alter the future course of resistance evolution. It is critical for industry, regulatory agencies and university and government scientists to work together to provide science-based, practical information to corn growers, crop consultants and the agricultural industry.

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INTEGRATED MANAGEMENT OF THE POTATO LEAFHOPPER IN ALFALFA

Elissa Chasen [1/], Eileen Cullen[2/] and Dan Undersander[3/]

Introduction

A fully developed integrated pest management (IPM) system uses all available strategies for a given pest or pest complex in a cropping system; incorporating host plant resistance, biological, cultural and physical controls and chemical control when necessary (Pedigo, 1999). Several such management strategies have been developed in alfalfa for the potato leafhopper (*Empoasca fabae*) (PLH). The first glandular haired varieties of alfalfa, bred for resistance to PLH were released for market in 1997. Field studies of these varieties have been met with varying levels of success. Lefko et al. (2000) observed that established resistant alfalfa stands could tolerate up to 2.5 greater the PLH pressure as a susceptible stand. However, when leafhopper pressure is low, resistant alfalfa has expressed some amount of yield drag (Hogg et al. 1998, Hansen et al. 2002). The presence of grasses in alfalfa fields has also been correlated to a reduction in PLH abundance. Degooyer et al. (1999) showed that both orchardgrass and bromegrass intercropped in alfalfa stands significantly reduced the number of PLH present, but noted it was not enough to keep populations below economic thresholds. Grasses are also promoted as an intercrop with alfalfa for the increase in digestible fibers and decrease in non-fiber carbohydrates they provide, which can help reduce incidence of ruminal acidosis (Lee, 2011).

The present study examined the effects of host plant resistance and orchardgrass intercrop on PLH population in alfalfa, as well as yield and forage quality response to PLH and the respective cropping systems. Effective IPM strategies aim to reduce the use of insecticides but chemical control is still an integral part of a successful IPM plan to reduce economic loss (Summers, 1998). This work also investigated potential yield response of reducing the current potato leafhopper economic thresholds in light of the growing value of the alfalfa crop.

Methods

Multi-year research experiments were established in two locations: one at Arlington, WI Agricultural Research Station (AARS) and two at the US Dairy Forage and Research Center (DFRC) in Prairie du Sac, WI. The AARS field study was spring seeded and the two field studies established at DFRC included a spring and fall seeding stand establishment. At both AARS and DFRC, experiments were arranged in complete randomized block with a 2 x 2 factorial design (4 total whole plot treatments). Factorial treatments were alfalfa variety (PLH-susceptible and PLH-resistant) and orchard grass intercrop (alfalfa intercropped with grass and direct seeded alfalfa).

Seeded May 17, 2010 at AARS, the whole plots were 85' x 22' and divided equally into three split plots, 28' x 22'. Split plot treatments consisting of an untreated control, an insecticide spray at half the current economic threshold (1/2 ET), and an insecticide spray at the current ET (table 1) were included to create a range in PLH density. Pioneer Hi-Bred International, Inc. (Arlington, WI) provided alfalfa seed including susceptible alfalfa 55V48 and resistant alfalfa 53H93 varieties.

[1] Graduate Research Assistant, University of Wisconsin, Department of Entomology, 1630 Linden Drive, Madison, WI 53706; [2] Associate Professor and Extension Entomologist, University of Wisconsin, Department of Entomology, 1630 Linden Drive, Madison, WI 53706, [3] Professor and Extension Forage Agronomist, University of Wisconsin, Department of Agronomy, Madison, WI 53706

Profit Orchardgrass was purchased from Welter Seed & Honey Co. (Onslow, IA). Seeding rates followed University of Wisconsin-Extension recommended guidelines (Undersander et al. 2004).

At DFRC, the fall seeding was planted August 16, 2011 and the spring seeding was completed April 12, 2012. Each plot was 60' x 30'. Seed was provided by Forage Genetics, International (Nampa, ID) including susceptible alfalfa WL354HQ and resistant alfalfa WL353LH varieties. Profit Orchardgrass was purchased from Welter Seed & Honey Co. and seeding rates followed University of Wisconsin-Extension recommended guidelines (Undersander et al. 2004).

Potato leafhopper populations were monitored weekly in each experiment using a 15-inch diameter sweep net to collect 20 sweep net samples per split plot at AARS, and 20 sweeps per plot at DFRC. At AARS, the pyrethroid insecticide Warrior II (active ingredient lambda-cyhalothrin) was applied at 1.6 oz/acre when PLH reached 1⁄2 ET and ET, to respective split plot treatments (Table 1).

Table 1. Potato leafhopper insecticide treatment timing at AARS trial (adapted from Cullen et al. 2012).

Alfalfa height	Treatment	PLH/sweep
0-4 inches	½ ET	0.1
0-4 inches	ET	0.2
4-8 inches	½ ET	0.3
4-8 inches	ET	0.5
8-12 inches	½ ET	0.5
8-12 inches	ET	1.0
12+ inches	½ ET	1.0
12+ inches	ET	2.0

Yield data were collected from each plot at each harvest using an Almaco plot harvester. Subsamples were oven dried at 60°C and yields expressed on a dry matter basis. Alfalfa quality (crude protein and neutral detergent fiber) was analyzed by near-infra red reflectance (NIR) methods on dried and ground alfalfa samples. Yield data was not recorded at DFRC.

Results

Potato Leafhopper Response

Host plant resistance suppressed PLH populations at different sampling points over the 5-site years, but most notably at peak leafhopper abundance time points in the seeding years (Figure 1). In general, there were fewer significant differences across sample dates for PLH abundance between varieties in production year stands (Figure 1). The effect of orchardgrass intercropped with alfalfa on potato leafhoppers was minimal. In the seeding years, there was no significant effect of orchard-grass at any sampling point. In production years, the effect of grass varied between locations. At AARS, orchardgrass suppressed PLH at three time points: July 12, 2011 (df=1, 22; F=13.57; p=0.0013), May 22, 2012 (df=1, 18; F=9.62; p=0.0062) and May 30, 2012 (df=1, 18; F=7.03; p=0.00162). Suppression effect ranged from 10-80% between the three sampling dates, but PLH densities were below economic threshold. Orchardgrass in the fall seeding at DFRC had a significant effect on PLH on May 30 (df=1, 10; F=9.28; p=0.0123) and June 6 (df=1, 10; F=7.55;

p=0.0206) at which points PLH were more abundant in plots with grass. Orchardgrass presence and host plant resistance did not have a significant interaction.

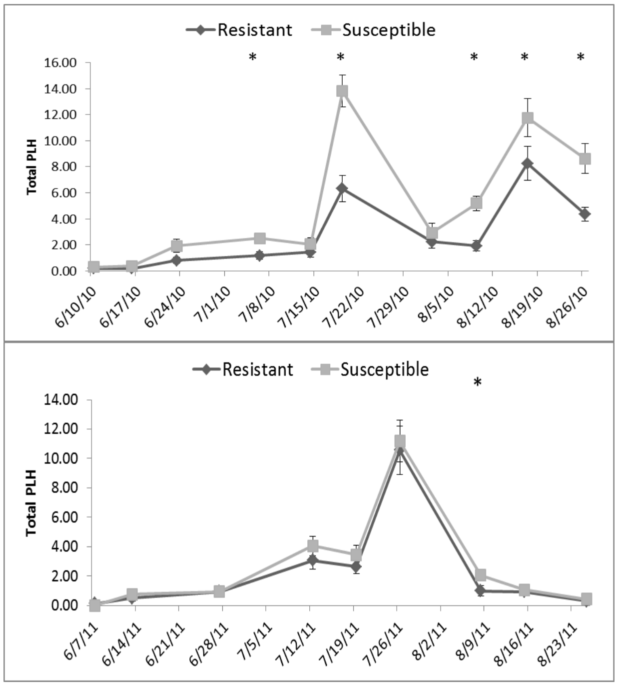


Figure 1. Alfalfa variety effects on potato leafhopper in 2010, seeding year (left) and 2011, 1st production year (right), Arlington , WI. Significant effects are noted with an asterisk at p<0.05.

Yield and Forage Quality Analyses

Yield and forage quality analyses are presented for AARS. Potato leafhopper had a significant negative impact on yield in the second crop of the seeding year (Table 3), which was also the only time that PLH populations reached economic threshold levels across 5 site years of this study. Although insecticide treatment timing did not have a statistically significant effect on yield during the seeding year at the AARS study site, yield trends were marginally higher for plots treated at the established economic threshold than at a reduced (1/2 ET) treatment timing (Table 2).

In third crop of 2011 yield response to PLH varied by alfalfa variety. The yield of susceptible alfalfa increased with increasing PLH pressure while the yield of resistant alfalfa decreased (Table 7), however, PLH pressure was below economic thresholds in both cases. Yield was significantly affected by variety at the first and second cutting of 2011, in which resistant alfalfa expressed a yield drag (Tables 5 and 6). Alfalfa/grass plots had a lower yield in the second cutting of 2010 (Table 3) likely due to later summer grass stand establishment. However, the first cutting of 2011 had significantly higher yield in plots where grass was present (Table 5).

Table 2. Mean yield by insecticide treatment within each cropping system at AARS on July 26, 2010.

Treatment	Yield (tons/acre)[a]
Susceptible alfalfa - no orchardgrass	
No spray	1.36 ± 0.08[a]
Economic Threshold[b]	1.45 ± 0.08[a]
½ Economic Threshold[c]	1.36 ± 0.08[a]
Susceptible alfalfa - with orchardgrass	
No spray	1.29 ± 0.08[a]
Economic Threshold[b]	1.28 ± 0.08[a]
½ Economic Threshold[c]	1.35 ± 0.08[a]
Resistant alfalfa - no orchardgrass	
No spray	1.31 ± 0.08[a]
Economic Threshold[b]	1.60 ± 0.08[a]
½ Economic Threshold[c]	1.50 ± 0.08[a]
Resistant alfalfa - with orchardgrass	
No spray	1.34 ± 0.08[a]
Economic Threshold[b]	1.44 ± 0.08[a]
½ Economic Threshold[c]	1.38 ± 0.08[a]

[a] Means followed by the same letter not significantly different.
[b] Economic threshold treatment sprayed on July 9; alfalfa height 0-4 inches; PLH/sweep=0.2.
[c] ½ Economic threshold treatment sprayed on July 7; alfalfa height 0-4 inches; PLH/sweep=0.1.

Crude protein was significantly affected by PLH on three cuttings. For the two in which the greatest leafhopper pressure was experienced, July 26, 2010 and August 1, 2011, this effect was negative (Tables 3 and 7). The July 5, 2011 crop had greater crude protein with PLH when their presence had been very low (Table 6). Variety had a significant effect on crude protein at each cutting (Tables 3-7). For all but the July 26, 2010, this effect was such that resistant alfalfa had higher protein levels. Plots without grass had higher crude protein than direct seeded alfalfa (Tables 4-6).

Discussion

At the DFRC site, the spring seeded experiment had higher PLH pressure than the fall seeded experiment. Seeding time interacted significantly with alfalfa variety (Figure 2). Spring seeded susceptible alfalfa had the greatest PLH pressure. By contrast, spring seeded resistant alfalfa had lower pressure similar to both the susceptible and resistant alfalfa in the fall seeded experiment. Because the experiment at DFRC was not designed to test the effect of seeding time on PLH (i.e., the seeding time was not randomized within the blocks), results from the statistical analyses should be inferred with caution (Figure 2).

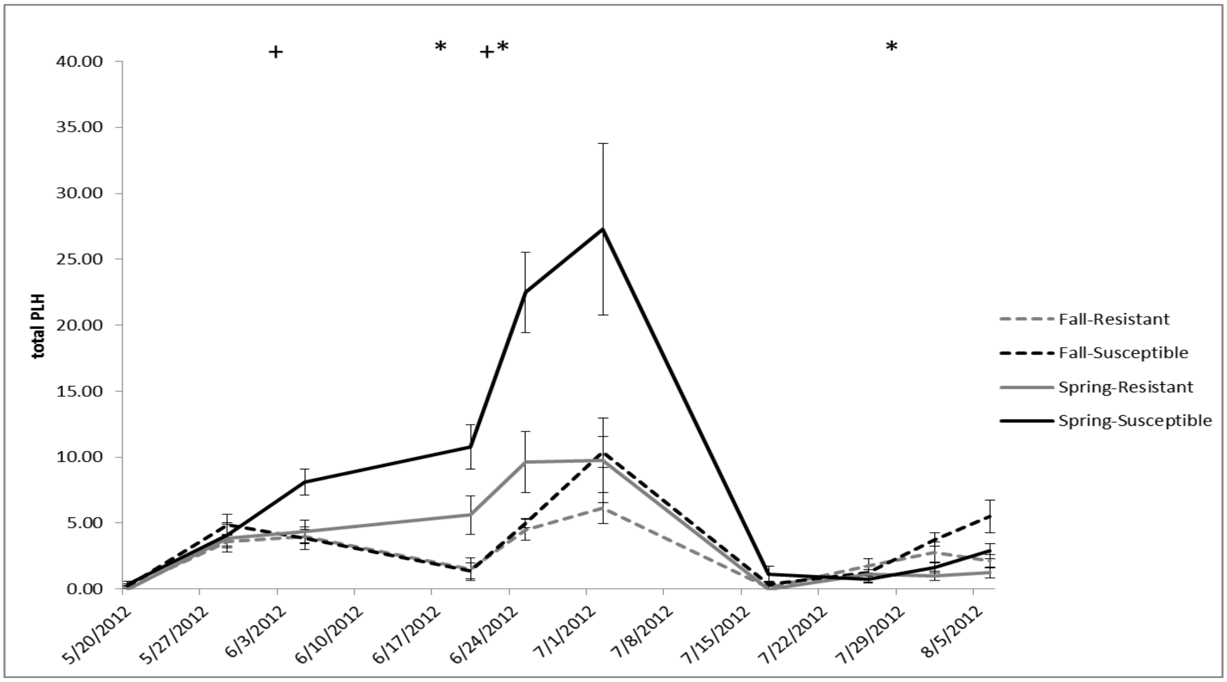
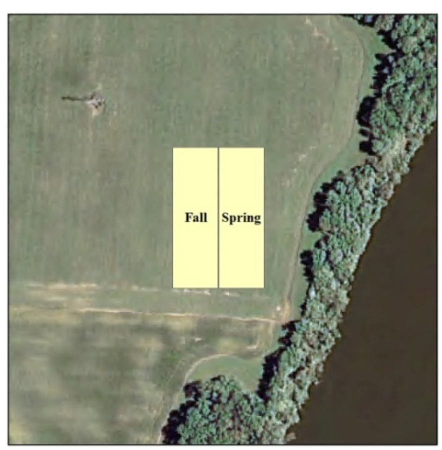


Figure 2. Seeding time and variety effects on potato leafhoppers at DFRC in 2012. Spring seeding was in seeding year and fall seeding was in 1st production year. Significant effects of seeding are noted with an asterisk and significant interactions between seeding and variety are noted with a plus sign.

There are other factors that could have led to this significant seeding time and seeding time x variety interaction effect but they do not seem to explain the observed results. For example, the trials were located adjacent to each other in a field with uniform cropping history and nutrient management history (figure 3). The only unique management between the two trials is that prior to seeding in the spring, the area was sprayed with Roundup herbicide (active ingredient glyphosate). Another possible factor is location within the field. Higher densities of PLH are found along field margins (Flinn et al. 1990a). However, both spring and fall seeded trials were located within a fall seeded field (figure 3) and the border between the field edge and the spring seeded trial had similar PLH pressure to the fall seeded research trial. Lastly, PLH abundance has been studied in relation to weed density. The spring seeding had considerably greater weed density than the fall seeding, but the relationship between weed density and PLH depends on the weed composition. The most prevalent weed by visual estimation was lambsquarters and this plant has been found not to promote PLH growth (Lamp et al. 1984a)

Figure 3. Layout of trials by seeding at DFRC in 2012. The crop surrounding both trials is fall seeded alfalfa.



Previous studies of resistant alfalfa have shown that the resistant trait is not expressed until the after the seeding year (Lefko et al., 2000). However, the present work shows that the resistant alfalfa effectively suppressed PLH during the seeding year. The mechanism responsible for resistance in alfalfa has been studied and discussed at length. Results from other field trials led researchers to conclude that mechanism(s) responsible are likely antibiosis (Hogg et al., 1998) and/or tolerance (Lefko et al., 2000). At our DFRC location, the mechanism may be nonpreference, considering the lower abundance of PLH found in resistant alfalfa compared to susceptible, as seen in Figures 1, left and 2. However, this phenomenon did not correlate with a yield benefit in resistant alfalfa, which may again have been due to the overall low PLH pressure.

Resistant alfalfa did express a yield drag for two of the four cuttings in 2011, which is congruent with previous findings in the absence of PLH or under low PLH pressure (McCaslin, 1998; Hansen et al., 2002). The presence of orchardgrass suppressed PLH on only a couple of sampling dates and two of the three sampling dates were before peak PLH abundance. Previous researches have observed this but in other works the effect of the grass on PLH abundance is more consistent (e.g., Lamp et al., 1984; Roda et al., 1997; Degooyer et al., 1999). It is possible that the low overall PLH populations obscured the grass effect.

It is documented in the literature that PLH feeding reduces crude protein in alfalfa (Flinn et al., 1990b). In the present study, PLH feeding had a negative effect on protein in two of the five harvests analyzed and had a positive effect on one of the harvests. Resistant alfalfa had a slight but statistically greater crude protein content at five of the six harvests analyzed. Hansen et al. (2002) similarly found resistant alfalfa to have higher protein levels while Dellinger et al. (2006) saw no difference in crude protein between a resistant and susceptible variety. Considering the connection between PLH feeding and a reduction in crude protein, the greater content of crude protein in resistant alfalfa may be mediated through the decreased feeding that occurs on resistant alfalfa compared to susceptible alfalfa. The presence of orchardgrass increased NDF which is one of the benefits of including it in dairy rations.

Takeaway Points

- Potato leafhoppers only had an impact on yield when established economic threshold populations were reached.
- Resistant alfalfa significantly suppressed potato leafhopper in the seeding year even when pest pressure was low.
- The effect of orchardgrass intercropped with alfalfa on potato leafhoppers was minimal.

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Table 3: Effects of potato leafhopper, alfalfa variety and grass presence on yield, crude protein and neutral detergent fiber on second crop, 2010 (July 26). Estimates for PLH are slopes for the regression and estimates for alfalfa variety and orchardgrass presence are y-intercepts. Significant effects on in **bold type**.

Independent Variable	Dependant Variable											
	Yield (tons/acre)				Crude Protein (%)				NDF (%)			
	Estimate	df	F	Pr>F	Estimate	df	F	Pr>F	Estimate	df	F	Pr>F
PLH	**-0.05**	**1**	**4.45**	**0.0378**	**-0.26**	**1**	**5.96**	**0.0168**	-0.42	1	2.98	0.0882
Alfalfa variety		1	1.16	0.284		**1**	**5.92**	**0.0172**		1	0.26	0.6141
Resistant	1.45				27.17				33.83			
Susceptible	1.40				27.69				34.08			
Orchardgrass presence		**1**	**4.01**	**0.0484**		1	1.03	0.3139		1	0.78	0.3792
Yes	**1.40**				27.69				34.08			
No	**1.49**				27.49				34.49			
Error		89				81				81		

Table 4: Effects of potato leafhopper, alfalfa variety and grass presence on yield, crude protein and neutral detergent fiber on third crop, 2010 (September 7). Estimates for PLH are slopes for the regression and estimates for alfalfa variety and orchardgrass presence are y-intercepts. Significant effects on in **bold type**.

Independent Variable	Dependant Variable											
	Yield (tons/acre)				Crude Protein (%)				NDF (%)			
	Estimate	df	F	Pr>F	Estimate	df	F	Pr>F	Estimate	df	F	Pr>F
PLH	-0.01	1	1.57	0.2131	0.02	1	0.19	0.6599	-0.13	1	1.23	0.2704
Alfalfa variety		1	0.02	0.902		**1**	**11.42**	**0.0011**		**1**	**7.16**	**0.0089**
Resistant	1.17				**23.96**				**42.03**			
Susceptible	1.17				**23.11**				**43.74**			
Orchardgrass presence		1	0.62	0.4342		**1**	**10.75**	**0.0015**		**1**	**9.9**	**0.0022**
Yes	1.17				**23.11**				**43.74**			
No	1.15				**23.89**				**41.86**			
Error		89				89				89		

Table 5: Effects of potato leafhopper, alfalfa variety and grass presence on yield, crude protein and neutral detergent fiber on first crop, 2011 (June 1). Estimates for PLH are slopes for the regression and estimates for alfalfa variety and orchardgrass presence are y-intercepts. Significant effects on in **bold type**.

Independent Variable	Dependant Variable: Yield (tons/acre)				Crude Protein (%)				NDF (%)			
	Estimate	df	F	Pr>F	Estimate	df	F	Pr>F	Estimate	df	F	Pr>F
PLH	0.00	1	0.02	0.8789	-0.14	1	2.83	0.096	**0.36**	**1**	**4.33**	**0.0404**
Alfalfa variety		**1**	**17.29**	**<.0001**		**1**	**4.36**	**0.0397**		1	2.57	0.1128
Resistant	**2.94**				**21.67**				40.83			
Susceptible	**3.12**				**22.16**				40.05			
Orchardgrass presence		**1**	**6.92**	**0.01**		**1**	**160.71**	**<.0001**		**1**	**176.98**	**<.0001**
Yes	**3.12**				**22.16**				**40.05**			
No	**3.02**				**24.84**				**34.14**			
Error		89				89				89		

Table 6: Effects of potato leafhopper, alfalfa variety and grass presence on yield, crude protein and neutral detergent fiber on second crop, 2011 (July 5). Estimates for PLH are slopes for the regression and estimates for alfalfa variety and orchardgrass presence are y-intercepts. Significant effects on in **bold type**.

Independent Variable	Dependant Variable: Yield (tons/acre)				Crude Protein (%)				NDF (%)			
	Estimate	df	F	Pr>F	Estimate	df	F	Pr>F	Estimate	df	F	Pr>F
PLH	0.03	1	0.69	0.4083	**0.59**	**1**	**8.91**	**0.0037**	**-1.22**	**1**	**5.73**	**0.0188**
Alfalfa variety		**1**	**28.46**	**<.0001**		**1**	**5.34**	**0.0231**		1	0.02	0.9015
Resistant	**2.08**				**22.14**				40.88			
Susceptible	**2.25**				**21.78**				40.83			
Orchardgrass presence		1	0.8	0.3725		**1**	**11.88**	**0.0009**		**1**	**21.79**	**<.0001**
Yes	2.25				**21.78**				**40.83**			
No	2.28				**22.32**				**38.92**			
Error		89				88				88		

Table 7: Effects of potato leafhopper, alfalfa variety and grass presence on yield, crude protein and neutral detergent fiber on third crop, 2011 (August 1). PLH had a significant interaction with alfalfa variety so individual slopes are given for each variety. Estimates for alfalfa variety and orchardgrass presence are y-intercepts. Significant effects on in **bold type**.

	Dependant Variable											
Independent Variable	Yield (tons/acre)				Crude Protein (%)				NDF (%)			
	Estimate	df	F	Pr>F	Estimate	df	F	Pr>F	Estimate	df	F	Pr>F
PLH		1	0.03	0.8659	**-0.08**	**1**	**4.51**	**0.0364**	0.04	1	0.3	0.588
PLH*Alfalfa variety		**1**	**13.46**	**0.0004**								
*Resistant	**-0.02**											
*Susceptible	**0.02**											
Alfalfa variety		1	0.67	0.4143		**1**	**16.86**	**<.0001**		1	1.05	0.3076
Resistant	1.63				**25.89**				37.68			
Susceptible	1.59				**25.11**				38.11			
Orchardgrass presence		1	2.77	0.0998		1	3.49	0.0651		**1**	**8.74**	**0.004**
Yes	1.59				25.11				**38.11**			
No	1.63				25.47				**36.85**			
Error		87				87				87		

SOYBEAN APHID: THINKING OUTSIDE THE CROP

Dave Hogg [1/]

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[1/] Professor, Dept. of Entomology, Univ. of Wisconsin-Madison.

RECAP ON TWOSPOTTED SPIDER MITE MANAGEMENT – OUR HIGHEST PRESSURE PEST DURING THE 2012 DROUGHT – WHAT SHOULD YOU REMEMBER?

Eileen Cullen [1/]

Populations of the Twospotted spider mite, *Tetranychus urticae* Koch, increase during periods of hot, dry weather. Representative grain yield reduction potential in soybean (40-60%), field corn (23%) and silage corn (17%) are significant (Klubertanz, 1994; Bynum, pers. comm.).

Spider mites damage plants by piercing cells and sucking sap. Mites often go undetected until damage is severe because of their tiny size and because spider mite feeding and drought stress symptoms are similar. It is important to be aware of twospotted spider mite potential under these conditions, recognize plant damage symptoms, and be able to identify live mite colonies in the field.

Spider mite feeding results in reduced chlorophyll content of leaves with small white or yellow spots, referred to as "stippling". These symptoms often start on the lower leaves in the canopy. Severe spider mite injury results from a combination of plant leaf cell and tissue disruption, along with water loss and heat stress typical of drought conditions.

Twospotted spider mites overwinter in Wisconsin as adult females in sheltered field margin areas. Spider mites reproduce quickly, with several overlapping generations within one growing season. Females can lay hundreds of eggs in a lifetime. Eggs hatch in 2-4 days; nymphs develop in 2-4 days; and adults can live up to 21 days with better survival in hot, dry environments. Depending on temperatures, twospotted spider mite generations are completed in 4-14 days with the fastest developmental rates above 91°F (Klubertanz, 1994).

Damage often begins along field edges where mites have migrated from adjacent fields, grasses and weeds, or in drier areas within a field. You may notice a semi-circle of yellowing plants along field edges or spots within the field. As populations increase and disperse, plant damage symptoms progresses upward in the canopy, plant leaves turn yellow to bronze and leaf drop can occur under heavy infestations.

Symptoms of twospotted spider mite feeding are often recognized before pest presence is confirmed. This is attributable to the small size of mites, feeding that occurs primarily on undersides of leaves, and sporadic nature of infestations. Adults are very small (less than 0.002 inch), yellow-green, with eight legs and two dark spots on the abdomen. Immature spider mites have 6 legs. A 10X magnification hand lens is necessary to see spider mite adults, nymphs and eggs on the underside of leaves. Webbing is often found on the underside of leaves.

Spider Mite Management Recommendations in Soybean

Field scouting should begin along field margins where infestations are likely to start. Upper, middle and lower canopy leaves should be examined for stippling. Turn soybean leaves over to confirm presence of spider mites with a 10X magnification hand lens. Adults can also be detected

[1/] Associate Professor and Extension Specialist, Department of Entomology, 1630 Linden Drive, University of Wisconsin-Madison, Madison, WI 53706.

by tapping soybean plants over a clipboard onto a white sheet of paper. Dislodged spider mites will be apparent by the dark abdominal spots observed as tiny specks moving on the paper.

No numeric economic thresholds have been developed for twospotted spider mite, infestions are sporadic and counting individual mites is not practical. In soybean, a 10-15% reduction in effective leaf area will justify insecticide application for mites from bloom (R1) through pod fill (R5) (Gray, 2005; DiFonzo, 2005). However, it is not easy to estimate 15% leaf discoloration. The following treatment guideline (Table 1) is recommended by extension entomologists throughout the Midwest for twospotted spider mite treatment timing in soybean.

Table 1. Treatment guidelines for two-spotted spider mite in soybean. (Cullen and Schramm, 2009).

Presence of mites	**Damage**	**Assessment**
Barely detected on undersides of leaves in dry locations or on edges of fields.	Barely detected.	1 - ***Non-economic***
Easily detected on undersides of leaves in dry locations or on edges of fields. Difficult to find on leaves within the field.	Foliage green, but stippling injury detectable on undersides of leaves, although not on every plant.	2 - ***Non-economic*, but keep monitoring**
Plants are infested when examined closely.	Heavy stippling on lower leaves progressing to mid-canopy.	3 - ***Treatment*** is warranted, especially if many immatures/ eggs are also present.
All plants heavily infested when examined closely.	Lower leaf yellowing. Stippling, webbing and mites common in mid-canopy. Mites and minor stippling on upper canopy.	4 - Effective ***rescue treatment*** may recover yield. Economic loss likely occurring at this level.
Mite colonies at high levels throughout the canopy.	Lower leaf drop common, yellowing and bronzing at mid-canopy.	5 - Rescue treatment may not protect remaining yield potential. However, new growth may resume if treated.

Before spot treatments are made, thorough monitoring of the field is recommended. Spider mite damage can progress quickly and edge treatments may not be effective. Treatment may be delayed if cooler temperatures with high humidity (e.g., morning dew) are expected. These conditions encourage growth of a mite-killing fungus in the field (see below).

It is important to understand which insecticides are labeled for twospotted spider mite on soybean and have efficacy against this pest. Insecticide active ingredient choices are largely limited to three active ingredients. These include the organophosphate active ingredients chlorpyrifos and dimethoate, and the pyrethroid a.i. bifenthrin. Premixes combining any two of these active ingredients would also be an option. Among the pyrethroid class of insecticides, other than bifenthrin, pyrethroids generally do not have good efficacy against spider mites, and some pyrethroids (a.i. permethrin) are associated with an increase or flare-up of spider mite populations following treatment (Ayyappath et al., 1996).

Spider Mite Management Recommendations in Corn

Twospotted spider mites do not usually cause economic damage in corn. However, during drought conditions when spider mites are active in soybean, yield loss potential may extend to corn.

Moderate infestations will result in leaf stippling and chlorotic spotting (pale yellow) on the leaf surface. Begin by checking for presence of spider mites on individual leaves on corn plants along field edges. Examine leaves from the lower canopy upwards and look for stippling and webbing on the underside of leaves. Use a 10X magnification hand lens and plant shake sample to confirm presence of live mites. Move into the field checking 2 plants at 20 locations.

Damage usually occurs after tasseling and effects on corn yield are more severe when mites damage leaves at or above the ear level. Severe infestations can cause entire leaves to turn yellow then brown, with symptoms usually beginning from the lower canopy and moving up. Grain corn is safe from further yield damage after full dent stage is reached.

There are more complex treatment threshold guidelines available (Porter et al., 2010), but a simple guideline is to treat corn when the lower one-fourth to one-third of the canopy is injured (stippling on most of the leaf surface area), mites are present in the mid-canopy and corn has not dented (Ostlie and Potter, 2012).

Insecticide product choices for twospotted spider mite in corn include the active ingredients dimethoate and bifenthrin. Chlorpyrifos is not labeled for twospotted spider mite in corn. Corn has additional options including the active ingredients propargite and spiromesefin (Cullen et al., 2012).

Biological Control and Additional Resources

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

Although rainfall reduces risk of damaging spider mite populations, thunderstorms alone will not eliminate infestations, particularly when rain arrives after large mite populations are established and when rain is followed by dry, hot conditions.

Familiarity with spider mite identification, injury symptoms, sampling methods, treatment guidelines, chemical control options and expectations, and natural control factors is important when monitoring soybean fields during periods of hot, dry weather. Additional resources to aid in twospotted spider mite management decisions include:

Spider mites in soybean – Integrated Pest Management. University of Wisconsin-Madison Integrated Pest and Crop Management. Field Diagnostic Video: http://ipcm.wisc.edu/video/

Cullen, E. and S. Schramm. 2009. Two-Spotted Spider Mite Management in Soybean and Corn. A3890. University of Wisconsin-Extension Cooperative Extension Publishing, Madison, WI. http://learningstore.uwex.edu/Two-spotted-Spider-Mite-Management-in-Soybean-and-Corn-P1358C31.aspx

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ODDBALL PESTS OF 2012 – THE NEW NORMAL?

Phil Pellitteri [1/]

Weather has had a major impact on the insects and their activity in 2012. A very mild winter, early spring warm-up, serious drought in the southern half of the state, numerous strong southerly airflows and an extended growing season all had influences this season. This will be a record-breaking year in the insect diagnostic lab for number of samples and e- mails with over 6,600 contacts for 2012.

The early warm-up in March brought in many southern migrants. Adult variegated cutworms and armyworms moths were collected in March a full three weeks earlier than any previous records, and large numbers of cutworm egg masses were found pasted on siding and windows in the northern part of the state.. By May and early June major (almost biblical) climbing cutworm problems were seen in central and northern counties. Large influxes of both aster and potato leafhoppers were recorded early and a number of "southern insects" including the Genista broom moth, citron bug, and large numbers of two species of migratory butterflies. Strawberry growers experienced eastern flower thrips problems 2012 and a new tospovirus (likely thrips transmitted) was found on soybeans in the state this year.

The drought caused major spider mite outbreaks on soybeans, corn, vegetables and ornamentals. Dry weather also caused large populations of lace bugs, thrips, false chinch bugs, and boxelder bugs. The plant stress of 2012 will cause major increases in wood boring beetles including two-lined chestnut borer, bronze birch borer and I*ps* bark beetles on conifers.

The extended growing season caused some insects to attempt extra generations such as squash vine boresr, Colorado potato beetles and boxelder bugs. We saw a similar insect response in 1988. Spring degree days accumulations were 3 weeks ahead of the norm, which caused people to miss treatment windows for a number of insects. This was the type of year you did not want to rely on normal calendar dates for treatments.

Not all insects did well in 2012. The early warm weather caused early egg hatch and Eastern tent caterpillar and gypsy moth populations seemed to suffer. It was a bad year for native butterflies but we did see an influx of southern species that are not seen every year. Soybean aphids did not like the heat, and it was a quite year for multi-colored Asiann lady beetle invasions.

New state records for 2012 include the squash attacking Citron Bug *Leptoglossus gonagra ,* and the fig fruit fly (*Zarpionus indianus*,) , plus we found overwintering adults of the Brown Marmorated Stink bug in Brown, Dane, and Jefferson counties and the first recorded nymph in the state. We had the first recorded crop damage from the spotted winged drosophila in 15 counties with major problems in fall raspberries.

[1/] Distinguished Faculty Associate, Department of Entomology,1630 Linden Drive, Univ. of Wisconsin-Madison , Madison, WI 53706.

The biggest ongoing long-term impact on insect activity is the lack of significant cold temperatures in the winter. This has allowed many insects to expand their range northward in the last two decades. I tease that the "governor moved us to Missouri a few years back" but there has been a dramatic change in "southern" insect activity in the state and those trends are expected to continue.

PREPAREDNESS FOR EMERALD ASH BORER: WHAT IS AN EFFECTIVE APPROACH?

Chris Williamson [1/]

American elms succumbed to the Dutch elm disease in 1970s, consequently maples and ash dominate the urban landscape, and account for more than 40% of Wisconsin's urban forest. And history tends to repeat itself; to this end, an invasive insect called Emerald ash borer (EAB) now threatens ash trees in North America. EAB is an exotic insect (beetle) from Asia and was first discovered in southeast Michigan in 2002. Since its discovery, the beetle has destroyed more than 50 million ash trees in the Midwest region, including Wisconsin in 2008.

Only true ash species (i.e., *Fraxinus* spp) such as green ash, white ash, blue ash, and black ash are vulnerable to emerald ash borer. Green ash (*Fraxinus pennsylvanica*) and white ash (*Fraxinum americana*) are the most common ash species in Wisconsin. Emerald ash borer is a small metallic green beetle about 3/8 to ½ inch long and 1/16 to 1/8 inch wide that emerge from the inner bark from late May till September, creating a D- shaped exit hole. Its emergence peaks between mid-June till early July, especially during warm sunny days. A female beetle lays 30-90 eggs underneath the bark crevices and the eggs hatch in about 7 to 10 days. The adult beetles have a short life and they survive only for about 3 to 6 weeks. After the egg hatches, a tiny creamy-white colored larva immediately begins chewing through the bark and feeds on the inner bark tissue for several weeks. This is the destructive stage of the beetle's life cycle disrupting the movement of nutrients and water uptake to the tree. A full grown larva averages about 1.5" in length and has series of bell shaped body segments. While feeding, the larva creates a distinct serpentine gallery packed with its own frass (waste + sawdust). Larvae can reside inside the healthy bark for a year or two and begin to overwinter in late autumn in the feeding tunnels that they create on the outer sapwood. Transformation from the larva into the adult (pupation) occurs over the winter months (November-early May) and the adult beetle emerges in late May. Typically EAB has a one year life cycle.

EAB attacks both healthy and stressed ash trees. When populations are high, it can kill large ash trees in less than 3 years and smaller ash trees within 2 years. However, at low population densities or in a newly infested tree, detecting EAB can be very challenging because the symptoms are often subtle and occur mostly on the top crown region of the tree. As its density builds to moderate or high, external symptoms become more prominent. When checking for EAB presence on an ash tree, it is important to consider at least two or more combinations of signs and symptoms.

[1/] Professor and Extension Specialist, Department of Entomology, Univ. of Wisconsin-Madison.

Symptoms:

Crown dieback – Canopy thinning and dieback of branches on the upper and outer region of the crown

Epicormic sprouts – Excessive shoot growth (suckers) arise from the lower trunk and at the base of the tree.

Bark split – Vertical fissure on the outer bark revealing larval feeding galleries beneath

Wood pecker damage – Sensing the larval presence underneath the bark, a wood pecker strips pieces of bark (flecking) and excavates holes on the trunk

Signs:

D -Shaped exit hole – As the adult beetle emerge from underneath the bark in June and July, it creates a D -shaped hole approximately 1/8" in diameter

Serpentine galleries – When loose bark is peeled, distinct S- shaped feeding galleries packed with frass (waste) can be noticed underneath

What you can do?

A) **Prevention and Diversification:**

1) To limit the spread of EAB, do not move any hardwood firewood, ash nursery stock, unprocessed wood waste from pruning, removal or storm damage, ash bark and wood chip mulch that are more than 1" size out of Brown County.

2) Do not plant ash trees in landscape. Diversify with alternatives to ash and maple such as Kentucky coffee tree, ginkgo, baldcypress, Turkish filbert, swamp white oak, chinkapin oak, dutch elm disease resistant hybrid elms, disease resistant crab apples, Japanese tree lilac, apple serviceberry. To learn more about alternatives to ash, please visit www.emeraldashborer.wi.gov

B) **Treatment Options:**

Homeowners living in a quarantined county or within 15 mile radius from a known EAB infestation can treat their high value ash trees using a systemic insecticide which is up taken by tree roots. However several factors influence the effectiveness of the insecticide including the cost of the treatment and the pre-existing health condition of the tree. In general:

1) Insecticidal treatments are most effective as a preventive strategy on healthy ash trees that have a full crown and intact bark on its branches and trunk.

2) Ash trees that are already infected with EAB and exhibit less than 50% canopy dieback can still opt for insecticide treatment. Any signs of its recovery can be noticed in the second year after treatment. However trees that have lost more than 50% canopy may not recover from its decline. Thus, insecticide treatments are not suggested.

3) Most insecticidal products recommended for homeowners need annual application and are applied as a soil drench. The best timing for soil drench application depends on the size of the tree. To determine the amount of insecticide to apply, simply measure the circumference of the tree using a tape at a chest height at 4.5' above the ground to figure out the size of the tree. Trees less than 47" circumference are best treated in early spring (mid April – mid May) and larger trees (greater than 47"circumference) are best treated either in fall (September) or spring (mid April- mid May). Research findings suggest that spring insecticide treatments are favored over fall, however fall applications are acceptable.

4) The following systemic insecticides containing imidacloprid as the active ingredient are effective as a soil drench in treating ash trees less than 47" circumference – Bayer Advanced Tree and Shrub Insect Control, Ferti-lome Systemic Tree and Shrub Drench, Optrol, Bonide Tree and Shrub Insect Control, Ortho Max Tree and Shrub Insect Killer, Gordon's Tree and Shrub Insect Killer.

5) Make sure to read the product label to determine the rate of application and safety protocols. Before drenching, rake up any mulch, leaf litter or landscape cloth around the base of the tree trunk to about 18-24" to facilitate a direct contact of the insecticides with the soil. The soil needs to be in moist condition at the time of application. If the soil is very dry, irrigate around the base of the tree few hours prior to insecticide application or if the soil is too wet, allow it to dry out for few days. Measure the volume of application needed as directed in the label and slowly pour the solution around the base of the tree trunk. Replace the mulch after the solution is completely absorbed in the soil. Click on the YouTube video link below for detail demonstration on soil drench application http://www.hort.uwex.edu/articles/protecting-your-tree-emerald-ash-borer

6) Trees larger than 47" circumference can still be drenched by homeowner using Optrol (imidacloprid) or contact professionals for other treatments. You can find the list of certified arborist for hire at http://www.isa-arbor.com/faca/findArborist.aspx

7) Professionals have access to additional products with unique application techniques. A trunk injection technique with Treeäge (emamectin benzoate), a restricted use product (RUP) available only to certified and licensed applicators, has quicker uptake by the tree (irrespective of soil condition) and effective for at least 2 years. However, trunk injection can creates wounds on the tree and repeated application can cause potential injury. Other products that can be applied via trunk injection method are IMA-jet (Imidacloprid), Imicide (Imidacloprid), Inject-A-Cide B(Bidrin), Pointer (Wedgle). Soil injection is another method of treatment by professionals where the products (Merit, Xytect) are applied within 18" of the trunk and placed between 2 to 4 inches beneath the soil surface.

8) Insecticide treatments are typically cost prohibitive in woodlot areas or for large number of ash trees in communities.

INCIDENCE AND IMPACT OF LATE BLIGHT IN POTATO AND TOMATO IN WISCONSIN

Amanda J. Gevens[1,] Anna C. Seidl[2], and Amilcar Sanchez Perez[2]

Introduction

Late blight is a potentially destructive disease of potatoes and tomatoes caused by the fungal-like organism, *Phytophthora infestans*. This pathogen is referred to as a 'water mold' since it thrives under wet conditions. Symptoms include leaf lesions beginning as pale green or olive green areas that quickly enlarge to become brown-black, water-soaked, and oily in appearance. Lesions on leaves can also produce pathogen sporulation which looks like white-gray fuzzy growth. Stems can also exhibit dark brown to black lesions with sporulation. Tuber infections are dark brown to purple in color and internal tissues are often reddish brown in color and firm to corky in texture. The time from first infection to lesion development and sporulation can be as fast as 7 days, depending upon the weather.

Two mating types are needed to produce sexual, persistent soil-borne oospores. The population is largely clonal outside its center of origin in the Toluca Valley of Mexico, relying on production of asexual sporangia for persistence. In the U.S., clonal lineage (also referred to as genotype or strain) US-1 (A1 mating type) was the predominant clonal lineage until the late 1980s-early 1990s, when US-8 appeared. US-8 was the opposite mating type (A2) and was insensitive to mefenoxam, a fungicide with exceptional activity against oomycetes, but with a specific mode of action that effectively selects for insensitivity. New clonal lineages have predominated epidemics in recent years with varying levels of mefenoxam resistance. Late blight pathogen populations in the U.S. have and continue to experience major genetic changes or evolution. The end result is the production of pathogen isolates with unique genotypes and epidemiological characteristics. As such, continued investigation of this pathogen is necessary to maintain best management strategies in susceptible crops.

Our objective was to monitor for late blight on a state-wide basis and characterize *P. infestans* in a timely manner to inform appropriate management recommendations and enhance understanding of the pathogens introduction and persistence in Wisconsin.

RESULTS & DISCUSSION

The generally hot, dry weather of Wisconsin in the 2012 production season made for a year of good foliar disease control in potato and vegetable crops. In potato, but for minor incidences of early rhizoctonia and blackleg, and some later early blight, the season seemed destined to make its way through to harvest without account of late blight.

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[1]Assistant Professor and Extension Plant Pathology, University of Wisconsin-Madison
[2]Graduate Research Assistant, Plant Pathology, University of Wisconsin-Madison

However, mid-July brought isolated, and in some parts of the state, intense rain storms, adding the critical third angle to the disease triangle (recall the other two: disease-susceptible plants and pathogen). The manner in which the pathogen was introduced in 2012 is not well understood, but we know that sources can include infected potato seed or tomato transplants, infected potato volunteers, or aerial movement of inoculum from sites of disease. By 18 July, potatoes in Antigo and Plover areas had reached or exceeded late blight disease thresholds (DSVs of ≥18) and preventative fungicides for control were initiated. By 31 July, the first case of late blight was confirmed in state, with several counties to follow in the months of August and September (Table 1).

Table 1. Characterization of *Phytophthora infestans* isolates causing late blight in Wisconsin tomato and potato crops in 2012.

County	Crop	Date of Detection	Clonal Lineage of the Late Blight Pathogen
Barron	Potato/Tomato	31 July 2012	US-23
Adams	Potato/Tomato	31 July 2012	US-23
Portage	Potato/Tomato	2 August 2012	US-23
Oneida	Potato	4 August 2012	US-23
Waushara	Potato/Tomato	20 August 2012	US-23
Marathon	Potato/Tomato	22 August 2012	US-23
Rusk	Tomato	23 August 2012	US-23
Sheboygan	Tomato	24 August 2012	US-23
Sauk	Tomato	10 September 2012	US-23
Eau Claire	Tomato	14 September 2012	US-23

In 2012 across the U.S., late blight challenged both tomato and potato crops in over a dozen states along the eastern seaboard, the Midwestern states, and in isolated cases along the west coast. Predominating the epidemics was late blight clonal lineage US-23, a lineage only recently identified and characterized by the allozyme banding pattern at the glucose phosphate isomerase (Gpi) locus of 100/100 (2), is of the A1 mating type, and has some sensitivity to mefenoxam. In our UW-Plant Pathology Laboratory, US-23 isolates have shown to be prolific producers of sporangia (airborne spores), and have a cooler optimum growth temperature than other recent strains, US-22 or US-24.

Over the past 4 years, late blight isolates were collected from potato and tomato from across the state. A lab technique known as allozymes genotyping revealed 3 banding patterns which profiled US-22, US-23, and US-24. In our phenotype testing, all isolates of US-22 were sensitive to mefenoxam, while isolates of US-23 and US-24 showed partial insensitivity. US-22 isolates were of the A2 mating type, and US-23 and US-24 isolates were of the A1 mating type. Isolates of opposite mating types were geographically separated in the state in 2010. We have only identified single mating types (A1) in WI in the past 2 years, reducing the potential risk for recombination and production of soil persistent oospores (Figure 1).

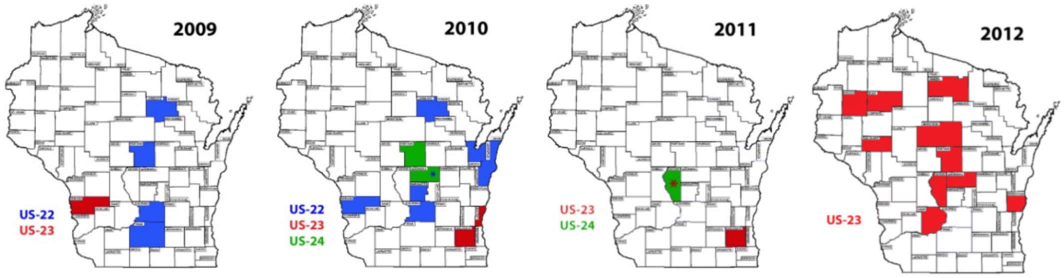

Figure 1. Occurrence of late blight in potato and/or tomato crops in Wisconsin during 2009 to 2012. Blue-colored counties indicate *P. infestans* clonal lineage US-22. Red counties indicate US-23. Green counties indicate US-24.

In each of the recent 4 years of late blight epidemic in Wisconsin, inoculum sources have likely been variable resulting in inconsistent clonal lineage and geographic patterns in each year. The late blight in WI in 2009 was associated with the nationwide epidemic likely initiated by infected tomato transplants, thus one clonal lineage, US-22, predominated. In 2010, the sources of late blight are unknown, but US-22 may have overwintered on plant material protected under the early heavy snowfall; US-24 was found only on potato in central WI, and US-23 was found only on tomato, primarily in areas of WI with concentrated suburban tomato gardens. In 2011, WI had an early (7 July) and isolated detection of late blight on tomato in Waukesha Co. caused by US-23. Late blight did not again reappear until confirmed on 26 and 27 August in Waushara and Adams Cos. (both US-23 and US-24). The US-23 clonal lineage was the only lineage identified in the state in 2012. Due to the late blight field signature in potato fields in late-July 2012, in addition to early season detects of US-23 in potato fields in other U.S. production regions, it is likely that US-23 was disseminated in the seed potatoes. Table 2 provides further detail on characteristics of common clonal lineages identified in Wisconsin during 2009-2012.

Table 2. Characterization of *P. infestans* clonal lineages US-22, US-23, and US-24 identified in Wisconsin during 2009 to 2012.

Clonal lineage	**Mating type**	**Optimum growth temp**	**Host comments**	**Years found in WI**	**Resistance to mefenoxam**
US-22	A2	24ºC	Tomato and potato, poor pathogen on pepper, eggplant, tomatillo	2009, 2010	Sensitive
US-23	**A1**	**18ºC**	**Tomato and potato**	**2010, 2011, 2012**	**Intermediately resistant**
US-24	A1	20ºC	potato	2010, 2011	Intermediately resistant (great variability among isolates)

With the recent presence of the late blight pathogen in the state and likelihood of disease-favorable weather conditions in upcoming years, it is critical that producers regularly scout their plants for disease. If late blight is suspected, contact your county extension agent, a crop consultant, the plant disease diagnostic clinic at UW-Madison, or myself. Additionally, protectant fungicides can manage late blight when applied in advance of infection and when re-applied as the crop grows. Wisconsin fungicide recommendations for late blight can be found in the University of Wisconsin Extension Publication entitled "Commercial Vegetable Production in Wisconsin," publication number A3422 (http://learningstore.uwex.edu/assets/pdfs/A3422.PDF) and additional information is provided in weekly newsletters during the growing season (provided at the vegetable pathology website: http://www.plantpath.wisc.edu/wivegdis/).

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ENVIRONMENTAL FATE OF SYSTEMIC NEONICOTINOIDS: A POTATO CASE STUDY

Anders Huseth and Russ Groves [1/]

Introduction

To date, the in-plant distribution of the in-furrow, systemic neonicotinoid classes (IRAC MoA 4A) of insecticides are relatively unknown in potato. Variable insecticide concentration and distribution over time is thought to affect resistance development in numerous insect pests, including key pests of potato (Gould, 1984, Isaacs, 2002, Daniels et al., 2009). Dynamic insecticide expression in the crop creates sub-lethal refuges promoting the evolution of behavioral and physiological mechanisms of resistance (Hoy et al., 1998). Documentation of insecticide within potato foliage throughout the growing season will generate a concentration profile for systemic use patterns. Insecticide expression patterns will better inform times at which the crop expresses sub-lethal insecticide doses that have direct implications for resistance management of key insect pests in potato. Connecting the amount of insecticide delivered to the proportion taken up by the plant season-long is a key factor in documenting overall in-plant concentration and environmental fate of insecticides.

Concern for groundwater quality has sparked a discussion as to the potential impacts of water, nutrient and insecticide use patterns in Wisconsin's agro-ecosystem. Recent positive detections of neonicotinoids by the Wisconsin Department of Agriculture Trade and Consumer Protection (WI-DATCP) in groundwater throughout the state have begun a discussion addressing not only the above ground concentration of neonicotinoids within the plant but what possible losses may be occurring below ground. Several studies have documented the chemical properties of neonicotinoids and their interaction with biota in the soil, composition of the soil and movement of compound into the water. Unfortunately, few have documented the relative tradeoffs between application of labeled neonicotinoid rates in potato, in-plant expression of insecticide and losses into the environment.

Objective

The objective of this project is twofold: 1) quantify in-plant concentration of thiamethoxam in potato between emergence and senescence. 2) directly compare season long thiamethoxam concentration in water leachate for three systemic and a foliar use patterns in potato. Documentation of temporal insecticide translocation in water will provide an improved understanding of insecticide delivery technologies that may contribute negative environmental impacts on soil, water, and human health.

Project History

The research presented on in-plant neonicotinoid expression was conducted in the 2010, 2011 and 2012 growing seasons. Forthcoming results will be presented as part of an emerging

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[1/] Research Assistant and Associate Professor, Department of Entomology, 537 Linden Dr. Univ. of Wisconsin-Madison, Madison, WI 53706.

body of analysis determining both temporal and spatial (between plant) insecticide concentration variability in potato. Characterization of neonicotinoid leachate from potato was a project component that was deployed with several systemic use patterns in the 2011 and 2012 growing season.

Approach

Field experiment: Insecticide treatments of thiamethoxam (Platinum 75SG & Actara 25WG, Syngenta, Greensboro, NC) were selected to represent a common, at-plant potato neonicotinoid and represent the majority of neonicotinoid groundwater detections by WI-DATCP from 2008-2010. Commercially formulated insecticide products at maximum labeled rates for potato in Wisconsin will be applied (Boerboom et al., 2010).

A randomized complete block design with four treatments (e.g., in-furrow, seed treatment, impregnated polyacrylamide and foliar) and an untreated control was be planted using the cultivar Russet Burbank. Each plot had a zero tension pan-type water collection lysimeter installed directly beneath the potato hill at a depth of 75 cm. Systemic insecticides was be applied at-planting using a hand-held, CO_2 pressurized sprayer as a directed spray to the seed. Polyacrylamide horticultural copolymer granules was be impregnated at an application rate of 16 $^{kg}/_{ha}$. Thiamethoxam insecticide solutions (0.834 g/250 ml D.I. water) were mixed with 75 g polyacrylamide then slowly stirred until all liquid is absorbed. Impregnated granules were dried for 24 hours at 20°C. Treated granules were divided into even quantities per row (9.8 g per 20 feet imidacloprid, 9.6 g per 20 feet thiamethoxam) and evenly distributed.

Lysimeter chemical quantification: Lysimeters were sampled on a bi-monthly frequency. Following collection samples will be maintained at 4-6°C. Water samples will be analyzed monthly by the WI DATCP-Bureau of Laboratory Services with LCMS. Established standard operating procedures developed by WI DATCP-EQ will used for the analysis of neonicotinoid residues.

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PEST MANAGEMENT OPTIONS IN PROCESSING SNAP BEANS

Russell L. Groves[1] Brian Flood[2], Don Caine[2], Mike Johnson[2], Mick Holm[3], and Scott A. Chapman[1]

Abstract. Effective, economical, and efficient season-long management of key insect pest species in commercial, succulent snap bean continues to be a challenge for many locales in the Midwest. Much of the processing snap bean crop in the upper Midwest is now treated with an at-plant, seed treatment including thiamethoxam, (Cruiser® 5FS). This prophylactic approach is designed to mitigate risk of damage by both seed corn maggot (SCM), *Delia platura*, and the potato leafhopper (PLH), *Empoasca fabae*. Cruiser applied at the labeled rates of 1.28 fl oz / 100 lb of seed, has been demonstrated to protect the crop from the early season seed maggot pressure as well as the damage resulting from immigrant potato leafhopper populations for nearly 50 days. Unfortunately, the Cruiser seed treatments will not protect the crop against infestation by the European corn borer. As a result, if degree day accumulations are favorable for a flight of European corn borer at a vulnerable stage of snap bean development (e.g. flowering to pin bean stage), a foliar spray of insecticide continues to be warranted. The current project proposes to continue with these evaluations and compare an experimental and a commercially registered anthranilic diamide, cyazypyr (HGW86 20SC), and rynaxypyr (Coragen® 1.67SC), respectively, as both in-furrow and seed treatment applications for the control of European corn borer in succulent snap beans.

Introduction. We continue to work in this area of investigation (seed and in-furrow treatments) and add insecticide applications with the starter and side-dress fertilizer application. European corn borer (ECB), *Ostrinia nübilalis*, is a perennial pest of snap bean in the Great Lakes region of North America, areas throughout the Midwest and also in the Mid-Atlantic States. Although ECB infestations in snap bean fields are typically low, this insect is considered a major threat to the processing industry because larvae may be processed and packaged in cans with the beans, thereby contaminating the product. Consequently, the threshold for ECB-contaminated beans in cans is very low. Despite a wealth of information for managing ECB in snap bean, this insect continues to threaten processing snap bean production in the areas mentioned above. Investigating approaches to improve insect pest management and integrate reduced-risk pest management options into snap bean pest management is among the Midwest Food Processor Association's highest priorities for research in 2009.

Insecticide control is the best option for managing ECB infestations in snap bean. ECB only threatens the snap bean crop during an approximately 14-day window, from bud stage (26 days before harvest) to the pod formation stage (12 days before harvest). Thus, only 1 to 2 applications are generally needed to manage this pest. Control of ECB before bud stage or within 12 days of harvest is rarely needed because larvae that hatch from eggs laid during

[1/]Department of Entomology, University of Wisconsin, 1630 Linden Drive, Madison, WI 53706. groves@entomology.wisc.edu.
[2/]Del Monte Foods, 1400 Plover Rd., Plover, WI 54467
[3/]DuPont Crop Protection, 4902 Wakanda Drive. Waunakee, WI 53597

these periods will not bore into market-sized pods. Every season, fields are sprayed 1 to 3 times with an insecticide application proven to provide adequate control of ECB. Yet, ECB larvae continue to be detected in beans that come through processing plants as internal contaminants. Based on spray records, many fields that had ECB-contaminated beans were sprayed one time, approximately 30 days before harvest. This approach is taken so that the insecticide can be tank mixed with a fungicide for white mold control. Unfortunately, timing of this tank mix is likely too early for effective ECB control and reduced contamination.

Research is needed to identify (1) insecticides that have longer residual activity to provide more flexibility in timing sprays for ECB control, and (2) alternative delivery systems such as in-furrow or side-dress applications plus seed treatments of systemic insecticides for ECB control that could replace the need for multiple foliar sprays. Reducing this need for sequential foliar sprays would minimize the number of require passes over the production field and ultimately reduce control costs. Fortunately, two novel insecticides from the diamide class of insecticides (Group 28; Insecticide Resistance Action Committee; http://www.irac-online.org) have emerged with systemic activity against ECB, corn earworm, beet armyworm, as well as several other Lepidopteran insect pests. The active ingredients include rynaxypyr and cyazypyr, but only rynaxypyr has a federal label. In January 2010, DuPont received an amendment from EPA that adding snap bean to its current rynaxypyr (Coragen) label. Both Coragen and HGW 86 (cyazypyr) were considered very effective against both SCM and ECB in recent snap bean trials conducted in.

The purpose of this project is to evaluate rynaxypyr and cyazypyr applied via different methods for controlling ECB in processing snap bean. The expected outcome of this research is that we will identify an approach for ECB control that will be more effective and easier to use than relying on multiple, well-timed foliar sprays. One potential outcome may be developing an insecticide seed treatment that provides season-long protection against ECB which could be coupled with existing seed treatment technologies. The benefits of this project are obvious, especially if a seed treatment is effective. Even an in-furrow or foliar application of one of these new systemic insecticides could provide major benefits in increasing the flexibility of timing applications to obtain better control (i.e., a tank mix with a fungicide for white mold control may be more effective). Despite the systemic nature of this new chemistry, EPA has viewed its environmental and toxicological profiles very favorably.

Table 1. Damage estimates of stems and pods, and total pod weights harvested.

Treatment	Rate	Application Type[1]	19 July		
			Proportion of Damaged Stems	Proportion of Damaged Pods	Pod weights (lbs)
Untreated	-	-	0.15 a	0.05 a	5.13 b
Coragen 1.67 SC	3.5 fl oz/a	IF	0.07 b	0 b	6.05 ab
Coragen 1.67 SC	5 fl oz/a	IF	0.02 b	0 b	6.08 ab
Coragen 1.67 SC	7 fl oz/a	IF	0.01 b	0 b	6.3 ab
Verimark 20 SC	10 fl oz/a	IF	0 b	0 b	6.03 ab
Verimark 20 SC	13.5 fl oz/a	IF	0 b	0 b	6.8 ab
Coragen 1.67 SC	5 fl oz/a	F-Pre	0.01 b	0 b	6.8 ab
Coragen 1.67 SC	7 fl oz/a	F-Pre	0.01 b	0 b	5.8 ab
Verimark 20 SC	10 fl oz/a	F-Pre	0 b	0 b	6 ab
Verimark 20 SC	13.5 fl oz/a	F-Pre	0 b	0.002 b	7.13 a
Coragen 1.67 SC	5 fl oz/a	F	0.02 b	0 b	6.4 ab
Benevia 10 SE	13.5 fl oz/a	F	0.01 b	0 b	6.85 ab
		P	0.004	0.089	0.62
		LSD	0.07	0.003	1.76

[1]IF = In-Furrow; F-Pre = fertilizer pre-mix; F = foliar

MANAGING IRRIGATION ON THE VARIED VEGETABLE FARM

A.J. Bussan [1/]

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[1/] Professor, Dept. of Horticulture, Univ. of Wisconsin-Madison, Madison, WI 53706.

ECONOMICS OF MANAGING NITROGEN FOR SWEET CORN

Matt Ruark and Paul Mitchell 1/

Nitrogen (N) management for processing sweet corn in Wisconsin has proven to be a complex issue. Sweet corn has a relatively large N demand and, to ensure complete kernel development, requires maintaining plant available N in the soil profile throughout the growing season, which can be a challenge on sandy soils. Current N guidelines for sweet corn in the University of Wisconsin Extension Publication A2809 (Nutrient Application Guidelines for Field, Vegetable and Fruit Crops in Wisconsin) suggest 150 lb/ac of N for soils with less than 2% soil organic matter and 130 lb/ac of N for soils with 2 to 10% soil organic matter, based on a yield range of 2 to 10 ton/ac. The guidelines also suggest split-applications or sidedress applications of N on coarse-textured (sandy) soils. Most, if not all, sweet corn production in the Central Sands is on coarse-textured soil with less than 2% soil organic matter and grown with split-applications of N. To evaluate the current A2809 guidelines for N application, on-farm N rate trials were conducted in 2009, 2010, and 2011, on four fields per year, for a total of twelve site-years. All fields were located in Adams County, WI. All plots had 60 lb/ac of N applied before V4 and 45 lb/ac of N applied as fertigation at tassel (VT stage). Six different N rates were then added as sidedress at V6-V8: 0, 25, 50, 75, 100, and 125 lb/ac of N, resulting in total N applications of 105, 130, 155, 180, 205, and 230 lb/ac of N.

When analyzed by each site-year, application of N over 155 lb/ac resulted in statistically significant yield increases only 17% of the time – in only 2 of 12 site-years. However, plot-to-plot variation was quite large, resulting in the lack of ability to determine yield differences of 1 ton/ac. Based on these results, the N application guideline for sweet corn of 150 lb/ac is adequate from the standpoint that yield losses may occur at rates less than this amount (Fig. 1).

With this data set, we can analyze all the data together to evaluate the economic benefit of N applications to sweet corn. Since the minimum amount of N that would be applied is 155 lb/ac, we focus our analysis on determining if there is an economic advantage to applying N above this rate. Relative to the yield at 155 lb/ac of N, the average yield gain for an extra 25 lb/ac of N was 0.13 ton/ac, 0.27 ton/ac for an extra 50 lb/ac of N, and 0.42 ton/ac for an extra 75 lb/ac of N. The variability of this extra yield also increased with the additional N (Fig. 2). In short, it appears that on average, small yield gains can be achieved with additional N above 155 lb/ac. However, the question remains as to whether there is an economic benefit to applying this additional N. In other words, is the value of the potential yield gain worth the risk of applying extra N (the cost of applying more N fertilizer)?

For this analysis, we used a current estimate of N fertilizer cost of \$0.50/lb-N and the state average price of Wisconsin sweet corn in 2010 (\$74/ton) and 2011 (\$110/ton) as reported by the USDA National Agricultural Statistics Service. Based on this N fertilizer price and the yield data reported in Fig. 2, we calculated the average economic return at both sweet corn prices. These calculations were made separately for each site-year, and then averaged across site-years. At a sweet corn price of \$110/ton, the average economic gain was \$1/ac for 25 lb/ac of extra N, \$4/ac for 50 lb/ac of

1/ Assistant Professor, Dept. of Soil Science and Associate Professor, Agricultural and Applied Economics, Univ. of Wisconsin-Madison.

extra N, and $9/ac for 75 lb/ac of extra N. However, with a sweet corn price of $74/ton, the average economic <u>loss</u> was $3/ac for 25 lb/ac of extra N, $5/ac for 50 lb/ac of extra N, and $6/ac for 75 lb/ac of extra N. However, Fig. 3 shows the tremendous amount of variability that exists around these average gains and losses. For example, with a sweet corn price of $110/ton, though the average gain for an extra 75 lb/ac of N was $9/ac, the observed range was from a gain of about $140/ac to a loss of over $100/ac.

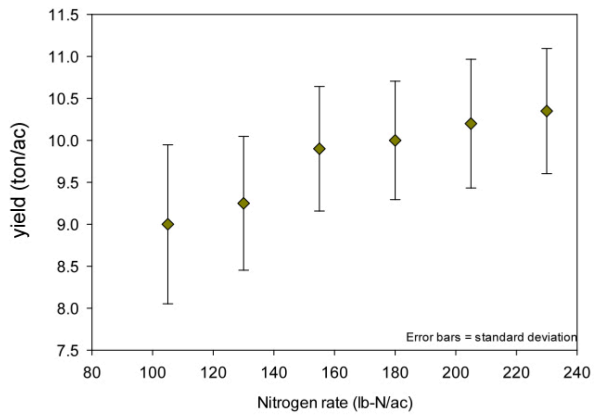

Figure 1. Average sweet corn yield across six nitrogen rates (yields averaged across sites and years).

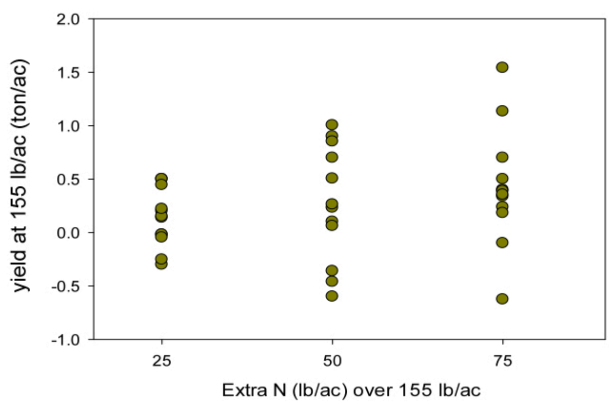

Figure 2. Yield gain or loss with 25, 50, or 75 lb/ac of extra N compared to yield at 155 lb/ac of N (average yields at each of 12 site years, 2009-2011).

Considering all site-years' worth of data, large economic gains or losses can occur with applying extra N to sweet corn, but *on average* there is likely little economic gain. This is especially true when the cost of N is high and the price of sweet corn is lower than average. It is important to consider these economic issues and use price calculations to confirm an economic need for applying more than 155 lb/ac of N.

Finally, several caveats apply to this analysis. For the yield data collected here, the N was split applied, with plots receiving N early (pre-V4) and late (VT). It is possible that the split application method led to optimum N use efficiency and played a role in seeing little benefit above 155 lb/ac of N. Large rainfall events can leach large quantities of N from the root zone on sandy soils. The split applications used here reduced the risk of large amounts of N in the soil at any given time to potentially be leached. If N were applied with fewer applications, the yield benefit from extra N may be greater, but only because the extra N would compensate for the amount of N that is leached. It is also important to note that based on current data we have collected, it is not clear if we can predict which fields would be the most responsive to extra amounts of N fertilizer.

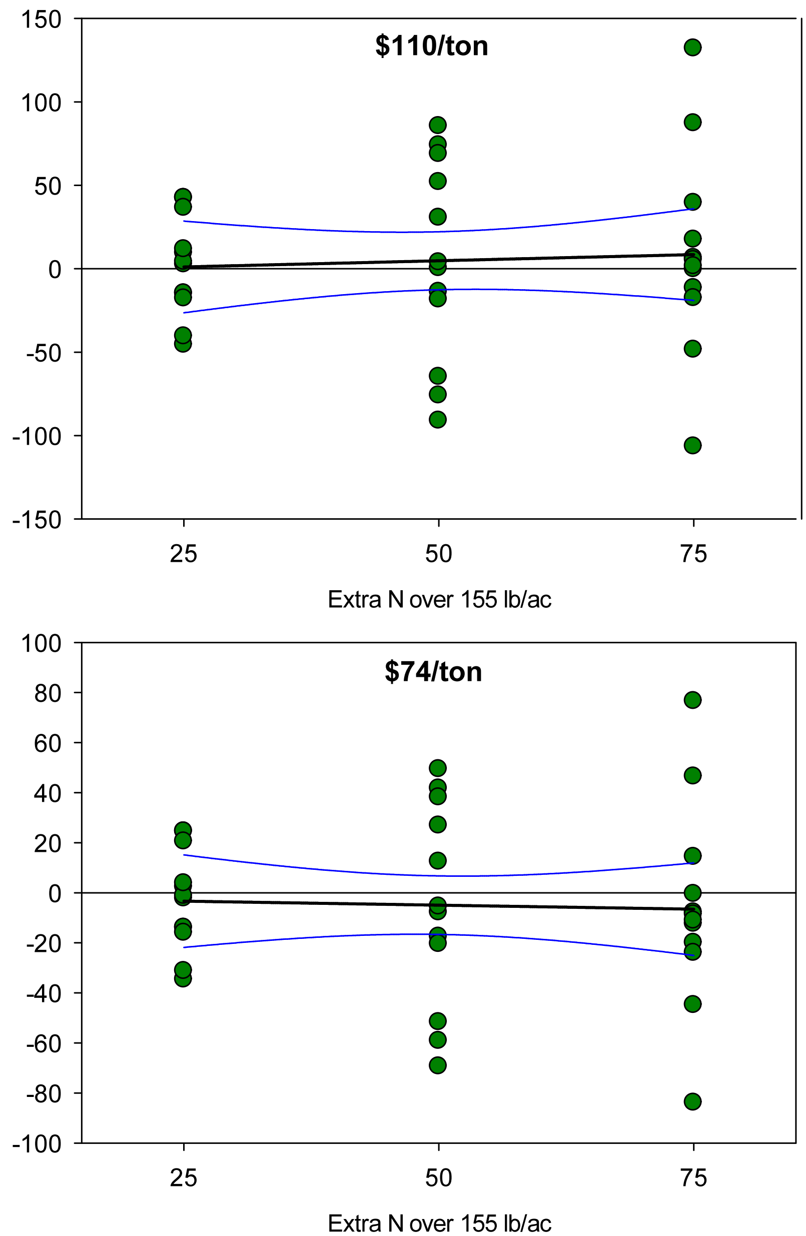

Figure 3. Average economic gain or loss with extra N, with a N price of $0.50/lb of N and sweet corn prices of $110/ton or $74/ton. Each data point within each N rate is one site-year. Reference lines are at $0, indicating no net gain or loss. Slopes of regression lines are not significantly different than zero.

NITRIFICATION INHIBITOR CLAIMS – ARE THEY REAL?

D.W. Franzen [1/]

Nitrogen management continues to be difficult due to transformations of nitrogen fertilizers that are possible when applied to soil and the uncertainties of weather (Cabrera et al., 2008). Nitrate fertilizer is subject to leaching (Randall et al., 2008) or denitrification (Coyne, 2008) depending on the water content of the soil and water movement through the soil. Ammonium forms of N can be fixed (Kissel et al., 2008), or can be transformed to nitrate through the activities of specific soil bacteria (Norton, 2008). Because of these and other processes, nitrogen use efficiency is low.

Nitrogen is often applied to crops in the North Central region of the US before planting. The first 4 to 6 weeks after planting, corn will only require about 5% of the N applied. The following 2 to 4 weeks of growth require a large proportion of the total season requirement. To address some of the delayed N requirement issues of winter wheat, much of the crop is top-dressed in the spring. In corn, some growers use side-dress applications; however spring preplant application is most common, with fall application preferred by growers in some Northern states. To increase nitrogen use efficiency and thereby increase yields or decrease N rates, a number of products have been developed to delay an N transformation process so that the period of time in which the N source is available for uptake is closer to the time the crop needs the available N. One of the groups of products developed to delay the bacterial process that transforms ammonia or ammonium fertilizers to nitrite/nitrate are the nitrification inhibitors.

Nitrapyrin

N-Serve®, or nitrapyrin (2-chloro-6-[trichloromethyl] pyridine) has been studied and commercially used since the late-1960's. Work by Janssen (1969), summarized by Hergert and Wiese (1980) showed that nitrapyrin was active as a nitrification inhibitor and that the degree of nitrification was influenced by nitrapyrin rate as a ratio of nitrapyrin to anhydrous ammonia. Greater N recovery with nitrapyrin than anhydrous ammonia alone was measured in April (190 days after application), June (230 days) and July (280 days) when anhydrous ammonia was applied from late October to early November.

Illinois studies in the mid-1970's showed that when injected into anhydrous ammonia or applied with urea the rate of nitrification decreased (Figures 1 and 2) (Touchton et al. 1978a, 1978b; Touchton et al., 1979a); however rainfall during the years of the experiments did not result in consistent increase in corn N uptake or corn yield in Illinois (Touchton et al., 1979b). Lack of yield response from the use of nitrapyrin was also reported in Iowa by Blackmer and Sanchez (1988); however Stehouwer and Johnson (1990) reported higher corn yield from fall-applied N with nitrapyrin related to higher N availability later in the season.

[1/] Professor and Extension Soils Specialist, North Dakota State University, Fargo, ND.

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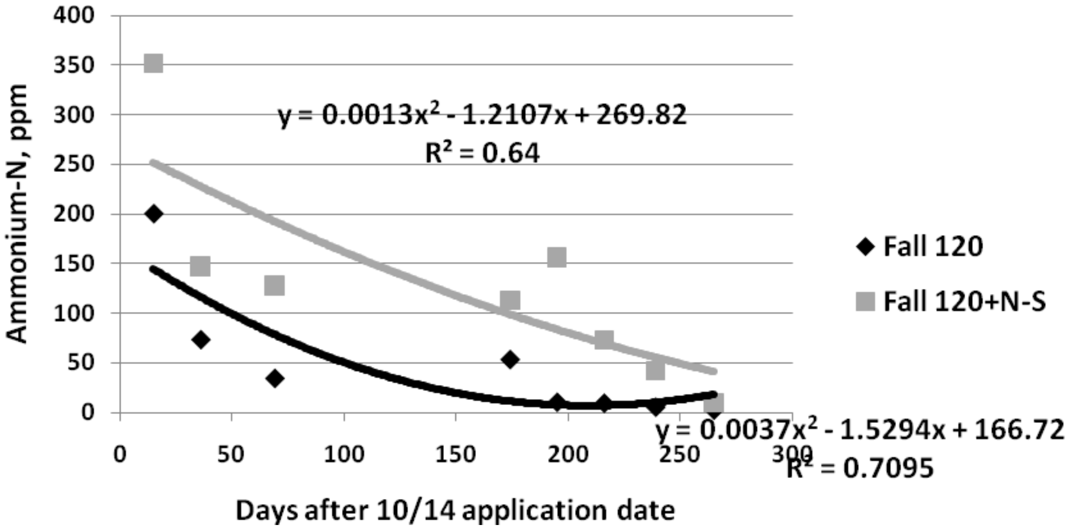

Figure 1. Ammonium-N concentration in soil after 120 lb/acre N as anhydrous ammonia was applied October 14, 1975 with and without 1 lb/acre ai (2X labeled rate) N-Serve® (nitrapyrin). Differences between treatments were significant at all sampling dates through day 239 (Touchton et al., 1978).

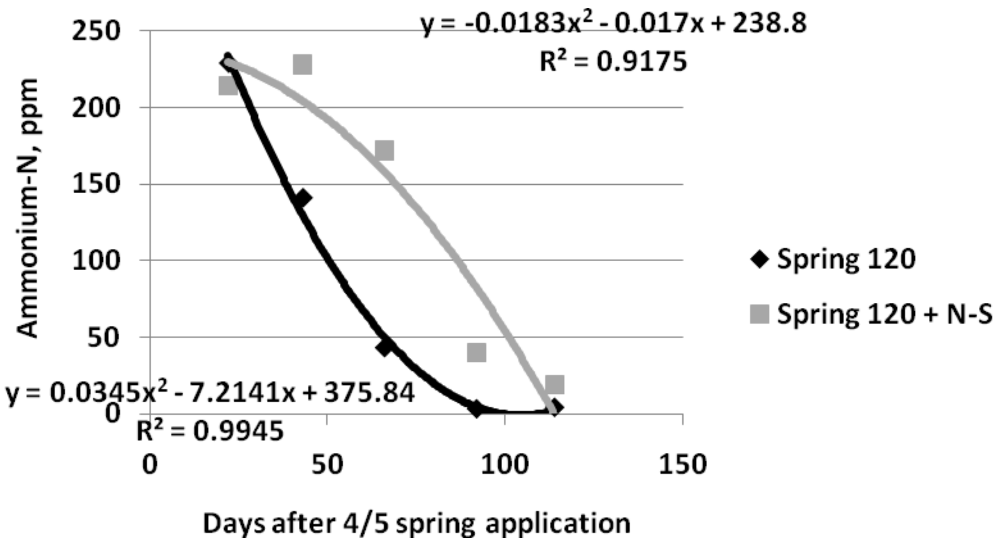

Figure 2. Ammonium-N concentration in soil after 120 lb/acre N as anhydrous ammonia was applied April 5, 1976 with and without 1 lb/acre ai (2X labeled rate) N-Serve® (nitrapyrin). Differences between treatments were significant at days after application all days after application through day 114 (Touchton et al., 1978).

Higher corn yield with nitrapyrin in fall-applied N was also reported by Randall et al. (2003) and Randall and Vetsch. (2005) in Minnesota; however, spring-applied N was highest yielding with greatest N-use efficiency. N-Serve® is labeled for immediate incorporation or injection and not as a surface-applied product. Yield increases over the seven Minnesota study years were 15 bushels per acre more for fall anhydrous ammonia + N-Serve over fall anhydrous ammonia alone, and 27 bushels per acre more for spring anhydrous ammonia compared to fall anhydrous ammonia (Randall et al., 2008)

A Wisconsin study (Hendrickson et al.,1978) found that on May 6, 1976 following an October 6, 1975 application of anhydrous ammonia, 53% of the recoverable N was ammonium-N with nitrapyrin (0.5 lb/acre ai) compared with 11% ammonium-N without. Nitrapyrin also increased the ammonium-N in Minnesota (Malzer, 1977) through June 8 of the following spring.

Grain yield increases with the use of a nitrification inhibitor have been inconsistent due to the variability of rainfall necessary to lead to nitrate leaching in sandier soils or denitrification in high clay soils. Malzer et al. (1979) recorded a corn yield increase with the optimum N rate with fall anhydrous ammonia application with nitrapyrin, but a split application of N resulted in similar yield with nitrapyrin as without. Hergert et al. (1978) showed that the benefit of nitrapyrin use under irrigated sands increased as the irrigation water as a percent of evapotranspiration increased. Differences between use of nitrapyrin and without were most pronounced at irrigation water as a percent of evapotranspiration of 86% and higher.

Instinct® is an encapsulated nitrapyrin formulation that can be applied to fertilizer left on the soil surface for up to 10 days for delay of ammonium fertilizer nitrification. It received its label in 2009. Research is ongoing at a number of Universities. University of Nebraska studies in 2008 and 2009 (Ferguson et al., 2008, 2009) showed no yield benefits to the use of nitrapyrin (GF-2017, Instinct); however, the plots were hampered by heavy rainfall in June (2008) and spatial variability (2009). In Wisconsin, 2 years of work with Instinct® resulted in corn yield increases in 2008, but not in 2009 (Laboski, unpublished data). In Illinois, there were no yield increases due to the use of Instinct with UAN over six site-years (Fernandez, 2010). Iowa (Killorn, unpublished data) and Minnesota (Randall, unpublished data) research also showed no yield increase with Instinct compared to N fertilizer alone.

Research on DCD, dicyandiamide, or cyanoguanidine, has shown that it can be used as a nitrification inhibitor, although research has generally shown that its activity may be shorter than nitrapyrin (Bronson et al., 1989). Products that contain DCD in the US include Super-U® (IMC Phosphate Company licensed exclusively to Agrotain International LLC) and Guardian® fertilizer additive (Conklin Company, Inc.). DCD contains about 67% N and was examined as an N source early in the last century (Reeves and Touchton, 1986). It was found to decrease crop yield when rates exceeded about 36 lb/acre (Cowie, 1918). The Guardian label recommends a 2% addition to fertilizer. The content of DCD in Super-U is not stated. It is unlikely that growers would over apply either product to the point of crop phytotoxicity. A review of North Central states research on DCD was published by Malzer et al. (1989). The review concluded that DCD was similar to nitrapyrin in its nitrification inhibition. Yield differences between fertilizer treated with DCD and fertilizer alone were inconsistent and limited to those soils and conditions where nitrate was lost through leaching or denitrification. The greatest value of either nitrification inhibitor would be in soils where nitrate loss through leaching or denitrification is more likely. A summary by Malzer et al. (1989) is reproduced in Table 1.

Table 1. Summary of corn grain yield responses to DCD and nitrapyrin at N rates equal to or less than optimum for fine-textured Midwest soils (from Malzer et al., 1989).

	DCD			Nitrapyrin		
	No. of comparisons			No. of comparisons		
	Total	With significant advantage	Average response	Total	With significant advantage	Average response
			%			%
Timing						
Fall	4	1	+1.6	2	0	-0.2
Spring	15	3	+3.4	7	1	-0.4
Sidedress	3	1	+1.4	3	2	+8.1
N Source						
Ammonium sulfate	2	0	-1.0	0	0	-
Anhydrous ammonia	6	1	+3.6	6	1	-1.8
Urea	4	4	+2.2	6	2	+1.1

In contrast to the relatively low frequency of corn responses in the Midwest, potato responses were more consistently positive (Malzer et al., 1989).

The rate of ammonium-N remaining in the soil following ammonia application with both nitrapyrin and DCD treatments was explored at four Illinois locations by Sawyer (1985). Within 30 days of a fall application, there were no differences between the control and the DCD and nitrapyrin treatments in % remaining ammonium-N. In the spring, the DCD and nitrapyrin treatments provided greater % remaining ammonium-N compared to the control at 3 of 4 locations. The differences are presented in Figure 3 for the Urbana and Dekalb locations. Spring application of DCD and nitrapyrin was even more effective at some sites (Figure 4).

There is considerable interest in the use of nitrification inhibitors with liquid manure applications. In response to reports of poor corn growth due to injected liquid manure in Illinois, placement studies with and without nitrapyrin were conducted on similar soils. The results of one study showed that the use of nitrapyrin increased corn plant and grain N concentrations, but did not translate into a yield increase (Sawyer et al., 1991). In another study, the use of nitrapyrin was useful in lowering soil nitrite levels in the liquid manure band, which was one reason why poor corn growth was observed in the banded liquid manure fields (Sawyer et al., 1990).

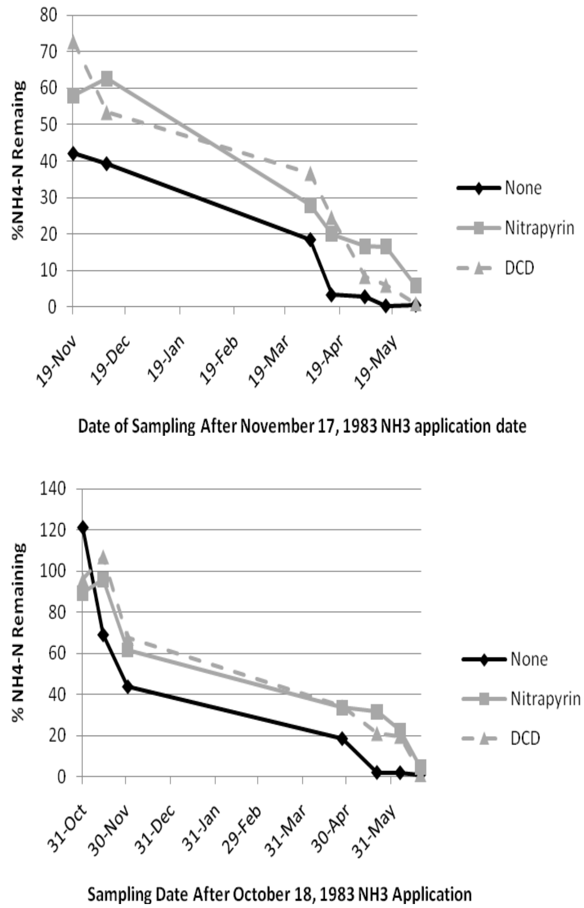

Figure 3. Percent NH_4-N remaining after fall NH_3 application at Urbana (left) and Dekalb (right) (from Sawyer, 1985).

Nitrification and urease inhibitors- the nitrification portion of activity or inactivity

Ammonium thiosulfate (ATS) and several additional commercial thiosulfates have nitrification (Goos, 1985; Janzen and Bettany, 1986) properties. In the process of identification of thiosulfates as nitrification inhibitors, it was noted that the compounds would not be expected to perform as well as some other alternative nitrification and urease inhibitors due to the shorter decomposition period for ATS compared to nitrapyrin (Goos, 1985). Thiosulfate activity is regulated by its concentration (effective at S rates of 25 mg kg^{-1} (Goos and Johnson, 2001).

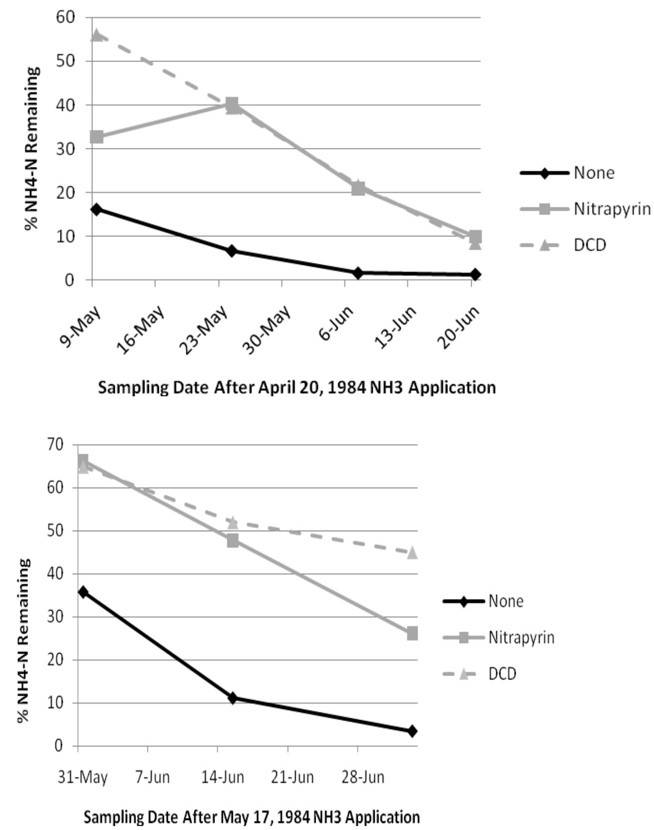

Figure 4. Percent NH_4-N remaining after spring NH_3 application at Monmouth (left) and Brownstown (right) (from Sawyer, 1985).

Thiosulfate readily breaks down rapidly in temperatures of 15^{o}C. In a laboratory study at 15^{o}C, ATS was essentially mineralized in about a week. Under cooler temperatures; however, significant thiosulfate remained after 2 weeks in two of three soils, with mineralization complete in all soils by week 3. When thiosulfate was placed in a band with aqua ammonia in the fall in North Dakota (October 3, 1996), thiosulfate resulted in similar spring (May 12, 1997) ammonium and nitrate levels as aqua ammonia treated with nitrapyrin (Goos and Johnson, 1999). Spring wheat yields of aqua ammonia treated with thiosulfate and nitrapyrin were similar, and both were greater than aqua ammonia alone.

Cautions were expressed by Janzen and Bettany (1986) on high rates of banded ATS (over 100 ppm) due to nitrite accumulation from ATS inhibition of not only the ammonium to nitrite process, but the nitrite to nitrate process. The rate used by Goos (1985) was about 43 ppm if expressed as a band with radius 2 inches, which did not accumulate nitrite in the Janzen Bettany (1986) study. Recently, the use of thiosulfate has been reexamined. In Kansas, the application in the spring of a 5 and 10% calcium thiosulfate by volume solution with UAN had similar yield as urea broadcast in no-till (Tucker and Mengel, 2007).

Nutrisphere-N is a product marketed by SFP (Specialty Fertilizer Products) LLC, Leawood, Kansas. The formulation for dry fertilizer is a 30 to 60% maleic itaconic co-polymer calcium salt. The pH of the dry formulation is between 2.5 and 5 according to the label. The rate of use is 0.5 gallon per ton of urea/ammonium sulfate. The formulation for liquid fertilizer is a 40% minimum maleic-itaconic co-polymer. The pH of the liquid product is between 1 and 2 according to the label/MSDS. The rate of mixing with liquid N products is 0.5 gallon Nutrisphere-N per 99.5 gallons of fertilizer solution. A gallon of Nutrisphere-N liquid or dry formulation weighs 9.6 pounds per gallon. Nutrisphere-N is marketed as both a urease inhibitor and a nitrification inhibitor. Marketing literature explains that the activity of Nutrisphere on nitrification is related to its binding to copper ions necessary for the nitrification process in soil bacteria.

The most consistent yield increases and crop uptake of N from the use of Nutrisphere-N has been through work by Gordon (2008). In 2 years of corn at Scandia, KS and 2 years of grain sorghum at Belleville, KS, yield increases to the use of Nutrisphere-N were similar to those achieved with urea-Agrotain and ESN (Tables 2 and 3).

Table 2. Effects of N additive, averaged over source (UAN and urea) and N rate on corn grain yield, earleaf-N and grain-N, Scandia, KS (2-year average) (from Gordon, 2008).

Treatment	Yield, bu/acre	Earleaf N, %	Grain N, %
Check	152	1.72	1.13
Urea/UAN	168	2.57	1.26
ESN	185	2.96	1.33
Nutrisphere-N	183	2.96	1.35
Agrotain	183	2.98	1.36
LSD 5%	6	0.09	0.04

Table 3. Effects of N source and rate on grain sorghum yield, Belleville (2-year average) (from Gordon, 2008).

Treatment	N-rate, lb/acre	Yield, bu/acre
Check	0	71
Urea	40	108
	80	122
	120	128
ESN	40	120
	80	130
	120	132
Urea + Agrotain	40	116
	80	129
	120	133
Urea+ Nutrisphere	40	120
	80	133
	120	132
LSD 5%		5

The consistent results from Gordon (2008) are very curious considering that careful laboratory experiments by Goos (2008; 2012) have shown that Nutrisphere-N has no nitrification ability (Figures 5 and 6).

To test these products for nitrification, another incubation study was conducted (Goos, 2012). Urea treated with Instinct (Nitrapyrin) (Figure 5) and Super U (containing DCD) decreased nitrification, while all other treatments had no effect. In another series of experiments, (Goos, unpublished data) showed that the mode of action claimed for any urease activity by Nutrisphere was flawed.

It is clear from the laboratory experiments that there is no nitrification inhibition by Nutrisphere when used at label rates. Goos observed some small nitrification inhibition when the Nutrisphere for liquid fertilizer is applied in a concentrated band. He attributes this to the strong acidity of the liquid formulation, and not to the Nutrisphere itself (Goos, personal communication, 2010). Acid conditions are known to inhibit nitrification bacteria (Schmidt, 1982).

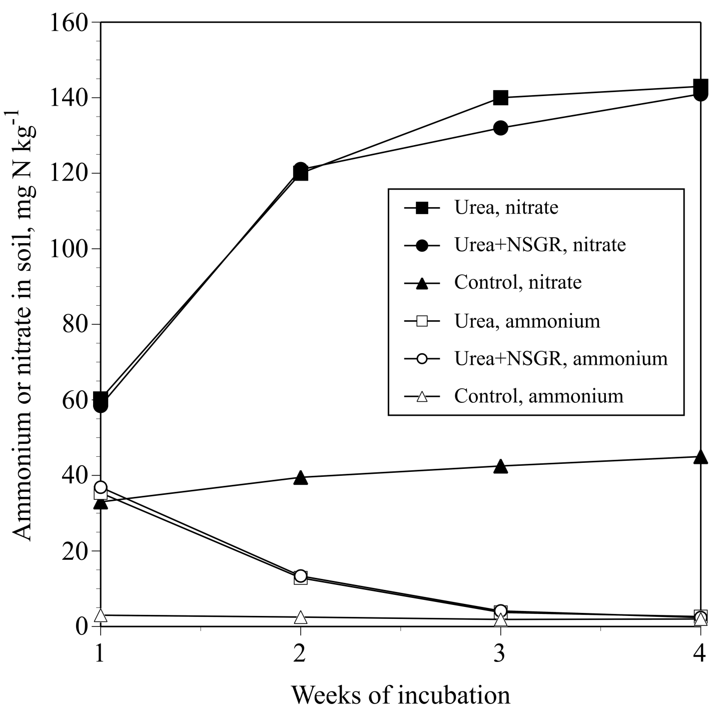

Figure 5. Ammonium and nitrate in a Renshaw soil as influenced by length of incubation and application of urea granules, and urea granules treated with Nutrisphere-N for granular fertilizers (NSGR) (experiment by R.J. Goos; cited in Franzen et al., 2011).

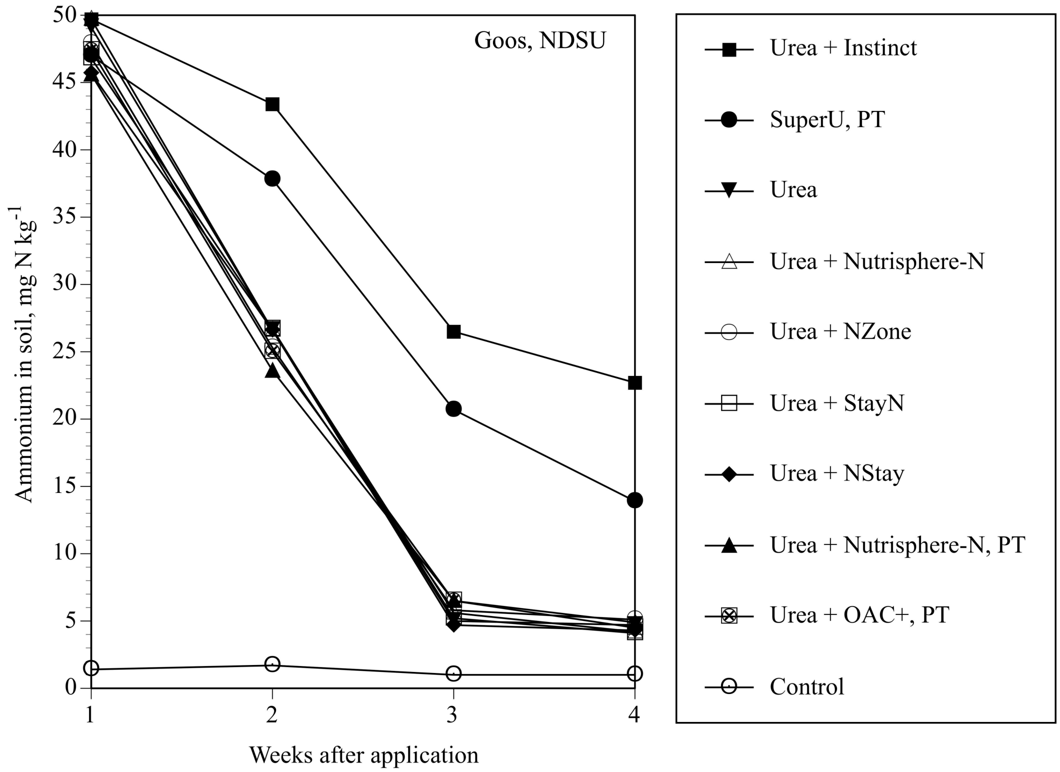

Figure 6. Residual ammonium in a sandy loam soil incubated with urea granules, or urea granules treated with various additives. PT=granules received pretreated, other additives applied to urea by the researcher (from Goos, 2012).

In the field, it is uncommon to consistently find yield or quality responses to the use of Nutrisphere at labeled rate. In North Dakota studies on spring wheat at 8 locations, there were no yield increases or grain N uptake increases with Nutrisphere compared to urea (Franzen et al., 2011). Two additional North Dakota studies on corn showed no yield increase with the use of Nutrisphere (NDSU Carrington Research and Extension Center, unpublished data). In Kansas (Tucker and Mengel, 2008), there were no increases due to Nutrisphere with UAN over UAN surface banded or injected in grain sorghum in 2007. In two years of corn in Kansas, there were no yield increases from the use of Nutrisphere-N UAN compared to surface applied UAN at three total sites (Weber and Mengel, 2009). In 2009, there was no response to Nutrisphere + UAN broadcast on grain sorghum compared to broadcast UAN alone in Kansas at three locations (Weber and Mengel, 2010). There was one sorghum yield increase with surface banded Nutrisphere + UAN compared to UAN surface banded alone and two non-responsive sites. The yield increase with surface band but not broadcast suggests that perhaps the acidity of the Nutrisphere may have delayed nitrification at this site (Schmidt, 1982).

At Waseca, MN in 2009, there was no corn yield difference between urea and urea with Nutrisphere applied in the fall (Randall and Vetsch, 2009). Grain and stover N between urea and urea with Nutrisphere were similar. In Illinois, at two locations in 2008

Nutrisphere-urea was lower in yield than urea, and similar in yield at the two locations with UAN and Nutrisphere-UAN (Ebelhar and Hart, 2009). At Dixon Springs in 2009, Nutrisphere urea, UAN, and ammonium sulfate treatments did not result in higher corn yield than the N sources with Nutrisphere-N (Ebelhar and Hart, 2010), although main effects for Nutrisphere-N on corn yield were significant. In Arkansas and Mississippi, Nutrisphere-N had no effect on rice yields in three field studies compared with urea (Franzen et al., 2011). In South Dakota, Nutrisphere-N did not result in higher corn yield in 2007 (Bly and Woodard, 2007), 2008 (Bly et al., 2008), or 2009 at 2 sites (Bly et al., 2009).

In Idaho, there were no spring wheat yield increases with Nutrisphere over 2 years (Jeffrey Stark, personal communication, 8/23/2010). In barley, however, there were yield increases in 2008 and 2009 with Nutrisphere, but no increase in grain protein over similar rates of urea. Plant N uptake with Nutrisphere was similar to urea without Nutrisphere, suggesting that the yield increase in barley came from some other response other than enhanced N nutrition (Stark, 2008; 2009).

Laboratory studies with Nutrisphere-N show no effect on nitrification or urease activity. Therefore, it is not surprising that the great majority of studies with Nutrisphere show no yield effects. What is surprising is that there are studies that show yield effects, but not from increased N nutrition. The results from Gordon (2008) suggest that under some conditions, Nutrisphere may have some effect on plant growth and development and even N nutrition not related directly to urease inhibition or nitrification. However, the company probably needs to reexamine its label as a nitrification inhibitor and urease inhibitor.

Summary

Certain nitrogen additives provide growers with options for extended activity of nitrogen nutrition for their crops. Their economics depends on rainfall following application, application methods, timing and soil characteristics, especially soil texture. Nitrapyrin has been effective in delaying nitrification. Dicyandiamide (DCD) has also been shown to be effective in delaying nitrification. Thiosulfates have been shown to delay nitrification, but the body of literature to support their use is much smaller than that of nitrapyrin. NBPT (Agrotain) is an effective urease inhibitor. Thiosulfates have shown some urease inhibition characteristics, but again, the body of literature that supports their use is small.

Nutrisphere has been shown to be ineffective as both a nitrification and urease inhibitor. The data that support the use of Nutrisphere is small in comparison to the data that does not support its use. If one accepts that the laboratory studies, conducted in a similar manner to those used to evaluate products like nitrapyrin of DCD containing products, show that Nutrisphere is not a nitrification or a urease inhibitor, than there must be other explanations for small number the field studies that show a yield benefit to the use of the product and in some circumstances even show an accumulation of N. The very acidic nature of the liquid formulation of Nutrisphere suggests that in banded applications, the nitrification delay may be associated with the acidity of the solution more than the Nutrisphere itself. Other new products, including Stay-N, NStay and NZone have failed to support their claims as nitrification inhibitors in careful laboratory experiments.

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EFFICACY OF INSTINCT TO IMPROVE NITROGEN USE EFFICIENCY OF MANURE AND FERTILIZER

Carrie A.M. Laboski and Todd W. Andraski[1]

A variety of research has been conducted to assess the efficacy of the nitrification inhibitor Instinct in Wisconsin from 2008 through 2012. Several studies have focused on the use of Instinct with UAN and urea as well as dairy manure. Initial research with UAN applied preplant with and without Instinct on a deep well drained silt loam, found a 5 bu/a yield increase, which was not significant, in two of three years. In both of these years, there was excessive rainfall that resulted in 30 to 40 lb/a of N loss from preplant applied N. In another study, Instinct applied with urea significantly increased corn grain and silage yield when applied in fall and spring. However, application of Instinct with liquid dairy manure did not increase grain yield, but did result in significantly greater silage yield. In general, measurement of nitrate and ammonium concentrations in soil demonstrate that ammonium N concentrations are greater and nitrate N concentrations are lower where Instinct was applied compared to where it wasn't. This suggests a lower likelihood of N loss from leaching or denitrification where Instinct was applied, even though it didn't always translate into greater yield.

[1] Associate Professor and Researcher, Dept. of Soil Science, 1525 Observatory Dr., Univ. of Wisconsin-Madison, Madison, WI 53706

VOLATILIZATION LOSSES FROM UREA

D.W. Franzen [1/]

Nitrogen fertilizer in the form of urea is subject to ammonia volatilization through the activity of the urease enzyme found ubiquitously in soil (Kissel et al., 2008). Nitrogen volatilization is especially prevalent when urea is applied to the soil surface, as in no-till systems when growers have not invested in sub-surface application tools. To decrease possible ammonia volatilization losses a number of products have been developed to delay urease activity.

Urease Inhibitors

The compound that has most consistently decreased urea volatilization when mixed with urea or urea-ammonium nitrate solutions is NBPT (N-(n-butyl) thiophosphoric acid triamide). NBPT is marketed as Agrotain® (Agrotain International LLC). The mechanism for NBPT is to lock onto the urease enzyme binding sites, preventing the enzyme from reacting to the urease (Manunza et al., 1999).

Agrotain (NBPT) decreases the rate of ammonia volatilization from urea applied to the surface as dry urea or urea-ammonium nitrate solutions (Brouder, 1996; Table 1). Ammonia volatilization losses from urea at Brandon, MB decreased from 40 mg to 2 mg and from 88 mg to 12 mg with Agrotain in two separate studies for a 7-day period after application (Grant, 2004).

In a recent Kansas study (Weber and Mengel, 2009), urea was applied in three site years to the soil surface after corn emergence using a number of nitrogen extending additives including Agrotain. The Agrotain treatment was superior to urea alone by 25 bushels per acre in one of the three site years. The two locations that received significant rainfall immediately following applications did not receive a yield benefit from the Agrotain treatment. In sorghum, urea + Agrotain and urea + SuperU were 11 and 12 bushels per acre respectively greater in yield than urea broadcast alone (Weber et al., 2009a). At two drier locations there were no yield differences between urea + Agrotain and urea alone.

A 14-year study in southern Illinois (Ebelhar et al., 2010) showed a 3 bushel corn yield advantage of urea + Agrotain compared to urea broadcast in conventional till surface and incorporated over 12 years of treatments. In no-till, urea+ Agrotain held an 11 bushel/acre advantage over urea surface applied over 4 years of treatments. Another study in southern Illinois (Varsa et al., 1999), Agrotain treated UAN surface dribbled was superior to UAN surface dribble alone (Table 2).

[1/] Professor and Extension Soils Specialist, North Dakota State University, Fargo, ND.

Table 1. Mean corn yield from Purdue Agronomy Farm, SEPAC, Pinney Purdue and Kosciusko locations with urea and UAN alone and treated with NBPT (Brouder, 1996, citing work by Phillips, Mengel and Walker, 1989, unpublished work, Purdue, University).

Fertilizer treatment	Yield, bu/acre
Control- (20 lb N/acre in starter only	99
Urea broadcast, surface	130
Urea + NBPT broadcast, surface	143
UAN broadcast, surface	135
UAN + NBPT broadcast, surface	140
UAN dribbled, surface	139
UAN spoke injected	142
UAN coulter injected	147
UAN knife injected	145

Table 2. No-till corn yield as affected by N fertilizer sources, Agrotain and placement in Illinois (fFrom Varsa et al., 1999).

	Belleville	Dixon Springs		
Treatment	Yield, bu/acre			
Control (0N)	34	53	62	73
Urea	106	120	98	100
Urea + Agrotain	134	143	112	112
UAN, surface	123	137	103	107
UAN + Agrotain, surface	128	145	107	114
UAN, dribble	139	137	108	112
UAN + Agrotain, dribble	143	152	110	120
UAN injected	172	176	123	121
Anhydrous ammonia	158	166	122	130

In Kentucky, 50 lb N/acre was applied preplant to all corn plots (Schwab and Murdock, 2009). Side-dress applications of urea and UAN with several additives or formulations were applied to the soil surface at 6-leaf stage. Higher yields than urea alone were achieved with urea + Agrotain and SuperU. Higher yields than UAN alone were achieved with UAN + Agrotain and UAN + Agrotain Plus (combination of NBPT and DCD formulated for use with UAN) (Table 3).

Table 3. Yield for side-dressed no-till corn in Hardin County, KY (from Schwab and Murdock, 2010).

Treatment	Yield, bu/acre
Check (50 lb N/acre preplant N only)	117d*
Urea	158c
Urea + Agrotain	201b
SuperU	201b
UAN	150c
UAN + Agrotain	179bc
UAN + Agrotain Plus	175bc
Ammonium nitrate	239a

* Numbers followed by the same letter are not significantly different (5%)

Additional Possible Urease Inhibitors

Ammonium thiosulfate (ATS) and several additional commercial thiosulfates have soil urease inhibiting properties (Goos, 1985). In the process of identification of thiosulfates as soil urease inhibitors, it was noted that the compounds would not be expected to perform as well as some other alternative nitrification and urease inhibitors due to the shorter decomposition period for ATS compared to nitrapyrin (Goos, 1985). One study was unable to duplicate urease inhibition results, but used different methods than originally presented at rates of ATS from 3.3 to 33 times the rates of Goos, 1985 (McCarty et al., 1990). Thiosulfate activity is regulated by its concentration (effective at S rates of 25 mg kg^{-1} (Goos and Johnson, 2001).

Thiosulfate readily breaks down rapidly in temperatures of 15^{o}C. In a laboratory study at 15^{o}C, ATS was essentially mineralized in about a week. Under cooler temperatures; however, significant thiosulfate remained after 2 weeks in two of three soils, with mineralization complete in all soils by week 3. Cautions were expressed by Janzen and Bettany (1986) on high rates of banded ATS (over 100 ppm) due to nitrite accumulation from ATS inhibition of not only the ammonium to nitrite process, but the nitrite to nitrate process. The rate used by Goos (1985) was about 43 ppm if expressed as a band with radius 2 inches, which did not accumulate nitrite in the Janzen Bettany (1986) study. Recently, the use of thiosulfate has been reexamined. In Kansas, the application in the spring of a 5% and 10% calcium thiosulfate by volume solution with UAN had similar yield as urea broadcast in no-till (Tucker and Mengel, 2007).

Nutrisphere-N is a product marketed by SFP (Specialty Fertilizer Products) LLC, Leawood, KS. The formulation for dry fertilizer is a 30 to 60% maleic itaconic co-polymer calcium salt. The pH of the dry formulation is between 2.5 and 5 according to the label. The rate of use is 0.5 gallon per ton of urea/ammonium sulfate. The formulation for liquid fertilizer is a 40% minimum maleic-itaconic co-polymer. The pH of the liquid product is between 1 and 2 according to the label. The rate of mixing with liquid N products is 0.5 gallon Nutrisphere-N per 99.5 gallons of fertilizer solution. A gallon of Nutrisphere-N liquid or dry formulation weighs 9.6 pounds per gallon. Nutrisphere-N is marketed as both a urease inhibitor and a nitrification inhibitor. The activity of the product on urease is theoretically based on its binding to nickel ions necessary for the formation and function of the enzyme. The most consistent yield increases and crop uptake of N from the use of Nutrisphere-N has been through work by Gordon (2008). In 2 years of corn at Scandia, KS and 2 years of grain sorghum at Belleville, KS, yield increases to the use of Nutrisphere-N were similar to those achieved with urea-Agrotain and ESN (Tables 4 and 5).

Table 4. Effects of N additive, averaged over source (UAN and urea) and N rate on corn grain yield, earleaf-N and grain-N, Scandia, KS (2-year average) (from Gordon, 2008).

Treatment	Yield, bu/acre	Earleaf N, %	Grain N, %
Check	152	1.72	1.13
Urea/UAN	168	2.57	1.26
ESN	185	2.96	1.33
Nutrisphere-N	183	2.96	1.35
Agrotain	183	2.98	1.36
LSD 5%	6	0.09	0.04

Table 5. Effects of N source and rate on grain sorghum yield, Belleville (2-year average). (from Gordon, 2008).

Treatment	N-Rate, lb/acre	Yield, bu/acre
Check	0	71
Urea	40	108
	80	122
	120	128
ESN	40	120
	80	130
	120	132
Urea + Agrotain	40	116
	80	129
	120	133
Urea+ Nutrisphere	40	120
	80	133
	120	132
LSD 5%		5

The consistent results from Gordon (2008) are very curious considering that careful laboratory experiments by Goos (2008) and Norman (Franzen et al., 2011) have shown that Nutrisphere-N has no urease inhibitor ability (Fig. 1-4, Table 6).

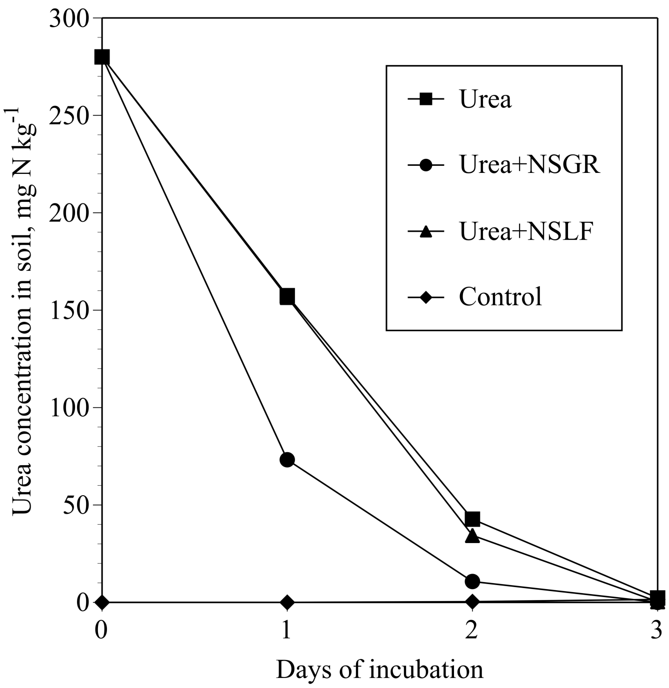

Figure 1. Urea remaining in an Overly soil, as influenced by time of incubation, and application of urea, urea plus Nutrisphere-N for granular fertilizers (NSGR), and urea plus Nutrisphere-N for liquid fertilizers (NSLF) (experiment by R.J. Goos; cited in Franzen et al., 2011).

Table 6. Cumulative ammonia volatilization losses for urea, ammonium sulfate, urea + NBPT, and urea + 0.25% Nutrisphere (NSN) from a Dewitt silt loam soil during a 15-day laboratory incubation at 25°C. (Norman data, University Arkansas, Fayetteville) (from Franzen et al., 2011).

	Days after N source application			
	3	7	11	15
N sources	Cumulative NH_3 loss, % of N applied			
Urea	14.5	35.9	51.8	56.9
Ammonium sulfate	0.1	0.2	0.5	0.6
Urea + NBPT†	0.006	2.7	12.9	18.3
Urea + 0.25% NSN	17.6	42.2	57.8	62.7
LSD(0.05)‡	12.2			
LSD(0.05)§	9.6			

†NBPT= N-(n-butyl) thiophosphoric triamide
‡LSD to compare means between N sources within the same sampling time.
§LSD to compare means between sampling time within the same N source.

Additional studies on possible urease inhibition by Nutrisphere, and some newer products including Stay-N (Loveland, Products Inc., Greeley, CO- a calcium heteropoly saccharide/calcium aminoethylpiperazine/Alkylarylpolyoxethylene glycols product) N-Stay, N-Zone (AgXplore, similar ingredients to Stay-N) and OAC a proprietary material from Simplot with an unknown composition. The methods used in these studies are available from (Goos, 2012).

In an incubation study (Fig. 2), UAN untreated had the highest level of ammonia loss, followed by UAN treated with Nutrisphere for liquid fertilizer. UAN with ammonium thiosulfate (ATS) or calcium thiosulfate (CTS) had similar, but less ammonia loss compared to UAN with Nutrisphere, but more loss than either UAN with NBPT (Agrotain) or UAN with both Agrotain and CTS (the least loss in the trial. Having previously shown that Nutrisphere is not a urease inhibitor, the likely reason for the lower ammonia loss with Nutrisphere compared to UAN is the acidic nature of the Nutrisphere for liquid fertilizer, which would tend to retain some of the ammonia from immediate loss through forming ammonium ions after urease split the urea in the UAN. As support for this conclusion, the study was performed using granular urea and Nutrisphere for granular urea, which is not as acidic as the Nutrisphere for liquid fertilizer. The results from Nutrisphere on its ability to retain ammonia after urease activity were similar to all products except NBPT (Agrotain) (Fig. 3). Three additional products, Stay-N, N-Stay and N-Zone similarly did not inhibit urease activity as exhibited by ammonia losses similar to the check. The company that markets N-Zone has not claimed to be a urease inhibitor, but claims to inhibit nitrification.

In another series of laboratory experiments conducted in 2012, (Goos, unpublished data, presented at American Society of Agronomy meetings, Oct. 2012, Cincinnatti, OH) urease activity of Nutrisphere was reevaluated. Experiment 1 compared Nutrisphere treated UAN with UAN alone. There was no effect on urea remaining after incubation compared to the untreated UAN (Fig. 4). showed that the mode of action claimed for any urease activity by Nutrisphere was flawed. There was no indication that any of 13 organic acids, including maleic and itaconic acids, had exceptional abilities to sequester Ni ions. NBPT, however, had a relatively high ability to sequester the Ni ion, and this might contribute to the activity of this compound on its selectivity for urease enzyme. Urease activity was not affected by Nutrisphere any of six experiments conducted by Goos.

Goos performed six experiments in 2012, reported at the American Society of Agonomy meetings, October 2012, and currently submitted for publication that investigated the urease activity of Nutrisphere and other products and also investigated the alleged mode of action of maleic and itaconic acid (the active ingredients in Nutrisphere) for urease activity.

The first experiment was conducted with UAN with and without Nutrisphere. The results (Fig. 4) showed no activity of the Nutrisphere-UAN compared to UAN alone.

Experiment 2 compared urea remaining after soil incubation with Nutrisphere-treated urea pretreated by a supplier and treated by the researcher, urea alone and urea with Agrotain Ultra (an NBPT formulation). The only product that increased the concentration of urea remaining in the pots at 2 day measurements to 10 day measurements was the Agrotain Ultra (Fig. 5).

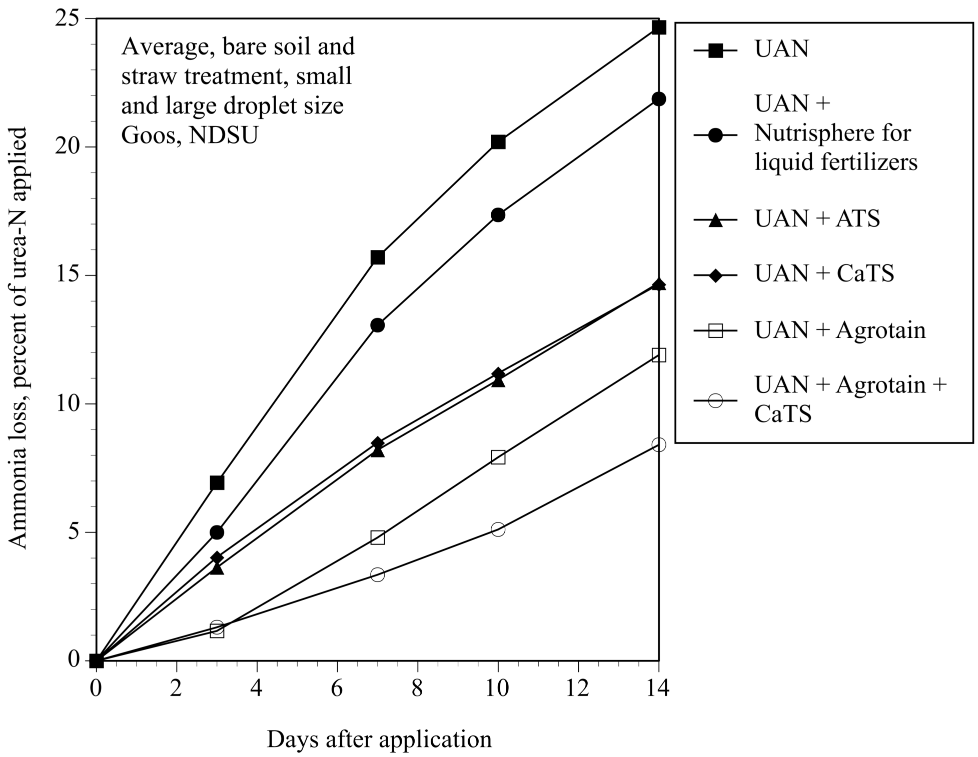

Figure 2. Ammonia loss from soil treated with UAN plus additives over 14 day incubation (from Goos, 2012).

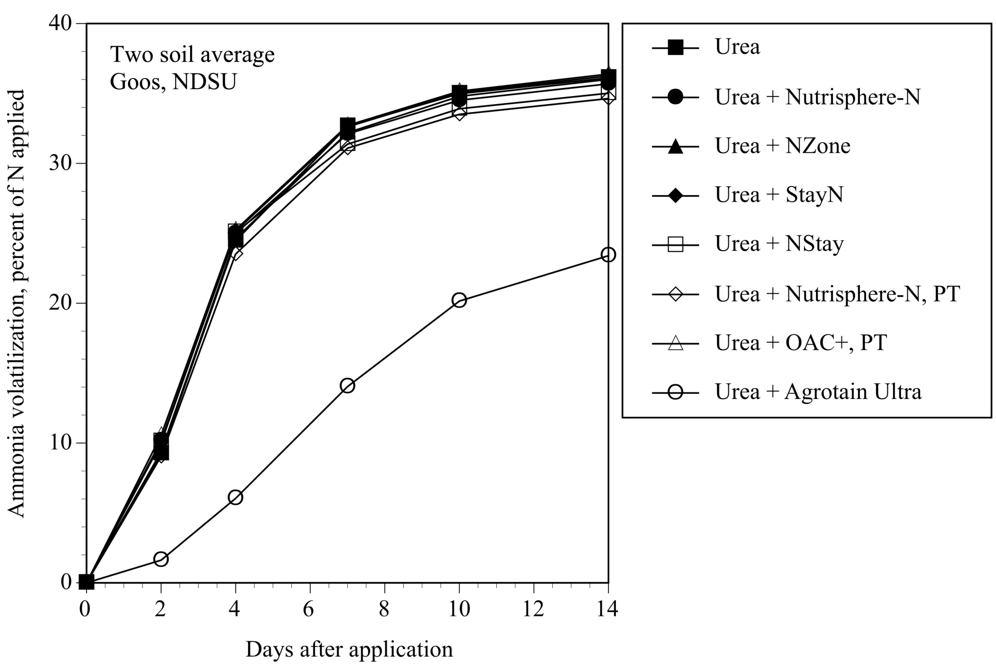

Figure 3. Ammonia loss from urea-N treated soil over 14 day incubation (from Goos, 2012).

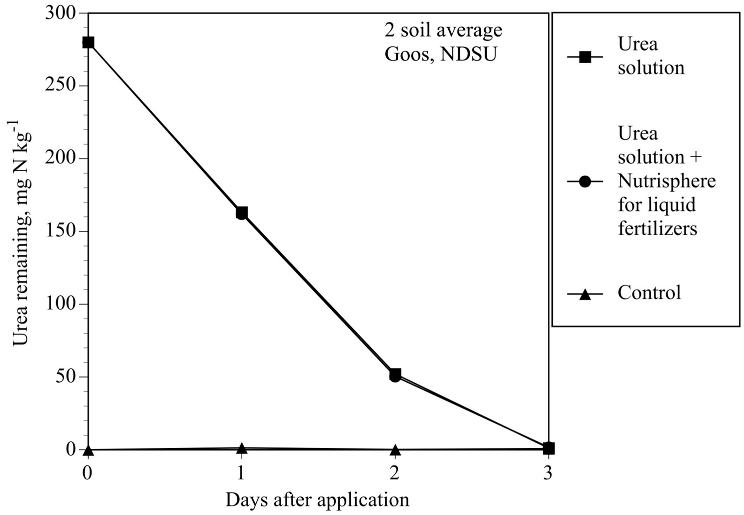

Figure 4. Urea remaining after UAN with and without Nutrisphere for liquid fertilizers, 2012 (unpublished data).

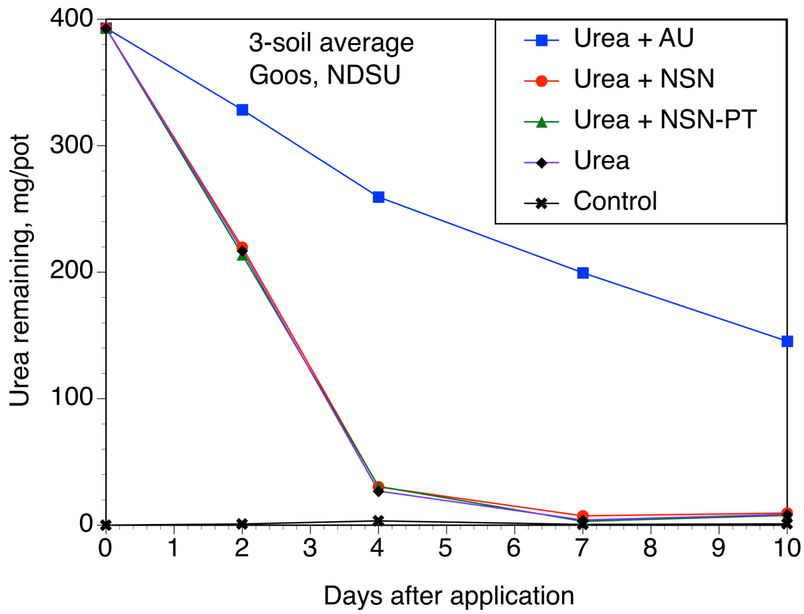

Figure 5. Urea remaining during an incubation, comparing the urease activity of urea with Agrotain Ultra (AU), urea with Nutrisphere pre-treated (PT) or treated by the researcher (NSN), or urea alone with a no-urea control.

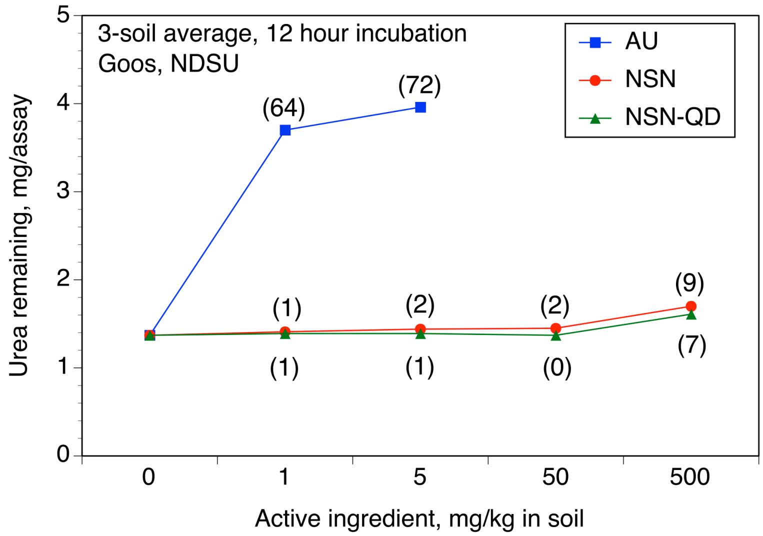

Figure 6. Urea remaining after treatment with either Nutrisphere N for urea (NSN) or Nutrisphere N Quick Dry (NSN-QD) and incubation for 12 hours at 25°C. Percent of original urea remaining is in parentheses (Goos unpublished, 2012).

In Experiment 3, 5 mg urea was mixed with 10 g soil. Urea was mixed with either then 1 to 500 mg of Nutrisphere (NSN) for urea or Nutrisphere quick dry (NSN-Q) for urea. These two Nutrisphere treatments were compared to urea alone and with 1 or 5 mg NBPT (Agrotain Ultra (AU). The soil was incubated for 12 hours at 25°C and the urea remaining was measured at the end of the experiment (Fig. 6). The Agrotain Ultra treatments of 1 or 5 mg NBPT resulted in 64% and 72% of the original urea remaining respectively. The lower NSN and NSN-QD rates of 1 and 5 mg were equivalent to labeled rates for the products. Urea remaining was less than 2% of the original rate for both treatments. Increasing the rate of NSN and NSN-QD by a factor of 10 did not improve the amount of urea remaining after incubation. Increasing the rate of NSN and NSN-QD by a factor of 100 improved the percent urea remaining to 7 and 9 respectively.

Experiment 4 was designed to test the theory of the Nutrisphere mode of action, which is to sequester Ni ions and pull Ni out of the urease enzyme, rendering it inactive. Thirteen carboxylic acids with different Ni+ stability constants were added to 5 mg urea at 50 mg/kg along with NSN, NSN-QD at 50 mg maleic/itaconic acid equivalent and AU at 1 and 5 mg/kg NBPT. The urea with and without additives were added to 10 g soil of three soils and allowed to incubate at 25°C for 12 hours. The urea remaining was then analyzed. NSN and NSN-QD were no more effective in urease inhibition compared to the thirteen carboxylic acids. AU at both rates had similar amounts of urea remaining compared with the results from Experiment 3 (Table
NSN and NSN-QD (Table 7).

Table 7. Experiment 4 treatments to test thirteen carboxylic acids, including the active ingredients in Nutrisphere was Nutrisphere for urea (NSN), Nutrisphere-Quick Dry (NSN-QD) and Agrotain Ultra (NBPT) (Goos, unpublished 2012).

Test inhibitor	Ni^{2+} stab. const. log K	Urea remaining mg	Percent inhibition %
None	--	1.07	--
Itaconic acid	1.8	1.17	2
Maleic acid	2.0	1.23	4
Malic acid	3.2	1.10	1
Oxalic acid	5.3	1.13	2
Citric acid	5.4	1.12	1
Salicylic acid	7.0	1.12	2
Imidodiacetic acid	8.1	1.14	2
NTA	11.5	1.11	1
EGTA	13.5	1.08	0
HEDTA	17.1	1.02	-1
EDTA	18.5	1.04	-1
DTPA	20.2	1.07	0
CDTA	20.2	1.04	-1
NSN	--	1.06	0
NSN-QD	--	1.04	-1
NBPT, 1 mg/kg	--	3.52	62
NBPT, 5 mg/kg	--	3.88	72

Except as noted, all materials added at 50 mg/kg

Experiment 5 was designed to test the activity of Nutrisphere and NBPT (Agrotain Ultra) on urea with a urease solution. 5 mL of THAM (tris(hydroxymethy)aminomethane), an organic buffer (0.2M, pH7), 5 mL jackbean urease solution, and 5 ml test inhibitor (4 mg/L NBPT as AU, 40 mg/L maleic/itaconic acid as NSN or NSN-QD were combined and shaken for 1 hour at room temperature; 5 mL of urea substrate (200mg/L) was added. The urea remaining from each treatment was measured after 5, 30, 60, 90 and 120 minutes of shaking (Fig. 7). Agrotain Ultra resulted in nearly all of the urea recovered. NSN and NSN-QD appeared to recover even less urea than the control, suggesting that urease activity might have been enhanced by their activity.

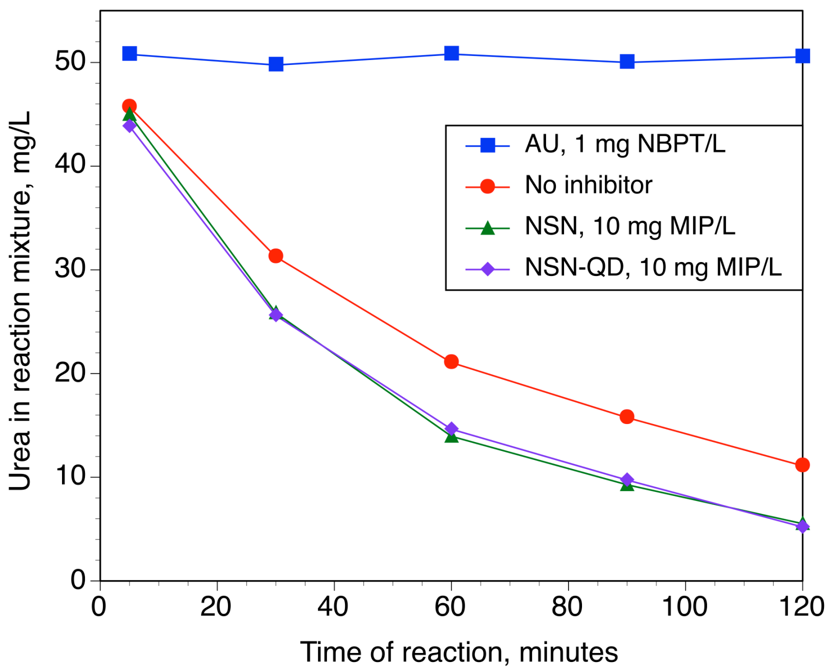

Figure 7. Amount of urea remaining in a jackbean urease solution with Agrotain Ultra (NBPT), Nutrisphere for urea (NSN) or Nutrisphere Quick Dry (NSN-QD) after reaction at 5, 30, 60, 90 and 120 minutes (Goos, unpublished data, 2012).

Experiment 6 tested the effect of NBPT (Agrotain Ultra) and maleic/itaconic acid (Nutrisphere for urea and Nutrisphere Quick Dry) concentration on urease activity. Five millilieters THAM buffer, 5 mL jackbean urease solution and 5 mL test inhibitor were mixed (0-04 to 4 mg/L NBPT as Agrotain Ultra; 0.04 to 400 mg/L maleic/itaconic acid (NSN or NSN-QD) and shaken for 1 hour; 5 mL urea substrate (200 mg/L) was added and shaken for 120 minutes. Urea remaining was analyzed.

The AU treatments exceeded the control in urea remaining at all concentrations of NBPT (Fig.8). The 1 mg/L treatment contained nearly all of the original urea. The NSN and NSN-QD treatments recovered no more urea than the control. The 10 mg/L and 100 mg/L treatments appeared to decrease the urea remaining compared to the control.

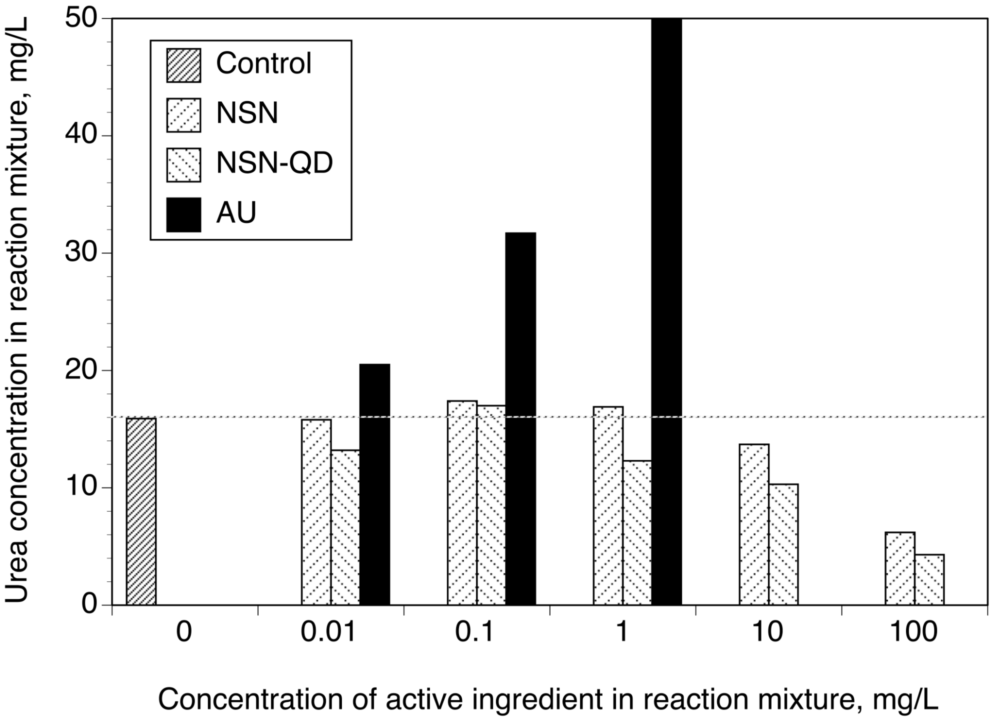

Figure 8. Urea remaining (50 mg/L original) treated with 0.01, 0.1 and 1 mg/L NBPT (Agrotain Ultra-AU), and 0.01, 0.1, 1, 10 and 100 mg/L maleic/itaconic acid as Nutrisphere for urea (NSN) and Nutrisphere Quick Dry (NSN-QD) after reaction with jackbean urease for 2 hours.

It is clear from the laboratory experiments that there is no urease inhibition by Nutrisphere when used at label rates or even greatly increased rates. In the field, it is uncommon to consistently find yield or quality responses to the use of Nutrisphere at labeled rate. In North Dakota studies on spring wheat at 8 locations, there were no yield increases or grain N uptake increases with Nutrisphere compared to urea (Franzen et al., 2011). Two additional North Dakota studies in corn with no yield advantage to Nutrisphere (NDSU Carrington Research and Extension Center, unpublished data). In Kansas (Tucker and Mengel, 2008), there were no increases due to Nutrisphere with UAN over UAN surface banded or injected in grain sorghum in 2007. In 2 years of corn in Kansas, there were no yield increases from the use of Nutrisphere-N UAN compared to surface applied UAN at three total sites (Weber and Mengel, 2009). In 2009, there was no response to Nutrisphere + UAN broadcast on grain sorghum compared to broadcast UAN alone in Kansas at three locations (Weber and Mengel, 2010). There was one sorghum yield increase with surface banded Nutrisphere + UAN compared to UAN surface banded alone and two non-responsive sites. The yield increase with surface band but not broadcast suggests that perhaps the acidity of the Nutrisphere may have delayed nitrification at this site (Schmidt, 1982).

At Waseca, MN in 2009(Randall and Vetsch, 2009) corn yield and stover N between urea and urea with Nutrisphere were similar. In Illinois, at two locations in 2008 Nutrisphere-urea was lower in yield than urea, and similar in yield at the two locations with UAN and Nutrisphere-UAN (Ebelhar and Hart, 2009). At Dixon Springs in 2009, Nutrisphere urea, UAN, and ammonium sulfate treatments did not result in higher corn yield than the N sources with Nutrisphere-N (Ebelhar and Hart, 2010), although main effects for Nutrisphere-N on corn yield were significant. In Arkansas and Mississippi, Nutrisphere-N had no effect on rice yields in three field studies compared with urea (Franzen et al., 2011). In South Dakota, Nutrisphere-N did not result in higher corn yield in 2007 (Bly and Woodard, 2007), 2008 (Bly et al., 2008), or 2009 at 2 sites (Bly et al., 2009).

In Idaho, there were no spring wheat yield increases with Nutrisphere over 2 years (Jeffrey Stark, personal communication, 8/23/2010). In barley, however, there were yield increases in 2008 and 2009 with Nutrisphere, but no increase in grain protein over similar rates of urea. Plant N uptake with Nutrisphere was similar to urea without Nutrisphere, suggesting that the yield increase in barley came from some other response other than enhanced N nutrition (Stark, 2008. 2009).

In Kentucky, Nutrisphere-N urea performed similarly for corn grain yield as the urea check, while urea with Agrotain, SuperU or ESN poly-coated urea had higher corn yield than the check and yields were similar to those achieved with ammonium nitrate.

Laboratory studies with Nutrisphere-N show no effect on nitrification or urease activity. Therefore, it is not surprising that the great majority of studies with Nutrisphere show no yield effects. What is surprising is that there are studies that show yield effects, but not from increased N nutrition. The results from Gordon (2008) suggest that under some conditions, Nutrisphere may have some effect on plant growth and development and even N nutrition not related directly to urease inhibition or nitrification. However, the company probably needs to reexamine its label as a urease inhibitor.

Summary

Certain nitrogen additives provide growers with options for extended activity of nitrogen Availability to their crops. Their economics depends on rainfall following application, application methods, timing and soil characteristics, especially soil texture. NBPT (Agrotain) is an effective urease inhibitor. Thiosulfates have shown some urease inhibition characteristics, but again, the body of literature that supports their use is small.

Nutrisphere has been shown to be ineffective as a urease inhibitor. The data that support the use of Nutrisphere is small in comparison to the data that does not support its use. If one accepts that the laboratory studies, conducted in a similar manner to those used to evaluate products like Agrotain, show that Nutrisphere is not a nitrification or a urease inhibitor, than there must be other explanations for small number the field studies that show a yield benefit to the use of the product and in some circumstances even show an accumulation of N. Stay-N and NStay have failed to support their claims or urease inhibition in careful laboratory experiments.

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CONTROLLED-RELEASE FERTILIZERS AND NO-TILL CORN

Matt Ruark, Joe Lauer, Thierno Diallo, and Mike Bertram 1/

Introduction

Maintaining high corn yields on highly productive lands is essential for the sustainability of agricultural production in Wisconsin. Sustainability also relies on soil conservation practices and reduced energy inputs. Many growers have adopted no-till management practices to reduce energy costs, reduce soil erosion, and conserve soil organic carbon. However, no-till as a management practice remains an under-utilized conservation practice for corn-based production systems in Wisconsin. In Wisconsin, approximately 500,000 acres of corn is grown under no-till (Frazee et al., 2005), which ranks tenth among all states. More growers are likely to adopt no-till management practices if potential negative production implications can be overcome. Studies conducted on rain-fed, Corn Belt soils have mixed results with studies showing positive yield effects of no-till (Olson and Ebelhar, 2009; Grandy et al., 2006; Hussain et al., 1999) and negative yield effects of no-till (Bakhsh and Kanwar, 2007; West et al., 1996). For Wisconsin soils, suppressed yields have been shown to be a result of lower soil temperatures (Andraski and Bundy, 2008). In an effort to combat this yield decrease, Andraski and Bundy (2008) further suggest that an additional 30 lb/ac of nitrogen (N) may be required to maintain corn yields when managed with no-till. Increasing the N fertilizer rate adds an additional expense to the operation and does not guarantee that this N will be used efficiently by the crop. Further adoption of no-till as a tillage practice is unlikely unless these yield and economic gaps can be overcome. There are currently several fertilizer technologies, such as polymer-coated urea (PCU) and urease and nitrification inhibitors (U! and NI) which may be viable alternatives to conventional N fertilizer for improving yields in no-till corn and would alleviate the need for supplemental N in these systems. The objectives of this study were to evaluate the effect of different N fertilizer products on corn yield in long-term tillage and crop rotation trials. The N products evaluated are a PCU, urea with UI, and a product with both a UI and NI. The PCU evaluated was ESN® (Agrium, Inc.), the UI evaluated was Agrotain® (Agrotain, Ltd.) added to urea, and the UI+NI product was SuperU® (Agrotain, Ltd) which has the UI and NI chemicals impregnated into the urea granule.

Experimental Design

Two separate studies were conducted. The first was conducted at the Arlington Agricultural Research Station (AARS) from 2009 to 2012 within the Long-Term Corn-Soybean Rotation Trial. This trial was established in 1983 and includes each phase of a continuous corn rotation and corn–

1/ Assistant Professor and Extension Soils Specialist, Dept. of Soil Science; Professor, Dept. of Agronomy; Superintendent, Arlington Agricultural Research Station; Research Specialist, respectively, Univ. of Wisconsin.

soybean rotation managed with either conventional tillage practices or no tillage. Within each corn phase of each rotation, three split plots were established to evaluate three different N sources. In 2009 the sources were 190 lb/ac of ammonium nitrate (AN), PCU, and UI+NI and in 2010, 2011, and 2012 the sources were 175 lb/ac of AN, PCU, and UI+NI. The second study was conducted in 2011 and 2012 at both the AARS and the Marshfield Agricultural Research Station (MARS) within Long-Term Alfalfa-Corn Rotation Trial. However, only 2011 yields were available at this time. This trial was established in 2010 and includes each phase of a continuous corn rotation and a 2-yr alfalfa-2-yr corn rotation. In 2011, the study was conducted in the first year of corn following one-year of alfalfa (since the study was only established in 2010, the full rotation had not yet occurred). In 2011, eight split plots were established and included: (i) no fertilizer, (ii) low rate of PCU, (iii) low rate of AN, (iv-viii) high rate of AN, Urea, ESN, UI, and UI+NI. At AARS, the low and high rate for continuous corn was 130 and 165 lb/ac of N, respectively and for corn following alfalfa was 85 and 125 lb/ac of N, respectively. At MARS, the low and high rate for continuous corn was 90 and 125 lb/ac of N, respectively and for corn following alfalfa was 45 and 85 lb/ac of N, respectively.

Results and Discussion

Corn-Soybean Rotation

Table 1. Corn yields at the AARS long-term corn-soybean rotation trial with different sources of nitrogen fertilizer (AN=ammonium nitrate, PCU = polymer coated urea, and UI+NI=urease inhibitor and nitrification inhibitor). In 2009 the nitrogen rate was 190 lb/ac and in 2010-2012 the rate was 175 lb/ac. Significant (α=0.10) differences were only reported within the same tillage and crop rotation treatment; means followed by different letters indicate significant differences.

			Corn Yield				
Tillage	Prev. Crop	N Source	2009	2010	2011	2012	Average
			bu/ac				
Chisel	Corn	AN	224	260	193	172	212
		PCU	212	261	186	157	204
		Urea+UI+NI	213	249	188	161	203
	Soybean	AN	246	268	*210 b*	201	231
		PCU	240	272	*223 a*	196	233
		Urea+UI+NI	249	268	*201 b*	206	231
No-Till	Corn	AN	207	*224 ab*	183	160	194
		PCU	207	*236 a*	186	167	199
		UI+NI	207	*216 b*	177	161	190
	Soybean	AN	248	264	*223 a*	203	235
		PCU	241	253	*218 ab*	182	224
		UI+NI	239	255	*208 b*	201	226

Alternative N sources (PCU and UI+NI) did not consistently outperform ammonium nitrate. When advantages were apparent in a single year (e.g., PCU in corn following soybean with chisel plow in 2011), they did not translate to consistent benefits over the long-term. To put things in perspective if N costs $0.20 extra per pound and an optimal N rate is 160 lb/ac of N, the extra cost is $32.00 per acre. This would only require a 4.5 bu/ac gain in yield (at $7 corn). These modest yield gains are difficult to ascertain statistically. When looking at 3-year average yields, there does not appear to be a clear recommendation that can be made for using certain N products in specific cropping systems. An underlying issue in this study is that the N rates used may have not been the most economically optimum N rates. The N rates applied here are above or within the high range of the recommended N application based on a nitrogen:corn price ratio of 0.10. Based on these results, there is not a consistent benefit of alternative N products on loamy, high yield potential soils when they are applied at maximum N rates. Future research will focus on evaluating these products at lower rates on high-yield potential soils.

Corn-Alfalfa Rotations

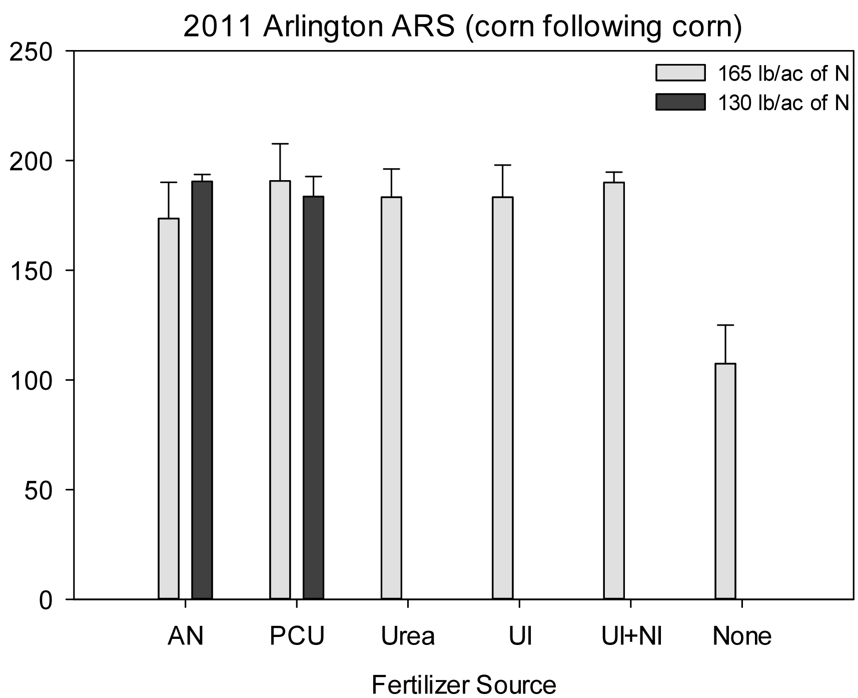

Figure 1. Corn yields in no-till corn following corn at Arlington ARS in 2011. Error bars are standard error.

Results in 2011 did not show conclusive benefits of any alternative fertilizer products compared to ammonium nitrate or urea. However, it is interesting to note that yields were slightly greater when corn followed alfalfa compared to corn at Arlington, and yields were much greater for corn following alfalfa compared to following corn at Marshfield. Also, with one-years growth of alfalfa was enough to supply enough N to produce optimum yields (Fig. 2), where treatments without N fertilizer in corn following corn resulted in reduced yields (Fig. 1) (i.e., the no N treatment produced similar yields to with N treatments). At MARS, a lower yielding site compared to AARS, there was no significant effect of any fertilizer treatment and treatment yields produced much greater variation (i.e., larger standard errors) compared to the AARS site.

Conclusions

While additional years of trials must be conducted to evaluate these products over a range of growing conditions, it is clear that there was not a benefit when weather conditions do not favor N loss (as in 2011) and when applied at optimum rates on high producing soils. These products are likely to have the biggest benefits on sandy soils and on tile-drained soils, especially in years with above average rainfall.

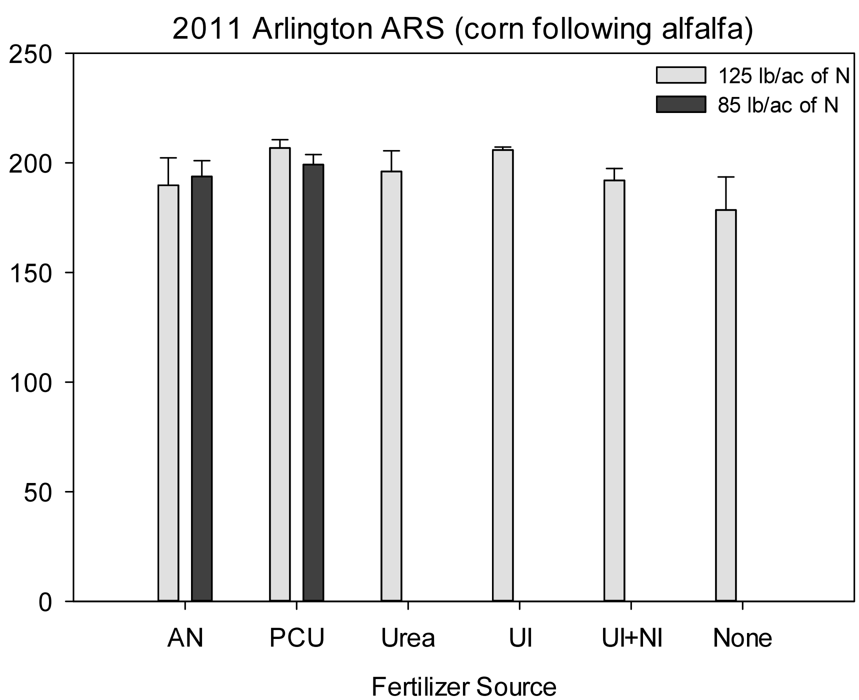

Figure 2. Corn yields in no-till corn following one-year of alfalfa at Arlington ARS in 2011. Error bars are standard error.

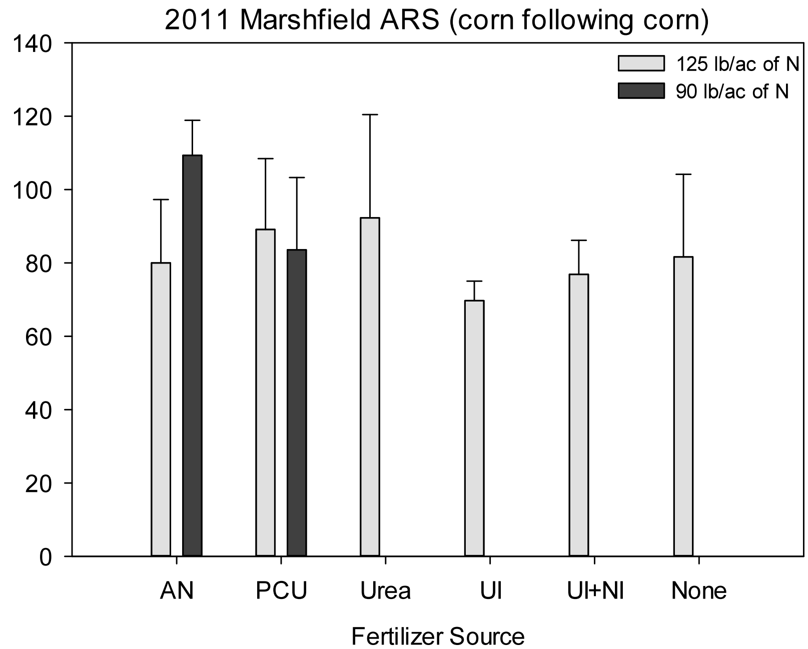

Figure 3. Corn yields in no-till corn following corn at Marshfield ARS in 2011. Error bars are standard error.

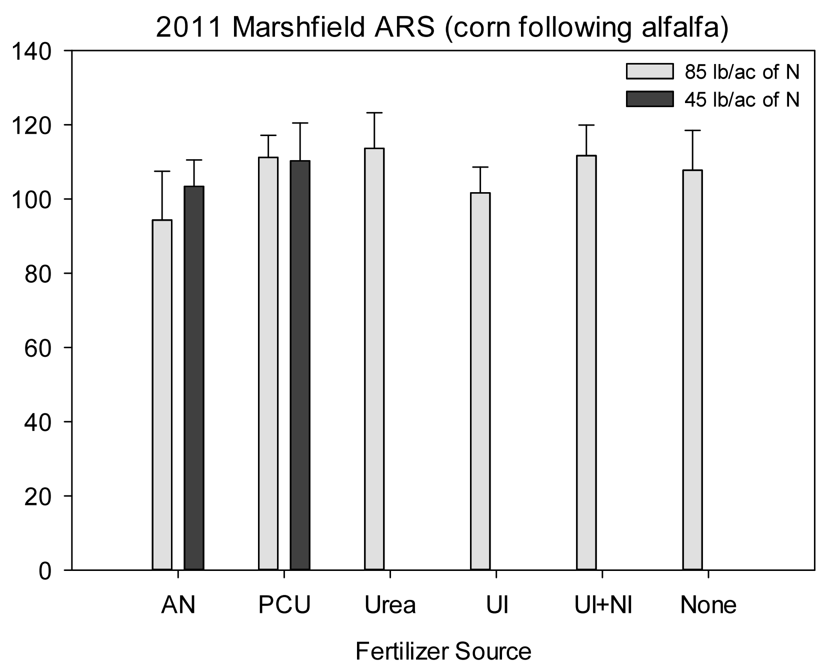

Figure 4. Corn yields in no-till corn following one-year of alfalfa at Marshfield ARS in 2011. Error bars represent standard error.

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DISCOVERY FARMS: 12 YEARS OF LESSONS LEARNED

Kevan Klingberg [1/]

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[1/] Outreach Specialist, Discovery Farms, PO Box 429, 40195 Winsand Dr., Pigeon Falls, WI 54760.

ARE NEMATODES REALLY A PROBLEM IN CORN?

Ann E. MacGuidwin[1/]

Introduction

Four out of every five animals on earth is a nematode, so it is not surprising that corn and soybean fields are teeming with many members of this diverse group of invertebrates. In 2012 the Wisconsin Soybean Marketing Board expanded the long-running soybean cyst nematode (SCN) testing program to include the "complete nematode test" so producers can monitor total nematode pressure in four fields every year at no charge. This sampling program was used to estimate the current distribution and damage potential for nematode pests of corn in Wisconsin. As of November 30, 2012 the program received 315 samples for analysis. Thirty-five samples arrived before July 1st so the results could be used to explain crop performance in 2012. Samples that arrived after July 1, 2012 were useful for predicting nematode pressure for the 2013 crop.

Methods

Soil samples submitted for SCN testing were assayed for all nematodes by extracting nematodes from soil using sieving and sucrose centrifugation methods and from root fragments in the soil using a 48-hour incubation. *Pratylenchus* (root lesion), *Hoplolaimus* (lance), *Paratylenchus* (pin), *Helicotylenchus* (spiral), *Tylenchorhynchus* (stunt), *Paratrichodorus* (stubby-root), *Mesocriconema* (ring), *Xiphinema* (dagger) and *Longidorus* (needle) were counted. A nematode risk index for corn was computed for each sample received before July by assigning a low- (10 points), moderate- (25 points), or high- (50 points) risk value for each genus, based on the number present in the sample, and summing the accrued points to one index score. The assay was sensitive for detecting SCN so the presence of absence of this nematode pest was noted and quantified in a separate assay.

Results and Discussion

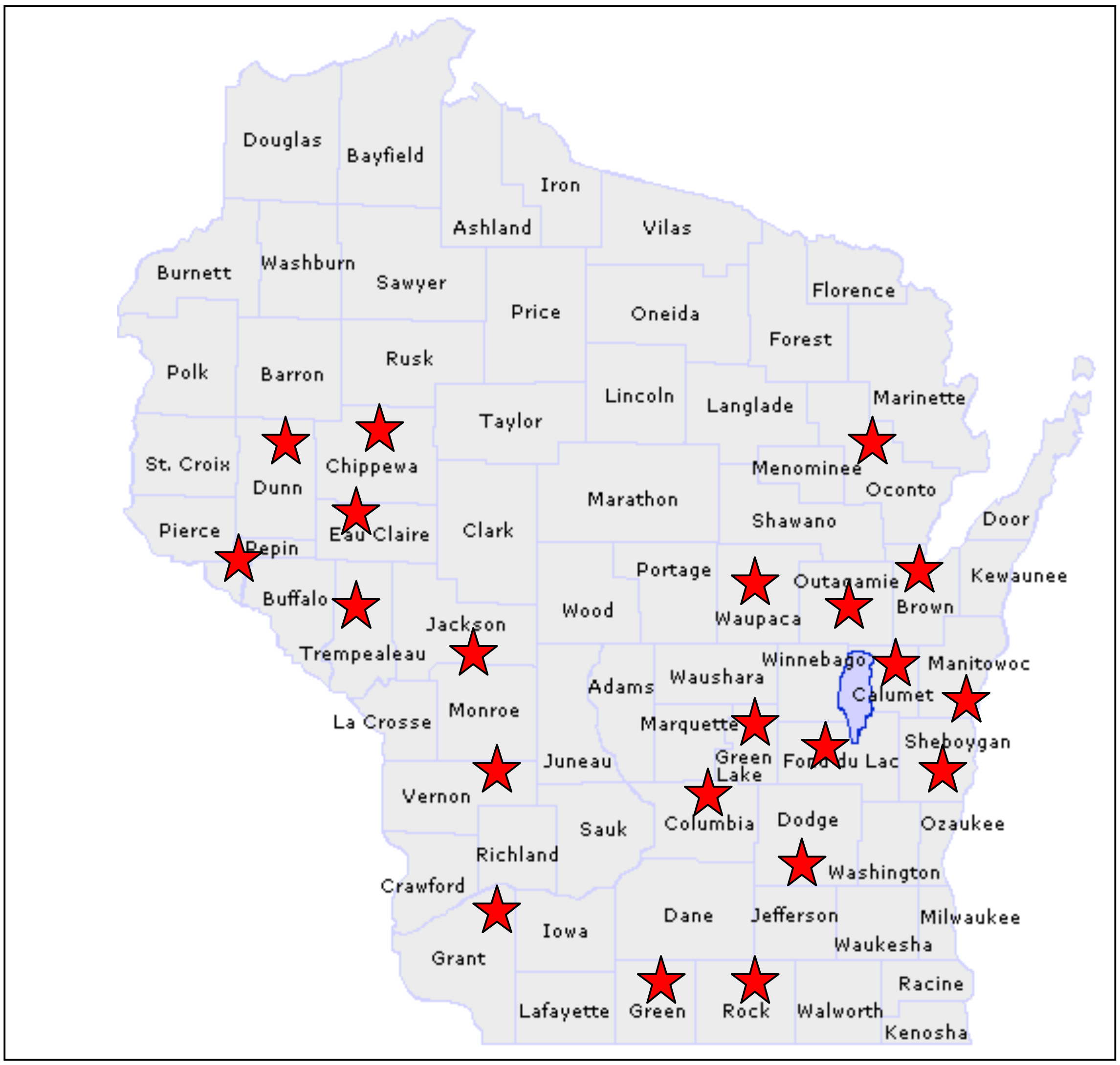
The average score for the total nematode risk index for spring samples was 40, indicating a moderate risk of nematode damage for the fields sampled prior to July 1st. All of the samples collected in the spring contained root lesion nematodes. The second and third most common nematode pests were spiral (80% of the samples) and lance (34%) nematodes. The most common nematode genera detected in the fall were root lesion (96% of the samples), spiral (70%), and dagger (29%). Needle and lance nematodes were not recovered from any samples collected in the fall and stunt, ring, and stubby root nematodes were rare in fall samples so the total nematode risk index was only used for samples collected before July 1st.

The focus for our analysis turned to root lesion nematodes because they were so common. Based on the 315 samples submitted, 96% were positive for root lesion. Damage threshold values for

[1/] Professor, Plant Pathology Dept., 1630 Linden Dr., Univ. of Wisconsin-Madison, Madison, WI, 53706.

root lesion were set at 200 and 400 per 100 cc soil for spring and fall samples, respectively. The spring threshold was based on a consensus of regional nematologists and the fall threshold was doubled to accommodate a 50% rate of winter kill, the most extreme rate of overwinter mortality that occurred during a 4-year study of corn (MacGuidwin and Forge, 1991). Based on these thresholds, 20% of the samples representing 41 producers were above the damage threshold for root lesion nematodes. The fields at risk for root lesion damage were distributed throughout Wisconsin in 21 counties (Figure 1).

Figure 1. Counties represented by samples testing above threshold for root lesion nematodes (*Pratylenchus spp*.) in 2012. Threshold = 200 nematodes per 100 cc soil for samples collected up to June 30th and 400 nematodes per 100 cc soil for samples collected after September 1.



Submitters included information about the sample collection site so it was possible to characterize the fields with above-threshold population densities of root lesion nematodes. Almost all fields were on a corn / soybean rotation with the majority of the fields in the soybean phase when samples were collected, as might be expected for a SCN soil testing program (Table 1). Loam or silt loam was the most common soil texture class for the at-risk fields, contrary to the common perception that nematodes only build to damaging levels in sandy soils.

Table 1. Percentage of samples above threshold for root lesion nematodes classified by crop planted in 2012 and soil texture.

Previous Crop	% of Samples
soybean	57
corn	35
other or unknown	8

Soil Texture	% of Samples
sand or sandy loam	22
silt loam or loam	41
clay or clay loam	11
not designated	26

The data show that root lesion nematodes are common in fields with a soybean – corn rotation in Wisconsin and that one fifth of the fields sampled in 2012 are infested with population densities that exceed damage thresholds for corn. Many issues are yet to be resolved such as the influence of soil texture on nematode damage, the impact of tillage and other factors on the buildup of nematode populations, and variation among root lesion nematode species for causing yield loss. We did not identify nematodes to species, but we did note that about 30% of the samples characterized "at risk" for nematode damage contained males, a diagnostic indicator for the species of most concern in soybean rotations – *P. alleni* and *P. penetrans*.

Damage thresholds of root lesion and other nematodes for corn have been generalized from a few studies and need more verification at the field scale. New seed treatments to manage nematodes may provide a return on investment at root lesion population densities lower than our current thresholds. Nematicidal seed treatments improved yield in a root lesion-infested corn field at the Hancock Research Station in 20112 (MacGuidwin and Conley, unpublished data) and appear to be a promising new technology for nematode management.

Soybean is an excellent host for the nematodes that damage corn, but the effect of nematode pests other than SCN is often overlooked. The Wisconsin Soybean Marketing Board is currently funding research on the damage potential of root lesion nematodes on soybean and our results to date show *P. penetrans* can be more damaging to soybeans than corn in sandy soils. Given the potential to damage both corn and soybean, the widespread distribution of the pest in Wisconsin, and the number of fields that currently support high population densities, every producer and crop consultant should be familiar with root lesion nematodes.

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CAN MANAGEMENT IMPACT AFLATOXIN IN CORN?

Alison E. Robertson[1]

Introduction

Aspergillus ear rot is caused by the fungus *Aspergillus flavus* and is recognized as an olive-green powdery mold that usually occurs at the ear tip or in association with damaged kernels. The fungus infects corn ears soon after pollination when the silks are yellow-brown but still moist. Infection and colonization of kernels are favored by hot (>86F), dry conditions during grain fill.

The fungus, *A. flavus*, may also produce a potent mycotoxin called aflatoxin. Hot, dry conditions with warm (>70F) nights and low kernel moisture (<35%) favor the production of aflatoxin. Not all strains of *A. flavus* produce aflatoxin. Grain contaminated with aflatoxin can cause feeding and reproductive disorders in swine, cattle and poultry, and has been associated with esophageal cancer in humans. For these reasons, the FDA has established an "action level" of 20 ppb for aflatoxins in corn for interstate commerce.

Aflatoxin does not occur uniformly throughout a load of grain, thus sampling grain to test for aflatoxin can be very difficult. It is recommended that a composite sample of at least 10 lb of corn be collected from a load of grain. Two methods may be used to test for aflatoxin contamination. The black light test tests for the presence of the fungus in the grain (<u>not</u> aflatoxin) by detecting "glowers", which are kernels that glow greenish-gold, within the sample. If there are greater than eight "glowers" in a 5-lb sample, the sample should go for further testing. There are several commercial test kits available that can quantify the level of aflatoxin in a grain sample.

Aflatoxin in Iowa in 2012

The 2012 growing season in Iowa was hot and dry and thus favorable for development of Aspergillus ear rot and aflatoxin contamination. Concerns about aflatoxin were high. The FDA approved a temporary blending policy for aflatoxin in Iowa so that corn containing more than 20ppb of aflatoxin could be blended with corn containing less than 20 ppb for use in appropriate animal feed when a compliance agreement was filed with the Iowa Department of Agriculture and Land Stewardship (IDALS) before the grain was used (Hurburgh and Robertson, 2012).

To monitor Aspergillus ear rot development in Iowa, the disease was assessed in seven corn fungicide trials that were done in various parts of the state. Percent ear rot was recorded on five ears per plot within 48 hours prior to harvest. Grain samples were collected and harvested and transported to the Grain Quality Initiative Laboratory on central campus. Grain characteristics and the number of "glowers" in each sample were measured. The concentration of aflatoxin in grain samples is currently being determined.

Aspergillus ear rot was amongst the ear rot found in three of the seven fungicide trials; at Armstrong (two trials), and Ames (one trial) (Table 1). Mean ear rot severity was very low and

[1] Associate Professor, Department of Plant Pathology and Microbiology, 351 Bessey Hall, Iowa State University, Ames, IA 50010

ranged from 0 to 1.55 percent at Armstrong, and was less than 1.0 percent at Ames and Nashua. The number of "glowers" in the trials at Armstrong ranged from 0 to 4.7 (mean 1.1) per lb of grain and were found in 50 percent of plots, and 0 to 6.1 (mean 2.3) per lb and occurred in 30 percent of plots. At Nashua and Ames, there were far fewer "glowers". In Ames, 10 of 80 plots had 0 to 3.1 (mean 0.1) per lb "glowers". The aflatoxin content in these grain samples is currently being tested. There was no evidence of a fungicide effect on ear rot severity.

Table 1. Mean percent ear rot severity and mean number of "glowers" in grain samples collected from fungicide trials at 7 locations in Iowa in 2012.

Location	Mean ear rot severity (range) (%)	Mean number of "glowers" /lb (range)
Ames	<0.1 (0 to 2.0)	0.1 (0 to 3.1)
Armstrong 1	0.2 (0 to 1.2)	1.1 (0 to 4.7)
Armstrong 2	0.4 (0 to 2.0)	2.3 (0 to 6.1)
Crawfordsville	0.1 (0 to 2)	0
Kanawha	0.5 (0 to 11.0)	0
Nashua	<0.1 (0 to 3.0)	0
Sutherland	0.1 (0 to 0.8)	0

The mean aflatoxin level of Iowa corn in 1983 and 1988 was 20ppb, however, despite similar weather conditions; the incidence of aflatoxin in Iowa corn in 2012 was far less than expected – less than 20 percent of the crop with greater than 20ppm aflatoxin (Hurburgh and Robertson, 2012).

Managing Aflatoxin Contamination

To reduce aflatoxin contamination in corn, farmers must start by managing Aspergillus ear rot in the field. The following practices can be done to reduce development of ear rot and aflatoxin production:

- control insects that may damage ears or grow hybrids with insect resistant traits;
- manage crop stress, e.g., plant at recommended populations, fertilize adequately, manage weed competition
- scout for ear rot at black layer and target fields in which more than 10 percent of ears have signs of ear rot for an early harvest;
- adjust combine settings to minimalize damage to grain;
- ensure storage bins are clean, and cool (<40F); and
- dry grain to 14 percent moisture immediately after harvest to prevent further mold development in the bin.

Syngenta Crop Protection does have a product Afla-Guard® that is registered on corn to reduce aflatoxin contamination. The product contains a strain of the fungus that does not produce aflatoxin. The product is applied prior to tasseling/silking and the idea is that this atoxigenic strain of the fungus colonizes the ear and thus prevents endemic toxigenic strains from colonizing the ears. In field trials over several years at the University of Texas, an application of Afla-Guard® has usually (but not always) lowered levels of aflatoxin in corn compared with an untreated control (Isakeit et al., 2009; Isakeit et al., 2011). No such data are available for the Midwest.

It is possible to reduce aflatoxin levels in contaminated grain. Removal of fines using a rotary screen may reduce the level of aflatoxin since damaged and broken kernels usually have the highest levels of the toxin. Ammoniation by a trained professional may also reduce aflatoxin levels in the grain, but can only be done for on-farm livestock feeding use since the FDA does not allow ammoniated grain to be shipped for interstate commerce.

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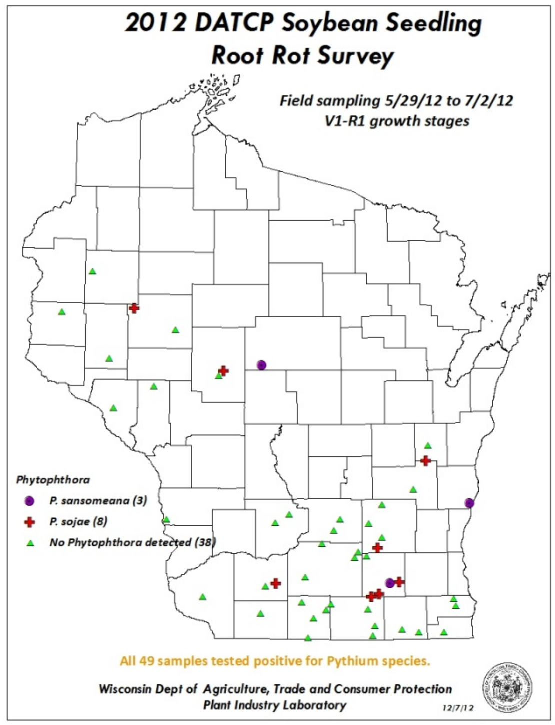
2012 DATCP WISCONSIN CROP DISEASE SURVEY

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

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

Phytophthora Root Rot of Seedling Soybeans

A new Phytophthora species was detected in Wisconsin soybean fields during the annual early season survey for soybean root rot diseases. Soybean roots from three fields in Jefferson, Marathon and Sheboygan counties tested positive for *Phytophthora sansomeana*, a species of Phytophthora previously unreported on soybean in Wisconsin. From May 29 to July 2, 49 randomly selected soybean fields in early vegetative stages were visited throughout Wisconsin. At each field, 20 soybean plants were carefully dug up and transported to DATCP's Plant Industry Laboratory for testing.



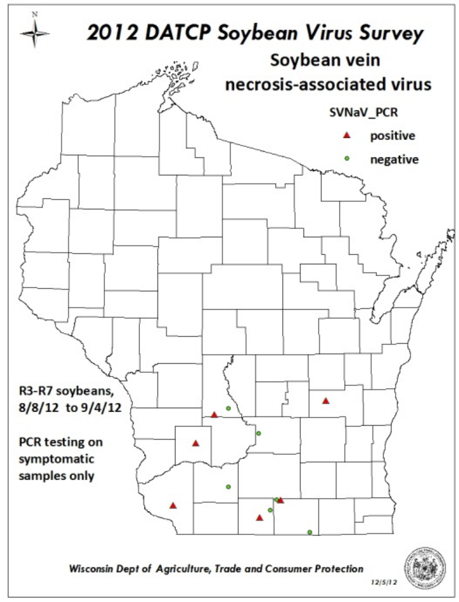
Seedling roots were tested for the presence of the Phytophthora and Pythium pathogens using DNA-based techniques. Out of 49 total samples, eight (16%) tested positive for *P. sojae*, the primary causal agent of soybean root rot in Wisconsin. Three of the 49 samples tested positive for *Phytophthora sansomeana*.

It remains to be seen what effect this new species has on soybean production in Wisconsin and if resistance to *P. sojae* will also be effective against *P. sansomeana*. The reported host range of the pathogen besides soybeans includes corn, white cockle and white clover and Douglas fir. Plant Industry Laboratory reported isolation of the organism from Fraser firs grown in Wisconsin for Christmas trees in 2011.

All samples also tested positive for a variety of Pythium species, and most of these species are known to cause damping-off in soybeans.
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.

1 DATCP Pest Survey, CAPS Program, 2811 Agriculture Dr., Madison WI 53718, adrian.barta@wi.gov
2 DATCP Plant Industry Laboratory, 4702 University Ave, Madison, WI 53702

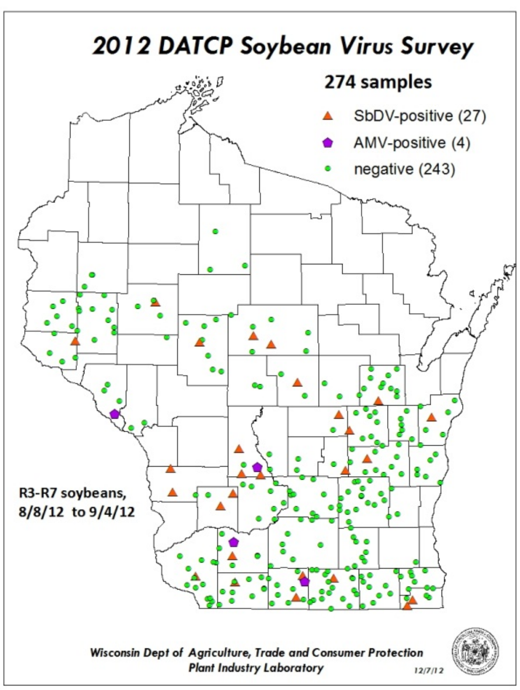
Soybean Virus Survey

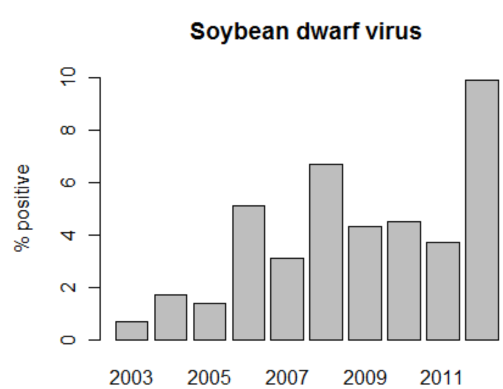


A new virus, the soybean vein necrosis-associated virus (SVNaV), was detected in Wisconsin soybean fields in summer of 2012. Soybean leaflets with unusual symptoms alerted UW researchers and DATCP Plant Pathologists to check for this virus, which that was first found in TN in 2008. The DATCP summer survey collected 274 soybean samples from soybean growing counties in the state (August 8 to September 6). A subset of six leaf samples that showed vein necrosis and chlorosis tested positive for SVNaV. SVNaV is a tospovirus, a group of viruses that are often transmitted by thrips. How SVNaV spreads in soybeans needs to be studied further. UW and DATCP are collaborating on this survey for SVNaV. See this UW article by Profs. D. Smith and K. Willis

http://fyi.uwex.edu/fieldcroppathology/files/2012/10/SVNaV.pdf

Plant Industry Laboratory continued a multi-year survey for virus diseases of soybeans using RT-PCR. Twenty-seven (9.9%) samples tested positive for soybean dwarf virus (SbDV). This is an increase from 2010 (7.7%) and 2011 (3.7%).

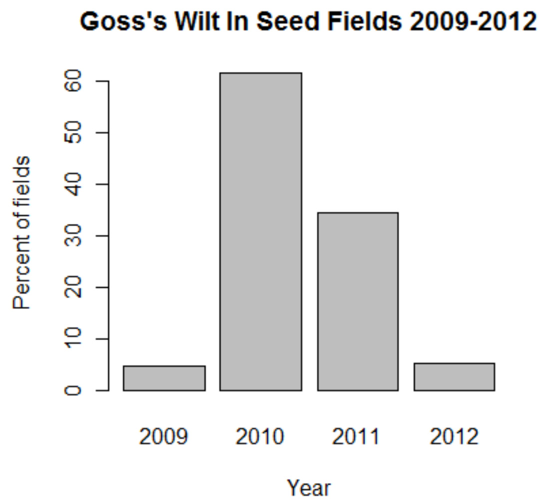




Detection of AMV was comparatively low in 2012, with only 4 samples testing positive. Statewide average soybean aphid counts were at the lowest level since the original detection in 1999.

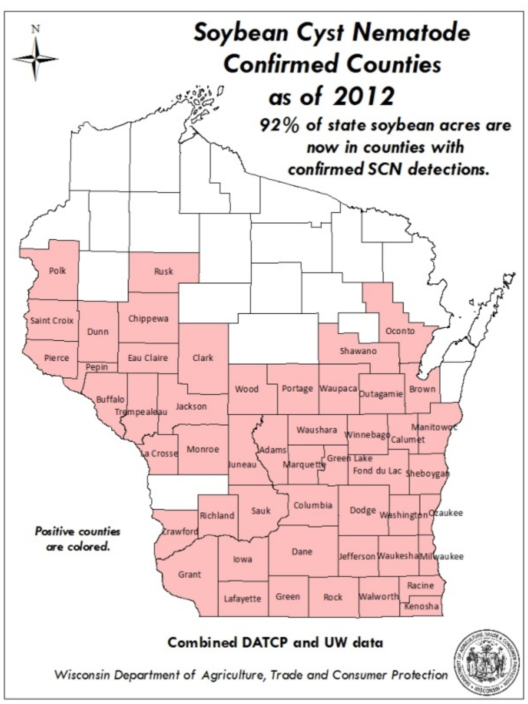
Seed Corn Survey

A total of 57 corn samples from seed plots in five counties (Columbia, Dane, Eau Claire, La Crosse, and Rock) were tested to meet export requirements. Stewart's wilt (caused by *Pantoea stewartii*) was not detected in any sample. Three of the 57 samples (5%) tested positive for Goss's wilt (*Clavibacter michiganensis* pv. *nebraskensis*). In 2012 Goss's wilt was found in Dane, Eau Claire, and La Crosse Counties. Wheat streak mosaic virus (WSMV), maize dwarf mosaic virus (MDMV) and high plains virus (HPV) were not detected in corn. WSMV and its vector the wheat leaf curl mite are not known to occur in Wisconsin.



Soybean Cyst Nematode Survey

No new counties were confirmed for soybean cyst nematode in 2012, leaving the number of Wisconsin counties where the nematode is known to occur at 50, comprising 92% of the soybean acreage in the state. Soybean growers in any part of the state are strongly urged to test fields for the presence of soybean cyst nematode. Information on testing is available at http://soybean.uwex.edu/documents/SoybeanCystNematodeSampling_2011b.pdf



GOSS'S WILT: A 2012 RECAP AND LOOKING AHEAD TO 2013[1]

Alison E. Robertson[2]

Introduction

Goss's wilt is a disease of corn caused by the Gram positive bacterium *Clavibacter michiganensis* subsp. *nebraskensis* (Cmn). The disease was first identified in Nebraska in Dawson County in 1969 (Clafin, 1999). Over the next decade, the disease was reported in 53 Nebraska counties and five of the six bordering states where it resulted in substantial (40 to 60 %) yield loss. Corn breeders successfully identified genetic resistance in field corn, and thereafter the disease occurred sporadically and rarely caused yield loss.

Within the past six years, Goss's wilt has re-emerged as a threat to corn production throughout the western Corn Belt. Since 2006, the disease has been confirmed in more than 60 Nebraska counties (Jackson et al, 2010). In Iowa, Goss's wilt was confirmed for the first time in 25 years in 8 counties in 2008, and by 2011 it had been confirmed in over 80 counties (Robertson, *unpublished data*). Yield losses of 50 percent or more due to Goss's wilt have already been documented during this more recent epidemic. Furthermore, fields with a high severity of Goss's wilt have a higher prevalence of stalk rot and consequently lodging and harvest complications.

Besides increasing in prevalence in NE and IA, Goss's wilt also is spreading east and north across the Corn Belt. The disease was reported for the first time in Indiana in 2008 (Ruhl et al., 2009), where it caused yield losses of up to 60 bushels/acre in the north-western part of the state (Wise et al, 2010), in Minnesota in 2009 (Malvick et al., 2010) and in Texas in 2010 (Korus et al., 2010). Sporadic outbreaks of the disease during the past three years have been reported in Illinois and Wisconsin.

The exact cause for resurgence of the disease is unknown, but is likely due to a combination of factors including continuous corn combined with conservation tillage practices that favor survival of the pathogen, widespread use of Goss's wilt susceptible hybrids and weather conditions during the growing season that favor infection and disease development (Jackson et al., 2007).

Symptoms

Goss's wilt symptoms may be easily mistaken for other diseases including northern leaf blight, Stewart's wilt and drought or heat stress. In Iowa, Goss's wilt usually appears soon after silking as leaf blight symptoms in the top canopy of the plant. Lesions are large, grey to reddish and start at the tips of the leaves and extend downwards, often along the edge of the leaf. Cigar-shaped lesions may also occur away from the edge of the leaf. Rather than a distinct delimitation between diseased and healthy tissue (like with northern leaf blight), the border of Goss's wilt lesions is usually indistinct and may be grey-green. Within this "border", the characteristic freckles associated with Goss's wilt are seen. The freckles are one of the characteristic symptoms

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[1] Funding acknowledgment: USDA-NIFA North Central Integrated Pest Management
[2] Associate Professor, Dept. of Plant Pathology and Microbiology, 351 Bessey Hall. Iowa State University, Ames, IA 50010.

that MUST be used to correctly diagnose this disease. The bacterium often oozes out of lesions and dries on the surface of the leaf as shiny exudates. This exudate is often more visible on the underside of the leaf. The pathogen can also infect the vascular system of the plant, and then wilting can occur. This symptom is more common on young plants. Discoloration of a few bundles in the vascular system may occur together with a wet, slimy stalk rot.

Disease Cycle

The primary source of inoculum for Goss's wilt is Cmn-infested corn residue. The bacterium can survive at least 10 months in surface residue. Dissemination of the bacterium from the residue to corn has not been studied but it is hypothesized the bacterium is splashed dispersed onto the leaves of young corn seedlings. Smidt and Vidaver (1986) isolated Cmn from the surfaces of apparently healthy corn plants in early June, and these epiphytic populations of the bacterium increased on the leaves throughout the growing season. Physical damage to the plant by hail, wind or sand is necessary for infection by the bacterium, and all plant parts can be infected. Unlike Stewart's wilt, insects are not known to be involved with spread of the disease or infection and disease development. The optimum temperature for disease development is approximately 80F. Another source of inoculum may be seed, since the bacterium is seedborne and can be seed transmitted at very low rates (0.1-0.4% in inoculated seed).

Ongoing Research

In 2011, Drs Tamra Jackson-Ziems and Greg Kruger at the University of Nebraska, and I received funding from USDA-NIFA to conduct various research projects on the epidemiology of Goss's wilt. The first objective was a survey of Goss's wilt throughout the Corn Belt. Corn leaf samples with and without symptoms of Goss's wilt were collected from 486 fields in eight states in 2011, and tested for the presence of Cmn. Data on the history of the field, hybrid, and agronomic practices were also collected and subjected to Classification and Regression Tree (CART; Breiman and Friedman, 1984) and Random Forest (Breiman, 2001) analyses to identify environmental and agronomic risk factors for Goss's wilt. The top five risk factors for Goss wilt disease development that were identified were: Goss's wilt hybrid rating, planting population, crop rotation, planting date and percent surface crop residue.

The second objective of this research project was to assess the genetic diversity of Cmn. Dr Jackson's lab is currently assessing the genetic diversity of the Cmn isolates collected from the survey and comparing it with the genetic diversity of isolates collected during the first epidemic during the 1970s to 1980s.

In Iowa, we have been studying the role of epiphytic Cmn in disease development in different agronomic environments. Preliminary work suggests that for disease to occur, a threshold population of Cmn needs to occur on the surface of the leaves. Furthermore populations of Cmn are greater on susceptible hybrids compared to tolerant hybrids, and when Cmn-infested surface residue is present versus no surface residue.

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UNDERSTANDING FUNGICIDES TO IMPROVE THEIR USE AND EFFICACY

Damon L. Smith [1/]

Introduction

Fungicides have become a major component of plant disease management plans for agronomic crops. Fungicides are applied to prevent or slow epidemics of disease caused by fungi. Unlike insecticides and herbicides, which are used to kill insects and weeds, fungicides are applied to form a barrier to protect plant organs from infection. Performance of fungicide products can be affected by many factors including timing of application, off-label rates, poor product choice for the pathogen of concern (e.g. active ingredient is not effective against the organism), fungicide resistance, etc.

Don't Forget The Plant Disease Triangle

One of the best ways to improve the efficacy of a fungicide is to use it in conjunction with other cultural practices. A great model to use when considering an integrated disease management approach is to consider the plant disease triangle. The plant disease triangle demonstrates that it takes a virulent pathogen, a susceptible host, and favorable environment occurring at the same time for the development of a plant disease. If any one of these components is missing a plant disease will not occur. Likewise, if a component of the triangle is manipulated in some way, the magnitude of a disease can be affected. For instance, the host component can be manipulated by using plants that have genetic resistance against the pathogen of interest. Also, managing plant stress and using hybrids/varieties that are well adapted to an area equates to plants that are less likely to be predisposed to a plant disease. Manipulating the environmental component of the triangle can be much more difficult. However, the environment immediately around a plant (microenvironment) can be changed, to a certain extent. For example, managing soil fertility can provide an environment favorable for plant growth and reduce plant disease. Changing plant population and spacing or reducing irrigation can change the microenvironment and can also reduce plant disease. The pathogen component can be manipulated in several different ways. Excluding a pathogen from an area is an excellent way to control plant diseases. Using certified pathogen-free seed and cleaning field implements between fields could prevent the introduction of a pathogen to a non-infested field. Eradication can also be applied to pathogens. This strategy can be very difficult because it can be nearly impossible to remove all infested plants and/or soil from an area to completely rid it of a pathogen. Sanitation can be widely utilized too, whereby pathogen infested plant material is removed or buried. As mentioned previously, fungicides are also used to manipulate the pathogen.

Fungicides, Fungicide Mode of Action, and Fungicide Mobility

The word 'fungicide' implies that a chemical will kill a fungus. This can be misleading as many of the products used to control fungi are actually only fungistatic (meaning they simply inhibit the growth or reproduction of a fungus and are not directly toxic to the organism).

[1/] Assistant Professor, Department of Plant Pathology, 1630 Linden Drive, University of Wisconsin-Madison, Madison, WI, 53706.

Fungicide mode of action defines how the product actually affects the fungal organism. For instance, the demethylation inhibitor (DMI) fungicide group (contains the triazoles) inhibits a specific enzyme in fungi that plays a role in sterol production. Sterols are necessary for the development of cell walls in fungi. Therefore, the application of DMIs results in abnormal fungal growth, repressed growth, and in some cases death. All fungicides within the DMI group have this same mode of action. One of the strategies to manage fungicide resistance development is to rotate fungicide mode-of-action. Considering the example of using DMI fungicides above in a proper rotation, the crop manager must choose a fungicide that is not in the DMI group for a subsequent application. This is analogous to a pitcher in baseball. Pitchers don't typically throw the same style of pitch each time. They rotate fastballs, with screwballs, with sliders, etc. This same approach should be adopted when developing a fungicide program. Care should also be taken during the development process to identify products with pre-mixed active ingredients in different mode-of-action groups. For instance if a pre-mix product is chosen that contains a Fungicide Resistance Action Committee (FRAC) 3 (DMI compound) and also a FRAC 11 (strobilurin compound) then the next fungicide application should ideally be a product that does not contain either a FRAC 3 or 11 compound.

Fungicide mobility is separate from fungicide mode of action. By understanding mobility and mode of action and how the two work in unison to control a fungus in a crop plant, the better the disease management decision-making process can be for plant management practitioners. Fungicides have one of two types of mobility: contact or penetrant. Regardless of the mobility, fungicide products work best when applied prior to symptom development and pathogen reproduction (spore production). Applying fungicides close to the onset of an epidemic will yield the best control of diseases caused by fungi.

Contact fungicides are applied to the surface of a plant and do not move into plant tissue. They can be washed from the plant and degrade by exposure to the weather. Therefore, contact fungicides must be reapplied regularly to re-establish protection on previously treated plant organs, or applied to protect new plant growth. Contact fungicides act by forming a protective barrier against fungal invasion. Therefore, they must be applied prior to fungal infection.

Penetrant fungicides can move into plants after being applied to the surface. Due to the movement of the fungicide into the plant, these fungicides are generally considered 'systemic' fungicides. This can be misleading as the degree of systemicity can vary among fungicides. *Local penetrant* fungicides move just short distances, such as into the waxy plant cuticle and remain in that location. *Translaminar penetrants* can move through the cuticle between cells toward the opposite side of the leaf. *Acropetal penetrants* are xylem-mobile (xylem elements are the water conducting vessels of plants) and move between cells along a water potential gradient. Acropetal penetrants only move upwards in plants. *Systemic penetrants* move through cells and follow sugar gradients in plants. Therefore, systemic penetrants can move upward and downward in plants. Very few fungicides are considered systemic penetrants. Regardless of the level of systemicity, penetrant fungicides have very limited 'curative' ability. Penetrant fungicides will only stop or slow infections within the first 24- to 72-hours after fungal penetration. Therefore, best control of fungal infections with penetrant fungicides will be achieved when these products are applied on a preventative schedule.

Fungicide Resistance in Fungi

Fungicide resistance results from genetic adjustment of the fungus, which leads to reduced sensitivity to a fungicide. Genetic mutations in fungi that result in fungicide resistance are thought to occur at low frequency and can be governed by a single gene or multiple genes. Mechanisms that lead to reduced sensitivity to a fungicide can vary, but include a change in the target site, active export of the fungicide out of the fungal cell, breakdown of the fungicide active ingredient, and reduced fungicide uptake. Fungicide resistance occurs when the frequency of resistant fungal strains in the population outnumbers the fungicide-sensitive individuals. This arises through repeated and exclusive use of fungicides with high-risk for fungicide resistance development. Selection pressure can be high when repeated fungicide applications are used to control many of the foliar diseases of field crops. Risk of fungicide resistance development is low for seed treatments and soilborne pathogens, which require just one or two applications per season for control.

Practices that Result in Fungicide Resistance

Application of fungicide at the wrong time (ex. after the fungus has begun sporulating) or with inadequate coverage can result in poor control of a pathogen and lead to reapplication thereby resulting in many fungal individuals being exposed to fungicide. Using inadequate rates can also lead to poor control necessitating the need to apply fungicides frequently, exposing many fungal individuals to fungicide. Excessive application of fungicide where a need is not justified can also lead to higher risk of fungicide resistance. Other practices that result in exposure of unnecessarily high populations of fungal individuals to many fungicide applications include using susceptible hybrids/varieties, inadequate or excessive fertilization, excessive and/or frequent irrigation, continuous cropping, and poor sanitation.

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WHAT'S GOING ON WITH THE FARM BILL AND DOES IT MATTER?

Paul Mitchell [1/]

{This page provided for note taking}

[1/] Associate Professor, Agricultural and Applied Economics, Univ. of Wisconsin-Madison, Madison, WI 53706.

CURRENT TRENDS IN FARMLAND VALUES: CAN THE CURRENT BOOM CONTINUE?

Bruce L. Jones [1/]

{This page provided for note taking}

[1/] Director, Renk Agribusiness Institute and Professor, Agricultural & Applied Economics, Univ. of Wisconsin-Madison, Madison, WI 53706.

UNDERSTANDING MANURE: DIFFERENCES IN MANURE TYPES AND NUTRIENT CHARACTERISTICS

John Peters[1]

Introduction

The nutrient credits from applied manure vary by animal species and the manure management system in place on the farm. Traditionally, the most common approaches have been liquid handling systems (minimal bedding) and solid manure systems, which is a more highly bedded management strategy. In more recent years, practices such as running the manure through a digester or composting process as well as liquid-solid separation have become more common. These actions can have a significant impact on total nutrient content and potential availability of the nutrients when field applied. The use of sand bedding has replaced wood products as a bedding source on many farms as well.

With any change in management there is the potential for a significant shift in the manure characteristics and nutrient content. The best way to track these changes is though a comprehensive manure sampling and testing program. In cases where this is not practical, book values exist to give an estimate of the typical nutrient content for a specific manure type. This can be an effective strategy but only if the manure on the farm is relatively normal or typical.

Manure analysis results summarized in this paper were provided by the following laboratories. The cooperation of these laboratories in providing their data for these tables is greatly appreciated.

AgSource Laboratory
Dairyland Laboratory
Rock River Laboratory
UW Soil and Forage Laboratory

Nitrogen

First-year nitrogen (N) availability varies with animal species and management system as well as whether or not the manure is incorporated and how much time has elapsed between application and incorporation (Table 1). This is because nitrogen in manure is in both inorganic (immediately available) and organic (not immediately available) forms. Nearly all the inorganic form is present as ammonium. Ammonium is easily volatilized to ammonia and lost if manure lays on the soil surface. Research now shows that after 1 hour, a large portion of the ammonium is assumed to have volatilized unless significant rainfall has occurred. This volatilization loss may continue at a lower rate for several more days unless the manure is incorporated. For this reason, the N credits for surface-applied, unincorporated manure are less than when manure is incorporated or injected. Also, manure with higher dry matter content typically has a lower percentage of the readily available ammonium N than lower dry matter (liquid) manures. For this reason higher dry matter (solid manure) will have a lower first year available N credit than liquid manure from the same animal species.

[1] Director, UW Soil Testing Laboratories and Extension Soil Scientist, Dept. of Soil Science, Madison, WI.

Phosphorus and Potassium

Phosphorus (P) in manure is present in both inorganic and organic forms. For most animal species, the inorganic P forms are dominant. Wisconsin research has demonstrated that first-year availability of manure P is equivalent to the availability of commercial fertilizer applied at the same rate of total P_2O_5. Potassium (K) in manures is largely in the inorganic form and is readily available to plants. Because there is some inherent variability in spreading manure evenly across the field and also variability with the nutrient content of each load of manure, the first-year availability of P and K is assumed to be 80% of the total. No second- or third-year credit is given for manure P or K (Table 1). Any manure P or K applied, but not credited in the first year, is best accounted for by subsequent soil testing.

Table 1. Estimated nutrient availability for various manures.

	N					
	Time to incorporation					
Species	> 72 hours or not incorporated	1 to 72 hours	< 1 hour or injected	P_2O_5	K_2O	S
First-year availability	**% of total**					
Beef: liquid (≤ 11.0% DM)[a]	30	40	50	80	80	55
Beef: solid (> 11.0% DM)	25	30	35	80	80	55
Dairy: liquid (≤ 11.0% DM)[a]	30	40	50	80	80	55
Dairy: solid (> 11.0% DM)	25	30	35	80	80	55
Goat	25	30	35	80	80	55
Horse	25	30	35	80	80	55
Poultry[b]	50	55	60	80	80	55
Sheep	25	30	35	80	80	55
Swine	40	50	65	80	80	55
Veal calf	30	40	50	80	80	55
Second-year availability						
All species	10	10	10	0	0	10
Third-year availability						
All species	5	5	5	0	0	5

[a] If dry matter (DM) is < 2.0% and NH_4-N is > 75% of total N, the following equation for first-year N availability may be used in an effort to better account for the high concentration of NH_4-N found in these manures: first-year available N = NH_4-N + [0.25 x (Total N – NH_4-N)], assuming manure is injected or incorporated in < 1 hour.
[b] Poultry includes chicken, duck, and turkey.

Second- and Third-year Credits

Manure nutrients are available to crops the second and third years after application. For all nutrients other than P and K, second- and third-year availabilities are estimated at 10% and 5%, respectively, of the total amount applied in the first year. The sum of the first-, second-, and third-year availabilities for a nutrient does not equal 100%. This is because some losses will occur, particularly with N, and because manure applications are not always uniform in rate and composition across a field. These estimates of nutrient availability are agronomically conservative to ensure that adequate nutrients are available for the crop.

Laboratory vs. Book Value

To calculate the nutrient credits from manure, it is necessary to know the application rate and total nutrient content of the manure. Total nutrient content can be measured on a manure sample sent to most soil testing laboratories. Where specific nutrient analysis for a manure is unknown, typical nutrient contents (also called book values) based on animal species and management can be used. In Table 2, the typical total nutrient content of samples analyzed by Wisconsin based laboratories between 1998 and 2012 are summarized. These values probably give an acceptable estimate for the "typical" producers, especially if sampling methods do not represent the pit, pack or gutter adequately. However, an analysis of a well-sampled system may give a better estimate of nutrient value for individual farms especially if herd and manure management is not "typical". Because manure nutrient content can vary greatly from farm to farm, and book values represent an average nutrient content, it is preferable to occasionally have all manure types on a farm analyzed.

Table 2. Typical total nutrient content of manures tested in Wisconsin (1998–2012).

	DM[a]	N	P_2O_5	K_2O	S
Solid manure	lb/ton				
Beef	29	13	8	12	1.9
Dairy: semi-solid (11.1–20.0% DM)	15	8	4	6	0.8
Dairy: solid (> 20.0% DM)	33	9	4	7	1.2
Goat	43	13	7	10	2.0
Horse	33	10	6	8	1.3
Poultry: chicken	57	49	44	33	3.0
Poultry: duck	36	12	10	9	1.8
Poultry: turkey	59	51	44	31	3.8
Sheep	34	19	9	24	2.2
Swine	19	18	13	10	2.0
Liquid manure	lb/1,000 gal				
Beef	3	16	7	15	1.6
Dairy: liquid (< 4.0% DM)	2	14	4	14	1.1
Dairy: slurry (4.1–11.0% DM)	6	24	8	21	2.2
Goat	4	17	8	19	1.7
Poultry	2	12	7	9	1.3
Swine: finish (indoor pit)	5	43	18	28	3.2
Swine: finish (outdoor pit)	2	18	7	10	1.0
Swine: (farrow-nursery, indoor pit)	2	21	8	13	1.0
Veal calf	1	9	3	16	0.6

[a] DM = dry matter

Even though on average the actual farm values compare well to established Wisconsin book values in many cases, the actual analysis values can range widely from the book value estimates (Table 3). This could be the result of different management practices on farms or other on farm differences, or improper sampling techniques. Taking multiple samples over time and averaging these values will help reduce the potential for using a single anomalous laboratory result as the basis for crediting nutrients on a farm.

Table 3. Variability in analyzed manure total nutrient values, WI 1998-2012.

Solid manure

Animal type	Nutrient	Total samples	Wisconsin Median	Std. dev.	Min.	Max.
			--------lbs/ton--------			
Dairy	N	10743	8.8	8.2	0.2	189
	P_2O_5		3.8	9.2	0.1	266
	K_2O		7.0	21.3	0.1	1090
Beef	N	1083	13.1	7.1	1.0	62
	P_2O_5		7.8	13.5	1.3	219
	K_2O		11.5	12.4	0.2	162
Chicken	N	532	49.1	27.5	12.5	226
	P_2O_5		44.4	30.1	5.2	132
	K_2O		32.7	17.7	1.8	104
Turkey	N	1657	51.4	15.8	1.3	558
	P_2O_5		44.4	11.7	2.1	113
	K_2O		31.2	6.6	2.9	59
Poultry	N	1312	45.0	18.8	0.7	145
(all others)	P_2O_5		47.9	29.5	1.4	223
	K_2O		34.9	19.2	0.7	151

Liquid manure

Animal type	Nutrient	Total samples	Wisconsin Median	Std. dev.	Min.	Max.
			--------lbs/1000gal--------			
Dairy	N	19085	19.5	9.5	0.1	354
	P_2O_5		6.9	14.5	0.1	1078
	K_2O		17.8	10.1	0.1	737
Beef	N	480	15.8	61.6	0.1	1303
	P_2O_5		7.0	8.3	0.1	46
	K_2O		15.2	9.8	0.1	56
Swine	N	1787	43.2	63.1	0.8	2266
-finish	P_2O_5		18.0	11.5	0.1	127
(indoor pit)	K_2O		28.0	11.2	0.3	88
Swine	N	159	18.2	18.4	0.9	73
-finish	P_2O_5		7.2	14.7	0.2	82
(outdoor pit)	K_2O		10.5	10.1	0.3	43
Poultry	N	612	12.2	12.4	0.1	91
	P_2O_5		7.1	12.2	0.1	96
	K_2O		9.0	6.4	0.1	66

Changes in Dairy Manure Nutrient Content by Digestion

Passing liquid dairy manure through an anaerobic digester has become increasingly popular. The process has the potential to change the dry matter and nutrient content, which could affect its performance as a nutrient source when applied to cropland. A study is currently looking at a comparison of raw vs. digested liquid dairy manure as a nutrient source when applied to crop fields. As a part of this study, the manure was tested both before digestion (raw) and following passing through an anaerobic digester. The raw manure had a higher dry matter content, which resulted in a lower ash content (Table 4). The digested manure had a much higher C:N ratio and a somewhat higher ratio of ammonium-N to total N. The field study is ongoing to address what affect digestion has on liquid dairy manure as a nutrient source.

Table 4. Effect of anaerobic digestion on characteristics of liquid dairy manure.

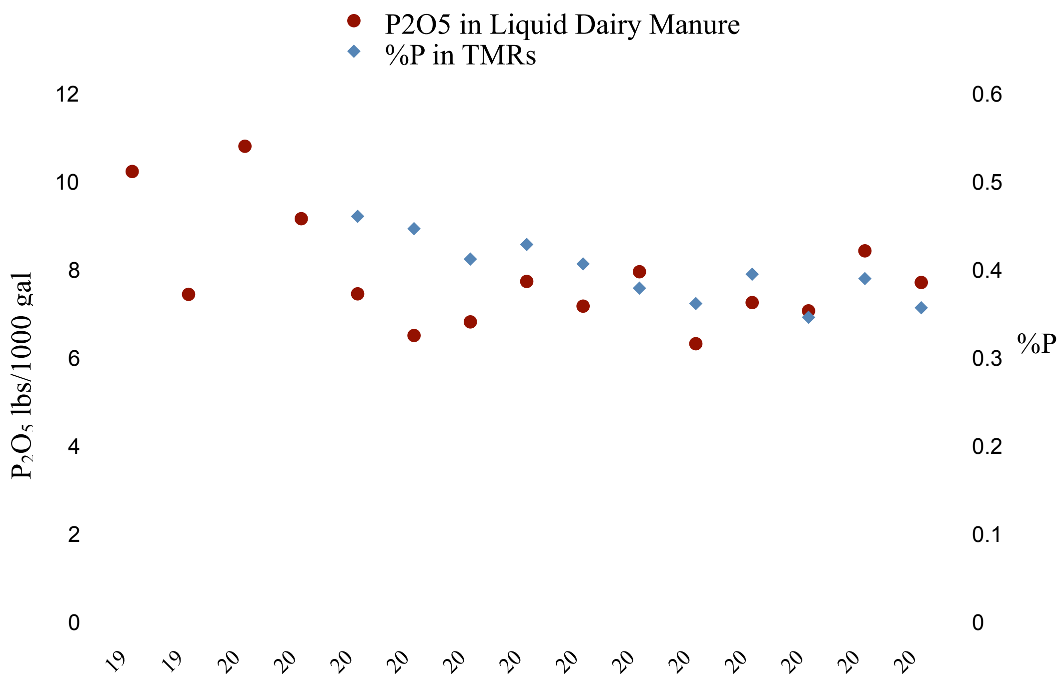
Source	Manure type	Year	%DM	% ash	Total N	Total P_2O_5	Total K_2O	C:N	NH_4-N
					---------lbs/1000 gal--------				% of TN
Site 1	raw	2011	5.9	22.5	22.3	10.0	18.2	8.8	49
Site 2	raw	2011	10.4	17.2	26.6	10.8	23.4	13.4	45
Site 1	raw	2012	6.3	17.5	20.8	8.7	17.0	10.7	45
Site 2	raw	2012	8.5	16.9	23.5	9.7	21.9	13.0	48
Average			7.8	18.5	23.3	9.8	20.1	11.5	47
Site 1	digested	2011	5.3	32.1	25.0	12.9	21.2	6.3	57
Site 2	digested	2011	3.2	32.2	19.3	6.1	18.8	4.9	51
Site 1	digested	2012	3.4	30.2	24.7	7.9	20.6	4.1	60
Site 2	digested	2012	5.5	23.8	20.8	7.1	20.3	8.2	54
Average			4.4	29.6	22.5	8.5	20.2	5.9	56

*Laboratory data from Carrie Laboski, personal communication

Changes in Phosphorus Content of Liquid Dairy Manure over Time

For the past 11 years, the UW Soil and Forage Analysis Laboratory has been conducing a program to thoroughly evaluate TMRs for dairies. One of the outcomes of this has been the ability to monitor total P levels in these TMR rations. During this same time period there has been a tremendous amount of extension effort put into getting information to dairy farmers as to the appropriate levels of total dietary P in rations. In general, most dairy rations originally contained significantly more P than was necessary for herd health and proper milk production. Over this period of time there has been a steady decline in the average total P content of dairy TMRs. There has been a similar downward trend in liquid dairy manure P levels over this same time period (Fig. 1). This is another example of a changing farm management strategy having a direct influence on the nutrient content of manure generated by that farm.

Fig. 1. Long term trends in P levels in liquid/slurry dairy manure vs. TMRs.



Summary

The use of manure analysis as a tool in on farm nutrient management has increased greatly in the past 15 years. During this same time period, there has been a lot of innovation in technology and changes in farm management practices that have also affected manure nutrient content. Changes in bedding materials, housing and manure handling facilities have occurred as well as treating manure by digestion, composting or liquid-solid separation. Using book values has traditionally been one way to attempt to properly credit applied nutrients from manure. However, if manure varies from the old established norms, as is often the case when a farm management strategy is changed, using a standard value may be inappropriate. By following recommended sampling guidelines and keeping long-term records, the appropriate manure nutrient content values can be obtained for a farm that reflects the management system in place.

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MANAGING FOR MANURE CONSISTENCY IN APPLICATION

Becky Larson [1/]

Land application of manure is the most common end product use in Wisconsin and throughout the nation. Application of manure provides the necessary nutrients for crop production and provides organic matter essential to soil health. When applied correctly manure serves as a beneficial soil amendment and fertilizer, however when over applied, manure can be the cause of substantial environmental consequences. Therefore, management of manure applications if critical to limit negative environmental impacts. Application rates play a key role in accurately applying manure. Unfortunately, the variability in manure and lack of process controls makes accurate application difficult. Key practices in frequency and methods of sampling, agitation, and application equipment can minimize the variation in manure consistency reducing the chance for over application. Recent and previous research has shown the importance of manure management practices during agitation and application and how they can effectively be used to reduce environmental impact while increasing crop yields due to accurate application.

[1/] Assistant Professor & Extension Specialist, Biological Systems Engineering Department, University of Wisconsin-Madison and University of Wisconsin-Extension.

FREQUENCY, MAGNITUDE AND TIMING OF LARGE STORM EVENTS ON SEDIMENT AND NUTRIENT LOSS

Eric T Cooley [1/] and Aaron Wunderlin[2/]

Numerous climatic studies have shown that weather patterns are changing in Wisconsin and other Midwestern States. Precipitation events are becoming more extreme in both volume and intensity and are occurring with larger variation on a state and regional basis. The timing and magnitude of these more extreme events plays a vital role in the potential for sediment and nutrient loss from agricultural land.

To assess the magnitude of a precipitation event, Depth-Duration-Frequency (DDF) charts are commonly used to evaluate rainfall depths (inches of rain) for different durations (e.g., 30 min, 1 h, 24 h). These values are then compared to statistical frequency of similar sized events to determine a ranking of a storm. A common example is the 25-year/24-hour event that is used as a design criteria in technical standards for sizing best management practices to be effective to a given storm size. An example in northeast Wisconsin is the value of 5.29 inches of precipitation received in a 24 hour period. This is the 25-year/24-hour storm event that should statistically occur once every 25 years.

Edge-of-field runoff data was collected on five Discovery Farms throughout Wisconsin and compared to the local DDF values for each precipitation event that occurred during the non-frozen ground period. On the five Discovery Farms locations, 59 site-years of data were evaluated that comprised a variety of farming systems and practices in different regions of the state. The magnitude of each non-frozen ground precipitation event was calculated and was assessed to determine if an edge-of-field runoff event occurred. Of the 2,400 total non-frozen rain events that occurred on the five farms, only 246 (or 10%) of the rain events resulted in edge-of-field runoff. Individual farm values ranged between 8 and 14%. During the 7-year evaluation period, with some farms only collecting data during a portion of this period, four 10-year events, two 25-year events, and one 100-year events were observed.

Table 1. Non-frozen ground precipitation and runoff from five Wisconsin farms and median depth and duration of precipitation events resulting in runoff.

				Median storm producing runoff	
	Farm years	Rain events	Runoff events	Depth (in)	Duration (hr)
Farm 1	**5.5**	471	44	0.61	4.16
Farm 2	**4.3**	399	40	0.75	4.67
Farm 3	**3.3**	308	27	1.03	3.86
Farm 4	**6.3**	639	52	1.07	2.94
Farm 5	**7.5**	583	83	0.90	2.90
% runoff			**10%**		

[1/] Research Coordinator, U. W. Discovery Farms, P.O. Box 935, 4319 Expo Drive, Manitowoc, WI 54221.
[2/] Research Technician, U. W. Discovery Farms, P.O. Box 935, 4319 Expo Drive, Manitowoc, WI 54221.

In addition to observing that the largest precipitation events typically did not result in the largest runoff events, it was also observed that the largest runoff events often did not correspond with the largest sediment or nutrient loss. Taking into account both frozen and non-frozen ground runoff events, a single runoff event was observed to account for the majority of sediment or nutrient loss for the year. Many of the high sediment loss events occurred during the spring of the year, once the ground was thawed; whereas high phosphorus and nitrogen loss events occurred on both frozen ground and spring runoff events.

Table 2. Occurrence of non-frozen ground precipitation events of a given magnitude based on regional Depth-Duration-Frequency values on five Wisconsin farms.

	Farm Years	**<1 yr**	**1 yr**	**2 yr**	**5 yr**	**10 yr**	**25 yr**	**100 yr**
Farm 1	**5.5**	36	1	4	1	1	0	1
Farm 2	**4.3**	37	1	0	1	1	0	0
Farm 3	**3.3**	22	3	2	0	0	0	0
Farm 4	**6.3**	39	9	2	0	1	1	0
Farm 5	**7.5**	71	6	2	2	1	1	0
Total	**27**	205	20	10	4	4	2	1

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MANAGING SPRAY IRRIGATION OF NUTRIENTS

John Panuska [1] and Jim Leverich [2]

Optimal crop production requires nutrient application. Land application of nutrients is a common practice in Wisconsin and occurs as both animal manure and chemical fertilizers. Conventional practices have involved nutrient application during the spring or fall and at quantities sufficient to ensure adequate supply throughout the growing season. This requires applying additional nutrients to compensate for anticipated losses through both surface and subsurface pathways and/or mineralization in the soil. Mechanisms for these losses can include manure in surface runoff and tiles or nutrients dissolved in stormwater runoff.

Nutrient losses represent a cost to producers as well as the environmental cost from downstream impacts. Nutrients lost from upland areas enter streams, lakes and groundwater resulting in impairment to beneficial use. Oxygen demanding organic matter, bacteria, pathogens and nutrients from manure can pose public health and environmental risks. In addition, it is costly to transport liquid manure from the farm to land application areas. These costs increase with distance along with increased wear on public roads.

One approach to address the aforementioned challenges is to use new technologies to separate manures into solids, concentrated slurries and thin liquids. The rapidly evolving bioproducts industry continues to develop new uses for manure solids in products such as fertilizer, landscape mulch and wall board. The manure solids and concentrated slurries also contain the majority of the phosphorus (P), a nutrient of concern for water quality. These manure solids can be sold or transported to fields and concentrated slurries can be pumped or transported to P deficient fields located at greater distances from the farm at a significantly reduced cost. The thin liquid fraction contains nitrogen and potassium, both essential nutrients for crop growth. Existing spray irrigation technology can be used to apply this fraction to crops throughout the growing season at a rate commensurate with crop growth and uptake (spoon feeding). Nutrient application in this manner decreases the time between application and plant uptake, thus decreasing the surface and subsurface loss risk.

The management goal of manure spray irrigation is to maximize plant nutrient uptake. Essential elements include application rate, timing and volume. The application rate should not exceed 0.25 inches per hour to prevent rapid transport via macropores. Timing should be during periods of active plant growth and total volume should be managed to not exceed the root zone storage capacity and thus prevent deep drainage. Irrigation scheduling and soil moisture monitoring can be used to reduce deep drainage risk. This includes only irrigating to 70% of field capacity to provide a soil water storage buffer for natural rainfall. Discussion will include some of the benefits, challenges and yet unanswered questions of this method of nutrient application.

1/ Natural Resources Extension Specialist, Biological Systems Engineering Department, UW-Madison, 460 Henry Mall, Madison, WI 53706, jcpanuska@wisc.edu.

2/ On-Farm Research Coordinator, UW Extension, 10384 Gardener Avenue, Sparta, WI 54656 james.leverich@ces.uwex.edu

MONITORING GROUNDWATER NITROGEN CONCENTRATION IN SANDY SOILS UNDER VEGETABLE PRODUCTION

N.J. Bero, M.D. Ruark, and Birl Lowery [1/]

Abstract

Current nitrogen (N) fertilizer management practices for vegetable farming have led to elevated levels of nitrate-nitrogen in the local groundwater. A study was conducted at the Hancock Agricultural Research station to determine if controlled release fertilizer, specifically Environmentally Smart Nitrogen (ESN®), could reduce groundwater N concentration. Field experiments were conducted using Russet Burbank potato and Overland sweet corn, planted in Plainfield sand. Four fertilizer rates in potato were evaluated: 1) 0 N control, 2) 224 kg ha^{-1} of N as ESN®, 3) 280 kg N ha^{-1} as ESN®, and 4) 280 kg N ha^{-1} as a split application of ammonium sulfate (AS) and ammonium nitrate (AN). Sweet corn fertilizer rates were: 1) 0 N control, 2) 168 kg N ha^{-1} as ESN®, 3) 168 kg N ha^{-1} as AS-urea-urea, and 4) 224 kg N ha^{-1} as AS-urea-urea. Both studies included three replicates to create twelve 14.6 m by 15.2 m field plots. Three groundwater monitoring wells placed diagonally across plots were installed and sampled weekly during the growing season and monthly during winter for assessing nitrate. Bromide tracer was used to evaluate solute flux and spatial distribution of N leaching potential among plots. Bromide tracer showed that plot size was sufficiently large with no plot-to-plot contamination from N migration and the time for groundwater to flow to adjacent plots is longer than the growing season. Therefore, in-season contamination is minimal, and thus nitrate measurements were from respective plots. Trends indicate that ESN® reduced the amount of nitrate leaching to groundwater. However, highly variable background nitrate concentrations in the groundwater made it difficult to show statistical significance. The effective use of groundwater monitoring wells requires careful consideration of depth to groundwater, groundwater flow direction, and variability of groundwater nitrogen concentration.

Introduction

Nitrate contamination from agricultural processes is a significant problem in the Central Sands Area (CSA) of Wisconsin. Given the sandy nature of soils in the CSA they have a small amount of organic matter and limited nutrient and water holding capacity. These characteristics require intensive management of agriculture for adequate crop production. It has been documented that elevated fertilizer rates, and to some extent extensive irrigation, has contributed to concentrations of nitrate-N in the groundwater that are 2-4 times the Minimum Contaminant Level (MCL) of 10 ppm as recommended by the U.S. EPA (EPA, 2009). Elevated levels of nitrate from reactive N and its derived pollutants in water may be hazardous to human health via three main pathways. These pathways are the formation of methemoglobin resulting in blue baby syndrome, indirectly by the eutrophication of surface waters, and by the formation of carcinogenic N-nitroso compounds (Wolfe and Patz, 2002).

[1/] Research Specialist, Assistant Professor, and Professor, Dept. of Soil Science, 1525 Observatory Drive, University of Wisconsin-Madison, Madison, WI 53706.

Controlled-release fertilizers, in particular ESN® (Agium, Inc, Denver, CO) show promise in reducing the amount of nitrogen reaching groundwater. Previous studies evaluating the significance of fertilizer type on nitrogen leaching using ESN® have concentrated on the root zone, and data from these studies on controlled-release nitrogen fertilizer indicate reduced leaching (Wilson et al., 2010). However, determining the impact of contolled-release fertilizers and nitrate reaching groundwater has only been inferred from these root-zone measured data (Shrestha et al., 2010), and no study has been conducted that has directly monitored fertilizer effect on groundwater nitrate concentrations in the CSA area.

Controlled-release fertilizers must produce yields similar to the yields of traditional management methods at comparable cost if it is to be rapidly adopted as a management practice by growers. The use of ESN® effectively increased potato yield and quality when compared to urea applied in split or single applications, appears to have improved N use efficiency, with reduced rates proving to be more effective than the grower's standard practice full rates, and has the potential to reduce residual soil nitrate. Therefore, ESN® may result in reduction in groundwater contamination (LeMonte et al., 2009).

Previous research at the Hancock Agricultural Research Station indicates that water and solute applied uniformly to soil surfaces did not flow through the entire vadose zone, but rather preferential flow paths constituted the dominant flow pattern in this soil (Kung, 1990). Preferential flow paths, such as finger flow and funnel flow, may affect location where solute enters the water table as well as measured concentration levels (Brown et al., 2000). It has been shown that Br^- and nitrate-N also move at comparable rates through the unsaturated zone in the Plainfield sand (Saffigna and Keeney, 1977). The placement of wells is very important in determining effect of solute flux on groundwater quality (Kung, 1990). Given Kung's findings, researchers at the Hancock Agricultural Research Station have moved to so-called large-scale plots that are on the order of 15 × 15 m in anticipation of avoiding the preferential flow problem. Therefore, we need to assess the fate of nitrogen fertilizer applied to these large-scale plots and determine whether a groundwater well sampled within a given plot represents NO_3-N concentrations specific to that plot. Conservative tracers can be applied, measured, and assessed to determine if the preferential flow paths are present and affecting the NO_3-N measurements.

The objective of our study was to investigate fertilizer effect on groundwater NO_3-N concentration, yields, and plant growth parameters in sandy soils under potato production, using the best management practices currently available compared with new controlled release, polymer coated urea (PCU) technology. We also wanted to determine if a so-called large-scale 15 by 15 m plot size, which has been widely used recently at the Hancock Agricultural Research Station for solute flow studies, is of sufficient size that vertical preferential flow paths would not move solute to a neighboring plot through the application of conservative tracers.

Materials and Methods

This study consisted of a field experiment was conducted at the Hancock Agricultural Research Station in a Plainfield Loamy Sand soil. The study included twelve 14.63 m by 15.24 m plots, in a randomized complete block design, dividing the field into two strips, which were six plots long. The study used four fertilizer treatments in three blocks (Fig. 1). Each replicate consisted of applications of a 0 N control, 224 kg N ha^{-1} as ESN® (LPCU), 280 kg N ha^{-1} as ESN® (RPCU), and 280 kg N ha^{-1} as AS-AN (RCONV). Potatoes were planted on 29 April 2010 and 25 April 2011. In 2010, ESN® was applied 19 days after planting (DAP) and conventional fertilizer was split, with 1/3 applied as AS also at 19 DAP and 2/3 applied as AN at 35 DAP. Potato fertilization in 2011 was split with AS application on 28 and AN application on 60 DAP. Fertilizer was applied by hand on the top of the hill, incorporated mechanically during hilling. Three groundwater monitoring wells were installed in each plot, and wells were installed at a depth of 9.75 m from the soil surface, with 1.5 m screens in 2010. Wells were installed approximately 3.35 m below the water table, leaving the top of the screen 2.13 m below the water table. This was done to account for seasonal drawdown of the water table from agricultural activities. The second year wells were installed at a depth of 9.14 m with 2.28 m screens at 1.52 m of depth into the water table. Second year wells were installed such that the water table intersected the well screen for the entire growing season. Sweet corn followed potato in each year, and was planted on 27 May 2011 and 29 May 2012. Fertilizer treatments were a 0 N control, 168 kg N ha^{-1} as ESN® (RPCU), 168 kg N ha^{-1} as AS-Urea-Urea (RCONV), and 224 kg N ha^{-1} as AS-urea-urea (HCONV). Fertilizer was applied to the soil surface by hand and not incorporated. The ESN® was applied at planting both years. Conventional fertilization was split with applications at the V5, V8, and tassel stages as AS, urea, and urea respectively. In 2011 V5 fertilization was on 25 DAP, V8 fertilization was 39 DAP, and tassel fertilization on 67 DAP. In 2012 V5 fertilization was on 29 DAP, V8 fertilization on 42 DAP, and tassel fertilization on 57 DAP. Bromide was applied to two plots on 14 October 2010 after the first potato growing season and on 9 March 2012 prior to the second corn growing season at a rate of 112 kg ha^{-1}.

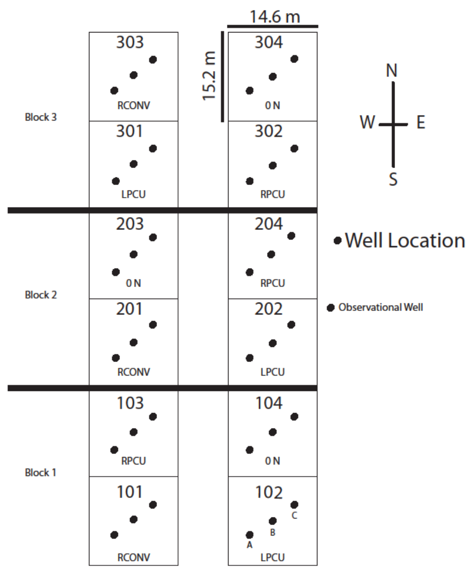

Figure 1. Plot diagram and well locations for both years of potato and sweet corn.

Laboratory analysis was done using microplate methods. Nitrate determination was completed with the single vanadium chloride reagent method used by Doane and Horwath (2003). Bromide used a colormetric method from Lepore and Barak (2009).

Potatoes were harvested 123 DAP in 2011 and 140 DAP in 2012. Potato yields were obtained by mechanical harvesting of 3.05 m sections of four rows in each plot, and graded at the Hancock Agricultural Research Station. The mechanical grader separated potatoes into B grade (<85 g), 85 to 113, 114 to 170, 171 to 283, 284 to 368, 369 to 454, and > 454 g. Culled (damaged or diseased) potatoes were removed manually. Yields are reported as marketable, which excludes B grade and culled potatoes, or total, which includes all grade sizes and culls. Sweet corn was harvested on 89

DAP in 2011 and 77 DAP in 2012 and yields were obtained from the hand harvesting of 4 6.1 m rows in each plot and are reported in total fresh weight and dry weight.

Results and Discussion

Yield

Neither year showed statistically significant differences between yields in treatments receiving N suggesting that ESN® can produce as effectively as conventional practices. Potato yields were greater in 2011 compared to 2010. In 2010 weather was above average in warmth and above average in precipitation compared with 2011 which was dry and warm. The ESN® release rate is dependent on temperature, and with a warmer year, may have released N more quickly and then the increased precipitation caused it to leach at a rate faster than plant uptake. This would have also been the case with the AS-AN plots, which could explain why the yield differences are not statistically significant. This is important as ESN® produced equivalent yields as conventional techniques in an anomalous weather year. The dry 2011 most likely helped minimize leaching and yields increased as compared with 2010. Previous studies show ESN® has produced generally higher yields (of potato) than conventional management practices(Wilson et al., 2010).

Sweet corn yields were greatest in the conventional treatments. The dry weather conditions in both years limited leaching of nutrients from the soil profile. The benefit of controlled release fertilizer is withstanding significant leaching events from rainfall, and with little rainfall in the 2011 and 2012 growing season, the main benefit of controlled release fertilizer was not realized.

Nitrate

There were no significant differences between treatments and with respect to groundwater nitrate concentration. There was a large amount of variability in nitrate concentrations indicated by the large range of significant differences (Fig. 2), and weekly standard error bars (Fig. 3). After years of constant decline, the water table elevation increased by 1.0 m during the 2010 growing season, and this resulted in the well screens being approximately 3 m below the surface of the groundwater. The N measurements for 2010 are therefore reflective of the bulk groundwater, not the nitrate reaching the water table surface (the interface of the saturated and unsaturated zones). On 14 October 2010, the middle well in each plot was raised such that the well screen intersected the water table. Afterward, nitrate concentrations increase, and a large flush of nitrates was also seen during the spring thaw, and as noted by Zvomuya et al (2003) this may occur as a PCU may release nitrogen after crop removal which can be observed during spring thaw. The potato field in 2011 had lower initial nitrate concentrations as compared with 2010, and several wells had N concentrations less than the EPA MCL. However, with wells that had screens intersecting the water table for the entire growing season, there were still no statistically significant differences between treatments. A winter flush of N was also observed in 2011.

Sweet corn nitrate concentrations show similar variability and there were no statistically significant differences between treatments. All wells had screens that intersected the water throughout the sampling period.

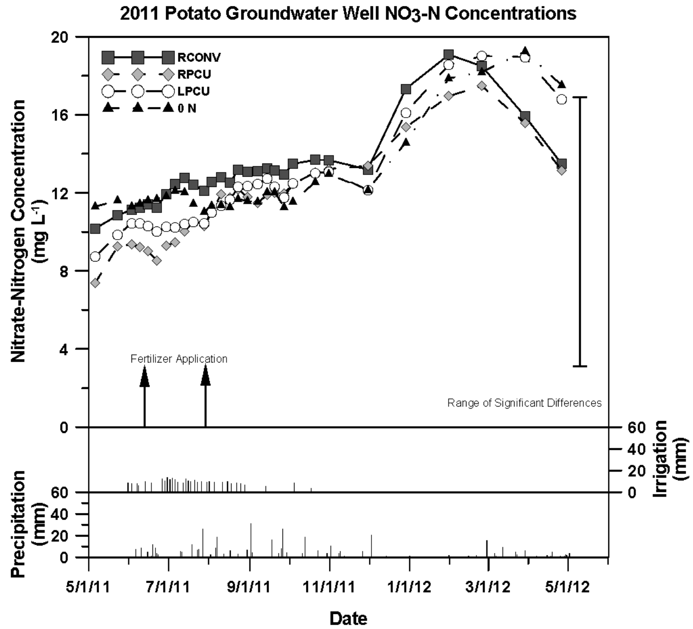

Figure 2.Measured average nitrate-nitrogen concentrations for the 2011 potato growing season through the winter of 2011. RCONV – 280 kg N ha^{-1} as 93 kg ha^{-1} ammonium sulfate applied at emergence and 187 kg N ha^{-1} as ammonium nitrate, RPCU – 280 kg N ha^{-1} as ESN® applied at emergence, LPCU – 224 kg N ha^{-1} as ESN® applied at emergence.

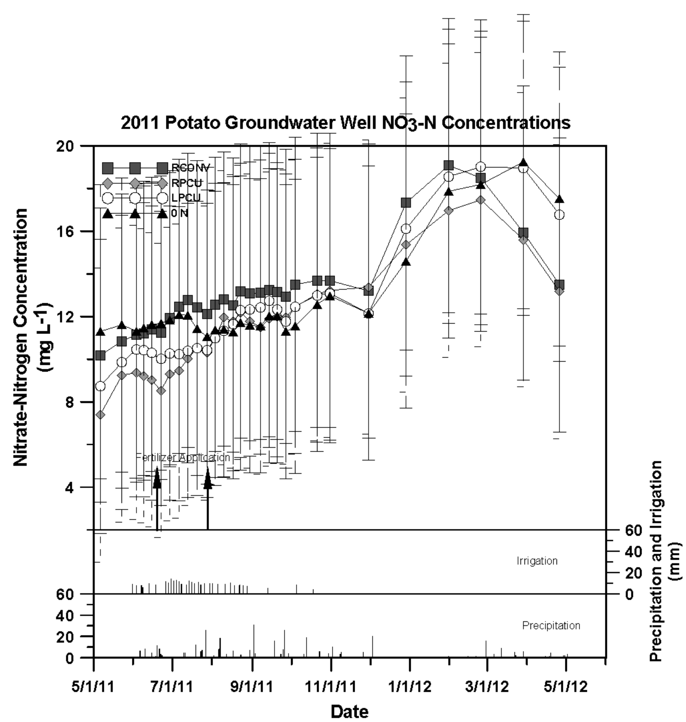

Figure 3.Measured average nitrate-nitrogen concentrations for the 2011 potato growing season through the winter of 2011 with error bars inserted. RCONV – 280 kg N ha^{-1} as 93 kg ha^{-1} ammonium sulfate applied at emergence and 187 kg N ha^{-1} as ammonium nitrate, RPCU – 280 kg N ha^{-1} as ESN® applied at emergence, LPCU – 224 kg N ha^{-1} as ESN® applied at emergence.

Bromide Tracer

Bromide breakthrough only occurred in wells within the applied plots (Fig. 4 and 5). This indicates that plot size is large enough to account for preferential flow from the soil surface to the water table. Bromide breakthrough took 3 weeks in 2010, because transport was supported by water input of 3.5 cm every 3 days. In 2012, when only natural rainfall and in season irrigation provided transport, breakthrough occurred after 8 months. The summer of 2012 was very dry, and this shows the importance of frequency and intensity of water input on the time it takes for surface applied chemicals to reach the groundwater. After reaching the groundwater, bromide moved to adjacent plots from transport due to groundwater flow. The flow in this area is to the southwest, and is indicated by bromide breakthrough in the plots located to the southwest of the applied plots. Some bromide occurred in plots to the direct south in the first potato field. This breakthrough is indicative of irrigation pumping and the field's location within the cone of depression of the irrigation well.

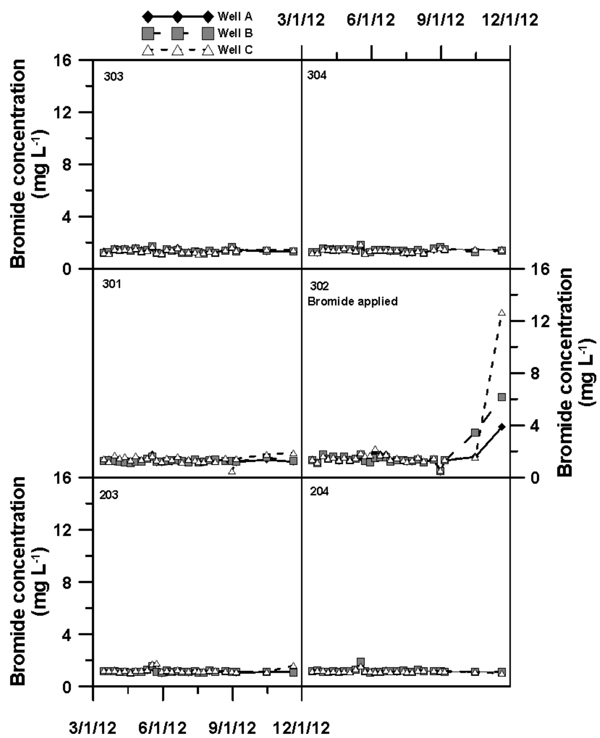

Figure 4. Bromide concentrations in the north six plots of the second field where bromide was applied on 9 March 2012. The first sample date represents the day on which bromide was applied.

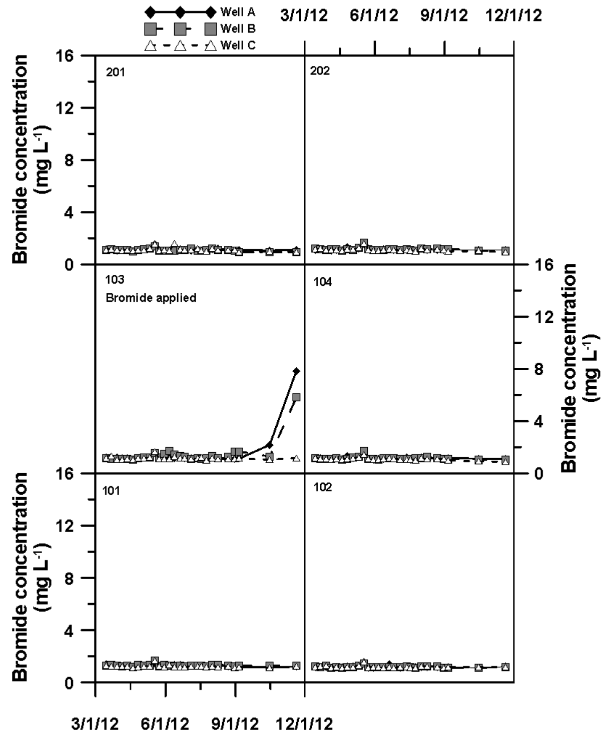

Figure 5. Bromide concentrations in the south six plots of the second field where bromide was applied on 9 March 2012. The first sample date represents the day on which bromide was applied.

Conclusions

The controlled-release product ESN® shows promise in limiting the amount of nitrate that accumulates in the bulk groundwater. However, monitoring methods and well positioning are critical for accurate assessment of leaching to the water table surface. Management practices using controlled-release fertilizers could be adopted by potato farmers in sandy soils requiring intensive fertilization, however more research should be conducted with sweet corn. However, attention needs to be placed on depth of well, length of well screen, direction of groundwater flow, proximity to irrigation wells, and the duration of experiment. Additional data analysis will be completed to determine the effect of evapo-transpiration on the rate at which solute moves to the groundwater.

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NO-TILL PRODUCTION USING THE ROLLER-CRIMPER AND COVER CROPS IN THE UPPER MIDWEST

Erin Silva[1,2]

Introduction

No-till production has become a common practice across the U.S. in conventional cropping systems. Approximately 35.5% of U.S. cropland planted to eight major crops (barley, corn, cotton, oats, rice, sorghum, soybeans, and wheat) was managed through no-till operations in 2009 (Horowitz et al., 2010). No-till systems provide environmental benefits, such as reduced soil erosion, increased soil organic matter, decreased runoff and improved soil infiltration, and improved soil structure and aggregate stability (Langdale et al., 1992; Moldenhauer et al., 1983; Edwards et al., 1992; Uri et al., 1999). No-till systems can also provide economic benefits with reduced fuel and labor costs due to less tractor passes over the field (Siemans et al., 1992).

Current practices used in no-till production systems rely on herbicides for weed management, thus preventing certified organic and herbicide-free growers from integrating these practices into their operations. However, research demonstrates the potential for herbicide-free no-till systems utilizing cover crops that produce high levels of residue biomass, suppressing weed emergence through the creation of a physical barrier when managed as a killed mulch (Teasdale and Mohler, 1993). Managed in this fashion, cover crops can inhibit weed growth by preventing light from reaching the soil surface or through allelopathy (Teasdale and Mohler, 2000). The quantity of mulch produced through cover crop management is highly correlated with the degree of weed suppression attained.

The objective of this study was to evaluate the biomass production and weed suppression of five different cover crops (winter rye (*Secale cereal L.*), winter triticale (*x Triticosecale* spp. L.), winter barley (*Hordeum vulgare* L.,), Austrian winter pea (*Lathyrus hirsutus* L.,), and hairy vetch (*Vicia villosa* L.,) when integrated into the no-till organic systems and terminated using two different methods, roll-crimping and sickle-bar mowing.

Materials and Methods

Research was conducted at the University of Wisconsin Arlington Agricultural Research Station (UWAARS). Winter rye (variety not stated, Albert Lea Seed Co., Albert Lea, MN), winter triticale ('Fridge' awnless, Albert Lea Seed Co., Albert Lea, MN), winter barley ('McGregor', Albert Lea Seed Co., Albert Lea, MN), Austrian winter pea (variety not stated, Albert Lea Seed Co., Albert Lea, MN), and hairy vetch (variety not stated, Albert Lea Seed Co., Albert Lea, MN) were planted on September 8, 2009 and September 13, 2010 (Table 1). Small grain cover crops (winter rye, triticale, and barley) were planted with a 3-m wide no-till (NT) drill (Model 750, John Deere, Moline, IL) at a depth of 2.5 cm and a row width of 19 cm at a rate of 269 kg ha^{-1}. Vetch was drilled at a rate of 33.6 kg ha^{-1} and Austrian winter pea at a rate of 44.6

[1] Organic Production Specialist, Department of Agronomy, 1575 Linden Dr., Univ. of Wisconsin Madison, Madison, WI, 53706

[2] I would like to thank the North Central Region Sustainable Agriculture Research and Education program for funding this project.

kg ha^{-1} with the same equipment, at a 5.0 cm depth and 19 cm row spacing. The cover crop control plot was lightly disked (3.7 m wide) to manage early season weeds, and then prepared for row crop planting using a soil finisher (7.7 m wide). Small grain cover crops were rolled with a roller-crimper (4.6-m wide) (I and J Manufacturing, Gap, PA) or mowed with a sickle-bar mower (2.1-m wide) perpendicular to their direction of planting on May 28, 2010 and June 8, 2011. Operations were timed to occur when the small grains reached anthesis (Zadoks growth stage 60, visible pollen shedding) or legume crops reached flowering to early pod set (BBCH growth stages 59 to 70). The roller-crimper was filled with water, for a total mass of 1360 kg. Row crops were planted into each of the treatment plots with a 4.6-m wide conservation-tillage planter (Model 1750 Max Emerge Plus, Conservation Tillage, John Deere, Moline, IL1) set at a 76-cm row width at the same time as crimping and mowing.

Data Collection

Cover crop aboveground biomass was measured by harvesting three 0.50-m^{-2} quadrats per plots at a 2.5 cm cutting height before termination in mid-May. Samples were dried at 50°C until constant weight. Weed densities were determined in each of the plots in 2010 and 2011 by counting all emerged weeds in three 0.5-m^{-2} quadrats per plot immediately prior to termination and 12 weeks after planting (WAP). Weeds species were identified and classified as perennial broadleaves (PB), perennial grasses (PG), annual broadleaves (AB), and annual grasses (AG). At these same time intervals, weed biomass was determined by harvesting all weeds at ground level within three 0.5-m^{-2} quadrats at cover crop termination at 12 WAP and dried at 50 °C to constant weight. Weather data was obtained from a meteorological station located at the UW-AARS, operated by the Wisconsin State Climatology Office, from 2009-2011.

Results

Weather

Precipitation during cover crop establishment (September through December) was wetter in 2009 (27.97 cm) than in 2010 (23.55 cm); typical season average precipitation during this period totaled 24.87 cm. Precipitation during the cash crop production season was above normal in 2010 (66.37 cm, 40.08 cm average) and below average in 2011 (30.20 cm). Winter temperatures were similar in both years and neared average values. Snowfall was 86% of average in 2009-2010 and 108% of average in 2010-2011. Spring temperatures were significantly lower in 2011 than in 2010 (375 and 617 modified growing degree days, respectively), leading to a delay in cover crop maturity in 2011. Modified growing degree-day units during the production season, calculated using a base temperature of 10 °C and an optimum temperature of 30 °C, were 104% of average in 2010 and 91% of average in 2011.

Weed Control

A primary objective of this experiment was to compare the weed suppression of the different cover crop types. Analysis indicated a year x treatment effect and year x variety interaction; therefore, results are presented by year. The dominant weed species included lambsquarters (*Chenopodium album* L.), pigweed (*Amaranthus hybridus* L.) field pennycress (*Thlaspi arvense* L.), dandelion (*Taraxacum officinale* L.), common chickweed (*Stellaria media* L.), quackgrass (*Elymus repens* L.), barnyard grass (*Panicum Crus-Galli* L.), and yellow foxtail (*Setaria glauca* L).

Initial weed populations prior to termination (disking, crimping, or mowing) showed significant differences by year and by cover crop variety (Table 1). In 2010, initial weed densities were greater in the vetch (46.6 weeds m^{-2}), and barley (43.3 weeds m^{-2}) and lowest in the Austrian winter pea plots (18.4 weeds m^{-2}). In 2011, weed densities were overall lower in the cover crop treatments and showed different trends, with densities greatest in the triticale (25.6 weeds m^{-2}) and lowest in the hairy vetch (3.6 weeds m^{-2}) and rye (0.9 weeds m^{-2}) plots.

Weed suppression of mowed and crimped cover crop 12 WAP differed significantly by year and by mode of termination (MOT) as measure by both weed density and weed biomass (Table 2). In 2010, significant differences in densities of PG, AG, and PB weeds were observed in the roll-crimped versus mowed treatments, with grasses occurring at higher densities in the roll-crimped plots, and perennial broadleaves occurring at higher densities in the mowed plots. No significant differences were observed in the annual broadleaf densities or the total weed biomass in the roll-crimped and mowed plots. In 2011, no significant differences for MOT were observed for weed densities or biomass of the weed classes.

Weed biomass at 12 WAP differed by cover crop treatment as well (Table 2). The small grain plots demonstrated similar weed suppression as measure by total biomass in the crimped treatments and significantly different in the mowed plots. Significant differences were in the ability of the small grain cover crops to suppress weeds as measured by total weed biomass.

Conclusions

In conclusion, from the data collected in this experiment, it appears that winter rye performs most consistently in herbicide-free no-till system in the upper Midwest than other potential cover crop options. This is due to consistent high biomass production, consistent survivability over the winter, and biomass persistence through the production system.

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Table 1. Effect of cover crop type on pre-termination cover crop biomass, weed density, weed biomass at the University of Wisconsin Arlington Agricultural Research Station, 2010 and 2011 (2010: corn silage yield, and 2011: soybean yield, bu per acre).†

Year		Cover Crop Biomass	Weed Density	Weed Biomass	Crop Yield
		Mg DM ha^{-1}	no. m^{-2}	gm. m^{-2}	
2010	Hairy Vetch	3.67b	46.6a	1.2b	9.84
	Winter Rye	10.17a	25.4bc	0.26b	6.6
	Winter Triticale	14.56a	24.2bc	0.74b	4.3
	Austrian Winter Peas	6.29b	18.4c	0.31b	10.9
	Winter Barley	11.71a	43.3a	0.98b	6.4
2011	Hairy Vetch	5.00b	3.6c	5.5b	33.4
	Winter Rye	10.33a	0.9c	0.2b	48.2
	Winter Triticale	6.38b	25.6ab	5.0b	10.0
	Austrian Winter Peas	0.0c	--	--	40.6
	Winter Barley	10.33a	19.3b	0.4b	25.3

†Numbers in columns followed by different letters were significantly different at $P<0.05$ according to an analysis of variance; means were compared through the Tukey-Kramer procedure.

Table 2. Effect of cover crop and mode of termination on weed density of perennial grass weeds (PG), annual grass weeds (AG), perennial broadleaf weeds (PB) and annual broadleaf weeds (AB) densities, total weed biomass 12 weeks after planting at the University of Wisconsin Arlington Agricultural Research Station, 2010 and 2011.

Termination	Cover Crop	PG†	AG	PB	AB	Weed Biomass‡	PG	AG	PB	AB	Weed Biomass
		---no. m^{-2}---				g m^{-2}	---no. m^{-2}---				g m^{-2}
		---2010---					---2011---				
Crimped	Hairy Vetch	95.7b[§]	16.3	13.3a	6.7	20.7ab	4.7	4.0	19.3	26.7bc	364.6ab
	Winter Rye	68.3b	31.7	18.0a	11.3	38.8a	0.0	0.0	0.0	0.0c	0.0b
	Winter Triticale	277a	25	15.3a	7.0	35.0a	8.0	1.3	14.7	74.0ab	294.7b
	Winter Peas	56b	10	16.0a	1.56	19.3ab	---	---	---	---	---
	Winter Barley	83b	51	18.0a	4.3	25.0a	17.7	2	2.0	54.0ab	307.1b
	Control	0c	18	7.0b	7.7	1.6b	16.7	8	4.7	89.3a	865.1a
	Crimped Average	98.7A[¶]	24.7A	14.6B	6.9	23.4	12.0	3.1	8.1	48.8	366.3
Mowed	Hairy Vetch	62bc	17a	17.3ab	7.3	19.4bc	16.0	3.3ab	12.7	24.0bc	362.3ab
	Winter Rye	37bc	1b	23.3a	11.3	30.2b	0.7	0.0b	0.0	6.0c	42.1b
	Winter Triticale	220a	32a	20.7a	11.0	52.0a	7.3	0.7ab	11.3	57.3ab	319.3ab
	Winter Peas	62bc	18a	16.0ab	6.0	15.3bc	---	---	---	---	---
	Winter Barley	26bc	6b	22.0a	3.3	16.2bc	12.0	0.0b	3.3	47.3abc	502.9ab
	Control	5c	21a	7.3b	8.7	4.3c	16.7	8.0a	4.7	85.6a	845.6a
	Mowed Average	69.0B	16.0B	17.8A	8.0	22.9	11.5	2.4	6.4	44.8	418.1
Significance											
Variety		<.0001	<.0001	<.0001	ns[#]	<.0001	ns	.0001	<.0001	<.0001	<.0001
Treatment		0.0137	<.0001	0.0107	ns	ns	ns	ns	ns	ns	ns
V X T		ns	<.0001	ns	ns	ns	ns	ns	ns	ns	ns

† Weed densities were determined in each of the plots in 2010 and 2011 by counting all emerged weeds in three 0.5-m^{-2} quadrats per plot.
‡Weed biomass was determined by harvesting all weeds at ground level within three 0.5-m^{-2} quadrats and dried at 50 °C to constant weight.