Missouri
Soil Fertility and Fertilizers
Research Update
2008

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Agronomy Department
College of Agriculture, Food and Natural Resources
University of Missouri

Thank You
Missouri Fertilizer and Ag Lime Distributors

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Researchers, being overtly curious people with a penchant to find out why or how to do it better, normally have a list of topics that they want to research. Perhaps you have a topic that is particularly perplexing to you? These people could very well be the one's to ask why? If they don't know, then perhaps you will have just suggested the next burning question that will become the object of new research. Any questions or ideas? If you do, send them too us at:

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Sanborn Field Update

Historic Sanborn Field: 2008 Growing Season

Randall J. Miles and Steven Troesser

Soil, Environmental, and Atmospheric Sciences Department

Introduction

Since the fall of 1888 researchers on Sanborn Field have explored the affects that different management schemes have on the properties of the soil. The longevity of the research on Sanborn Field has made it the third oldest research field in the world. Sanborn Field is located on the University of Missouri campus in Columbia, MO and consists of 44 separate plots with each plot's area (except plot 24) consisting of approximately 1/14 of an acre (.29ha) and measures 100.5ft by 31 ft (30.55 meters by 9.42 meter). Plot 24 is half as long as the other plots because the north half contains an automated weather station. A layout of the field can be seen on the plot plan diagram on the next page of the report. Plots numbered 1-7 and 9-39 are managed in an ongoing either monocrop or rotation crop scheme. Plots 40-44 are used for other research projects, teaching, and demonstration projects. Plot 45 was established to native warm season grass in 1990 and continues presently in this management scheme to assess carbon sequestration.

Sanborn Field is used for four primary uses: 1. Research, 2. Demonstration, 3. Documentation of the Past, and 4. Teaching. The following objectives reflect these uses:

A. Document soil changes, crop response and nutrient balance under selected crop sequences.
B. Collect and properly store soil and plant samples for use in the future as a means of identifying effects of environmental changes.
C. To continue to measure soil changes and crop performance in plots uniformly managed since 1888.
D. To demonstrate results of interaction that occurs through differential management of the soil-plant-environment continuum.
E. To serve as an on-campus laboratory for teaching where varied crops grown under different management schemes provide living examples to students.

Soil Sampling, Fertility Recommendation, and Fertility Applications

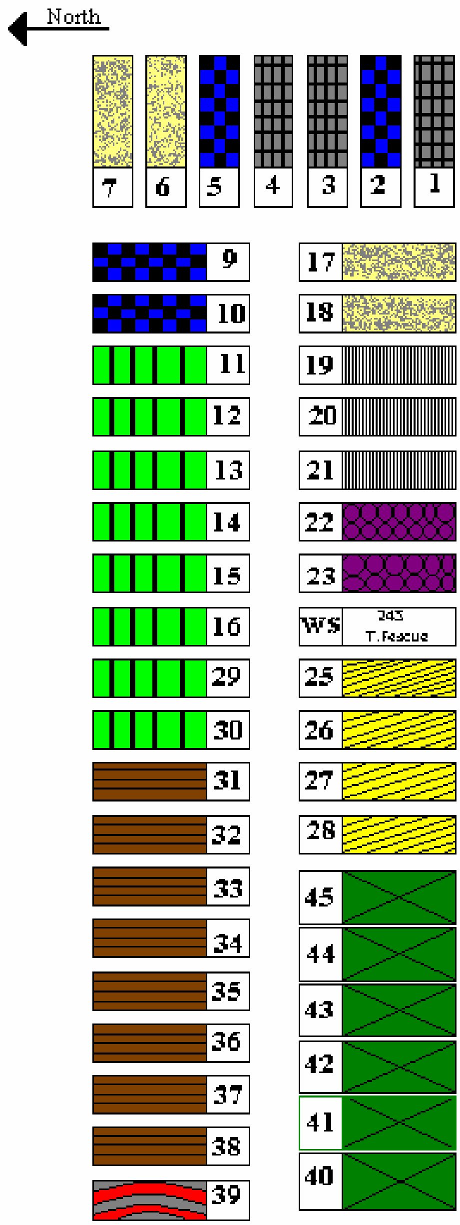
Soil sampling procedures set forth by the Second Century Plan call for the collection of soil testing samples every 5 years with the most recent set of samples being pulled in the fall of 2003. Every 25 years (1938, 1962, 1988), deep core samples have been taken from each plot. In 1962 and 1988, these samples were taken according to a systematic plan with the location of each core accurately measured from the permanent plot markers. The next set of deep cores is scheduled to be taken in 2013. All fertility and lime recommendations are made based on guidelines set forth in the Missouri Soil Testing program.

The manure applied to selected plots is sampled and analyzed. The manure used on Sanborn Field is collected from the Foremost Dairy Farm manure solids separated stockpile. Soil moisture of the plots and temperature determines the timing of the manure application. Due to the aroma of the manure and the proximity of the field to residential housing, manure is applied in the winter to forage plots and in tilled plots the manure is applied just prior to a tillage operation.

Sanborn Field

2nd Century Plot Plan

Initiated 1990-1991



Historical Cropping Systems

Continuous Corn
plot 6 Full Fertility Conventional Tillage
7 Full Fertility No-tillage
17 No Fertility
18 6 Tons Manure/acre per year

Continuous Timothy
plot 22 6 Tons Manure/acre per year
23 No Fertility

Continuous Wheat
plot 2 Full Fertility
5 6 Tons Manure/acre per year + Nitrogen
9 No Fertility
10 6 Tons Manure/acre per year

C-W-RC
plot 25 6 Tons Manure/acre per year
26 Full Fertility
27 No Fertility
28 Full Fertility minus Nitrogen

Cropping Systems Initiated in 1990

Continuous Soybeans
plot 39 Full Fertility

C-W-RC (since 1950)
plots 1, 3, & 4

GS-SB-W(rc green manure)
plots 19, 20, & 21-Full Fertility

C-SB-W-RC
plots 11, 13, 16, & 29-Full Fertility
plots 12, 14, 15, & 30-Full Fertility minus Nitrogen

C-SB-W(rc green manure)
plot 31 Full Fertility
32 Full Fertility minus Potassium
33 Full Fertility minus Phosphorus
34 6 Tons Manure/acre per year
35 No Fertility
36 Full Fertility(clover omitted)
37 Full Fertility
38 Full Fertility

Research, Teaching, and Demonstration
plots 24S(tall fescue), 40, 41, 42, 43, & 44 –
Full Fertility
45(warm season grass)-Burn Only

WS-Weather Station

Weather

The effects of weather conditions on growth and development of non-irrigated agriculture crops in Missouri plays a major roll. The weather data that is presented in Table 1 was collected from a weather station located on Plot 24 on Sanborn Field. In 1994, an automatic weather station was placed on the north half of plot 24. In 2003 the weather station was updated to allow for real time weather information to be obtained. This information is feed back to computer on campus and is available for viewing on the web at aes.missouri.edu/sanborn/weather/sanreal.stm.

Table 1. Temperature and precipitation data measured on Sanborn Field in 2006-07.

Month	**Maximum Temp. Avg.**		**Minimum Temp. Avg.**		**Precipitation Totals**	
	2007/08	31 year	2007/08	31 year	2007/08	31 year
2007						
September	84.1	78.8	61.3	56.1	1.62	3.12
October	71.7	67.4	51.3	45.5	2.96	3.03
November	56.9	53.7	36.1	35.1	1.99	3.37
December	40.7	41.6	25.9	24.5	3.02	2.24
2008						40.2
January	41.7	38.0	21.6	20.7	2.72	1..82
February	39.9	42.7	23.0	24.0	3.22	2.22
March	54.5	54.6	33.5	33.9	4.52	2.76
April	64.3	65.8	43.9	44.2	4.91	4.31
May	73.1	74.5	53.2	53.9	6.42	5.19
June	83.8	82.8	64.4	62.8	6.12	4.37
July	86.9	88.5	68.2	67.6	10.21	4.10
August	83.9	87.3	65.4	65.6	2.83	4.36
September	72.1	78.6	58.5	56.2	10.77	3.37
October	67.8	67.4	47.2	45.6	1.95	3.00
November	52.9	53.7	35.6	35.1	1.08	3.30
December	40.9	41.6	20.7	24.3	2.23	2.24
Total or avg.	63.3	61.2	45.4	42.4	56.98	41.04

Cropping Systems

Continuous Wheat: Plots 2, 5, 9, and 10

Continuous wheat has been grown on Sanborn Field since the fall of 1888. The management of each of these plots is the same expect for differences in the fertility treatments. These treatment consist of plot 2 receiving full fertility treatments, plot 9 with no treatment, plot 10 with 6 tons/acre applied annually and plot 5 having manure applied at a rate of 6 tons/acre plus 40# of N to the acre with ammonia nitrate (34-0-0) being the source. Yield results for the continuous wheat plots can be seen in Table 2.

Table 2-Harvest data of winter wheat from plots 2, 5, 9, and 10 on Sanborn Field in 2008.

		2008 Yield	2008 Yield	Average Yields	Average Yields
		Bushels/	Kilograms/	1978-2008	1978-2008
Plot	Treatments	Acre	Hectare	Bushels/Acre	Kg/Ha
2	Full Fertility	13.2	887	25.3	1700
5	Manure + N	21.5	1445	25.9	1740
9	None	15.6	1048	9.3	625
10	Manure	34.5	2318	29.4	1949

Continuous Corn: Plots 6, 7, 17, and 18

Historic plots 17 and 18 have been in continuous corn since 1889. The treatments for plots 17 and 18 are no fertility applications and 6 tons of manure per acre, respectively. Plots 6 and 7 have been in continuous corn since 1950 and both have received full fertility treatments based on yield goal and soil test. Plot 7 was established in 1971 as a no-till plot. Yield data from the continuous corn plots can be found in Table 3.

Table 3-Harvest data of corn from plots 6, 7, 17, and 18 on Sanborn Field in 2008.

		2008 Yield	2008 Yield	Average Yields	Average Yields
		Bushels/	Kilograms/	1978-2008	1978-2008
Plot	Treatments	Acre	Hectare	Bushels/Acre	Kg/Ha
6	Full Fertility	167.2	10,483	107.1	6715
7	Full Fertility	155.8	9,769	94.5	5925
17	None	27.6	1731	12.5	784
18	Manure	35.2	2207	51.6	3235

Continuous Soybean: Plot 39

In 1990 the Second Century Plan outlined that plot 39 would be in continuous soybean production. The reasoning for looking at such a system is to assess the changes in weed, insect, and disease pressures compared to soybean production in a rotation. This plot does receive a full fertility treatment. This plot yielded 29.5 bushels per acre (1981 kg/ha) in 2008.

Continuous Forages: Plots 22, 23, 24, and 45

The objectives of the continuous forage crops were to continue the treatments and management of the historical timothy plots (22 and 23) and to demonstrate alternative forages for teaching purposes (24S and 45). Timothy has been grown continuously on plot 22 and 23 since 1888. Plot 22 has received 6-tons of manure per acre annually and plot 23 has received no additional fertilizer applications. Periodic reseeding is required on these historical plots due to stand decline and weed encroachment**.** The tall fescue in plot 24 south (24S) is used for demonstration purposes. The reason this plot is designated as south is because the north half of this plot contains the Sanborn Field weather station. Yield results for plots 23, 24, and 25 can be found in Table 4.

Table 4. Harvest data from the continuous forage crops on Sanborn Field in 2008.

Plot	Crop	Treatment	2008 Forage Yields Tons/Acre	2008 Forage Yields Kg/Hectare	Average* Forage Yields Tons/Acre	Average* Forage Yields Kg/Hectare
22	Timothy	Manure	3.47	7772.8	3.11	6966.4
23	Timothy	None	2.17	4860.8	1.55	3472.0
24	Tall Fescue	Full Fertility	4.77	10684.8	4.27	9564.8

*Averages for plots 22, 23, 24 are based data from 1991-2008.

Three-Year Rotation (Corn-Wheat/rc-Red Clover): Plots 1, 3, 4, 25, 26, 27, and 28

The historic rotation plots 25, 26, 27, and 28 were initiated in 1888, whereas plots 1, 3, and 4 were started in 1950. The treatments for the plots is as follows: plots 1, 3, 4, and 26 receive full fertility, plot 25 receives 6 tons of manure per acre annually, plots 28 receives full fertility minus the additions of nitrogen, and plot 27 has no additional fertilizer added. The treatment on plot 28 was started in 1990 to evaluate the relative nitrogen contributions from the red clover in the rotation. Yield data for this three-year rotation can be seen in Table 5.

Table 5. Harvest data from the corn-wheat/rc-red clover rotation on Sanborn Field in 2007.

			Yield							
		2008	2008	2008	2008	2008	Average*			
Plots	Treatment	Crop	Grain	Grain	Forage	Forage	Grain		Forage	
			Bu/ acre	Kg/ ha	Tons/ acre	Kg/ ha	Bu/ acre	Kg/ ha	Tons/ acre	Kg/ ha
1	Full	Wheat/RC	19.3	1297			32.8	2206		
3	Full	RC			4.72	10,573			2.50	5606
4	Full	Corn	138.0	8652.6			136.1	8533		
25	Manure	RC			4.77	10,685			4.27	9559
26	Full	RC			4.35	9,677			3.95	8842
27	None	RC			5.45	12,208			2.94	6580
28	Full-N	RC			5.48	12,275			4.29	9610

*Average is based on the past 4 times that particular plot was in the same crop as the year 2008

Bu/acre = Bushels/Acre Full=Full Fertility Treatment Full-N=Full Fertility minus Nitrogen Treatment

Three-Year Rotation (Grain Sorghum-Soybeans-Wheat (rc): Plots 19, 20, and 21

This rotation was started in 1990 with the Second Century Plan. The objective of these plots is to obtain soil and crop data for a comparison to like rotations that use corn instead of grain sorghum.
Bird cages were built with chicken wire to keep the birds from the yield strips in the grain sorghum plot and in 2004 the cages where modified with a smaller mesh bird netting to remedy the problems that occurred in the past. Yields for this three year rotation can be found in Table 6.

Table 6. Harvest data form the grain sorghum-soybean-wheat (rc) rotation on Sanborn Field in 2007.

Plots	Treatment	2008 Crop	Yields 2008 Grain Bu/Acre	2008 Grain Kg/Ha	Average* Grain Bu/Acre	Average* Grain Kg/Ha
19	Full Fertility	Wheat/(Red Clover)	57.8	3884	51.9	3488
20	Full Fertility	Soybeans	29.8	2003	40.7	2735
21	Full Fertility	Grain Sorghum	No harvest	No harvest	**	**

*Average is based on the past 4 times that the particular plot was in the same crop as it was in 2008.
** Only one harvest in last 3 cycles
Bu/Acre=Bushels/Acre (red clover) is plowed down and no harvest yeilds are taken

Three-Year Rotation (Corn-Soybeans-Wheat (rc): Plots 31, 32, 33, 34, 35, 36, 37, and 38

This set of plots provides many different treatments for comparisons. All plots in the rotation except for plot 36 utilize a frost seeded red clover/lespedeza mix as a fall plow-down to supply part of the nitrogen to the proceeding crop. A lay out of the plot design is as follows:

Plot	Treatment
31, 37, 38	Full fertility treatments
32	Full fertility treatments minus the additions of potassium
33	Full fertility treatment minus the additions of phosphorus
34	Manure applied at a rate of 6 tons per acre per year
35	No treatment
36	Full fertility treatments minus the red clover/lespedeza plow-down

Yields for this three-year rotation can be seen in Table 7.

Table 7. Harvest data form the corn-soybean-wheat (rc) rotation on Sanborn Field in 2008.

			Yields			
Plots	Treatment	2008 Crop	2008 Grain Bu/Acre	2008 Grain Kg/Ha	Average* Grain Bu/acre	Average* Grain Kg/Ha
31	Full	Wheat/(rc)	40.1	2695	49.9	3355
32	Full-K	Wheat/(rc)	50.4	3387	52.5	3525
33	Full-P	Wheat/(rc)	30.4	2043	36.7	2463
34	Manure	Wheat/(rc)	28.9	1942	42.8	2874
35	None	Wheat/(rc)	28.3	1902	30.1	2021
36	Full-(rc)	Wheat	25.7	1727	40.3	2713
37	Full	Corn	186.4	11,687.2	139.5	8747
38	Full	Soybean	35.9	2412	37.4	2512

*Average is based on the past 4 times that particular plot was in the same crop as the year 2008.

Bu/acre = Bushels/Acre

(red clover) is plowed down and no harvest yields are taken

Four-Year Rotation (Corn-Soybeans-Wheat/rc-Red Clover): Plots 11, 12, 13, 14, 15, 16, 29, and 30

The main objective in this four-year rotation is to measure the impact of using no additional fertilizer nitrogen versus nitrogen application. Plots11, 13, 26, and 29 all receive fertilizer nitrogen and plots 12, 14, 15, and 30 do not receive any additional nitrogen. All the plots in this series receive full fertility application of fertilizer except the nitrogen which was stated earlier. Harvest data for this set of plots can be seen in Table 8.

Table 8. Harvest data from the corn-soybeans-wheat/rc-red clover rotation on Sanborn Field in 2008.

Plots	Treatment	2008 Crop	2008 Grain Bu/ acre	2008 Grain Kg/ Ha	2008 Forage tons/ acre	2008 Forage Kg/ Ha	Average* Grain Bu/ acre	Average* Grain Kg/ Ha	Average* Forage tons/ acre	Average* Forage Kg/ Ha
11	Full Fertility	Soybean	28.4	1908.5			40.7	2735		
12	Full Fertility-N	Soybean	34.3	2305.0			44.2	2970		
13	Full Fertility	Wheat/Red Clover	42.6	2862.7	2.23	4995	48.9	3286	1.68	3763
14	Full Fertility-N	Wheat/Red Clover	34.0	2285	2.36	5286	37.2	2502	3.78	8467
15	Full Fertility-N	Red Clover			5.60	12,544			6.85	15,351
16	Full Fertility	Red Clover			4.16	9318			3.99	8930
29	Full Fertility	Corn	130.2	8163.5			137.1	8598		
30	Full Fertility-N	Corn	112.7	7066.3			132.6	8318		

*Average is based on the past 3 times that particular plot was in the same crop as the year 2008.
Bu/Acre = Bushels/Acre
N/A=Not Applicable-no yields were taken

Agricultural Lime

Progress Reports

Title: Using Dolomitic Limestone and Timing of Phosphorus Fertilization to Maintain High Leaf Phosphorus and Magnesium Concentrations in Stockpiled Fescue During the Winter

PI: Dale G. Blevins, Professor & Kemper Fellow, Division of Plant Sciences

Objective: to maintain high phosphorus (P) and magnesium (Mg) concentrations in tall fescue leaves in late winter by using dolomitic limestone (Mg source) and the correct timing of P applications. The dolomitic limestone should provide more soil Mg and the (timing) application of half of the P fertilizer during winter months may boost leaf Mg concentration during these months.

Procedures: A K31, endophyte-infected, established tall fescue pasture was selected at the Southwest Center near Mt. Vernon, MO. Soil samples were collected in June and analyzed by the University of Missouri Soil Testing Laboratory (Table 1). The soil pHs for this plot area was below 6.0 and the Bray I P levels were 10 lbs/acre or lower. The Bray 2 levels were also extremely low. The soil Mg levels were in the medium range, according to the University of Missouri Soil Testing Laboratory. These soil test results are very typical of tall fescue pastures used in much of the state.

In mid-July, forage was cut and removed from the plot area. Plots were established with the following dimensions: 10' x 25' with 5' alleys. On July 19, dolomitic limestone (ENM = 467 & EMG = 137) was applied to specific plots at a rate of 0 or 2000 lbs/acre (Fig. 2). During late August, forage was harvested and removed from the plot area and, on September 7, 100 lbs N/acre (as urea) was applied to all plots. In mid-September, a total of 25 lbs P/acre was applied to the September P treatment plots and all other P treated plots were treated with 12.5 lbs P/acre, as 0-46-0, Then in October, the October plots were treated with their remaining 12.5 lbs P/acre, and in November and December, those specific P-treated plots received their remaining 12.5 lbs P/acre. January and February plots were treated with their final 12.5 lbs/P acre in 2008. Starting in October 2007, 20 of the most recently collared leaves from each plot were harvested monthly. Leaf samples from the September through December harvests are currently dried and are in the process of being ground, digested in nitric acid in our microwave digestion system, diluted, filtered and analyzed for macro- and micronutrient concentrations by ICP.

Results: Just a reminder that the key treatments in this study involve applying one-half of the P fertilizer (12.5 lbs/acre) in September and the other half (12.5 lbs/acre) in one of the months of the stockpiling season. The September treatment (a control treatment) received all 25 lbs P/acre in September. The split P applications in Nov and Dec were best for increasing leaf P concentrations form Jan through Mar (Fig. 1). The split application in other months also increased leaf P concentrations, but not as effectively as the Dec treatment. The Dec split P application was best for increasing leaf Mg concentration in Feb and Mar (Fig. 2). Interestingly, all of the P treatments ere effective at decreasing leaf K concentrations in Feb and Mar (Fig. 3). High leaf K concentration combined with low leaf Mg and Ca concentrations are considered important factors contributing to the cause of grass tetany in beef cows. Dolomitic limestone application was not very effective in increasing Ca concentrations of stockpiled tall fescue leaves in this study (Fig. 4). However, split P applications made from Oct through Feb were effective in increasing leaf Ca concentrations in late winter. All of the leaf Ca concentrations were about the 0.3% required in the diet of a lactating beef cow.

Summary: The design of this experiment was based on results that we observed on a poultry litter experiment where we used an equivalent amount of fertilizer applied in three installments to mimic the slow release of nutrients from litter. A Dec fertilizer treatment in that experiment increased leaf P in Jan

and Feb. Our hypothesis was that Dec P treatments might also increase leaf Mg concentrations, based on other research that we have done linking P fertilization with Mg uptake. Indeed this was the case in the present experiment, where the Dec treatment with 12.5 lbs P/acre increased leaf Mg concentration in Feb and Mar, and all P fertilization treatments increased leaf P concentrations each month of the study. In addition, the P application increased leaf Ca and lowered leaf K concentrations. In putting all of these results together, the macronutrient quality of the forage should be improved by the Dec application of P.

In summary, it looks as thought Dec P fertilization is good for improving forage quality of stockpiled tall fescue in late winter months.

Figure 1. Leaf P concentrations of stockpiled tall fescue following liming with dolomitic limestone and split P fertilization applications. Note that the December P fertilization split was best for increasing leaf P concentrations in late winter months.

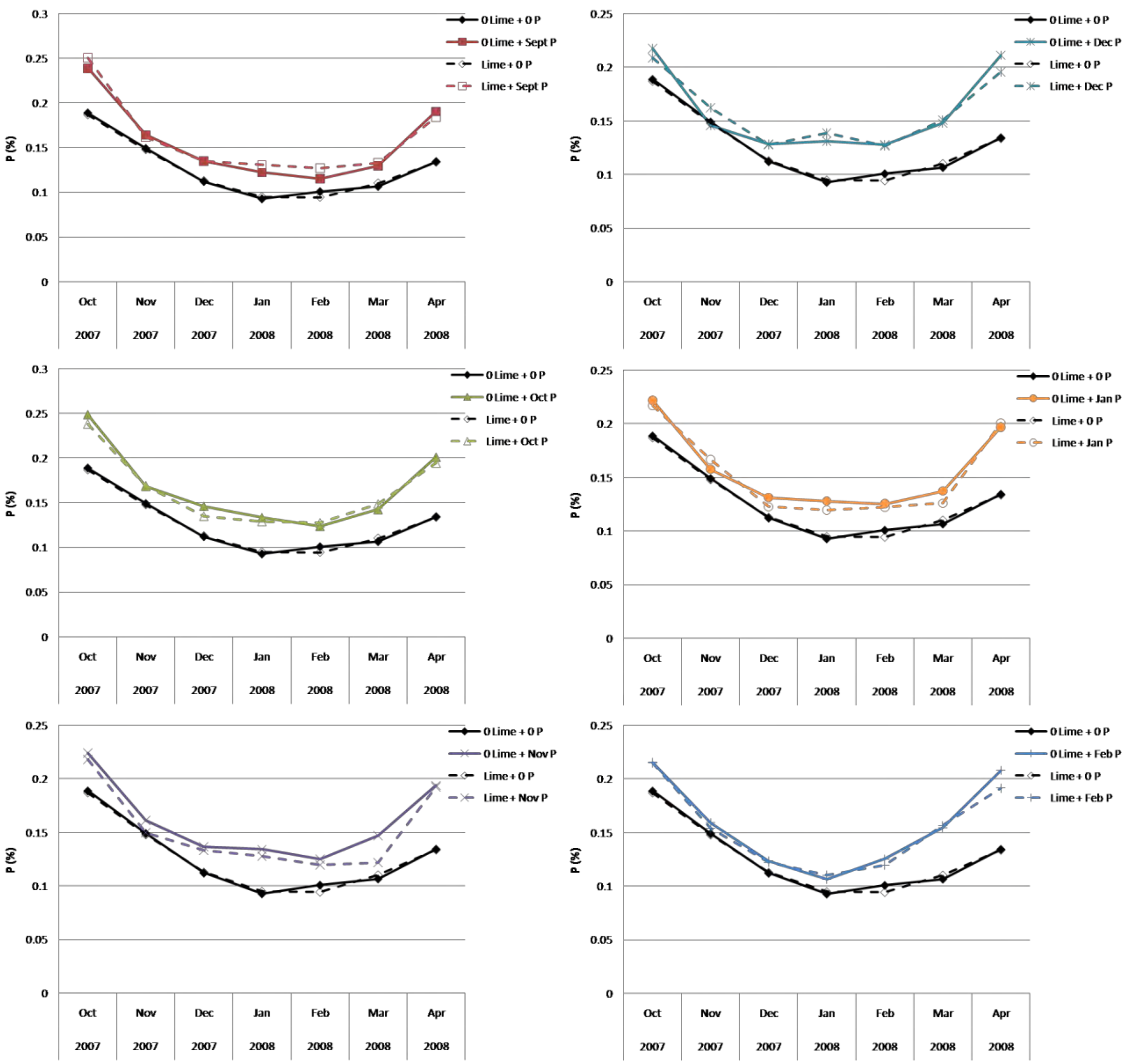


Figure 2. . Leaf Mg concentrations of stockpiled tall fescue following liming with dolomitic limestone and split P fertilization applications. Note that the December P fertilization split was best for increasing leaf Mg concentrations in late winter months.

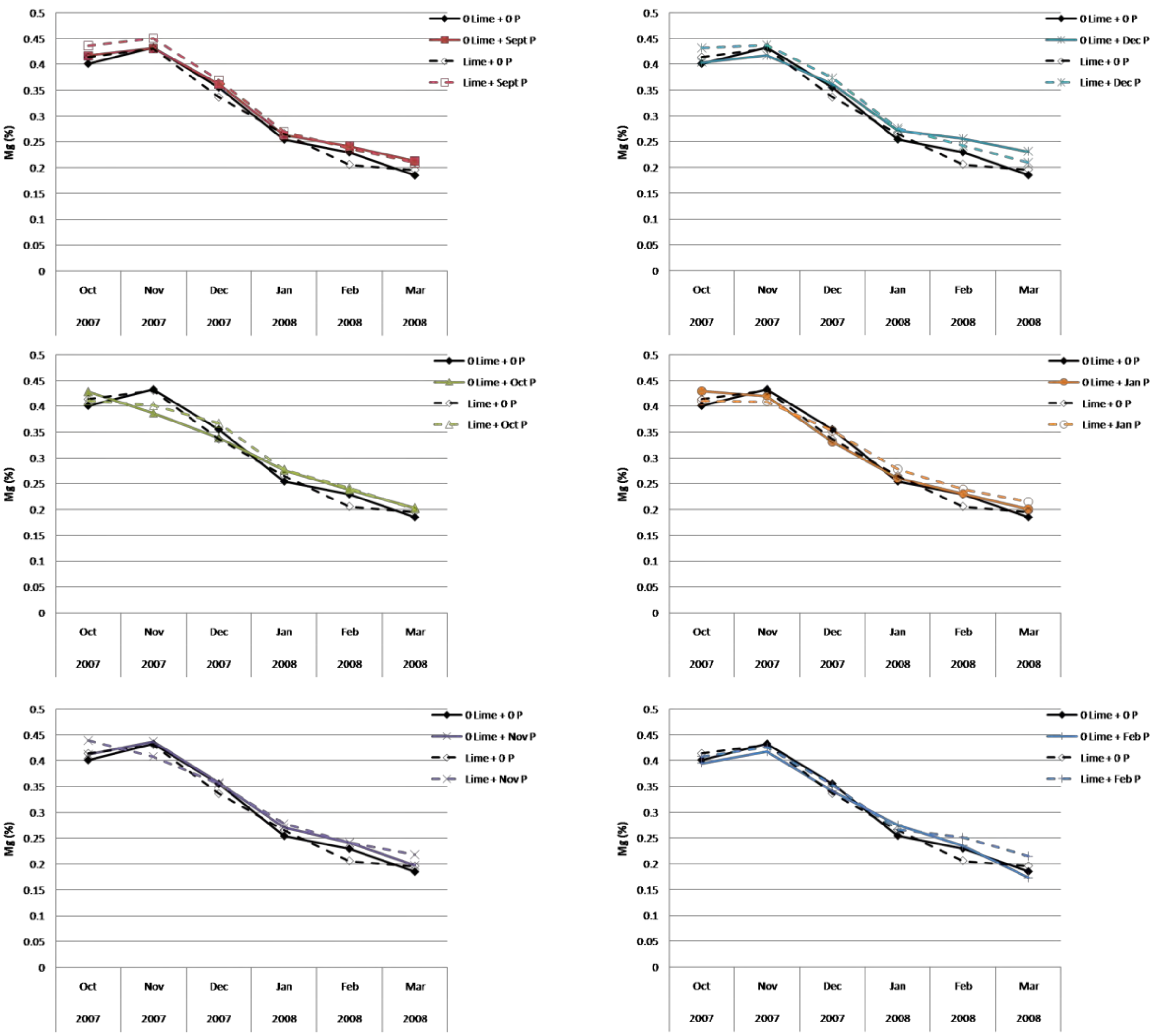


Figure 3. . Leaf K concentrations of stockpiled tall fescue following liming with dolomitic limestone and split P fertilization applications.

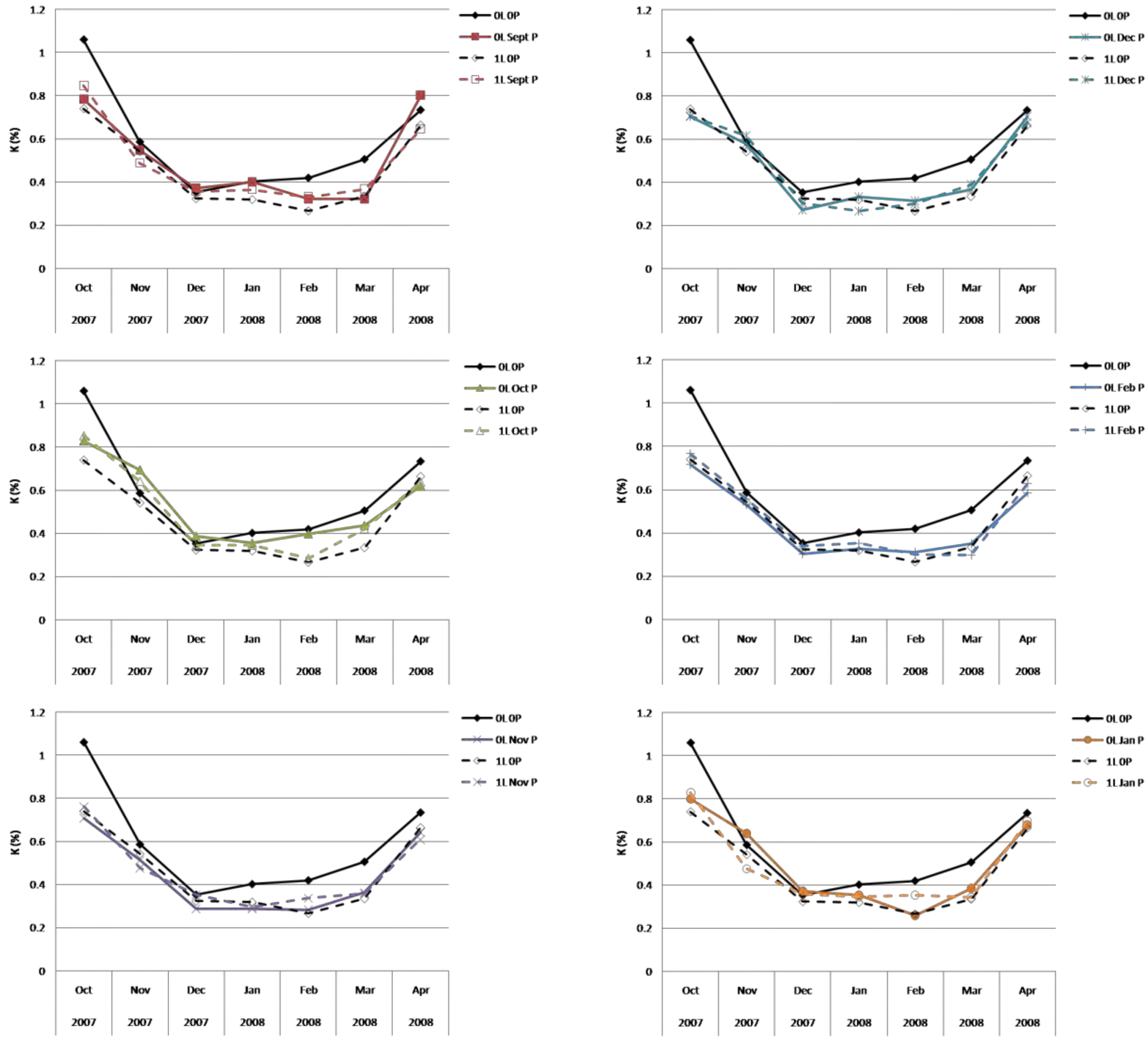
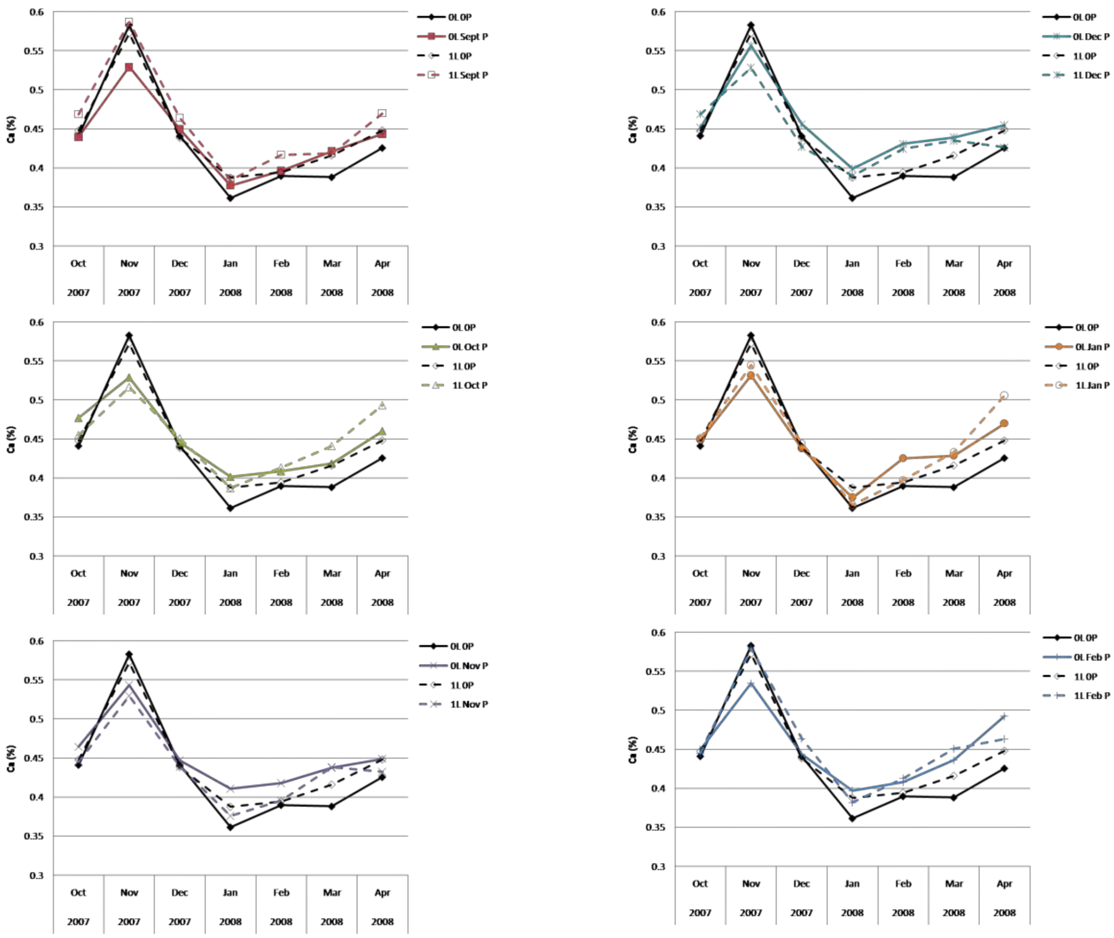


Figure 4. . Leaf Ca concentrations of stockpiled tall fescue following liming with dolomitic limestone and split P fertilization applications. Note that the December P fertilization split was a little better for increasing leaf Ca concentrations in late winter months.



Influence of pH on Carryover of Triketone Herbicides in Missouri No-till Corn and Soybean Rotations

Missouri Fertilizer and Lime Council

Progress Report, 2008

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Accomplishments in 2008:

- Lime and iron sulfate applications were made in late winter/early spring to maintain the desired range in soil pH levels. The soil pH treatments in this experiment are: 1) high lime, 2) low lime, 3) high acid (iron sulfate), 4) low acid (iron sulfate), and 5) 'no amendment' (limed just enough to maintain initial pH). Lime was applied to the 'high lime' plots and iron sulfate was applied to the 'high acid' plots. These applications were made based on the fall 2006 pH in each plot, as these plots had been maintained with varying soil pH levels at the Bradford Research and Extension Center for a number of years. A small lime application was also made to the 'no amendment' treatment (the first in 9 years) to counteract the acidifying effect of nitrogen fertilizer over that span and return the treatment to its original pH.
- One-half of the research area was no-till planted into corn while the other half of the research area was no-till planted into soybeans. Due to poor planting conditions that were experienced throughout the spring, corn was not able to be planted until May 15th, approximately 4 weeks behind normal planting for the Columbia location. The experiments were arranged in a split-plot design with four replications of four herbicide treatments and five soil amendment treatments/pH ranges. Soon after corn planting, a preemergence application of Dual II Magnum® (*S*-metolachlor) was made to reduce early season weed competition and reduce overall weed pressure. Dual II Magnum® is also labeled for use in soybean, thus there is no chance of carryover injury to soybean in 2008 as a result of applications of this herbicide. A Roundup Ready® corn and soybean hybrid was also utilized in these experiments in order to keep all plots weed-free throughout the season with applications of glyphosate (Roundup®).
- Herbicide treatments evaluated for carryover potential in 2009 were applied on June 21st to corn that was 29- to 30-inches tall. The herbicide treatments applied to each soil amendment treatment were 1) Callisto® at 3 fluid ounces per acre, 2) Impact® at 0.75 fluid ounces per acre, 3) Laudis® at 3 fluid ounces per acre, and 4) an untreated control.
- Unfortunately, a severe error was made soon after soybean emergence which eliminated any possibility of determining carryover injury to soybeans from the 2007 herbicide applications. Due to an error made in the mixing lab, all soybeans received an application of a non-labeled herbicide that killed all soybeans in this half of the 2008 experiment. As explained below, we are requesting a no-cost extension of this grant for one additional growing season in order to provide the results agreed to initially.

- Corn was harvested from all plots with a small plot combine and grain yields determined. Corn yields were taken in this set-up year in order to determine the response of corn to the varying soil pH's that have been established, but evaluating corn yield response to pH is not really a primary objective of this research. The soybean yields that will be collected over the course of the next two seasons in response to each herbicide and pH level will be one of the primary objectives of this research. The following table provides the 2008 corn yield results:

	Yield[a]	
Treatment	Corn	Soybean
	------------- Bu / A -------------	
Low Lime (avg. pH_s 6.6)	106 a	----
High Lime (avg. pH_s 7.1)	115 a	----
Low Acid (avg. pH_s 5.0)	113 a	----
High Acid (avg. pH_s 4.3)	111 a	----
No Soil Amendment (avg. pH_s 5.9)	109 a	----

[a]Means followed by the same letter are not different, $P \leq 0.05$.

Objectives for 2009:

- All corn plots from 2008 will be rotated into soybeans. A Roundup Ready® soybean variety will be no-till planted and early-season soybean stunting and injury in response to the previous corn herbicide treatments and pH levels will be evaluated visually and by measuring the heights of soybeans in response to each treatment. All soybean plots will be maintained weed-free throughout the season and yields determined.
- Conversely, all soybean plots from 2008 that were inadvertently killed with the corn herbicide treatments will be no-till planted with corn and the same four triketone herbicide treatments discussed previously will be applied to plots having the variation in soil pH values. As in the first year experiments, corn will be harvested and grain yields determined. Then, we are proposing a no-cost extension of this project in order to plant soybeans into these plots in 2010 and evaluate any carryover injury in the same manner as discussed previously. In this manner, we will still be able to provide two years of data pertaining to soybean carryover injury response to these herbicides and pH ranges as initially proposed.

Budget Request for 2009:

Category	2007	2008	2009	Total
Salary				
Research Associate (20% in years 1 & 2, 10% in year 3)	12,000	12,000	6,000	30,000
Fringe Benefits (31%)	3,720	3,720	1,860	9,300
Materials and Supplies (seed, stakes, herbicides, etc.)	1,000	1,000	500	2,500
Soil Analyses	800	800	800	2,400
Total	$17,520	$17,520	$9,160	$44,200

Nitrogen Management

Final Reports

Alternative Nitrogen Fertilizers for Tall Fescue Pastures

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Tall fescue grows on more than 12 million acres and provides forage for more than 4 million beef cattle in Missouri. About one-half of all tall fescue acres receive some nitrogen (N) fertilizer in spring. Most of these applications are made in March or early April. Another time in which tall fescue acres are fertilized with N is in late-summer for autumn stockpiling.

In past years, ammonium nitrate and urea have been the most popular sources of N for spring and late-summer fertilization. Ammonium nitrate is widely considered the "safest" source of N for forage production, particularly for late-summer applications, as the N in ammonium nitrate is much less likely to be lost to volatilization than is urea. However, ammonium nitrate has become a homeland security issue for the fertilizer industry because it can be used as an explosive. Additionally, few new ammonium nitrate plants have been constructed in the United States over the last 20 years, and given the current economic and security climate, domestic production is likely to decline over the next 10 to 20 years. These factors make ammonium nitrate more expensive than other N sources.

Given the pricing structure and potential problems with ammonium nitrate, urea is becoming more widely used as a N source for forage production. This is due to urea's wider availability and lower cost per N unit when compared to ammonium nitrate. In fact, in many rural parts of Missouri, the only source of N available for pastures is urea. While urea is a common source of N fertilizer for row crop applications in spring, its use for fertilization of pastures is problematic due to excessive nitrogen volatilization. Up to 40% of the N applied to pastures as urea can be lost due to volatilization if rainfall does not occur within 48 hours of an application. Given these problems, farmers are looking for a reliable and inexpensive source of N for pastures.

Some old and new technologies might help alleviate these problems. The most promising solutions are to use a non-volatilizing N source such as ammonium sulfate or to treat urea fertilizer with a volatilization inhibitor. Ammonium sulfate is a sulfur rich (24% S), cost competitive, non-volatilizing source of nitrogen. In addition, several companies have developed products reported to reduce or eliminate volatilization of urea under field conditions. While the technology behind these "urea stabilization products" varies, there has been little "head-to-head" testing under typical field conditions. Technologies that allow safe application of urea would alleviate concerns from farmers and the fertilizer industry, but research is needed to determine which of these products would be most useful for fertilizing pastures in Missouri.

Over the past three years, we have conducted experiments to examine the best alternative to ammonium nitrate fertilizer for spring and late-summer N applications to tall fescue pastures. Specifically, we have compared ammonium nitrate to ammonium sulfate, urea, coated urea products, and mixtures of ammonium sulfate with urea and mixtures of ammonium sulfate with ESN polymer coated urea as a source of nitrogen for tall fescue.

Procedures:

Experiment 1 (Spring applied N treatments).

Treatments: Established tall fescue was fertilized with 75 lb/acre N in mid-March at the Southwest Research and Education Center near Mount Vernon, MO and at the Bradford Research and Extension Center near Columbia, MO. Products were tested in 2005, 2006, and 2007 at Mt. Vernon and in 2006 and 2007 at Columbia. The sources of N are listed in Table 1 and include several urea based products already on the market, mixtures of some of these products, as well as untreated urea, ammonium sulfate, and ammonium nitrate as checks. The 75 lb/acre N rate was selected because it is a common fertilization rate for producers. Soil P and K levels were maintained at levels recommended by the University of Missouri Soil Testing Laboratory.

Experiment 2 (Late-summer applied N treatments).

Treatments: Established tall fescue was fertilized with 75 lb/acre N in mid-August at the same locations (but different plot areas) as described above for Experiment 1. The same sources of N were used as in Experiment 1. Our focus for this experiment was on autumn growth for stockpiling or deferred grazing.

Design: Each treatment in both experiments is replicated five times in a randomized complete block design. Individual plots are 10 ft. x 35 ft.

Measurements. For the spring N application (Experiment 1) forage yield was measured in late May, late July and early October in 2005, 2006, and 2007. For the late-summer application (Experiment 2) yield was measured in late November or early December. Forage yield was determined by clipping a 4-ft. x 25-ft. strip in each plot using a Hege sickle-bar harvester.

At each date, sub-samples of forage harvested from each plot were retained for forage quality analyses {crude protein (CP) and *in vitro* true digestibility (IVTD)}. Samples were dried at 122° F in a forced-air oven before being ground to pass a 1-mm screen. Crude protein and IVTD were measured using near infrared reflectance spectroscopy.

Results:

Experiment 1

<u>Forage Yield</u>. Our data show that only the initial harvest responded to N applied in March. Between 60 and 80% of the annual dry matter was harvested at the initial sampling date in May and few treatment differences were measured in the two subsequent harvests; thus yields are only shown for the initial harvest each year (Table 2). We hypothesized that the "coated urea" products might have yielded greater than uncoated urea products in the summer or autumn after application because of their slow N release activity. But typically, this was not the case.

Ammonium sulfate ranked in the top producing group at nearly all harvests and locations, but only produced more forage than ammonium nitrate in 2007 at Mt. Vernon. Tall fescue fertilized with ammonium sulfate produced over 1000 lb/acre more forage than that fertilized with urea in the spring of 2005 and 2007 at Mt. Vernon. Urea and ammonium nitrate produced equal amounts of forage in every case except that yields from plots fertilized with urea produced about 500 lb/acre less than ammonium nitrate in 2007. In each case precipitation was not recorded for 3 to 6 days after fertilizers were applied in mid-March. Thus, some volatilization of N as ammonia from the urea probably occurred.

Treating urea with Agrotain or using a coated urea product like Nurea or ESN would have theoretically prevented or slowed urea volitization. These different products however, were not equal. Adding Agrotain to the urea, likely prevented volitization and thus provided greater yields in the spring of 2007 at Mt. Vernon. However, yields from tall fescue fertilized with untreated urea and those fertilized with Agrotain treated urea were equal at all other times. Forage yields from tall fescue fertilized with Nurea were never different from those fertilized with untreated urea. Fertilizing with ESN polymer coated urea nearly always lead to poorer spring yields than just using untreated urea.

We should note that in Columbia ample precipitation was recorded each year within 5 days of the fertilizer application to get urea into the soil solution. An extended dry period after application may have resulted in more volatilization of urea and thus a comparative advantage for the "coated urea" products.

Thus far, our data show that a spring application of 75 lb/acre N increased yields by an average of 2354 lb/acre over the unfertilized control or about 31 lb of additional forage for each lb of N fertilizer applied. Ground moisture affected this relationship drastically as the range was 1800 to over 3500 lb/acre or 23 to 46 lb of additional forage for each lb of N fertilizer applied.

Forage Quality. When plots were fertilized in March, IVTD was rarely affected by the form of the fertilizer used. Only twice out of 15 harvests (3 harvests per year over 5 site-years) did treatments affect the digestibility of forage. In these two cases, the top ranking group was comprised of one third to one half of the treatments. Further, the unfertilized control showed the greatest IVTD in one of these instances. We ignored these small differences as they are not entirely germane to the research. Harvest month did affect IVTD of forage and the data are presented in Table 3. The general response was that forage harvested in spring was of lower digestibility than the regrowth harvested in summer and autumn.

The response of CP to fertilizer form was affected by year, location, and harvest month; these data are presented by harvest for each location and year. For plots fertilized in March, only the first harvest in May showed treatment effects in the first year (Table 4). There were no residual effects of the treatments on summer or autumn CP levels. The greatest concentration of CP was shared by four treatments that did not differ and had a 25% greater concentration of CP than the unfertilized control. ESN was a component in three of those four treatments and may have provided a constant supply of N longer in the spring to keep CP levels higher than the other treatments. It is noteworthy that all fertilizer forms increased CP concentrations over that of the unfertilized control.

In year, two another location was included in the experiment. Contrary to the first year, there were residual effects of fertilizer treatments on summer and autumn CP concentrations although at times these effects are perplexing to understand (Table 5). At the May harvest, no one treatment contained the highest level of CP at either location, but similar to the first year, treatments that had ESN as a component were in the top ranking group and they contained on average 20% greater CP concentrations than the unfertilized control. Treatments with polymer coatings such as ESN and Nurea were in the top ranking group in autumn at Mt. Vernon. In the summer and autumn at Columbia, the unfertilized control contained the greatest concentration of CP. This may be an artifact of poor forage yields. Fertilizer N was not used for DM production by the plants but instead stored for later use as metabolites.

Year 3 had several similarities to year 2. The treatments with ESN as a component were again in the group with the greatest concentration of CP at both locations in May (Table 6). These groups averaged 12 to 25% higher CP levels than the unfertilized control. At Mt. Vernon, no treatments differed in summer or autumn while at Columbia, the unfertilized control was one of two and eleven treatments with the greatest CP concentration in July and October, respectively.

Soil $pH_{(s)}$. It is well documented that using ammonium sulfate decreases soil pH more rapidly than most other sources of N. Thus we were interested in measuring the change in soil pH as successive applications of these different N sources were applied to the same plots. The final soil pH for each location is shown in Table 7. Only at Mt. Vernon did soil pH respond to the fertilizer treatments where plots fertilized with ammonium sulfate had lower pH than most of the other N sources. However, the magnitude of the response shows that soil pH did not change markedly. For instance, the amount of lime needed to bring the plots fertilized with ammonium sulfate to be equal with the untreated control would be about 50 ENM units which have a value of approximately $2.00/acre. Soil pH in plots fertilized with urea treated with Agrotain was greater than almost every other treatment. Perhaps the slow release technology of Agrotain provides a microenvironment with a continuous amount of highly alkaline ammonia in the soil solution.

Experiment 2

Forage Yield. For N applied in late-summer, many of the products yielded similarly and in most cases 10 or more of the products or product combinations showed equal yields (Table 4). Urea, ammonium nitrate, and ammonium sulfate had comparable yields in two of four site-years. Tall fescue fertilized with urea yielded 35 and 22% less than that fertilized with ammonium nitrate during the autumn of 2005 at Mt. Vernon and the autumn of 2007 at Columbia, respectively. In both of these years, no rain fell with 5 to 7 days of fertilizer application and only a small amount of rain (less than 0.51 inch) fell within 12 days of fertilizer application. Additionally, temperatures were typically in the upper 80's or low 90's for the two weeks following application. This is a classic example of the risk associated with using urea as the N source for late-summer applications to pasture. Treating urea with Agrotain or using Nurea provided enough protection from volatization that forage yields were equal to ammonium nitrate in all cases. However, polymer coated urea (ESN) yielded less than most other treatments. The ESN polymer coated urea has not shown much promise as a substitute for urea or ammonium nitrate for spring or late-summer N applications. We have yet to analyze the forage quality or soil fertility of samples collected in the autumn.

Forage Quality. When plots were fertilized in mid-August for autumn growth, the response of IVTD to fertilizer form depended on year and location. In year 1, eleven treatments made up the top group and the four that were not included all contained ammonium sulfate (Table 9). In year two, there were no treatment differences at Mt. Vernon, while at Columbia, seven treatments averaged 77.4% IVTD. This result was 3 percentage units greater than the unfertilized control. In year 3, fertilizer treatments did not affect the digestibility of forage.

Crude protein response depended on year and location also. At Mt. Vernon in year 1, treatments did not affect CP concentration in forage (Table10). In year 2, ten treatments were included in the top ranking group at Mt. Vernon and had a nearly 25% greater CP concentration than the unfertilized control. At Columbia, the top ranking group was comprised of 4 treatments that all contained ESN and this group had a nearly 20% higher CP concentration than the control. In year 3, ten treatments comprised the top ranking group and averaged 22% greater CP concentration than the unfertilized control.

Conclusions:

1. Using untreated urea is risky. Fertilizing tall fescue with untreated urea worked as well as ammonium nitrate in 4 of 5 site-years in spring. However, for late-summer applications, untreated urea yielded less than ammonium nitrate about half the time.
2. Urea treated with Agrotain provided growth responses equal to ammonium nitrate.
3. Yield of forage receiving ESN by itself or in mixtures with urea or ammonium sulfate often lagged behind other products.
4. Of the 13 times when crude protein was affected by treatment during experiment 1, ESN either by itself or in mixtures was in the top ranking group.
5. Ammonium sulfate was a consistently good product, with yields equal to or in a few cases, better than those from urea or ammonium nitrate.
6. IVTD was rarely affected by fertilizer form during the spring, summer, and autumn of experiment 1. In experiment two, approximately half of the treatments made up the top ranking group when fertilizer form affected forage digestibility.

Table 1. Nitrogen fertilization treatments tested at the Southwest Research and Education Center near Mount Vernon, MO and the Bradford Research and Extension Center near Columbia, MO. Each source is applied to deliver 75 lb/acre N. In addition, rate mixtures of ammonium sulfate/ESN, ammonium sulfate/urea and urea/ammonium sulfate/ESN are included.

Fertilizer Source	For mixture treatments	
	Rate applied (lb/acre S)	% N derived from ESN and/or Urea
Ammonium nitrate		
Urea	-	-
Ammonium sulfate	-	-
Urea treated with Agrotain	-	-
ESN polymer coated urea	-	-
Nurea	-	-
Nurea with 10% polymer N	-	-
Ammonium sulfate (10S)/urea	10	88
Ammonium sulfate (20S)/urea	20	75
Ammonium sulfate (40S)/urea	40	53
Ammonium sulfate (10S)/ESN	10	88
Ammonium sulfate (20S)/ESN	20	75
Ammonium sulfate (40S)/ESN	40	53
Equal N from urea, ammonium sulfate and ESN	28.6	67
Unfertilized control	-	-

Table 2. Forage yield in late May of tall fescue fertilized with different N sources at the Southwest Research and Education Center near Mount Vernon, MO and the Bradford Research and Extension Center near Columbia, MO. Each fertilizer was applied in mid-March to deliver 75 lb/acre of actual N to the same plots each year. The highest yielding treatment within a year and location is in bold type. Treatments that are not significantly different than the highest yielding treatment are marked with an asterisk.

Fertilizer Source	-------- Mt. Vernon -------- 2005	2006	2007	--- Columbia --- 2006	2007
	------------------------lbs/acre------------------------				
Ammonium nitrate	8080	3972*	3647	**4601**	4826*
Urea	7779	3680*	3139	4037*	4716*
Ammonium sulfate	**8832**	**3987**	**4183**	4407*	**4915**
Urea treated with Agrotain	8298*	3873*	3787*	4186*	4686*
ESN polymer coated urea	7133	2114	3371	2738	3673
Nurea	8140*	3408*	3400	4195*	4564*
Nurea with 10% polymer N	7366	3624*	3401	3918*	4308
Ammonium sulfate (10S)/urea	7925*	3716*	3577	3899*	4537*
Ammonium sulfate (20S)/urea	7572	3920*	3744	4303*	4397*
Ammonium sulfate (40S)/urea	7809*	3842*	3490	3548	4646*
Ammonium sulfate (10S)/ESN	7042	2285	3599	3375	3872
Ammonium sulfate (20S)/ESN	6674	2610	3670	3149	4104
Ammonium sulfate (40S)/ESN	7611	3493*	3765*	3803	4702*
Equal N from urea, ammonium sulfate and ESN	7498	3236	3829*	3988*	4831*
Unfertilized control	4231	1653	1565	1688	2166
LSD (0.05)	1023	626	420	790	553
Orthogonal Contrasts					
Urea vs. ammonium nitrate	NS	NS	0.009	NS	NS
Urea vs. ammonium sulfate	0.03	NS	<0.001	NS	NS
Ammonium sulfate vs. ammonium nitrate	NS	NS	0.007	NS	NS
Urea vs. urea treated with Agrotain	NS	NS	0.001	NS	NS
Urea vs. Nurea	NS	NS	NS	NS	NS
ESN mixtures vs. urea mixtures	0.02	<0.001	NS	0.02	0.04
Unfertilized control vs. all others	<0.001	<0.001	<0.001	<0.001	<0.001

Table 3. Concentration of IVTD in forage harvested from plots fertilized with different N sources at the Southwest Research and Education Center near Mount Vernon, MO and the Bradford Research and Extension Center near Columbia, MO. Each fertilizer was applied in mid-March to deliver 75 lb/acre of actual N to the same plots each year. Values are means of 15 treatments because treatment effects were not significant. Within a column, values with different letters differ at the 0.05 alpha level.

	----------Mt. Vernon----------			----------Columbia----------	
Year	2005	2006	2007	2006	2007
Harvest month	--------------------------------% of DM----------------------------------				
May	67.1b	74.4b	71.3b	72.6c	71.9c
July	81.3a	79.6a	78.7a	77.2b	80.8a
October	79.7a	74.6b	71.8b	82.9a	78.9b

Table 4. Concentrations of CP in 2005 of forage harvested from plots fertilized with different N sources at the Southwest Research and Education Center near Mount Vernon, MO and the Bradford Research and Extension Center near Columbia, MO. Each fertilizer was applied in mid-March to deliver 75 lb/acre of actual N to the same plots each year. The treatment with the greatest CP within a column is in bold type. Treatments that are not significantly different than the highest treatment are marked with an asterisk.

	----------Mt. Vernon----------		
Harvest month	May	July	October
Fertilizer Source	----------% of DM----------		
Ammonium nitrate	9.0	9.9	9.9
Urea	9.0	11.1	10.2
Ammonium sulfate	9.5	10.8	11.0
Urea treated with Agrotain	9.4	10.1	9.6
ESN polymer coated urea	**10.4**	10.0	10.6
Nurea	9.4	9.7	10.2
Nurea with 10% polymer N	8.9	10.5	11.2
Ammonium sulfate (10S)/urea	9.4	10.5	10.6
Ammonium sulfate (20S)/urea	9.7*	10.1	10.5
Ammonium sulfate (40S)/urea	9.4	10.4	11.0
Ammonium sulfate (10S)/ESN	9.9*	10.4	10.3
Ammonium sulfate (20S)/ESN	9.5	10.4	10.7
Ammonium sulfate (40S)/ESN	9.6*	11.2	11.4
Equal N from urea, ammonium sulfate and ESN	9.4	11.4	11.1
Unfertilized control	7.5	11.3	10.7
LSD (0.05)	1.0	NS	NS
<u>Orthogonal Contrasts</u>			
Urea vs. ammonium nitrate	NS	NS	NS
Urea vs. ammonium sulfate	NS	NS	NS
Ammonium sulfate vs. ammonium nitrate	NS	NS	NS
Urea vs. urea treated with Agrotain	NS	NS	NS
Urea vs. Nurea	NS	NS	NS
ESN mixtures vs. urea mixtures	NS	NS	NS
Unfertilized control vs. all others	<0.001	NS	NS

Table 5. Concentration of CP in 2006 of forage harvested from plots fertilized with different N sources at the Southwest Research and Education Center near Mount Vernon, MO and the Bradford Research and Extension Center near Columbia, MO. Each fertilizer was applied in mid-March to deliver 75 lb/acre of actual N to the same plots each year. The treatment with the greatest CP within a column is in bold type. Treatments that are not significantly different than the highest treatment are marked with an asterisk.

	----------Mt. Vernon----------			----------Columbia----------		
Harvest month	May	July	October	May	July	October
Fertilizer Source	---------------------------------% of DM---------------------------------					
Ammonium nitrate	9.8	10.1	8.6	8.4	9.8	11.5
Urea	9.1	10.5	9.0	8.4	10.6	12.0*
Ammonium sulfate	10.7*	9.4	9.3	9.0	10.5	11.3
Urea treated with Agrotain	9.7	9.8	9.2	8.1	11.3	11.5
ESN polymer coated urea	11.0*	10.0	**11.1**	**11.5**	11.4	11.7
Nurea	9.7	9.3	8.9	8.2	11.0	11.6
Nurea with 10% polymer N	10.0	9.8	**11.1**	8.2	10.7	11.5
Ammonium sulfate (10S)/urea	10.0	10.4	9.3	8.5	10.6	11.7
Ammonium sulfate (20S)/urea	10.3	10.3	9.5	8.1	11.4	12.1*
Ammonium sulfate (40S)/urea	9.7	10.2	9.7	8.3	10.9	11.8
Ammonium sulfate (10S)/ESN	**11.2**	9.9	11.0*	10.4*	10.7	11.4
Ammonium sulfate (20S)/ESN	11.1*	9.7	10.1*	9.8	11.5	11.6
Ammonium sulfate (40S)/ESN	10.5*	10.0	9.2	9.5	10.1	11.6
Equal N from urea, ammonium sulfate and ESN	11.1*	10.0	10.4*	9.2	9.4	11.8
Unfertilized control	8.7	10.6	9.2	8.7	**13.8**	**12.6**
LSD (0.05)	1.0	NS	1.3	1.4	1.7	0.7
<u>Orthogonal Contrasts</u>						
Urea vs. ammonium nitrate	0.001	NS	NS	NS	NS	NS
Urea vs. ammonium sulfate	NS	0.03	NS	NS	NS	0.02
Ammonium sulfate vs. ammonium nitrate	NS	NS	NS	NS	NS	NS
Urea vs. urea treated with Agrotain	NS	NS	NS	NS	NS	NS
Urea vs. Nurea	0.04	0.02	<0.001	NS	NS	NS
ESN mixtures vs. urea mixtures	0.001	NS	NS	<0.001	NS	NS
Unfertilized control vs. all others	<0.001	NS	NS	NS	<0.001	<0.001

Table 6. Concentration of CP in 2007 of forage harvested from plots fertilized with different N sources at the Southwest Research and Education Center near Mount Vernon, MO and the Bradford Research and Extension Center near Columbia, MO. Each fertilizer was applied in mid-March to deliver 75 lb/acre of actual N to the same plots each year. The treatment with the greatest CP within a column is in bold type. Treatments that are not significantly different than the highest treatment are marked with an asterisk.

	----------Mt. Vernon----------			----------Columbia----------		
Harvest month	May	July	October	May	July	October
Fertilizer Source	----------% of DM----------					
Ammonium nitrate	11.4*	10.1	10.7	9.5	11.9	14.9
Urea	10.2	10.2	9.9	9.0	11.8	15.3*
Ammonium sulfate	11.2*	9.5	9.7	10.6	11.9	13.5
Urea treated with Agrotain	11.0*	10.3	10.6	9.2	11.8	15.9*
ESN polymer coated urea	**12.2**	10.1	10.7	**11.9**	12.0	15.3*
Nurea	9.5	10.2	10.1	9.7	12.1	15.6*
Nurea with 10% polymer N	10.6	10.4	10.5	8.8	12.9*	14.8
Ammonium sulfate (10S)/urea	10.1	10.1	10.0	9.4	12.4	16.4*
Ammonium sulfate (20S)/urea	10.3	10.5	10.4	9.6	11.8	15.0*
Ammonium sulfate (40S)/urea	10.5	10.0	10.5	9.4	12.1	15.3*
Ammonium sulfate (10S)/ESN	12.0*	10.2	9.6	11.6*	11.5	15.9*
Ammonium sulfate (20S)/ESN	11.7*	10.2	10.4	11.1*	12.1	**16.8**
Ammonium sulfate (40S)/ESN	11.8*	9.6	9.0	10.2	12.0	16.2*
Equal N from urea, ammonium sulfate and ESN	11.8*	10.1	9.3	10.1	11.8	14.9
Unfertilized control	8.9	10.0	9.4	10.1	**13.6**	15.5*
LSD (0.05)	1.0	NS	NS	1.0	0.9	1.7
Orthogonal Contrasts						
Urea vs. ammonium nitrate	0.007	NS	NS	NS	NS	NS
Urea vs. ammonium sulfate	0.03	NS	NS	0.001	NS	0.02
Ammonium sulfate vs. ammonium nitrate	NS	NS	NS	0.03	NS	NS
Urea vs. urea treated with Agrotain	NS	NS	NS	NS	NS	NS
Urea vs. Nurea	NS	NS	NS	NS	NS	NS
ESN mixtures vs. urea mixtures	<0.001	NS	NS	<0.001	NS	NS
Unfertilized control vs. all others	<0.001	NS	NS	NS	<0.001	NS

Table 7. Final soil pH of plots treated with different sources of N fertilizer for three (Mt. Vernon) or two (Columbia) successive springs. Each fertilizer source was applied in mid-March to deliver 75 lb/acre of actual N to the same plots each year.

Fertilizer Source	Mt. Vernon	Columbia
	---------- pH(s) ----------	
Ammonium nitrate	5.92	6.92
Urea	5.86	6.92
Ammonium sulfate	5.62	6.76
Urea treated with Agrotain	6.08	7.16
ESN polymer coated urea	5.92	6.84
Nurea	5.94	6.90
Nurea with 10% polymer N	5.70	6.92
Ammonium sulfate (10S)/urea	5.80	6.94
Ammonium sulfate (20S)/urea	5.92	6.95
Ammonium sulfate (40S)/urea	5.70	6.86
Ammonium sulfate (10S)/ESN	6.04	7.02
Ammonium sulfate (20S)/ESN	5.88	6.92
Ammonium sulfate (40S)/ESN	5.56	6.86
Equal N from urea, ammonium sulfate and ESN	5.38	6.86
Unfertilized control	5.84	6.96
LSD (0.05)	0.33	NS
<u>Orthogonal Contrasts</u>		
Urea vs. ammonium nitrate	NS	NS
Urea vs. ammonium sulfate	NS	NS
Ammonium sulfate vs. ammonium nitrate	0.05	NS
Urea vs. urea treated with Agrotain	NS	NS
Urea vs. Nurea	NS	NS
ESN mixtures vs. urea mixtures	NS	NS
Unfertilized control vs. all others	NS	NS

Table 8. Autumn forage yield of tall fescue fertilized with different N sources at the Southwest Research and Education Center near Mount Vernon, MO and the Bradford Research and Extension Center near Columbia, MO. Each fertilizer was applied in mid-August to deliver 75 lb/acre of actual N to the same plots each year. The treatment with the greatest yield within a column is in bold type. Treatments that are not significantly different than the highest treatment are marked with an asterisk.

	---Mt. Vernon---		-----Columbia-----	
Fertilizer Source	2005	2006	2006	2007
	---------------------lb/acre---------------------			
Ammonium nitrate	**1932**	1918*	2700*	**2483**
Urea	1245	2201*	2865*	1935
Ammonium sulfate	1579*	2245*	2787*	2325*
Urea treated with Agrotain	1523*	1880*	2696*	2287*
ESN polymer coated urea	1249	1549	2117	1826
Nurea	1437*	2188*	2738*	2167*
Nurea with 10% polymer N	988	2176*	2725*	2003
Ammonium sulfate (10S)/urea	1696*	2282*	2539*	2041
Ammonium sulfate (20S)/urea	1259	2137*	**2877**	2018
Ammonium sulfate (40S)/urea	1903*	**2327**	2763*	2288*
Ammonium sulfate (10S)/ESN	1856*	1664*	2378*	2110*
Ammonium sulfate (20S)/ESN	1741*	2079*	2243	2044
Ammonium sulfate (40S)/ESN	1761*	1882*	2547*	2298*
Equal N from urea, ammonium sulfate and ESN	1822*	2312*	2819*	2212*
Unfertilized control	492	834	1721	1370
LSD (0.05)	582	668	629	430
Orthogonal Contrasts				
Urea vs. ammonium nitrate	0.01	NS	NS	0.01
Urea vs. ammonium sulfate	NS	NS	NS	0.05
Ammonium sulfate vs. ammonium nitrate	NS	NS	NS	NS
Urea vs. urea treated with Agrotain	NS	NS	NS	NS
Urea vs. Nurea	NS	NS	NS	NS
ESN mixtures vs. urea mixtures	NS	0.04	0.05	NS
Unfertilized control vs. all others	<0.001	<0.001	<0.001	<0.001

Table 9. Autumn concentrations of IVTD in forage harvested from plots fertilized with different N sources at the Southwest Research and Education Center near Mount Vernon, MO and the Bradford Research and Extension Center near Columbia, MO. Each fertilizer was applied in mid-August to deliver 75 lb/acre of actual N to the same plots each year. The treatment with the greatest IVTD within a column is in bold type. Treatments that are not significantly different than the highest treatment are marked with an asterisk.

	-------Mt. Vernon-------		--------Columbia--------	
Year	2005	2006	2006	2007
Fertilizer Source				
Ammonium nitrate	83.1*	80.9	76.7*	83.1
Urea	82.7*	77.6	76.8*	82.8
Ammonium sulfate	81.5	77.2	76.9*	81.9
Urea treated with Agrotain	82.5*	78.3	76.0	83.0
ESN polymer coated urea	83.7*	80.2	**78.5**	83.7
Nurea	83.9*	81.5	75.7	82.4
Nurea with 10% polymer N	**84.0**	80.1	76.1	82.6
Ammonium sulfate (10S)/urea	80.6	76.7	74.4	83.2
Ammonium sulfate (20S)/urea	83.7*	79.5	76.5	83.2
Ammonium sulfate (40S)/urea	81.9*	78.1	75.5	83.3
Ammonium sulfate (10S)/ESN	82.7*	79.7	77.9*	82.5
Ammonium sulfate (20S)/ESN	81.5	78.5	77.0*	82.4
Ammonium sulfate (40S)/ESN	82.3*	79.0	76.1	82.8
Equal N from urea, ammonium sulfate and ESN	81.1	77.4	77.8*	82.8
Unfertilized control	83.7*	78.1	74.4	79.7
LSD (0.05)	2.5	NS	2.1	NS
Orthogonal Contrasts				
Urea vs. ammonium nitrate	NS	NS	NS	NS
Urea vs. ammonium sulfate	NS	NS	NS	NS
Ammonium sulfate vs. ammonium nitrate	NS	0.03	NS	NS
Urea vs. urea treated with Agrotain	NS	NS	NS	NS
Urea vs. Nurea	NS	0.02	NS	NS
ESN mixtures vs. urea mixtures	NS	NS	0.008	NS
Unfertilized control vs. all others	NS	NS	0.003	<0.001

Table 10. Autumn concentrations of CP in forage harvested from plots fertilized with different N sources at the Southwest Research and Education Center near Mount Vernon, MO and the Bradford Research and Extension Center near Columbia, MO. Each fertilizer was applied in mid-August to deliver 75 lb/acre of actual N to the same plots each year. The treatment with the greatest CP within a column is in bold type. Treatments that are not significantly different than the highest treatment are marked with an asterisk.

	-----Mt. Vernon-----		------Columbia------	
Year	2005	2006	2006	2007
Fertilizer Source				
Ammonium nitrate	10.6	**13.5**	10.2	12.2*
Urea	8.5	11.6*	10.5	11.8*
Ammonium sulfate	10.5	12.2*	10.6	11.7*
Urea treated with Agrotain	9.1	11.8*	10.0	11.4
ESN polymer coated urea	10.3	13.0*	**12.5**	12.1
Nurea	9.7	12.4*	10.1	11.1
Nurea with 10% polymer N	9.9	12.6*	10.0	11.7*
Ammonium sulfate (10S)/urea	8.5	10.3	10.3	11.3
Ammonium sulfate (20S)/urea	9.8	12.1*	10.4	11.1
Ammonium sulfate (40S)/urea	8.6	11.1	11.2	11.8*
Ammonium sulfate (10S)/ESN	9.3	13.1*	12.1*	**12.5**
Ammonium sulfate (20S)/ESN	8.4	11.2	12.3*	11.6*
Ammonium sulfate (40S)/ESN	9.5	12.4*	10.8	12.3*
Equal N from urea, ammonium sulfate and ESN	9.0	11.3	11.4*	11.7*
Unfertilized control	8.9	9.3	9.6	9.3
LSD (0.05)	NS	2.4	1.4	1.1
Orthogonal Contrasts				
Urea vs. ammonium nitrate	0.04	NS	NS	0.03
Urea vs. ammonium sulfate	NS	NS	0.001	NS
Ammonium sulfate vs. ammonium nitrate	NS	NS	0.03	NS
Urea vs. urea treated with Agrotain	NS	NS	NS	NS
Urea vs. Nurea	NS	NS	NS	NS
ESN mixtures vs. urea mixtures	NS	NS	<0.001	0.01
Unfertilized control vs. all others	NS	0.001	NS	<0.001

Delineation of High Risk Field Areas for Variable Source N Fertilizer Applications to Optimize Crop N Use Efficiency

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Summary:

Research was conducted in 2007 and 2008 in Northeast Missouri to collect information related to spatial and temporal differences in soil water content and soil N availability across agricultural fields containing low-lying or depressional areas, to determine the spatial variability in crop response and plant N status due to application of different enhanced efficiency N fertilizer sources, and to develop and validate a computer program that would delineate the high risk N loss areas in a form that could be used for variable source N fertilizer application.

- In both years of this research, corn grain yields and plant N status increased significantly with an application of enhanced efficiency fertilizer sources (i.e. urea, polymer-coated urea (PCU), urea + urease inhibitor (UI) and urea + nitrification inhibitor (NI)) compared to the non-treated control depending on the landscape position. However, PCU was the only enhanced efficiency N source that had significantly higher average grain yields (20.4 bu/acre higher in 2007 and 50.0 bu/acre higher in 2008) compared to that of urea over all of the landscape positions.
- Maps of the grain yield differences between the enhanced efficiency N fertilizers and urea across the field indicate that in 2007 these enhanced efficiency fertilizers mainly outyielded urea in the low-lying areas of the field, probably due to differences in the fate of these fertilizers compared to urea under wetter soil conditions in the lower landscape positions of the field. These results confirm earlier research in the same field which observed consistently higher yields when PCU was applied compared to urea in low-lying areas.
- Higher than average rainfall in 2008 (approximately 35 inches during the growing season) and extended periods of saturated soils in the lower areas of the field, resulted in relatively higher yields in the upper landscape positions. Among the enhanced efficiency N fertilizers, PCU showed consistently higher yields compared to urea across all landscape positions.
- Maps of the net economic return for the enhanced efficiency fertilizers versus urea also show that strategic placement of these products in high risk areas of a field increased economic returns over a uniform application of urea or the enhanced efficiency fertilizers in claypan soils, especially in areas where there is variation in elevation and drainage.
- The relative performance of PCU, UI and NI in this research may be affected by the fact that all the fertilizers were immediately incorporated after application compared to surface application.
- Further testing and development of the variable source N fertilizer application strategy and an accompanying software tool are needed under different environmental conditions and on a farm field scale.

Materials and Methods

A field trial planted to corn was conducted in 2007 and 2008 at the University of Missouri Greenley Research Center in Northeastern Missouri. This field was previously mapped for elevation with a total station surveying instrument and apparent electrical conductivity (EC_a) using an EM-38 sensor. Relatively higher EC_a indicates a relatively shallow depth to the claypan subsoil layer. The field was selected because it contained contrasting landscape positions, including low-lying areas, and differences in depth to the claypan layer.

The field was separated into 10 x 750 foot plots which passed through the low-lying and sideslope areas of the field. Nitrogen fertilizer treatments consisted of a non-treated control and 150 lb N/acre of urea, polymer-coated urea (ESN, Agrium, Inc.), urea + NBPT (N-(n-butyl) thiophosphoric triamide) urease inhibitor (UI) at 1 gal/ton (Agrotain, Agrotain International), and urea + nitrapyrin nitrification inhibitor (NI) at 1 qt/acre (N-Serve, Dow AgroSciences) were applied in the spring prior to planting of corn. All the N fertilizer treatments were incorporated using a field cultivator immediately after application. The experimental design was a randomized complete block with four replications.

In each plot, sampling points were set up every 30 feet across the field to allow for periodic collection of soil samples from the 0 to 6 and 6 to 12 inch depths during the growing season for determination of soil water content and soil inorganic N (ammonium and nitrate-N). Three subsamples were taken at each point and composited. All the sampling points were georeferenced using a differential GPS. Figure 1 shows the distribution of soil water content on June 4th, 2007 indicating the variation in soil water content that occurred across this field. In general, the low-lying areas had higher relative soil water content compared to that of the areas with higher elevation. Two additional soil samplings were taken during the 2007 growing season and two soil samplings were taken in June and July, 2008. The soil water content and soil inorganic N levels from the 2008 samplings are still being analyzed.

Sub-plots of 28 ft in row length were established in each 750 foot long plot in order to assess the interactive effects of N treatment and landscape position on grain yield and plant N status. This resulted in approximately 23 to 27 subplots in each main plot. In order to assess the relative N status of the corn plants, chlorophyll meter readings were taken using a SPAD 502 Chlorophyll meter (Minolta Corp.) on 10 ear leaf subsamples on July, 30 2007 and August, 12 and 13, 2008. Ear leaf samples were collected on the same day for determination of tissue N concentration. Corn grain was harvested from the 28 foot row length between the sampling points on Sept. 19, 2007 and Oct. 6, 2008 using a two-row plot combine.

Relative yield performance of the enhanced efficiency N fertilizers (i.e., PCU, UI and NI) was assessed by taking the yield differences between the individual enhanced efficiency fertilizer and urea for each adjacent sub-plot in each replication. The relative economic benefit of the enhanced efficiency N fertilizer was assessed by calculating the increase or decrease in value of using the enhanced efficiency fertilizer compared to use of urea minus the additional cost of the enhanced efficiency fertilizer compared to urea. The calculations were based on a corn price of $4/bushel and an extra cost of $0.10/lb N for PCU, $0.05/lb N for UI and $0.06/lb N for NI.

The difference in cost of application for these enhanced efficiency fertilizers compared to that of urea were not included in the calculation.

Results

The differences in timing and amount of rainfall in 2007 and 2008 (Fig. 1A & B) had a large impact on crop growth and yields (Table 1). In 2007, heavy spring rain delayed treatment application and planting but cumulative rainfall during the growing season was only 11.9 inches (Fig. 1A). In contrast, the 2008 growing season was characterized by heavy rainfall throughout the season which delayed planting and resulted in standing water in the low-lying area of the field for extended periods (Fig. 1B). Poor seed germination in several low-lying subplots in 2008 led to poor or non-existent plant stands in those sub-plots (data not shown). Cumulative rainfall during the 2008 growing season was 35.0 inches, approximately three times greater than 2007.

Table 1 shows the average grain yields, chlorophyll meter readings and ear leaf tissue N across each plot for 2007 and 2008. The 2008 ear leaf tissue N concentrations are being analyzed. Based on this analysis, all N fertilizer applications increased grain yields over the non-treated control in 2007 and 2008. Grain yields with the excessive rainfall in 2008 were also generally lower than those of 2007. In comparing the performance of the enhanced efficiency N fertilizers, polymer-coated urea (PCU) had significantly higher grain yields compared to urea. It is important to note that the relative performance of the enhanced efficiency fertilizers may have been affected by the fact that in this research all the N treatments were immediately incorporated after application. For example, UI has been found to be effective in reducing ammonia volatilization of surface-applied urea. Therefore, incorporation of the urea may lower the relative effectiveness of the UI in reducing N loss.

The chlorophyll meter readings and the ear leaf tissue N concentration, which are relative measures of the N status of the plant, were significantly higher when N fertilizer was applied. However, the PCU treatment was the only enhanced N fertilizer treatment which had a consistently significantly higher average chlorophyll meter reading compared to urea in 2007 and 2008. Both the chlorophyll meter readings and ear leaf tissue N were good indicators of grain yield in 2007 (Fig. 2A) and 2008 (Fig. 2B) (ear leaf and yield data not shown) suggesting a large yield response to N availability in this field as influenced by landscape position and weather conditions.

Significant variation in grain yield response to each N fertilizer treatment also occurred across the field in both 2007 and 2008 (data not shown). In 2007, the highest yields tended to occur in the lowest landscape positions of the field, but in 2008 because of the excessive saturation of the soil, higher yields occurred in the higher landscape positions. An approach we are using to determine the areas in the field which would have the greatest grain yield response to the enhanced efficiency fertilizers is to map the differences in yields between urea and the enhanced efficiency fertilizer. Figures 3 and 4 show the results of mapping the differences in yield between the PCU-, NI- and UI-treated plots and the urea-treated plots. Positive yield differences indicate the enhanced efficiency N fertilizer-treated area yield was greater than the urea-treated area. When this yield difference is zero or negative then urea was equivalent to or greater than the enhanced efficiency fertilizer. Based on the yield differences and relative price difference between urea and enhanced efficiency fertilizers, we also mapped the net economic return from using these products compared to urea in 2007 (Fig. 3) and 2008 (Fig. 4).

The results of these analyses showed large differences in relative yield performance across the field which affected the relative economic return. For example, in 2007 the low-lying region in the field had greater yield response to the PCU fertilizer compared to urea (Fig. 3A). Based on an economic analysis, the increased value of using PCU versus urea minus its extra cost was highest in the low-lying area while urea was more cost-effective on the sideslope (Fig. 3B). In contrast, in 2008, the yield and economic benefits of using PCU was positive over the whole field and was highest in the upper positions of the field (Fig. 4A). For 2008, PCU showed the highest economic benefit of all the enhanced efficiency N fertilizer treatments with some locations in the field having over a $400/acre economic benefit by adding PCU compared to urea (Fig. 4A). Use of NI and UI also showed variation in yield and economic benefit compared to urea alone across the field in both years (Fig. 3B&C and 4B&C)). As with the use of PCU in 2007, these products also had areas of the field where use of these products resulted in a negative economic return compared to using urea alone, possibly due to lower grain yields or the extra cost of using these products.

An initial effort at developing software to delineate the areas in the field that will respond to enhanced efficiency N fertilizers was undertaken, but further funding is required to continue development and conduct testing for commercial use. This software would be of utility to producers who wish to apply the enhanced efficiency N fertilizers to areas of a field where the potential yield and economic benefits would be optimal. Further testing of what we are calling a "variable source" fertilizer application approach to N fertilization with enhanced efficiency N fertilizers needs to be undertaken in larger production fields, in different soil types, and with use of commercially available multi-bin fertilizer spreaders since all of the research conducted so far has been done on a relatively limited field area in claypan soils in Missouri.

Outreach and Training:

1. A M.S. graduate student in soil science and undergraduate students majoring in environmental science have been involved in working on this project as part of their training.

2. The research results were presented to growers and agricultural professionals by the M.S. student at the 2007 and 2008 Greenley Center Field Day in Northeast Missouri and the 2008 meeting of the North Central Extension-Industry Soil Fertility Conference in Iowa. In addition, the research was presented in a poster session at the 2008 National Meeting of the American Society of Agronomy in Houston, Texas.
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Table 1. Average grain yields, chlorophyll readings and earleaf tissue N across the field in 2007 and 2008 due to applications of different enhanced efficiency N fertilizers.
† Urea + urease inhibitor
§ Urea + nitrification inhibitor

N treatment	Grain yield		Chlorophyll reading		Ear leaf tissue N
	2007	2008	2007	2008	2007
	---------- bu/acre -----------		--------- Spad units ---------		-- % --
Control	70.0	29.1	33	27	1.30
Urea	130.1	48.9	51	31	2.02
PCU	150.5	99.8	55	40	2.15
Urea + UI†	133.4	61.1	52	31	2.00
Urea + NI§	136.8	57.6	52	32	2.14
$LSD_{(0.05)}$*	15.0	12.6	3	4	0.32

* $LSD_{(0.05)}$ = Least Significant Difference at $p < 0.05$

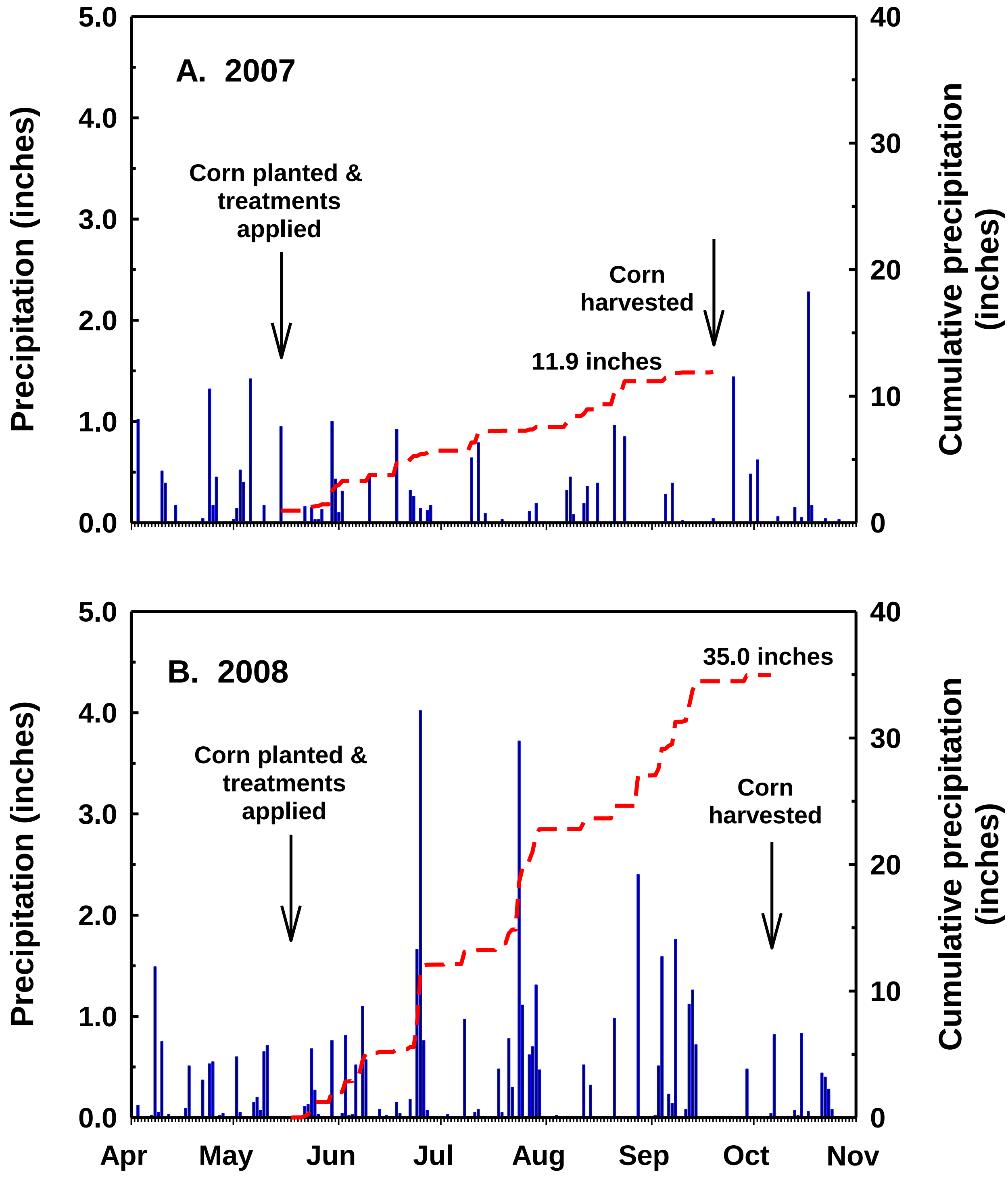

Figure 1. Daily and cumulative rainfall over the growing season at the Greenley Center in A) 2007 and B) 2008.

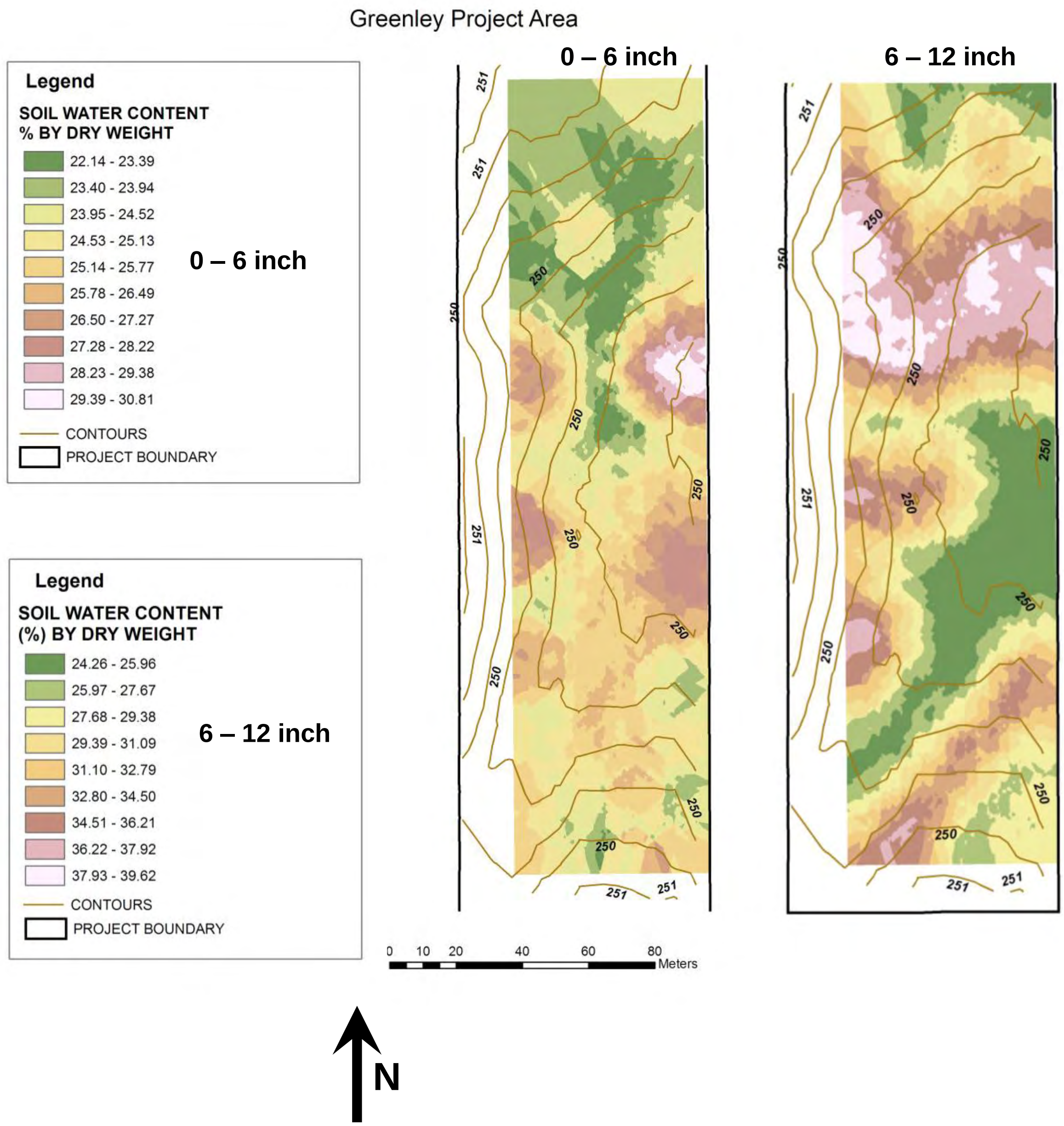

Figure 1. Map of soil water content distribution at the 0 to 6 and 6 to 12 inch depths in the experimental field on June 4, 2007. Lines represent the contour intervals with elevations above sea level given in meters.

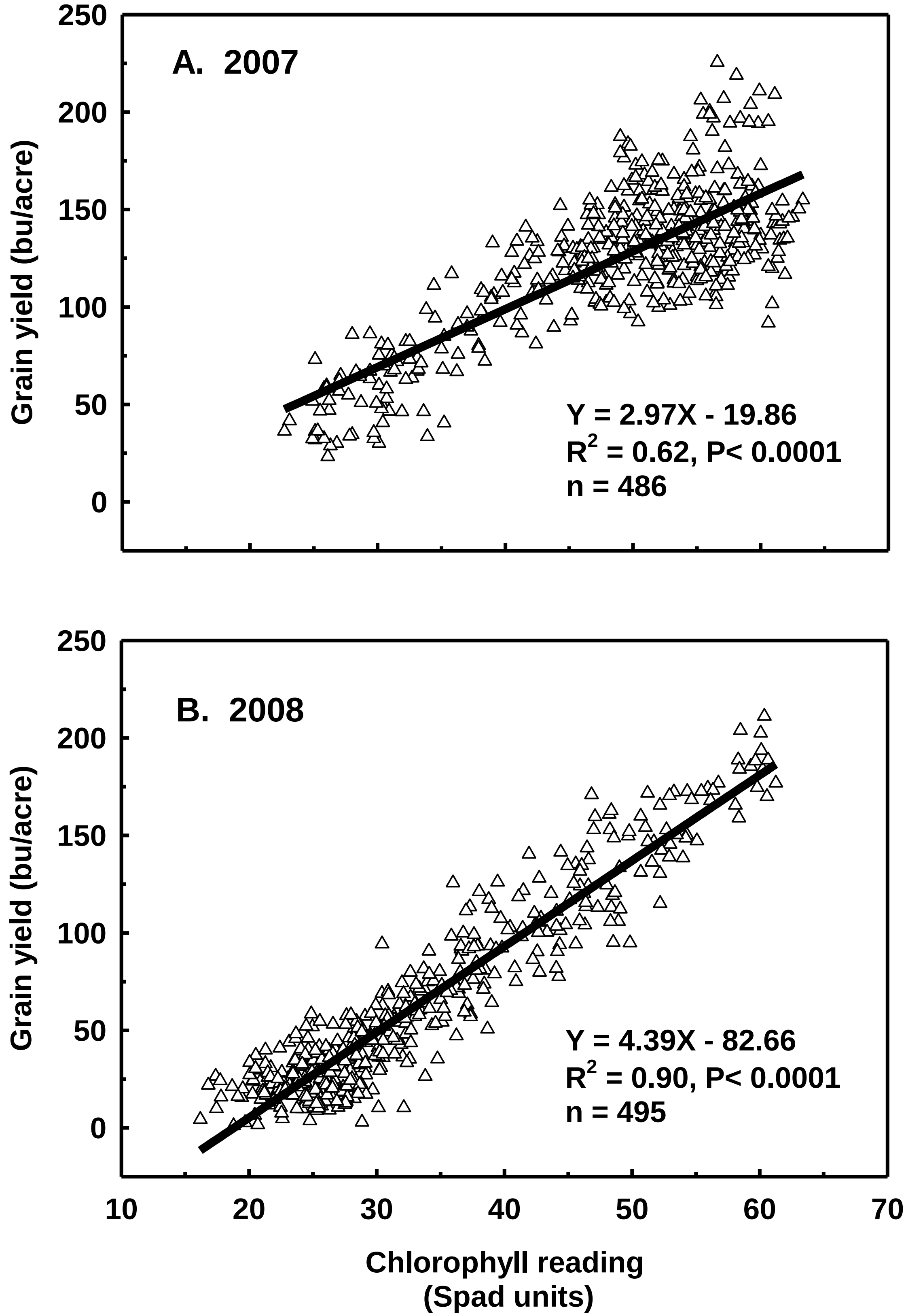

Figure 2. Relationship between chlorophyll meter readings and grain yield for all treatments in A) 2007 and B) 2008.

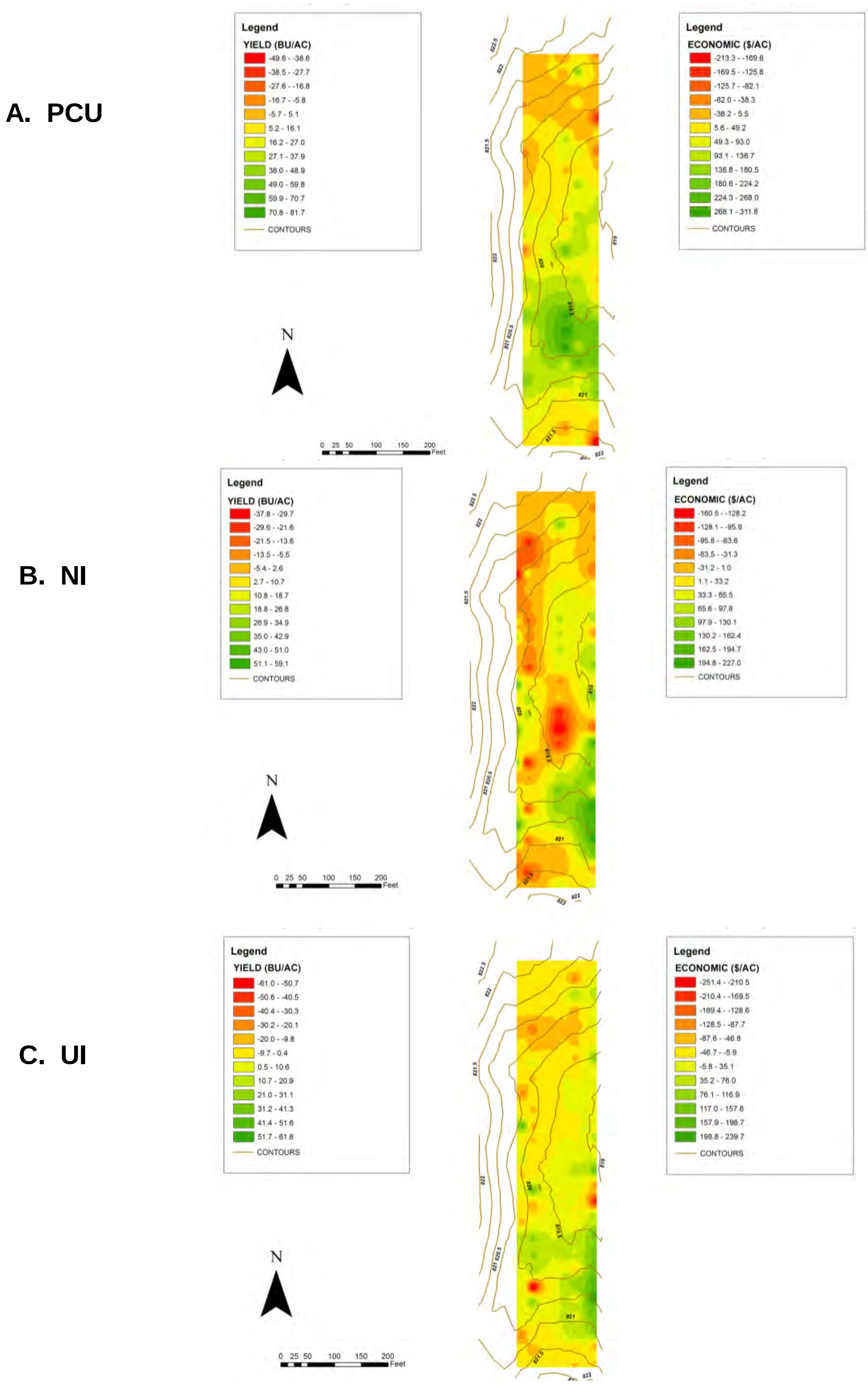

Figure 3. Field maps showing spatial differences in corn grain yields and economic benefits with application of polymer-coated urea (PCU), nitrification inhibitor (NI) and urease inhibitor (UI) compared to urea in 2007. Note the differences in legend scales among maps for each N treatment. Numbers along contour lines are elevation in feet above sea level.

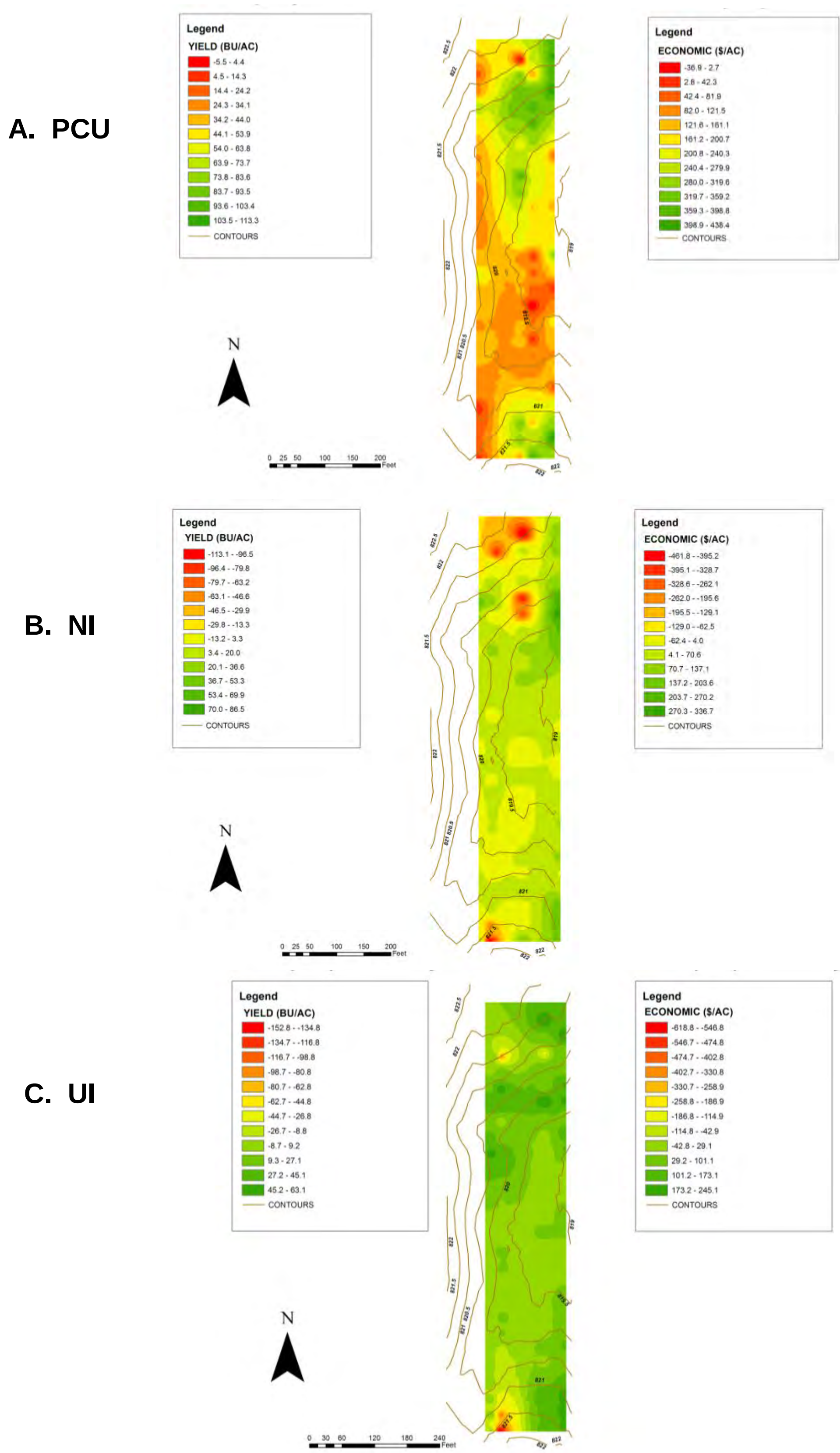

Figure 4. Field maps showing spatial differences in corn grain yields and economic benefits with application of polymer-coated urea (PCU), nitrification inhibitor (NI) and urease inhibitor (UI) compared to urea in 2008. Note the differences in legend scales among maps for each N treatment. Numbers along contour lines are elevation in feet above sea level.

Progress Reports

Addressing nitrogen controversies

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Objective:
The objective of this project is to collect data that will help to address several controversies about nitrogen management, including:

1) How do various nitrogen rate recommendation systems perform?
2) Is foliar N more efficient than soil-applied N, and is Coron more efficient than UAN?
3) Among the range of new N products and N-enhancement products, which are profitable to use and how do they rank?

Accomplishments for 2008:

- Three separate small-plot experiments (addressing objectives 1, 2, and 3 listed above) were conducted as planned at Bradford Farm near Columbia. All experiments used corn as the test crop.

Nitrogen rate recommendation systems experiment

- This experiment was planted on May 6. Due to the later-than-desired planting date, we decided to plant on May 6 despite borderline soil conditions for planting.
  - This resulted in stand problems, with average emergence of 50-60%.
  - There was rain during 9 of the 10 days after planting.
  - Weather was cool and wet and full emergence took nearly three weeks, so by the time we knew the severity of the problem it was too late for a replant (and soil conditions were still poor for planting anyway).
  - Of the three experiments, this was the only one with severe stand problems.

- By early August, all of the treatments with preplant nitrogen appeared severely nitrogen-deficient over the entire plant, and had the classic V-shaped nitrogen deficiency burn up the midrib on the leaf below the ear leaf.

- All sidedress nitrogen treatments had much better leaf color but also had V-shaped burn up the midrib on leaves below knee height indicating that they were deficient as well.

- Yields were low in this experiment, especially considering that lack of water was never a source of stress. Average yield for treatments receiving N was 94 bu/acre. Stand problems, N stress in all treatments, and late-germinating waterhemp that provided significant competition only in the sidedress treatments all contributed to the low yields.

- Nitrogen timing had a large effect on yield in this experiment.
  - Plots receiving preplant N had an average yield of 75 bu/acre (see table next page).
  - Plots receiving sidedress N had an average yield of 119 bu/acre. Although this yield is not very good, it's 44 bushels above the yield for preplant nitrogen. This is in agreement with the appearance of the plants as shown in the photos on the previous page.
  - If not for stand problems, the yield effect of N timing probably would have been larger. This is explained in more detail in the next bullet.

- Population at harvest ranged from 11,000 to 18,000 plants/acre and affected yield of some but not all treatments.
  - Average population was 13,900/acre, about half of the 27,700 seeds we planted.
  - This did not appear to be a yield-limiting factor in the treatments that received 140 lb N/acre or less preplant. In these treatments, yield level was the same from 11,000 to 17,000. Nitrogen availability apparently limited yield so strongly that extra plants did not increase yield.
  - In the treatment that received 180 lb N preplant, yield went up by about 3 bu/acre for every 1,000 plants/acre.
    - Yield increased by 22 bu/acre from 11,000 to 18,000 plants/acre.
    - This is a small increase for populations this low. It is probably related to the N limitation that clearly existed despite receiving 180 lb N/acre preplant.
  - Population effect on yield was larger for the sidedress N treatments, over 7 bu/acre for every 1,000 plants/acre. This is probably because these treatments were less N-limited and is probably a more typical population response at this population level.
    - Harvest population range was narrower for the sidedress treatments, from 12,700 to 17,100. Yield increased by 32 bu/acre from 12,700 to 17,100 plants/acre.
    - It appears that if populations had been better, yields with sidedress N would have been higher and the yield difference between preplant and sidedress N would have been larger.

- After two years, the most profitable systems are the two systems in which N rate is based on corn color (Crop Circle sensor and Minolta chlorophyll meter).
  - These systems gave profits nearly $100/acre/year above the profits given by preplant N management.
    - This is mostly due to the poor yields with preplant N in 2008.
  - They also out-performed sidedress N management based on soil nitrate testing (Iowa State University interpretations) by about $35/acre/year.
    - Yield was higher with color-based management in both years.
    - This cannot be explained by N rates applied in 2008, which were similar for the soil test and the Crop Circle sensors (and both higher than the chlorophyll meter).
    - The soil nitrate test recommended a very low N rate in 2007 which resulted in a yield penalty of about 20 bushels. Residual effects of this low N rate may explain the lower yield seen with this treatment in 2008, which was 9 bu/acre less than the color-based systems (statistically significant with $\alpha = 0.05$).

Table 1. Nitrogen rates recommended and corn yields produced by eight different recommendation systems in 2007-2008.

Nitrogen rate recommendation system	Nitrogen timing	Nitrogen rate(s) 2008	Yield 2008*	Nitrogen rate(s) 2007	Yield 2007	Gross minus N cost (2-year ave)**
		lb N/ac	bu/ac	lb N/ac	bu/ac	$/ac
Crop Circle sensor	V7†	147, 146, 168, 125, 158, 143‡	122	96, 110, 73, 116, 57, 40	156	481
Chlorophyll meter	V7	110	122	155	159	476
Sidedress soil test	V7	141	113	50	140	443
Yield goal / MRTN	preplant	140	79	140	162	390
Low	preplant	100	67	100	158	385
High	preplant	180	84	180	164	380
Preplant soil test	preplant	140	70	140	163	374
Check	-------	0	49	0	104	306

*2008 yields are different than each other (95% confidence) if they are 7 or more bushels apart.
**Used $4/bushel corn price, $0.65/lb N price as estimates of average corn and N prices over these 2 years.
†Growth stage V7 is about knee high corn.
‡A different N rate was applied in each of 6 replications for this treatment. It is feasible to use this sensor to change N rate automaticallly while fertilizing a field, and we felt that this ability would be most accurately reflected by diagnosing N rate for each plot separately.

- No statistical difference in profitability was found between the preplant N rates (100, 140, 180) after two years.
  - There is only a $5/acre/year difference between the low (100) and high (180) N rates. The yield difference between these two treatments has been almost exactly balanced by the difference in N fertilizer expense. However, the yield difference in 2008 (17 bu/ac) was larger than the difference in 2007 (6 bu/ac) and may reflect a trend for yield differences between the low and high rates to get larger over time.
  - Over these two years, the preplant soil nitrate test system has been exactly the same as the yield goal system, because not enough soil nitrate was found either year to justify reducing the N fertilizer rate. A credit is given only when soil nitrate-N is above 50 lb N/acre. The average profitability of these two treatments ($382/ac gross minus N cost) falls between the profitability for the low and high rates.

Foliar N efficiency experiment

- This experiment was designed to compare the ability of different foliar N sources to deliver N to corn, and to compare foliar applications with soil applications at the same rate and timing.
- A total N rate of 80 lb N/acre was used. This rate was chosen with the expectation that corn would be N-stressed and the ability of treatments to deliver N would be directly reflected in yield. The 80 lb was divided into three applications, 30 lb N preplant and two in-season applications of 25 lb N/acre.
- We wanted to test the ability of foliar treatments to deliver an amount of N that could make a substantial difference in yield. We chose 25 lb N/acre as the most that we thought we could apply without producing major leaf burn problems (based on previous MU experiments with foliar K on soybean by Motavalli and Nelson).
- All treatments received a broadcast application of ammonium nitrate preplant at a rate of 30 lb N/acre.
- All treatments received two in-season applications of N at a rate of 25 lb N/acre each time. Applications were made on July 2 (stage V10, waist high) and again on July 11 (V13, shoulder high). Treatments were forms of N used in these applications:
    - foliar CoRoN
    - foliar UAN
    - foliar urea
    - dribbled UAN (between rows)
    - broadcast ammonium nitrate
    - broadcast urea with Agrotain
    - check (no in-season N)

Table 2. Corn yields with foliar or dry N sources.

in-season N source	yield*	average burn rating**
dry urea with Agrotain	133	1
foliar urea	130	7.5
dry ammonium nitrate	126	4.5
UAN dribbled	122	0
foliar CoRoN	116	4
foliar UAN	112	8.5
no in-season N	69	0

*Yields are different than each other (95% confidence) if they are 9 or more bushels apart.
**0 = no burn, 10 = severe burn

- Foliar treatments did not show superior ability to deliver in-season N to a corn crop relative to soil-applied treatments.
    - Average yield with foliar N was 119 bu/acre, with soil-applied N was 127 bu/acre.
    - High soil moisture and frequent rainfall throughout the summer contributed to efficient use of soil-applied N. Water to deliver soil-applied N to roots was plentiful.

- Some yield differences were observed within foliar and soil-applied N sources.
  - Broadcast dry urea with Agrotain gave significantly higher yield than dribbled UAN.
  - Foliar urea gave significantly higher yield than foliar CoRoN or foliar UAN.

- Within N source, placement mattered for UAN but not for urea.
  - Dribbled UAN yielded 10 bushels more than foliar UAN. This was likely due to leaf burn, as UAN produced the highest leaf burn rating among all treatments.
  - Dry urea and foliar urea gave similar yields despite a fairly high leaf burn rating with foliar urea. The leaf burn associated with foliar urea was more gray 'tissue damage' compared with foliar UAN which produced a more yellow progressing to brown burn that was clearly death of the affected leaf tissue.

- Average yield response was 54 bu/acre to 50 lb N/acre applied in-season. This is an excellent yield response and shows that any of these methods of applying N would be highly profitable if corn was for some reason N-stressed and needed additional N.

<u>New N products and N-enhancement products experiment</u>

- This experiment was designed to test the new N products Calcium Ammonium Nitrate and Nurea, the new N-enhancement products ESN and Nutrisphere, along with the established N-enhancement product Agrotain. All treatments are dry broadcast N products.
- No-till corn is the test crop. Soybean was the previous crop.
- A nitrogen rate of 140 lb N/acre was used for all treatments, broadcast on May 1, followed by planting on May 6 at 27,700 seeds/acre.
- Average harvest population was 21,700 plants/acre.

Table 3. Yields with new dry N sources or N additives compared to standard dry N products.

Nitrogen source	Yield*
ESN	124
Urea + Agrotain	107
Calcium ammonium nitrate	106
Urea + Nutrisphere	104
Ammonium nitrate	102
Urea	93
Nurea	84

*Yields are different than each other (95% confidence) if they are 18 or more bushels apart.

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- Yields were not very good in this experiment considering the lack of drought stress.
  - Population was one reason. Average harvest population was 21,700 plants/acre and within the range of populations in this experiment, higher populations gave higher yields. Cold, wet planting conditions led to slow emergence and significant stand loss despite the late planting date (May 6).
  - Nitrogen timing (leading to N deficiency) was probably another reason.
    - This experiment was located immediately adjacent to the foliar N experiment reported above. Average yield of fertilized plots in that experiment were 20 bushels higher than in this experiment despite receiving 60 lb less N (80 lb N/acre in the foliar experiment vs. 140 lb N/acre in this experiment).
    - In the nitrogen rate systems experiment reported above, sidedress treatments yielded 44 bu/acre more than preplant treatments.
    - Both of these observations suggest that there was probably extensive loss of nitrogen from the preplant applications used in this experiment.

- ESN gave the highest yield, significantly higher (95% confidence) than all other treatments except urea + Agrotain. This is consistent with other experiments in Missouri where ESN increased yield under wet conditions. ESN appears to provide some protection from N loss during wet weather due to its slow-release properties.

- Calcium ammonium nitrate gave equivalent yield to ammonium nitrate. We expected and confirmed similar behavior for these two N sources. The chemical form of N is identical for the two, but with added calcium minerals in calcium ammonium nitrate to negate the explosive properties.

- Because of the high level of yield variability within treatments in this experiment, it took a large yield difference (18 bu) to be statistically different with 95% confidence.

- Untreated broadcast urea would be expected to often give lower yields than other sources due to volatilization loss of N.
  - This may have been the case in this experiment as yield with urea was 11 to 14 bu/acre less than with ammonium nitrate, calcium ammonium nitrate, urea plus Agrotain, or urea plus Nutrisphere. Statistically there is a 70 to 85% probability that these yield differences were true.
  - The 0.92 inches of rain that fell in the four days (mostly the first two days) after treatment application should have prevented any volatile N loss from urea. This suggests that the lower yields seen with urea are more likely to be accidental than due to N loss from this treatment.

- Although there is weak evidence that the urea additives (Agrotain and Nutrisphere) produced yield increases, this is counter to the expectation that there would be little N loss from untreated urea with 0.92 inches of rain in the four days after application.

- Nurea gave the lowest yield, significantly lower than all other treatments except urea.

Table 4. Details of experimental procedures for the three experiments in this project.

Operation	Experimental details for:		
	N rate rec. systems	Foliar / in-season N	New sources of dry N
Starting condition	Previous corn, no-till, 70-75% residue cover	Previous soybean, no-till, 20-30% residue cover	Previous soybean, no-till, 20-30% residue cover
Pre-plant soil sampling	April 15	none	none
Weed control: broadcast herbicide application	Gramoxone 2.0 pts/ac, Lexar 3.0 qts/ac, nonionic surfactant - 2 pt /100gal 4/16/2008	Gramoxone 2.0 pts/ac, Lexar 3.0 qts/ac, nonionic surfactant - 2 pt /100gal 4/16/2008	Gramoxone 2.0 pts/ac, Lexar 3.0 qts/ac, nonionic surfactant - 2 pt /100gal 4/16/2008
Pre-plant broadcast fertilizer treatments	3 fixed rate treatments & MO pre-plant soil test treatment 4/30/2008	All plots 30 lbs/ac N Source - Ammonium Nitrate 4/30/2008	7 treatments All pre-plant 5/1/2008
Planting	Planter: John Deere 7000 w/finger pickup Variety: Pioneer 34A20 RR2 Herculex xtra Seed drop: 27,700 Depth: 1.25" - 1.50" Conditions: Very Moist / Wet Emergence 21 - 24 days Planted 5/6/2008	Planter: John Deere 7000 w/finger pickup Variety: Pioneer 34A20 RR2 Herculex xtra Seed drop: 27,700 Depth: 1.25" - 1.50" Conditions: Very Moist Emergence 18 - 21 days Planted 5/6/2008	Planter: John Deere 7000 w/finger pickup Variety: Pioneer 34A20 RR2 Herculex xtra Seed drop: 27,700 Depth: 1.25" - 1.50" Conditions: Very Moist Emergence 18 - 21 days Planted 5/6/2008
In-season weed control (broadcast herbicide)	none	Roundup 20 oz/ac 6/19/2008	Roundup 20 oz/ac 6/19/2008
Side-dress Treatment Applications	June 30	July 2 July 11	none
Harvest	October 19	October 12	October 13

Objective for 2009

Repeat these three experiments:

- N rate recommendation systems
- Foliar vs. soil-applied N
- New N products/additives

Budget for 2009

Research Specialist time	$15,000
Benefits	4,500
Soil sample analysis	200
Field supplies and fuel	800
Total	**$20,500**

Sensor-based sidedressing for cotton

Peter Scharf, Gene Stevens, David Dunn, and Luciane Oliveira
University of Missouri, Division of Plant Sciences
Collaborator: Earl Vories, USDA-Agricultural Research Service

Objective:
Develop reliable sensor interpretations as a basis for on-the-go variable-rate N sidedressing of cotton.

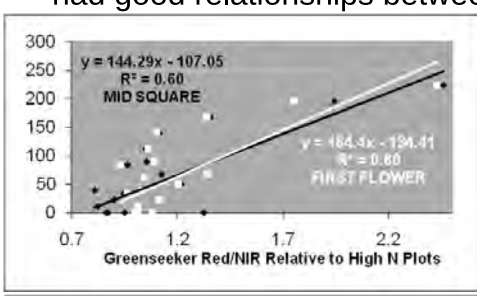
- ○ Determine sensor model and height that gives the best prediction of sidedress N need.
- ○ Determine the best growth stage for sensor-based sidedressing.
- ○ Develop recommendation equations to convert sensor readings to N rates.

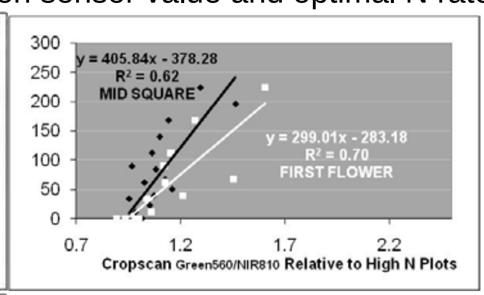
Accomplishments for 2008:

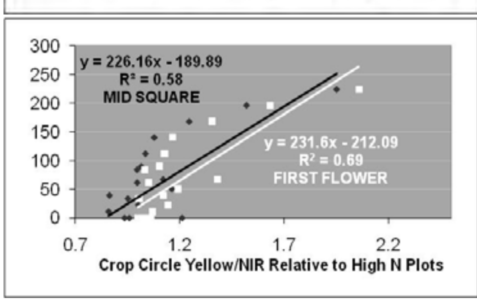
- All three sensor models gave good predictions of N need in the analyses we completed this year of our 2006-2007 data.
- For all three sensors, a height of 20 inches above the canopy gave the best predictions.
- Found that N rate recommendations were more reliable at the mid-square and early flower growth stages than at the early square growth stage.
- We developed recommendation equations for all three sensor models that can be used to convert sensor readings to N rates.
- We demonstrated sensor-based sidedressing in a 40-acre cotton field using a retailer's fertilizer applicator.
- Changed our experimental design to apply N at the time that the sensor readings give the best diagnosis–mid-square and early flower.

<u>Predicting N need with different sensors</u>

- Our experiments used Crop Circle, Greenseeker, and Cropscan sensors. All three had good relationships between sensor value and optimal N rate (graphs below).

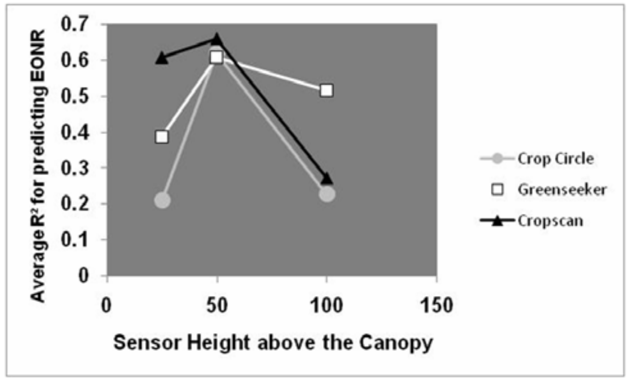






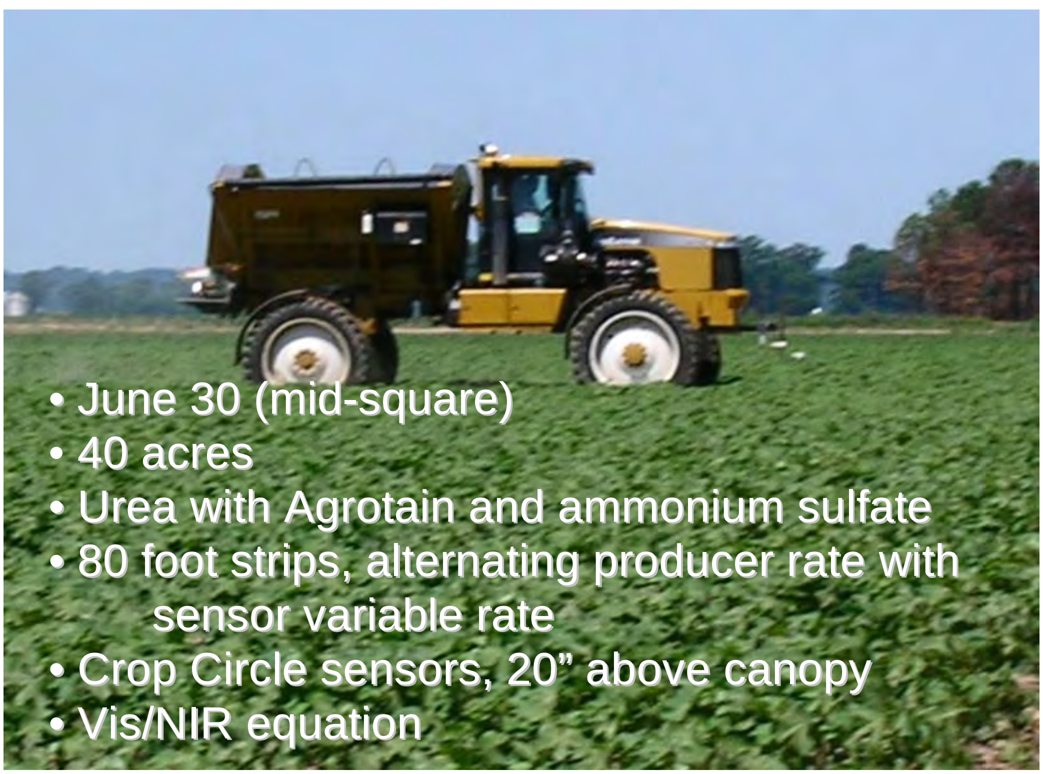
Effect of cotton growth stage and sensor height

- Although the early square stage seemed to be too early to accurately diagnose N need of cotton from sensor measurements, all sensors gave good predictions at mid-square and early flower stages (graphs on previous page). Equations were not statistically different for these two stages, giving at least a 10-15 day window to use them.
- We have combined the data in the graphs above to produce a single recommendation equation for each sensor that can be used from mid-square to early flower.
- The best predictions for each sensor were obtained using a height of 20 inches above the canopy. The Greenseeker also worked well at 40 inches above the canopy, and the Cropscan also worked well at 10 inches above the canopy. This is shown in the graph at right. A higher R^2 value means a more accurate prediction of N need.

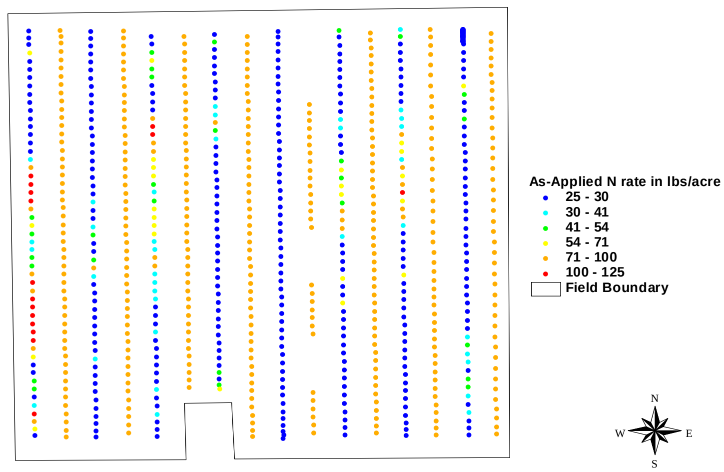


Field-scale demonstration in 2008

- With the successful development of equations to predict N need from sensor values, we decided to do a field-scale demonstration of variable-rate N application to cotton based on sensor measurements. The photograph below shows the demonstration in progress along with some of the details of the demonstration.



- The demonstration consisted of alternating strips of the producers N rate and strips where the N rate was variable and controlled by what the sensors saw.
  - The producer's sidedress N rate was 82 lb N/acre (orange dots on application map shown below).
  - With the sensors, most places in the field were diagnosed as having low N need and the 'floor' rate (which we had set at 25 lb N/acre) was applied (dark blue dots). However, in a few places the sensors saw stressed cotton, diagnosed high N need, and a high N rate was applied (red dots).
  - Average N rate based on the sensors was 36 lb N/acre, which is a savings of 46 lb/acre relative to the producer rate.

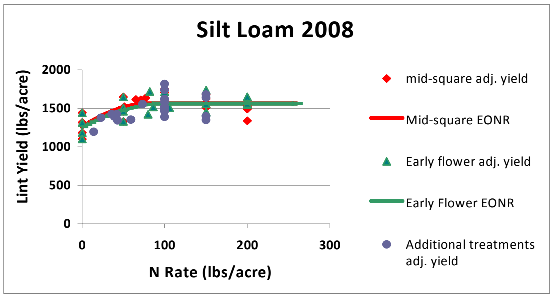


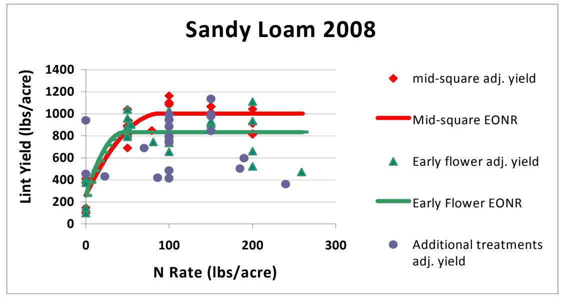
- We do not yet have the yield map for this field to analyze how the sensor-based sidedressing performed economically. However, ground observations throughout the summer and an aerial photo taken on July 18 did not reveal any problems or N stress associated with the lower N rates in the sensor-based strips.
- At harvest time, defoliant was applied to prepare the crop for harvest. In the strips where N rate was based on sensors, defoliation was more complete. The cooperating producer did not think that this influenced ease of harvest, but did think that it might have reduced leaf contamination of the harvested cotton. Leaf fragments in cotton can result in a lower price being paid for the cotton.

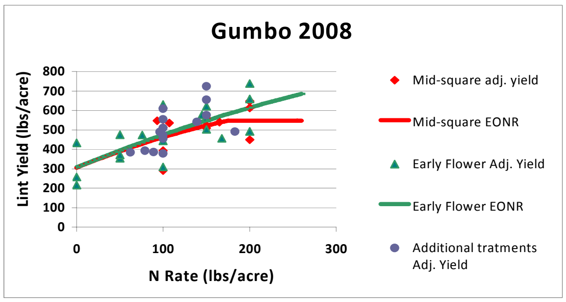
Sensor-based strips defoliated better

Nitrogen response experiments in 2008

- Since sensor measurements diagnosed N need more accurately at the mid-square to early flower growth stages, we modified the design of our small plot experiments for 2008 to apply a range of N rates at these stages.







- Yield response to N applied at these stages is shown above. This analysis is preliminary. There was little if any difference in yield response to N between the mid-square and early flower stages in the silt loam and gumbo experiments. In the sandy loam experiment, early flower was too late to apply N and yield potential was lost by delaying N application to this stage.
- Sensor data from the 2008 small-plot experiments has not yet been analyzed, but will be analyzed over this winter.

Utility of Polymer-Coated Urea as a Fall-Applied N Fertilizer Option for Corn and Wheat

Peter Motavalli, Dept. of Soil, Environ., and Atmos. Sci., Univ. of Missouri
Kelly Nelson, Div. of Plant Sciences, Univ. of Missouri, Novelty, MO

INTRODUCTION

Convenience, favorable soil conditions at the time of application, reduced equipment and labor demand, lower cost of nitrogen (N) fertilizer, and the ability to plant earlier in the spring following fall-applied N applications has favored fall-applied N in Missouri. Fall-applied N is particularly useful in conditions that limit nitrification especially in fine- to medium-textured soils (Bundy, 1986). However, fertilizer applications in the fall may increase risk of leaching under certain soil and weather conditions. Best management practices based on economic returns and N loss via subsurface drainage included fall N with nitrapyrin (N-serve), spring preplant and split applications of anhydrous ammonia in Minnesota (Randall et al., 2003a, 2003b). However, claypan soils in Missouri have relatively lower N leaching losses due to poor drainage through the subsoil clay layer. Farmers and custom applicators utilize weather stations that report soil temperatures at the 6 in. depth to time fall-applied anhydrous ammonia. Recently, supply of anhydrous ammonia for fall application has been limited to prepaid customers and regulations on anhydrous ammonia and ammonium nitrate may further affect availability of these N fertilizer sources. Alternatives for fall-applied N fertilizer need to be evaluated for their effects on corn and wheat performance to determine if they are cost-effective.

In two years of corn research, polymer coated urea (PCU) that was fall surface-applied for no-till corn had grain yields similar to anhydrous ammonia, but surface-applied PCU in the fall or as early preplant had lower returns than anhydrous ammonia (Nelson and Motavalli, 2007b). However, deep placement of fall-applied PCU increased yield 16 bu/acre more than deep banded urea, 28 bu/acre greater than broadcast applied PCU, and 8 bu/acre greater than anhydrous ammonia (Randall, personal communication). Nitrogen release in Missouri over the winter was less than 30% for fall applied PCU applications and there was more consistent N release when PCU was deep banded than when surface applied (Nelson and Motavalli, 2007b). Reduced efficiency of surface applied PCU may be due to denitrification losses over the winter months during freeze-thaw events. Deep banding PCU should improve efficiency and make it a cost-effective alternative to applying anhydrous ammonia. In Minnesota, soil temperatures freeze and remain frozen; however, no field research has evaluated corn response to deep banded PCU in Missouri in soils that go through several freeze-thaw cycles as an alternative to anhydrous ammonia. No research has evaluated fall strip tillage and N fertilizer management systems in Missouri. Finally, no research has compared deep banded PCU with anhydrous ammonia plus N-serve.

Wheat research in MO has evaluated application timings (Medeiros et al., 2005) and fall compared to split applications of PCU (Nelson and Motavalli, 2007a). Applications of PCU later than February resulted in grain yields less than other N sources (Medeiros et al., 2005). In four years of research, fall-applied PCU had the greatest N uptake and grain yields when compared to fall-applied urea alone (Nelson and Motavalli, 2007a). No research has evaluated fall application timings of PCU compared with other N sources to determine if a single fall application at the time of planting wheat or later had yields similar or greater than standard applications of ammonium nitrate. A single fall application would save farmers application cost of a split application in the fall and spring. Spring applications of N on wheat are usually challenging due to wet conditions and risk of N loss. In addition, research is needed to evaluate the response of wheat to blends of urea and PCU.

The objectives of this research are to: 1) evaluate yield response of fall-applied PCU compared with non-coated urea and anhydrous ammonia with and without N-serve for corn and 2) evaluate the effect of fall-applied timings of PCU and blends of PCU with non-coated urea (NCU) on wheat yields when compared to non-coated urea and ammonium nitrate.

MATERIALS AND METHODS

Corn. Two field trials with three replications at each trial were established at the Greenley Research Center in plots 10 by 70 ft. One trial followed soybean residue and the other followed red clover residue that was frost-seeded into wheat the previous year. Treatments included PCU and non-coated urea (NCU) at 125 lbs N/acre broadcast surface applied and deep banded using a Yetter® 2984 strip-till system equipped with high residue Maverick® units with a rolling basket and dry fertilizer application tubes. A Gandy Orbit Air ground drive fertilizer applicator was used to deliver PCU and NCU for the strip-tilled treatments. Dry fertilizer was placed approximately 8 inches deep in the strip tilled region. Nitrogen treatments were applied in the fall, early preplant (approximately 1 month before planting), and prior to planting. A non-treated and standard anhydrous treatment at 125 lbs N/acre was included as controls. The N application rate was reduced to determine the most efficient N sources. Fall, early preplant, and preplant treatments were applied in both studies on 20 November 2007, 7 April 2008, and 5 May 2008, respectively.

The soybean residue study was planted to 'DKC63-42' at 30,000 seeds/acre on 6 May 2008. In the clover residue study, 'DKC61-69' was planted at 30,000 seeds/acre on 29 May 2008. The planting date in the clover residue study was delayed 24 days after the preplant fertilizer application due to wet conditions in the heavy clover residue. The planter was equipped with Shark-tooth® residue cleaners used in tandem with a no-till coulter. The residue cleaners performed well in heavy residue of the no-till plots and provided a smooth seedbed above in strip-tilled plots. Grain yields were determined and grain collected to evaluate for starch, protein, and oil concentration. Grain moisture was adjusted to 15% prior to analysis. A gross margin will be calculated for each treatment to compare relative returns of fall compared with preplant treatments at the conclusion of the experiment.

Wheat. Research was conducted at the Greenley Research Center near Novelty, MO from fall, 2007 to summer, 2008. This research was arranged as a randomized complete block design with five replications in 10 by 30 ft plots. 'Pioneer 25R56' was no-till drilled following an application of 10-60-140 (N-P-K) on 5 October 2007 at 120 lbs/acre in 7.5 in. rows. Research was a factorial arrangement of N source and rate (PCU at 75 and 100 lbs N/a, urea at 75 and 100 lbs N/a, and ammonium nitrate at 75 and 100 lbs N/a, PCU 75%:urea 25% at 75 and 100 lbs N/a, and PCU 50%:urea 50% at 75 and 100 lbs N/a), and application timing (October, November, December, January, February, March, April). Polymer coated urea (PCU, ESN, Agrium), non-coated urea (NCU, fast release), 75:25 PCU:NCU, and 50:50 PCU:NCU fertilizer treatments were applied at 75 and 100 lbs N/acre on 5 October 2007, 17 November 2007, 14 December 2007, 16 January 2008, 13 February 2008, 12 March 2008, and 14 April 2008. Fertilizer release was monitored using mesh bags placed on the soil surface and soybean stubble placed over the top of the bags to simulate a fertilizer application. Mesh bags were removed at each application date and stored in a freezer. Fertilizer samples were washed in water, dried, weighed, and release was calculated based on the remaining fertilizer. Field plots were harvested with a small-plot combine. Grain moisture was adjusted to 13% prior to analysis. All data were subjected to analysis of variance and means separated using Fisher's Protected LSD (P=0.05).

RESULTS

The first of a three-year field trial was conducted with extremely wet soil conditions throughout the growing season in 2008. This provided a worst-case scenario for N fertilizer loss and an opportunity to evaluate fertilizer sources and strip tillage under extremely challenging weather conditions.

Corn following soybean residue. The strip-tilled bands could have been planted 3 to 4 days before the no-till plots (personal observation). Winter annual weeds are common in long-term no-till fields. Henbit was the primary winter annual weed present in this field (20-40/ft^2). Henbit plants were harvested prior to a burndown herbicide application due to visual differences in weed growth between treatments. Henbit dry weights were 60 to 70% greater when PCU or NCU was broadcast applied compared to anhydrous ammonia or a strip-till band application of PCU or NCU (data not presented). Corn grain yield was ranked anhydrous ammonia = anhydrous ammonia plus N-serve = NCU strip-till ≥ PCU strip-till > PCU broadcast = NCU broadcast (P=0.0001).

Corn following clover residue. Extremely wet conditions delayed planting 24 days after the preplant application timing. Soil moisture was high throughout the spring, 2008. The strip-till bands dried out before the no-till plots. Corn grain yield when averaged over application timing was ranked anhydrous ammonia = anhydrous ammonia plus N-serve = NCU strip-till = PCU strip-till > PCU broadcast > NCU broadcast (P=0.0001). There was no difference between PCU and NCU grain yields when strip tillage was utilized; however, corn grain yield was greater with PCU when fall and preplant applied when compared to NCU. Clover dry weights were approximately 20 to 25% greater when PCU or NCU was broadcast applied compared to anhydrous ammonia or strip-till band applied PCU or NCU (data not presented). No-till, broadcast urea had the greatest clover dry weights prior to a burndown herbicide application, and the lowest corn population (22,800 plants/acre) when compared to strip-tillage (24,200 plants/acre) at harvest. Strip-till application of PCU and NCU had grain yields similar to anhydrous ammonia at all of the application timings.

Wheat. Rainfall and distribution of rainfall events were extensive in the fall, 2007 and spring, 2008. Less than 20% of the PCU applied in October, 2007 was released by February, 2008 (Figure 3). Fertilizer released from the PCU applied from October, 2007 to February, 2008 was nearly 50% or greater by 15 June 2008. Less than 35% of the fertilizer was released when applied from 12 March to 15 June 2008. This indicates that residual fertilizer may be present for PCU applications in wheat. Application of PCU after 12 March required the presence of a fast release fertilizer source when applied at 100 lbs N/acre.

The non-treated check grain yield was 53 bu/acre. There was a significant grain yield response to all N treatments (Figures 4A and B). Grain yields at 100 lbs N/acre averaged 5 bu/a greater than 75 lbs N/acre (data not presented). Wheat yield was ranked PCU = 75:25

PCU:NCU ≥ 50:50 PCU:NCU ≥ NCU = ammonium nitrate for the October, November, December, January, February and March application timings (Figure 4B). However, the April 14 application timing resulted in grain yield rankings of ammonium nitrate = 50:50 PCU:NCU = NCU ≥ 75:25 PCU:NCU > PCU (Figure 4B). Icy conditions at the December application timing and frozen conditions at the February application timing were the primary environmental conditions that may have contributed to lower yields for these application timings. In general, there was a rate response to decreasing amounts of PCU as a ratio of the N fertilizer source for the October, January, and February application timings. PCU increased average grain yields 6 bu/acre when compared to NCU for the October to February application timings; however, PCU applications in mid-March and April were 4 bu/acre less than NCU. PCU applications in Northeast Missouri from mid-March and later should increase the amount of NCU in the blend to maintain maximum grain yields based on our results in 2008. Grain yields prior to mid-March were more variable in the NCU and ammonium nitrate treated wheat when compared to PCU or blends of NCU with PCU. Fall applications of PCU or a blend of PCU:NCU at 75:25 had yields similar to or greater than spring applied N in 2008.

SUMMARY

Corn

- In an extremely wet year, fall applied urea should be deep banded to improve crop performance.
- PCU and NCU were more effective when deep banded when compared to a surface broadcast application in 2008.
- Broadcast PCU increased yield compared to broadcast NCU following clover residue in 2008.

Wheat

- Fall applied PCU is an option for wheat production in upstate Missouri.
- A ratio of fast release N fertilizer with PCU is recommended for applications after February. A 50:50 ratio of PCU:NCU or 100% NCU would be more cost-effective for March and April N fertilizer applications.

Timetable:

October-December 2007	Prepare treatments, plot preparation, and apply fall application timings for corn and wheat studies
April-September 2008	Apply preplant N treatments soil sample in the spring and prior to harvest.
September 2008	Harvest
Oct-Dec 2008	Analyze and summarize results
2009	Repeat 2008 procedures
2010	Repeat 2008 procedures

References:

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

Medeiros, J.A.S., P. Scharf, and L. Mueller. 2005. Making urea work in no-till. Abstr. Am. Soc. Agron. Madison, WI. [non-paginated CD-ROM].

Motavalli, P.P., K.A. Nelson, S.A. Anderson, and 2005. Variable source application of polymer coated urea. Abstr. Am. Soc. Agron. Madison, WI. [non-paginated CD-ROM].
Nelson, K.A. and P.P. Motavalli. 2007. Fall applied polymer coated urea for wheat. Abstr. Am. Soc. Agron. Madison, WI. [non-paginated CD-ROM].
Nelson, K.A. and P.P. Motavalli. 2007. Nitrogen management using reduced rates of polymer coated urea in corn. Greenley Research Center Field Day Report. pp. 43-48.
NRCS. 2005. Conservation Security Program Watersheds FY-2005. http://www.nrcs.usda.gov/programs/csp/2005_CSP_WS/index.html. Accessed 7 December 2005.
Randall, G.W., J.A. Vetsch, and J.R. Huffman. 2003a. Corn production on a subsurface-drained mollisol as affected by time of nitrogen application and nitrapyrin. Agron. J. 95:1213-1219.
Randall, G.W., J.A. Vetsch, and J.R. Huffman. 2003b. Nitrate losses in subsurface drainage from a corn-soybean rotation as affected by time of nitrogen application and use of nitrapyrin. J. Environ. Qual. 32:1764-1772.

Proposed Budget:

CATEGORIES	2009 Year 2	2010 Year 3	TOTAL*
A. Salaries M.S. Graduate Research Assistant (50%)	$14,382	$14,670	$42,875
B. Fringe Benefits Fringe for graduate student	$1,995	$2,095	$5,990
TOTAL SALARIES AND FRINGE BENEFITS	$16,095	$16,765	$48,583
C. Travel			
Travel to field site	$623	$623	$1,869
Travel to professional meeting	$500	$500	$1,000
TOTAL TRAVEL COSTS	$1,123	$1,123	$2,869
D. Equipment	$0	$0	$0
TOTAL EQUIPMENT COSTS	$0	$0	$0
E. Other Direct Costs			
Laboratory reagents and supplies	$1,000	$1,000	$3,000
Field supplies	$1,500	$1,500	$4,500
Soil processing and analysis	$2,000	$2,000	$6,000
Publications/Documentation	$500	$500	$1,000
TOTAL OTHER DIRECT COSTS	$5,000	$5,000	$14,500
TOTAL REQUEST	$22,218	$22,888	$65,952

*Includes 2008 Year 1 budget

Justification:
Salaries and Fringe Benefits: Funds are requested for support of a graduate research assistant (50% time) based on set rates at the University of Missouri. Fringe benefits for the graduate student cover the cost of health insurance. If the graduate student does not require a third year then the requested funds will be used to partially fund a technician during that year.

Travel: Covers cost of travel to Greenley Farm at a rate of 44.5 ¢/mile. In the second and third years, $500 is requested to cover cost of travel and board for one researcher to attend a professional conference for presentation of results.

Laboratory Reagents and Supplies: Covers cost of laboratory reagents, sample containers, and other materials used in soil and plant tissue analyses.

Field Supplies: Cost of fertilizer, seed, plot preparation, planting, weed control and harvesting, soil samplers, flags, pots and other field supplies and operations.

Soil Processing and Analysis: Covers cost of drying, grinding and analysis of soil samples for ammonium and nitrate-N.

Publications/Documentation: Defrays cost of publication and documentation of results and conclusions.

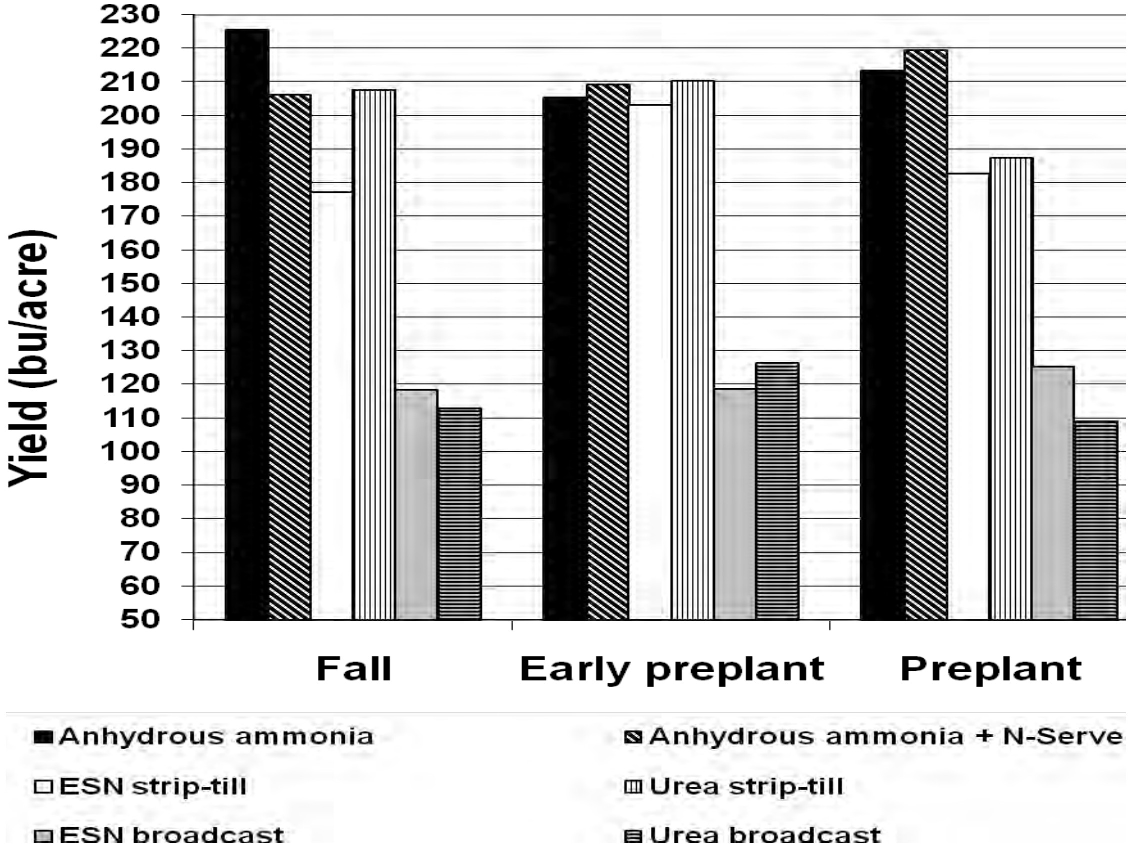


Figure 1. Corn grain yield response to N fertilizer sources applied in the fall, early preplant, and preplant following soybean residue in 2008. LSD ($P \leq 0.05$) was 25 bu/acre.

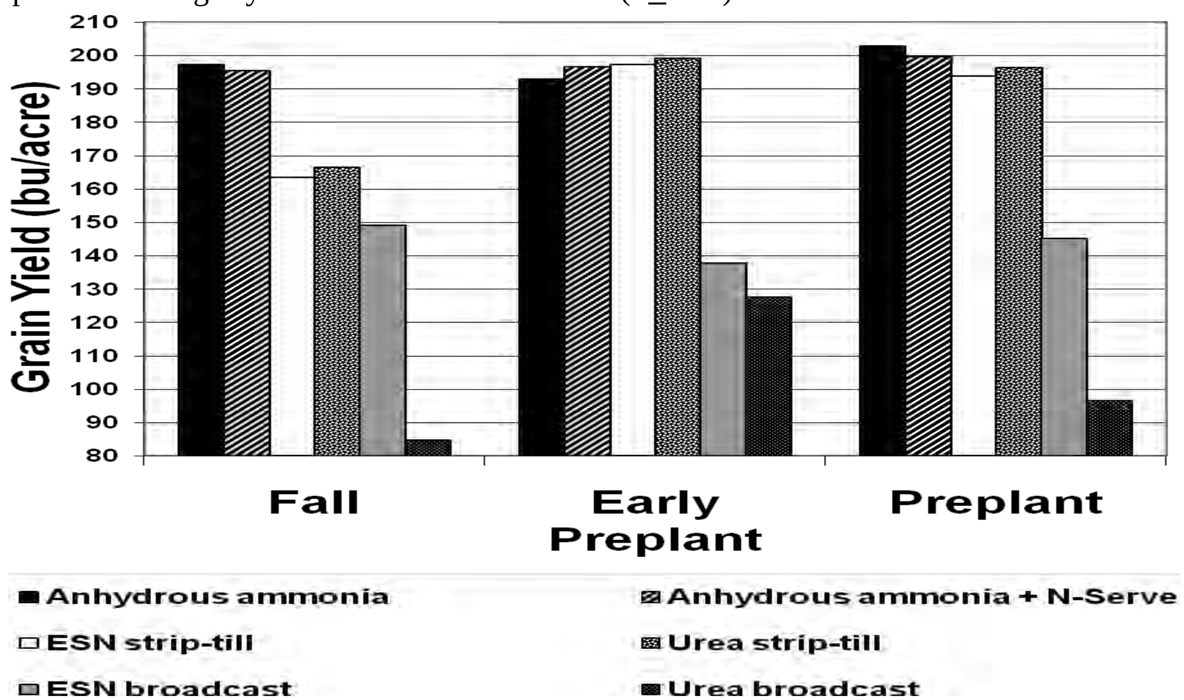


Figure 2. Corn grain yield response to N fertilizer sources applied in the fall, early preplant, and preplant following clover residue in 2008. LSD ($P \leq 0.05$) was 40 bu/acre.

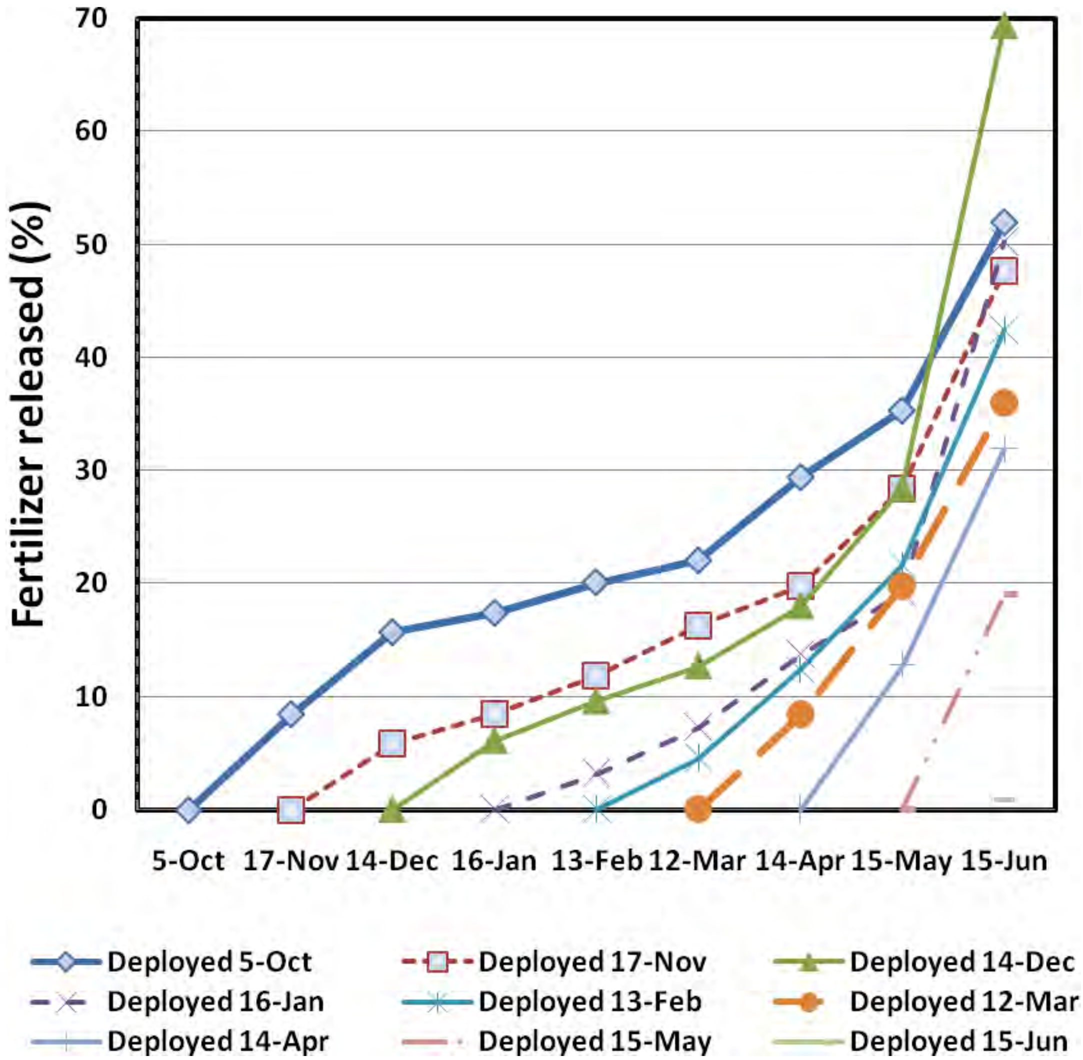


Figure 3. Polymer-coated urea (PCU, ESN) fertilizer release for individual application dates. The LSD ($P \leq 0.05$) was 5.

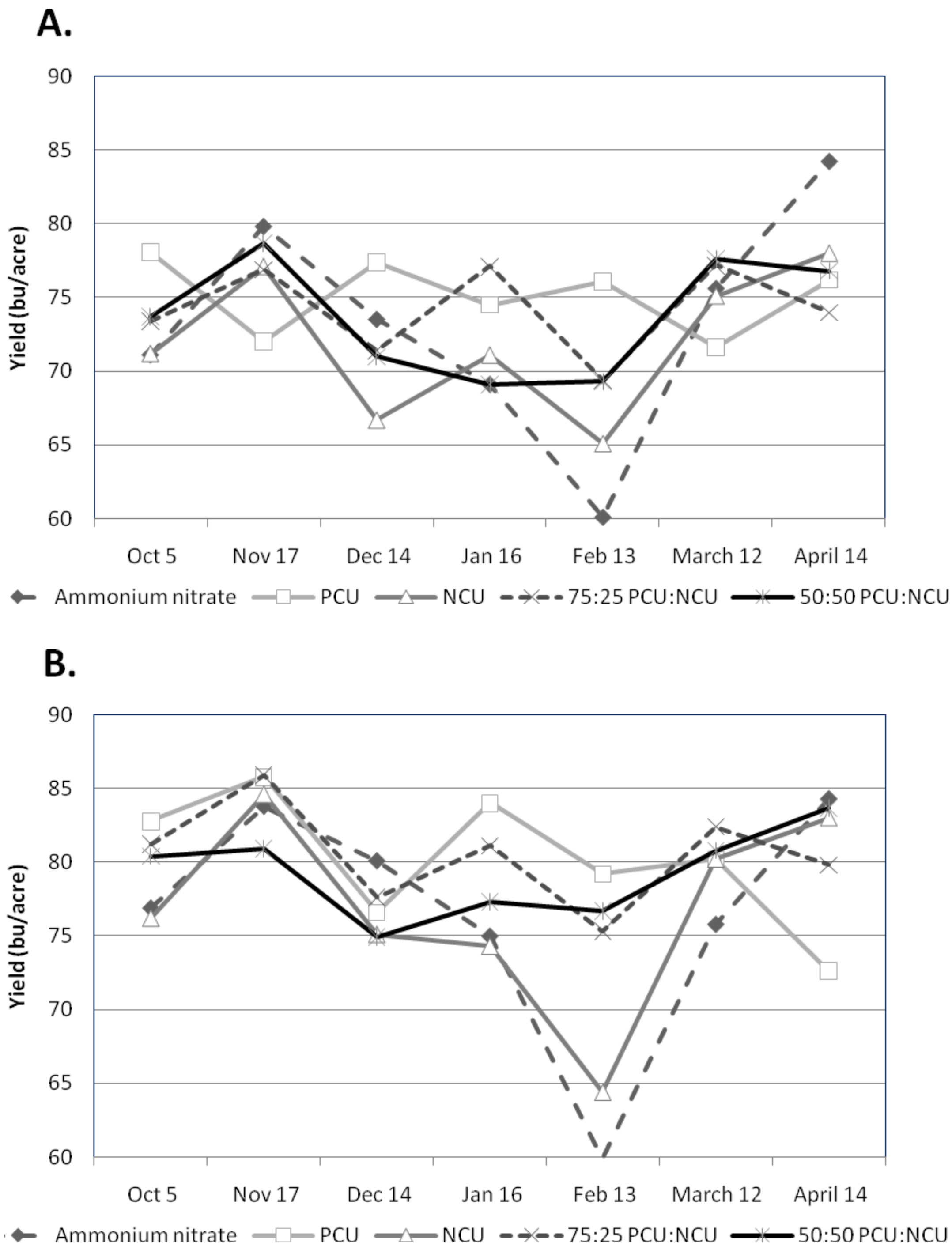


Figure 4. The effect of polymer-coated urea (PCU, ESN), non-coated urea (NCU), ammonium nitrate, 75:25 PCU:NCU, and 50:50 PCU:NCU application timings and ratios at 75 (A) and 100 (B) lbs N/acre on wheat grain yield in 2008. The non-treated control grain yield was 53 bu/acre. LSD ($P \leq 0.05$) was 4 bu/acre.

Phosphorus Management

Final Reports

Using Magnesium and Phosphorus Fertilization to Improve the Macronutrient Quality of Stockpiled Tall Fescue

Investigator: Dale G. Blevins, Professor of Agronomy, University of Missouri

Objective: To determine if phosphorus (P) and magnesium (Mg) concentrations in leaves of stockpiled tall fescue during winter can be increased by fertilization with both P and Mg.

Procedure: During summer 2006, an established stand of tall fescue (K31, endophyte infected) was selected at the University of Missouri, Southwest Research Center near Mt. Vernon. Soil samples were taken and sent to the University of Missouri Soil Testing Lab for analysis, and plot area selected contained only 6 lbs/acre of Bray I P. On September 20, forage was removed from the plot area and plots of 10' x 25' with 5' foot alleys were treated with combinations of 0, 50, 100, or 200 lbs P/acre (as 0-46-0) and 0 or 50 lbs Mg/acre (K-Mag). The use of K-Mag required that potassium (K) and sulfur (S) be added separately to all treated plots to balance K and S added in the K-Mag treatments. Plots receiving Mg were also treated with 50 lbs Mg/acre in September of the second season; however, P treatments were not repeated. Each treatment combination was replicated six times. From mid-October 2006 through mid-April 2007, and from mid-October, 2007 through mid-April 2008, 20 of the most recently collared leaves were harvested monthly from each plot. Samples were dried, ground and digested in nitric acid in a microwave accelerated digestion system (CEM Corp.). Digested samples were filtered, diluted and macro- and micronutrient concentrations were determined by ICP analysis.

Results: Leaf P concentrations in the stockpiled tall fescue increased incrementally with P treatment over the two year experiment (Fig. 1). All P fertilization treatments increased leaf P concentrations above the 0.2% P requirement needed by lactating beef cows during the first stockpiling season, but not during the second season. In general, Mg fertilization had little effect leaf P concentrations.

Leaf Mg concentrations increased with increased P treatment levels (Figs. 2 and 3). The addition of Mg fertilizer increased leaf Mg concentrations with all P treatments. Leaf Mg concentrations were maintained near or above the 0.2% requirement in plots receiving both P and Mg fertilizer. Importantly, 50 lb/acre P, along with the Mg fertilization, was effective in maintaining the leaf Mg concentration above 0.2% level required for lactating beef cows.

Bray I soil test P levels increased with 100 and 200 lbs P/acre treatments, but most of the P was "sorbed" by the soil, as shown by the increased Bray II P values (Fig. 4). Soil Mg levels increased with the 100 lbs Mg/acre (total) treatment, but was not changed by P application rate (Fig. 4). Soil pH decreased with increasing P fertilization rates and increased with the Mg applications (Fig. 4).

Application of 50 lbs P/acre increased forage yield >30% in both years, however greater rates of P did not impact yield much more that the 50 lbs/acre treatment (Fig. 5). Overall, Mg fertilization did not affect forage yield!

Conclusions: Although large amounts of P fertilizer (100 and 200 lbs/acre) increased both leaf P and Mg concentrations during the stockpiling periods, 50 lbs P/acre increased forage yields and effectively increased leaf Mg when applied with 100 lbs Mg/acre. On low P soils, stockpiled tall fescue leaf Mg concentrations may be maintained above the 0.2% requirement of lactating beef cows when Mg fertilizer is applied along with 50 lbs P/acre. The addition of Mg fertilizer may offset the need and cost of applying very large quantities of P fertilizer to tall fescue pastures in much of Missouri.

Figure 1. Response of leaf P concentrations to P and Mg fertilization of stockpiled tall fescue. All treatments are shown on this graph.

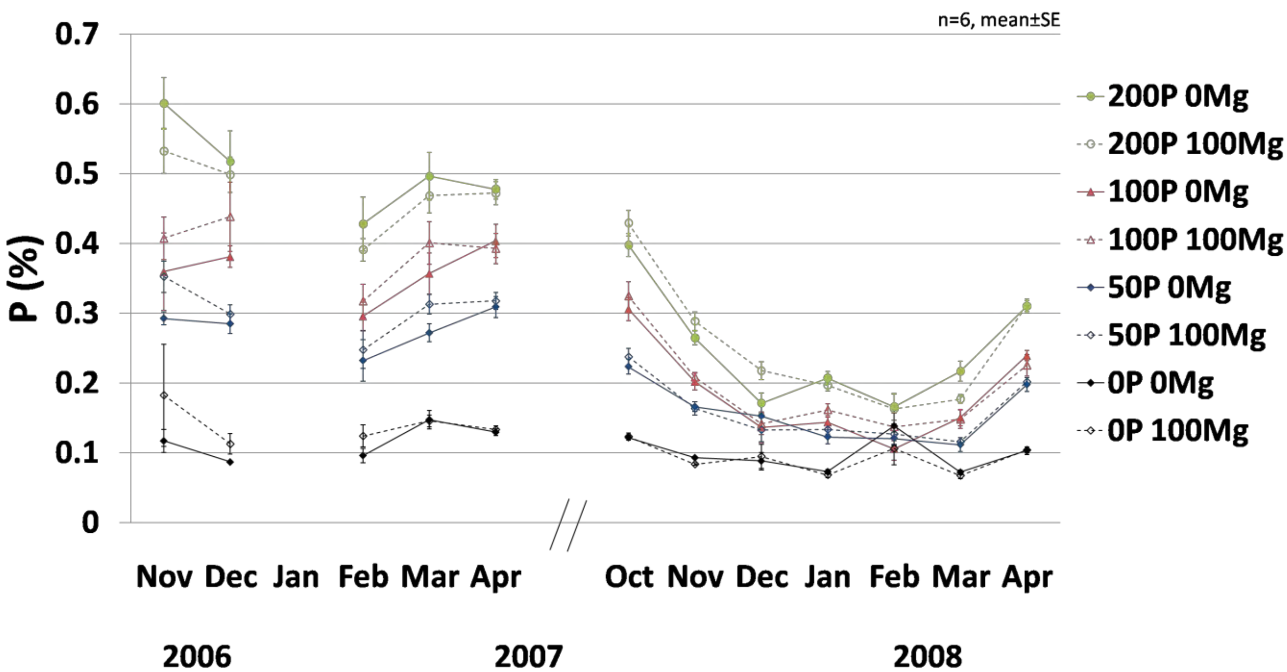


Figure 2. Response of leaf Mg concentrations to P and Mg fertilization of stockpiled tall fescue. All treatments are shown on this graph.

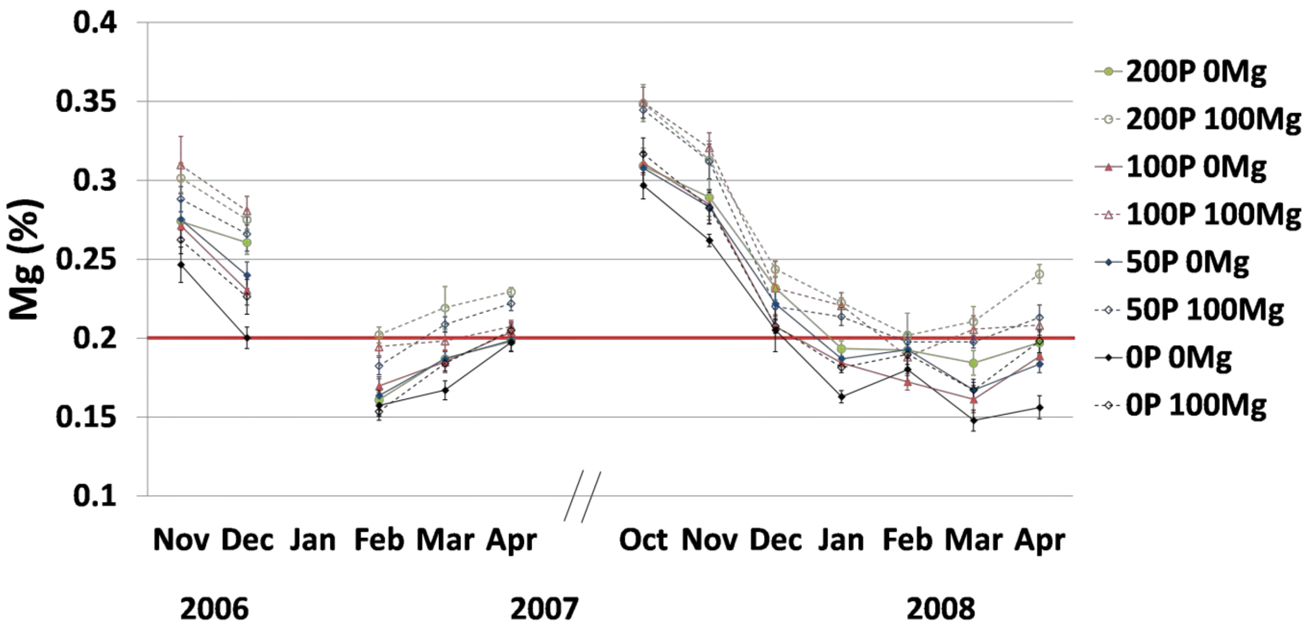


Figure 3. Response of leaf Mg concentrations to P and Mg fertilization of stockpiled tall fescue. Individual P treatments are shown on each graph for clarity.

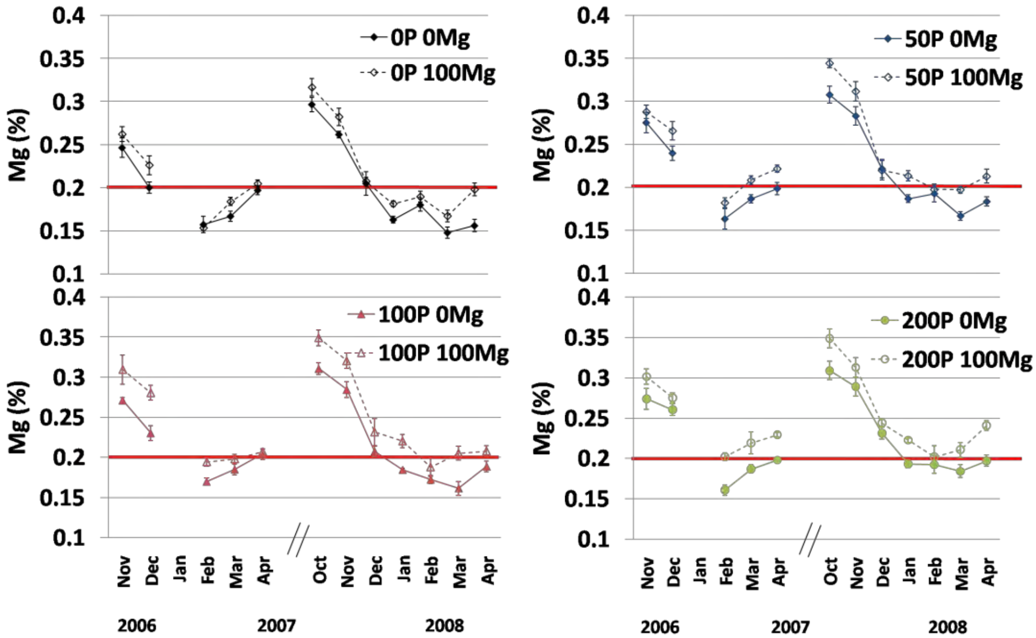


Figure 4. Soil test results following P and Mg fertilization of a stockpiled tall fescue pasture.

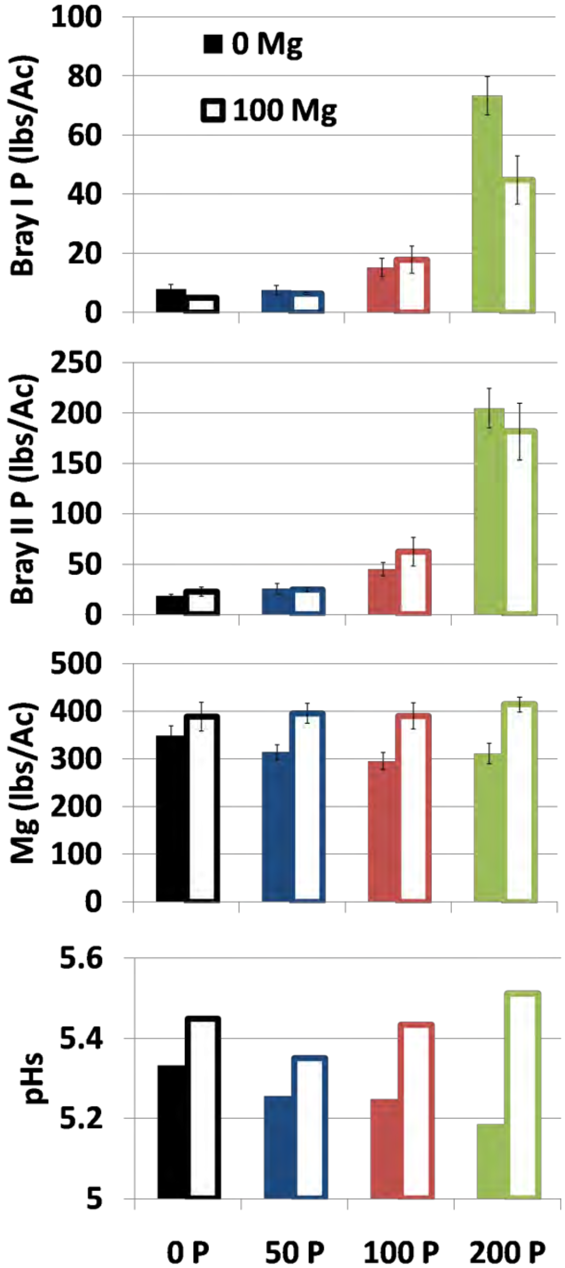
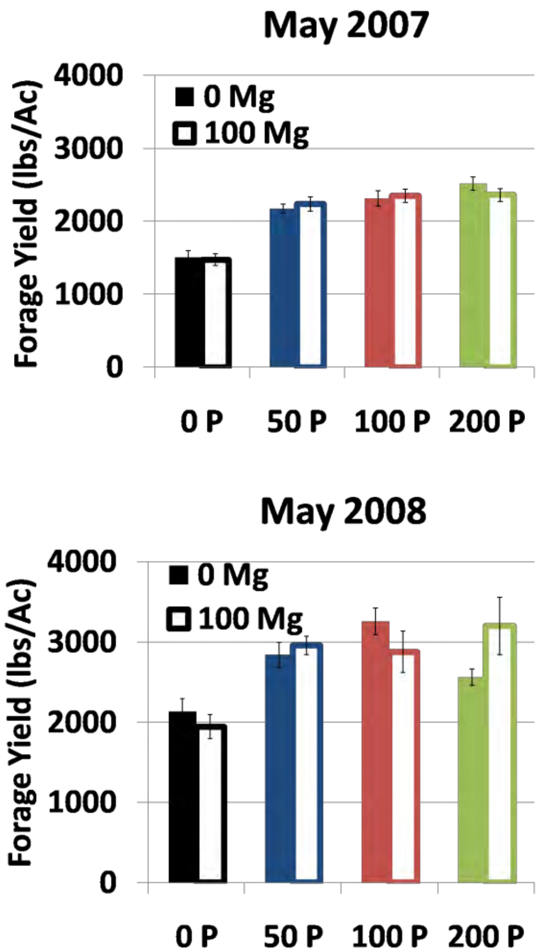


Figure 5. 2007 and 2008 tall fescue hay yields following P and Mg fertilization.



Miscellaneous Tests

Final Reports

Using Phosphorus, Ammonium-nitrogen and Strip-kill to Increase Tall Fescue Seed Production in Missouri

Investigator: Dale G. Blevins, Professor & Kemper Fellow, Division of Plant Sciences, University of Missouri-Columbia

Objective: to determine if tall fescue seed production in Missouri can be increased by late summer phosphorus (P) and ammonium (NH_4^+) applications in a strip-kill management system.

Procedure: During the summer of 2006, a PhD student, Will McClain, built a sprayer that will spray Roundup® approximately 7.5" wide strips and leave 7.5" wide strips for seed production (Fig. 1). The sprayer had a 10' boom and eight 4002 Tarjet nozzles placed 15" apart. During mid-September 2006, tall fescue (K31, endophyte infected) pastures at the SW Center (SWC) near Mt. Vernon and at Bradford Farm (Agronomy Research Center) near Columbia were selected and forage was removed to a height of 4". Soil samples were collected and tested for P, Mg, Ca and K concentrations. Plots were flagged at 10'x 20' (SWC) and 10' x 25' (ARC) with 5' alleys. Ten days after forage removal, Roundup® was applied in 7.5" wide strips leaving 7.5" wide strips of live tall fescue on stripkill plots. A Roundup® concentration of 1.6 oz/gal of water with 0.5 oz of crop oil/gal and 1.2 oz/gal of a blue tracking dye were used for the strip-kill process. The total volume of application was 31 gal/acre. One half of the plot area was <u>not</u> treated with Roundup® and these plots were used for conventional tall fescue seed production (controls). In late June 2007, tall fescue plots at both locations were harvested for seed yield with a 5' combine. Samples were weighed and seed yield was calculated. Subsamples of the seed were used for determination of weight per seed from the SWC study. On September 2007, plots were treated with 0 or 100 lbs P/acre from triple super phosphate (0-46-0) and 0 or 100 lbs of N/acre as either urea beads (N-guard) from Specialty Fertilizer Products, urea or ammonium nitrate.

Starting the second week of June 2008, the tall fescue was scouted to determine seed maturation. Seed was harvested with a plot combine at the SWC on June 18. The seed was air-dried in a greenhouse for a few days, then sieved to removed stems and trash, before dry weight measurements and calculation of seed yield. Over 90% of the tall fescue plots at ARC were severely lodged; therefore these plots were not harvested. The data from the first year at ARC, where the plants were severely damaged from the Easter 2007 freeze were also compromised; therefore data from this location were eliminated from this report.

Results: The stripkill method worked well for establishing seed yield plots in tall fescue pastures. The strips were killed in September 2006 (Fig. 1) and by November, they showed up nicely (Fig. 2). 2007 was not a great year for tall fescue seed production, with control plots averaging less than 150 bu/acre, while untreated stripkill plots yielded around 200 lbs/acre, the normal Missouri average (Fig. 3). The P fertilization treatments produced average seed yields of around 400 lbs/acre with all three N treatments and stripkill. With standard pasture production ammonium nitrate and urea produced yields that were higher than N applied with beads, when all of these plots were treated with P

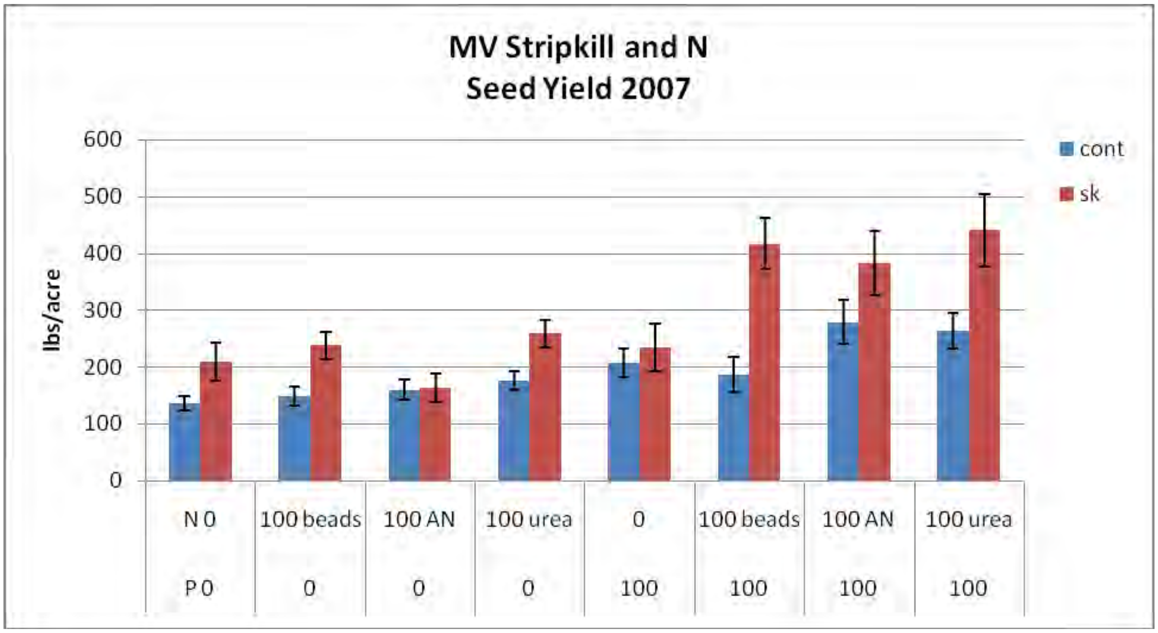
(Fig. 3). One of our stripkill and P treated plots that received 0 N in the fall produced over 1000 lbs/acre of seed. This combination of stripkill, P treatment and 0 fall N, averaged about 875 bu/acre of seed (Fig. 3). With stripkill and P treatment, the ammonium nitrate and urea treatments were better that N supplied with the beads. With regular pasture production, and P treatment, ammonium nitrate was the best N source (Fig. 3).

In 2008, the combination of P fertilization, stripkill and 0 N treatment in August produced double the seed yield of the 0N, 0P and regular pasture production control (Fig. 3). It is obvious that the two years in this study were completely different, weather-wise. The first year with P fertilization, stripkill and all three N treatments, the seed yields were much superior to any of the other treatments. However, in 2008, the P fertilization, stripkill, and 0 N in the fall treatment was clearly the best (Fig. 3). This N result supports the recommendation made years ago by our forage extension agronomist, Howell Wheaton (ref.), who recommended no N in the fall, and around 100lbs N in Dec or Jan. (Just a reminder that in the current study, all plots received 75 lbs N in mid-winter).

Conclusions: In both growing seasons, the highest yielding plots received P fertilization and were from stripkill treatments. In the second year, the best production season, clearly late August N applications caused problems in the P treated, stripkill plots. This project successfully showed that in a good production year, application of P onto low P tall fescue pastures, and using the stripkill can greatly improve tall fescue seed production in Missouri.

Figure 1. Will McClain using his “homemade” spray rig with Roundup and a tracking dye to kill 7.5” strips in tall fescue plots in September 2006.

Figure 2. Killed strips in November 2006 in plots of tall fescue that will be used for seed harvest in June of 2007.



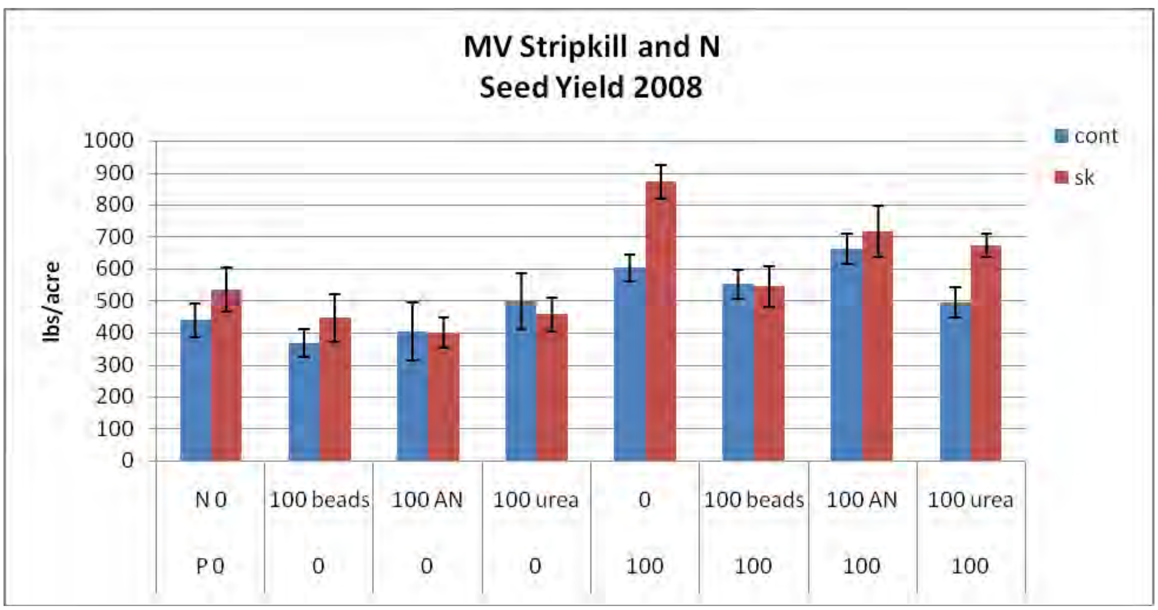


Figure 3. 2007 (top) and 2008 (bottom) tall fescue seed yields from plots at the University of Missouri Southwest Center near Mt. Vernon as a result of fall treatment with three nitrogen sources, two phosphorus treatment levels and stripkill versus comventional culture.

Progress Reports

ENVIRONMENTALLY SOUND HIGH IMPACT FORAGE MANAGEMENT RESEARCH BASED DEMONSTRATIONS FOR INCREASED LIVESTOCK PROFITABILITY BY INCREASING FORAGE PRODUCTION AND QUALITY

Todd Lorenz, Rich Hoormann, Wendy Flatt, Gene Schmitz, Joni Ross, Dustin Vendrely, Randa Doty and Rob Kallenbach

Objectives, including relevance of project to Missouri fertilizer/lime use:

Livestock producers and landowners read about basic forage plant, soil fertility, and animal management techniques that can improve pasture eco-systems, carrying capacity and ultimately farm profitability. However, many are not responsive to adopting these current forage management techniques. Many producers have not had access to research plots that demonstrate the short term and long term plant responses to fertility management changes. This project combines multiple demonstrations of University of Missouri research based forage fertility management practices on a strategically selected farmer field location that allows producers to follow changes in pasture eco-system and profitability per acre through on-site demonstrations and field days.

Procedure:

During the spring of 2007, a 5-acre field was identified and soil tested. Based on soil test results and discussions with Extension Specialists, fertilizer dealers and farmers, eight different fertilizer combinations were applied to field-scale plots containing primarily tall fescue (Table 1). Plot dimensions are 50 feet X 50 feet. Lime was applied as a sub-plot across all treatments. Fertilizer and lime were applied with commercially available fertilizer equipment. The legume fertilizer treatment was further split with red clover and lespedeza being hand seeded in 25 feet X 50 feet plots. A waste lime treatment was added in 2008.

Weather has impacted this research project. A late freeze in April 2007 may have reduced first cutting forage yields. 2008 was a very wet year, and yields may be higher than normal expectations due to very favorable moisture supplies throughout the growing season. For the months March through August 2008, 25.55 inches of rainfall were recorded at the research site. This was 8.36 inches more rainfall during 2008 compared to the same months during 2007.

Forage was harvested during May, August and October in 2007 and May, August and November in 2008 with a mechanical forage harvester. Four replications per treatment were harvested. Harvested forage was weighed and subsamples were taken for nutrient analysis. Harvest area was measured and dry matter yield was calculated. Subsamples were weighed, dried and re-weighed to determine moisture content. Subsamples were then sent to a commercial lab for protein, fiber and mineral analysis.

Results – Yield, nutrient analysis, economic analysis and education and outreach:

Yield: As expected, full fertility based on University of Missouri soil test results for a yield goal of 3 tons of hay per acre produced the most forage during 2007 and 2008 (Tables 2 and 3). Clearly, increasing fertilizer increased forage yield. The question remains, is the value of forage production and quality offset by the increased cost of the fertilizer?

It is interesting to note the yield response of the plots to phosphorus (P) fertilizer in 2008. Our initial soil tests in the spring of 2007 report available P at 6 lbs/acre. When comparing 2008 yields with 2007 yields, the plots that received P fertilizer had yield increases of -162, 4009, 1933, 2472, 2965 and 2079 pounds dry matter per acre. The plots that received no P fertilizer had -814, 840 and 914 pounds dry matter per acre yield increases. The plot that received P fertilizer and had a yield reduction of 162 pounds per acre was the full fertility treatment, however it was the highest yielding treatment for both years.

Nutrient Analysis: Nutrient analysis for protein, fiber and minerals has been completed for 2007 and the first two harvests for 2008. The 2008 nutrient analysis from the November harvest has not yet been received. In addition to yield, the production of nutrients, especially energy and protein, are important to beef cattle producers. We will further analyze the yield and quality data by estimating animal performance from each fertilizer treatment.

Statistical analysis will be completed on mineral concentrations to compare the treatments and possible mineral interactions and correlations. High concentrations of one mineral can negatively impact another, so the affected mineral is “tied up” and cannot be digested and utilized fully.

Economic Analysis: Preliminary economic analysis on yield and cost for 2007 are shown in Table 5 and for 2008 in Table 6. However, the economic impacts of forage fertilization involve more than the cost of fertilizer and the yield response. Forage quality and animal performance must also be evaluated. Economic analysis on these issues will be available in upcoming months.

Education and Outreach: Two educational workshops were held in our establishment year. On August 30, 2007, approximately 80 people from eight surrounding counties attended the first field day at the plots. Producers learned of the reasoning behind the fertility treatments, data that was being collected, how that data was going to be used and heard some preliminary data that had been obtained from earlier harvests.

Our second event was held in mid-November and approximately 30 people attended that event. Additional results were presented along with information about nutrient cycles in forage systems and winter feeding programs for beef cattle.

The third educational workshop was held in mid-June 2008. Twenty-five producers from the Montgomery County area toured the site and heard an update on research results. A winter 2009 event is planned so producers will have a chance to see the results and make forage fertilization decisions based on current fertilizer prices and expected results.

The regional specialists involved in the project continue to field questions and hear comments about the plots and the results being obtained there. Results being obtained from this study are highlighted at regional meetings, winter workshops and grazing schools.

The visibility of this project promises to keep forage fertility on the minds of area producers for years to come. The positive comments from farmers in the area indicate this has been well received by the public and they are learning from the results.

ENVIRONMENTALLY SOUND HIGH IMPACT FORAGE MANAGEMENT RESEARCH BASED DEMONSTRATIONS FOR INCREASED LIVESTOCK PROFITABILITY BY INCREASING FORAGE PRODUCTION AND QUALITY

Supplemental and Waste Lime overlay Progress Report

A low management pasture with high visibility was selected for the demonstration site in 2007. The original forage experiment is a replicated split plot design with lime and no lime on the main plots and treatments to include a control check, soil test recommended fertility, a typical retailer recommended pasture fertility package, 30 lbs P only, and 50 lbs N only. The affects of the “Easter” freeze of 2007 has given us concern about the total yield potential and has reduced our legume stand in our establishment year. The legume portion of the plot area will be over-seeded with legumes again for 2008 in order to simulate ergovaline dilution recommended practices. In addition to improving data quality in our first study, extending this study an additional year will allow us to add this supplemental experiment that will include treatments with Ag lime and various available waste lime products. Generating data by tracking soil pH and plant response (yield and plant composition) of applications of waste lime over time is critical to demonstrating the profitability of applying certified Ag lime materials.

Plots will be harvested three times annually to follow annual forage response to management changes and long term economic impact from increased productivity and quality. Forage analysis will be conducted on each of the treatments during each of the harvest to show forage quality variations in a year round forage production system. Statistical analysis of data collected will be performed and compared to other research areas. Field days will be conducted twice annually for the duration of the grant to provide demonstrations of proven research based concepts. These concepts will include but not be limited to: soil testing, liming, fertilizer materials, fertilization timing, grazing heights, extended grazing using legumes, grazing frequency, environmental quality and economic benefit of implementing these practices.

2008 Results

Monthly rainfall totals measured 8.36 inches greater than those recorded for the previous year on this same location. April through August rainfall totals were greater than the 30 year average.

Waste lime was applied on May 7, 2008 to the appropriate plots in this supplemental overlay. Three forage harvests were conducted (May 13, August 5, and November 11). Yearly yield totals reflected an increase of .2 ton/acre in the Agricultural Limestone application when compared to the Waste Lime. Even with this separation in the year of application, we expect this variation to widen with more reaction time in 2009.

Table 1. Plot layout and treatment identification.

	N only 50-0-0	Synergy 50-30-0	P only 0-30-0	K only 0-0-30	Dealer 50-30-30	Check 0-0-0	Soil Test 100-65-60	Legume 0-65-60	Legume 0-65-60	Waste Lime
Rep 1 No lime	101	201	301	401	501	601	701	801 rcl	901 lesp	111
Rep 1 Lime	102	202	302	402	502	602	702	802 rcl	902 lesp	112
Rep 2 No lime	103	203	303	403	503	603	703	803 rcl	903 lesp	113
Rep 2 Lime	104	204	304	404	504	604	704	804 rcl	904 lesp	114
Rep3 No lime	105	205	305	405	505	605	705	805 lesp	905 rcl	115
Rep 3 Lime	106	206	306	406	506	606	706	806 lesp	906 rcl	116
Rep 4 No lime	107	207	307	407	507	607	707	807 lesp	907 rcl	117
Rep 4 Lime	108	208	308	408	508	608	708	808 lesp	908 rcl	118

rcl= Red Clover, lesp = Lespedeza

Table 2. 2007 and 2008 Yield Results, lbs dry matter per acre.

Treatment	May `07	May `08	Aug `07	Aug `08	Oct `07	Nov `08	Total `07	Total `08
0-0-0	3097	960	3354	3936	752	1502	7203	6398
0-0-30	1950	920	3443	4404	564	1547	5957	6871
0-30-0	1541	1279	3666	4707	333	1633	5540	7619
0-65-60 lesp	3168	1724	2761	5465	586	1798	6515	8987
0-65-60 rcl	3092	3473	3233	5269	926	2518	7251	11,260
100-65-60	6332	4550	4421	4319	1239	2961	11,992	11,830
50-0-0	3086	2006	2591	3745	500	1266	6177	7017
50-30-0	2514	3037	2962	4442	352	1314	5828	8793
50-30-30	3327	3095	3178	4151	633	1825	7138	9071
Waste lime	--	5010	--	3810	--	1819	--	10,639
Avg by harv. date	3123	2605	3290	4425	654	1818	7067	8849

Table 3. Yield Ranking, lbs. dm/acre

Treatment	2007 Yield Ranking	2008 Yield Ranking	Yield difference (`08 vs.`07)
100-65-60	1	1	-162
0-65-60 rcl	2	2	4009
0-0-0	3	9	-814
50-30-30	4	3	1933
0-65-60 lesp	5	4	2472
50-0-0	6	7	840
0-0-30	7	8	914
50-30-30	8	5	2965
0-30-0	9	6	2079

Table 4. Income Ranking, $/acre

Treatment	`07 Income Ranking*	`08 Income Ranking**	Income difference (`08 vs.`07)
100-65-60	1	7	-$119.23
0-0-0	2	4	-$26.93
0-65-60 rcl	3	1	$77.30
50-30-30	4	5	$11.78
0-65-60 lesp	5	8	$4.35
0-0-30	6	6	$17.93
50-0-0	7	9	$11.88
0-30-0	8	2	$54.41
50-30-0	9	3	$66.88

* = 2007 yield and 2007 fertilizer prices
** = 2008 yield and 2008 fertilizer prices

Table 5. 2007 Forage Budget.

2007 Forage Budget - Clifton City Forage Plot

		N only	Synergy	P only	K only	Dealer	Check	Soil Test	Red Clover	Lespedeza
		50-0-0	50-30-0	0-30-0	0-0-30	50-30-30	0-0-0	100-65-60	0-65-60	0-65-60
Estimated Income/Acre										
May yield	lbs/acre	3084	2550	1578	1988	3357	3124	6370	3198	3125
August yield	lbs/acre	2591	2926	3667	3443	3178	3354	4421	2762	3234
October yield	lbs/acre	500	352	334	564	633	752	1239	586	926
Total yield	lbs/acre	6175	5828	5578	5994	7168	7230	12030	6546	7285
Income/acre	**$70.59 per ton**	**$217.94**	**$205.69**	**$196.87**	**$211.57**	**$253.00**	**$255.17**	**$424.58**	**$231.04**	**$257.11**
Operating costs/acre										
N - Urea (46% N)	$0.50	25.00	25.00	0.00	0.00	25.00	0.00	50.00	0.00	0.00
P - Phosphate	$0.34	0.00	10.20	10.20	0.00	10.20	0.00	22.10	22.10	22.10
K - Potash	$0.23	0.00	0.00	0.00	6.90	6.90	0.00	13.80	13.80	13.80
Application charge	$5.00/acre	5.00	5.00	5.00	5.00	5.00	0.00	5.00	5.00	5.00
Fertilizer cost/Acre		***$30.00***	***$40.20***	***$15.20***	***$11.90***	***$47.10***	***$0.00***	***$90.90***	***$40.90***	***$40.90***
Crop supplies		4.45	4.45	4.45	4.45	4.45	4.45	4.45	4.45	4.45
Custom hire & rental		13.50	13.50	13.50	13.50	13.50	13.50	13.50	13.50	13.50
Machinery fuel		4.94	4.94	4.94	4.94	4.94	4.94	4.94	4.94	4.94
Machinery repairs & maintenance		6.66	6.66	6.66	6.66	6.66	6.66	6.66	6.66	6.66
Operator & hired labor		6.38	6.38	6.38	6.38	6.38	6.38	6.38	6.38	6.38
Operating interest @ 8.75% x 1/2 year		3.79	3.79	3.79	3.79	3.79	3.79	3.79	3.79	3.79
Total Operating Costs/Acre		**$69.72**	**$79.92**	**$54.92**	**$51.62**	**$86.82**	**$39.72**	**$130.62**	**$80.62**	**$80.62**
Income Over Operating Cost/Acre		**$148.22**	**$125.77**	**$141.95**	**$159.95**	**$166.18**	**$215.45**	**$293.96**	**$150.42**	**$176.49**
Ownership Costs/Acre										
Farm business overhead		2.63	2.63	2.63	2.63	2.63	2.63	2.63	2.63	2.63
Machinery overhead		7.86	7.86	7.86	7.86	7.86	7.86	7.86	7.86	7.86
Machinery depreciation		8.31	8.31	8.31	8.31	8.31	8.31	8.31	8.31	8.31
Real estate charge		28.71	28.71	28.71	28.71	28.71	28.71	28.71	28.71	28.71
Total Ownership Cost/Acre		**$47.51**	**$47.51**	**$47.51**	**$47.51**	**$47.51**	**$47.51**	**$47.51**	**$47.51**	**$47.51**
Income Over Total Cost/Acre		**$100.71**	**$78.26**	**$94.44**	**$112.44**	**$118.67**	**$167.94**	**$246.45**	**$102.91**	**$128.98**

Hay yields and hay price are on a 100% dry matter basis. Hay valued at $70.59 dry matter basis equals $60 per ton as-fed at 85% dry matter.
Prepared by Randa Brunkhorst, MU Extension Agricultural Business Specialist

2008 Forage Budget - Clifton City Forage Plot

		N only	Synergy	P only	K only	Dealer	Check	Soil Test	Red Clover	Lespedeza
		50-0-0	50-30-0	0-30-0	0-0-30	50-30-30	0-0-0	100-65-60	0-65-60	0-65-60
Estimated Income/Acre										
May yield	lbs/acre	2006	3037	1279	920	3095	960	4550	3473	1724
August yield	lbs/acre	3745	4440	4707	4404	4098	3936	4319	5269	5465
November yield	lbs/acre	1266	1314	1633	1547	1825	1502	2961	2518	1798
Total yield	lbs/acre	7017	8791	7619	6871	9018	6398	11830	11260	8987
Income/acre	**$70.59 per ton**	**$247.67**	**$310.28**	**$268.91**	**$242.51**	**$318.29**	**$225.82**	**$417.54**	**$397.42**	**$317.20**
Operating costs/acre										
N - Urea (46% N)	$0.90	45.00	45.00	0.00	0.00	45.00	0.00	90.00	0.00	0.00
P - Phosphate	$1.01	0.00	30.30	30.30	0.00	30.30	0.00	65.65	65.65	65.65
K - Potash	$0.75	0.00	0.00	0.00	22.50	22.50	0.00	45.00	45.00	45.00
Application charge	$5.00/acre	5.00	5.00	5.00	5.00	5.00	0.00	5.00	5.00	5.00
Fertilizer cost/Acre		***$50.00***	***$80.30***	***$35.30***	***$27.50***	***$102.80***	***$0.00***	***$205.65***	***$115.65***	***$115.65***
Crop supplies		4.45	4.45	4.45	4.45	4.45	4.45	4.45	4.45	4.45
Custom hire & rental		13.50	13.50	13.50	13.50	13.50	13.50	13.50	13.50	13.50
Machinery fuel		4.94	4.94	4.94	4.94	4.94	4.94	4.94	4.94	4.94
Machinery repairs & maintenance		6.66	6.66	6.66	6.66	6.66	6.66	6.66	6.66	6.66
Operator & hired labor		6.38	6.38	6.38	6.38	6.38	6.38	6.38	6.38	6.38
Operating interest @ 8.75% x 1/2 year		3.79	3.79	3.79	3.79	3.79	3.79	3.79	3.79	3.79
Total Operating Costs/Acre		**$89.72**	**$120.02**	**$75.02**	**$67.22**	**$142.52**	**$39.72**	**$245.37**	**$155.37**	**$155.37**
Income Over Operating Cost/Acre		**$157.95**	**$190.26**	**$193.89**	**$175.29**	**$175.77**	**$186.10**	**$172.17**	**$242.05**	**$161.83**
Ownership Costs/Acre										
Farm business overhead		2.63	2.63	2.63	2.63	2.63	2.63	2.63	2.63	2.63
Machinery overhead		7.86	7.86	7.86	7.86	7.86	7.86	7.86	7.86	7.86
Machinery depreciation		8.31	8.31	8.31	8.31	8.31	8.31	8.31	8.31	8.31
Real estate charge		28.71	28.71	28.71	28.71	28.71	28.71	28.71	28.71	28.71
Total Ownership Cost/Acre		**$47.51**	**$47.51**	**$47.51**	**$47.51**	**$47.51**	**$47.51**	**$47.51**	**$47.51**	**$47.51**
Income Over Total Cost/Acre		**$110.44**	**$142.75**	**$146.38**	**$127.78**	**$128.26**	**$138.59**	**$124.66**	**$194.54**	**$114.32**

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Nutrient Removal Values for Major Agronomic Crops in Missouri
Update for 2008

Manjula V. Nathan, Yichang Sun, and David Dunn

Introduction:

Currently the soil Fertility Group is working on revising the University of Missouri (MU) Fertilizer and Lime Recommendations for Missouri. At this time, there are no research based values for nutrient removal available for major agronomic crops in Missouri. Since the source of nutrient removal values currently used by the MU Fertilizer and Lime Recommendations is unknown, it was suggested that we replace the existing values in MU recommendations with data on nutrient removal values from the National Beef Research Council and National Dairy Research council. Since the crop nutrient removal values vary depending on yields, variety grown, and environmental conditions, it would be more appropriate to use nutrient uptake values from Missouri rather than using the national values reported by the National Beef and Dairy Research Councils.

Objective:

- To obtain nutrient removal values for major agronomic crops in Missouri and use them in refining University of Missouri Fertilizer Recommendations.

Current Status:

Table 1 provides a comparison of the current removal rates used in MU fertilizer recommendations, the proposed removal rates based on National Beef Research Council and National Dairy Research Council, and the rates recommended by the Potash and Phosphate Institute (PPI, 2002).

Preliminary work was done in the year 2006 by collecting grain and forage samples for major agronomic crops in the state of Missouri. The samples were collected throughout the state of Missouri by working in collaboration with Missouri Department of Agriculture Grain Inspection Service Centers, MFA grain elevators, Agricultural Experiment Station Research Center and Farms and researchers. Three hundred and twenty six grain samples from major grain crops (corn, soybeans, wheat and sorghum) and 76 forage samples from the state of Missouri were collected during the 2006 growing season. The grain and forage samples were analyzed for N, P, K, and the moisture content was estimated. Based on grain nutrient percentages, the nutrient removal values were calculated. The mean values and other statistics for grain samples collected in 2006 are provided on Table 2 and Table 3. Since the grain nutrient removal values depend on the soil, environment, management practices and other factors effecting growth, and the values obtained in 2006 were significantly different from the proposed values (National Beef Research Council and National Dairy Research Council), it was decided that we continue this study for two more years to get truly representative values for Missouri to be included into the MU fertilizer recommendations.

In 2007, to-date we have collected 377 grain samples and all the samples have been analyzed for nutrient content and the nutrient removal values have been estimated. The mean values and other statistics for grain samples collected during the 2007 growing season are reported in Tables 2 and 3. The nutrient content and nutrient removal values for all the grain samples collected up to now are presented in Table 4.

Year 2008 Update:

In 2008, due to weather conditions we had in spring, the planting was delayed as a result harvest was delayed too. So far we have only collected about 280 grain samples, and most of the samples were received only in late November. We are still in the process of collecting more grain samples. At this time of this report only 105 grain sample analysis have been completed. So only a summary of the N, P, K grain samples analysis completed up to now is provided in Table 4. A completed report will be submitted when all the grain samples for the year 2008 are collected and lab analysis is completed.

References:

1. Fixen, P.E., Bruulsema, T.W., Johnson, A. M., Mikkelsen, R. I., Murrell, T. S., Snyder, C. S., and W. M. Stewart. 2005. Soil Test Levels in North America, 2005. Summary Update. PPI/PPIC/FAR Technical Bulletin 2005-1.
2. Nathan, M. V., Sun, Y., Abernathy, S., and D. Dunn. 2007. Summary of Soil Fertility Status in Missouri by County, Soil Regions and Cropping Systems 1996 – 2006. Annual Meetings Abstract. ASA, SSSA, CSSA Madison, WI.
3. Nathan, M., Sun, Y., and D. Dunn 2007. Nutrient Removal Values for Major Agronomic Crops in Missouri. *In*: Missouri Soil Fertility and Fertilizers Research Update 2006. Agronomy Miscellaneous Publ. #07-01, College of Agriculture, Food and Natural Resources, University of Missouri. P 100-107
4. Nathan, M., Sun, Y., and D. Dunn 2008. Nutrient Removal Values for Major Agronomic Crops in Missouri. *In*: Missouri Soil Fertility and Fertilizers Research Update 2006. Agronomy Miscellaneous Publ. #08-01, College of Agriculture, Food and Natural Resources, University of Missouri. P 128-144

Table 1: Comparison of Current University of Missouri, Proposed (National Research Council), and International Plant Nutrition Institute's Recommended Nutrient Removal Values for Agronomic Crops.

		N removal			P_2O_5 removal			K_2O removal		
Crop	**Yield Unit**	**Current**	**NRC**	**IPNI**	**Current**	**NRC**	**IPNI**	**Current**	**NRC**	**IPNI**
Barley	bushel	0.96	0.87	1.1	0.38	0.33	0.4	0.24	0.29	0.35
Corn Grain	bushel	0.9	0.74	0.75	0.45	0.32	0.44	0.30	0.25	0.29
Corn Silage	ton	9.0	9.9	8.3	3.6	4.1	3.6	9.0	10	8.3
Oats	bushel	0.64	0.6	0.8	0.26	0.26	0.25	0.19	0.17	0.2
Rice	pound	0.013	-	-	0.0065	-	-	0.004	-	-
Sorghum grain	pound	0.014	0.018	0.015	0.0093	0.0067	0.0075	0.006	0.0047	0.0038
Sorghum silage	ton	13.0	10	-	4.6	3.5	-	10	15	-
Soybean	bushel	-	3.4	4.0	0.84	0.80	0.80	1.44	1.30	1.40
Wheat	bushel	1.26	1.18	1.5	0.60	0.50	0.5	0.30	0.30	0.35
Alfalfa-grass hay	ton	-	54	50	10.0	11	14	45	53	54
Bermuda grass hay	ton	50	30	41	9.0	11	11	34	40	45
Clover-grass hay	ton	-	55	45	8.2	13	14	38	57	54
Cool season grass hay	ton	40	38	34	9.0	12	16	34	47	47
Lespedeza-grass hay	ton	-	-	-	8.8	-	-	20	-	-
Sudan grass hay	ton	40	27	36	6.9	8	14	19	52	52
Warm season grass hay	ton	-	-	-	2.0	-	-	14.6	-	-

Table 2. Yearly Variation in Grain Nutrient Percentage for Grain Crops in Missouri (2006 - 2007)

Crops		Nutrient Percentage %					
		N		P		K	
		2006	2007	2006	2007	2006	2007
Corn	**Mean**	1.434	1.491	0.445	0.310	0.602	0.473
	STD	0.209	0.221	0.075	0.035	0.085	0.083
	N	141	214	141	214	141	214
	Min	1.079	0.968	0.260	0.211	0.364	0.234
	Max	2.129	2.100	0.646	0.404	0.837	0.738
	Mean ± 2.5 STD	0.911 - 1.956	0.939 - 2.043	0.258 - 0.633	0.223 - 0.398	0.388 - 0.815	0.265 - 0.681
Soybeans	**Mean**	4.878	5.779	0.443	0.623	1.598	1.872
	STD	0.499	0.394	0.034	0.050	0.143	0.245
	N	87	83	87	83	87	83
	Min	3.499	4.901	0.356	0.484	1.215	1.254
	Max	6.301	6.423	0.550	0.744	1.952	2.982
	Mean ± 2.5 STD	3.631 - 6.125	4.794 - 6.764	0.357 - 0.529	0.497 - 0.729	1.240 - 1.956	1.259 - 2.485
Wheat	**Mean**	1.828	2.218	0.336	0.425	0.467	0.557
	STD	0.324	0.308	0.044	0.037	0.078	0.123
	N	52	71	52	71	52	71
	Min	1.380	1.836	0.245	0.351	0.308	0.389
	Max	2.838	3.248	0.454	0.545	0.646	0.922
	Mean ± 2.5 STD	1.017 - 2.638	1.448 - 2.988	0.226 -0.447	0.333 - 0.517	0.271 -0.663	0.250 - 0.863
Sorghum	**Mean**	1.699	1.522	0.814	0.306	0.952	0.499
	STD	0.171	0.167	0.084	0.029	0.106	0.089
	N	17	19	17	19	17	19
	Min	1.469	1.252	0.629	0.251	0.729	0.369
	Max	2.166	1.846	0.948	0.378	1.106	0.699
	Mean ± 2.5 STD	1.271 - 2.127	1.105 - 1.938	0.604 - 1.023	0.234 - 0.378	0.687 – 1.217	0.277 - 0.720

Table 3. Yearly Variation in Nutrient Removal Values for Grain Crops in Missouri (2006 - 2007)

Crops		Nutrient Removal Values lbs/bu					
		N		P_2O_5		K_2O	
		2006	2007	2006	2007	2006	2007
Corn	**Mean**	0.678	0.705	0.479	0.334	0.343	0.270
	STD	0.099	0.105	0.081	0.038	0.049	0.047
	N	141	214	141	214	141	214
	Min	0.511	0.458	0.279	0.227	0.208	0.133
	Max	1.007	0.994	0.695	0.435	0.477	0.421
	Mean ± 2.5 STD	0.431 - 0.926	0.444 - 0.967	0.278 - 0.681	0.239 - 0.428	0.221 - 0.465	0.151 - 0.388
Soybeans	**Mean**	2.546	3.017	0.526	0.739	1.005	1.177
	STD	0.260	0.206	0.041	0.060	0.090	0.154
	N	87	83	87	83	87	83
	Min	1.826	2.558	0.422	0.574	0.764	0.789
	Max	3.289	3.353	0.653	0.883	1.228	1.876
	Mean ± 2.5 STD	1.896 - 3.197	2.502 - 3.531	0.424 - 0.627	0.589 - 0.889	0.780 - 1.230	0.792 - 1.563
Wheat	**Mean**	0.948	1.151	0.397	0.501	0.292	0.348
	STD	0.168	0.160	0.052	0.044	0.049	0.077
	N	52	71	52	71	52	71
	Min	0.716	0.953	0.289	0.414	0.192	0.243
	Max	1.473	1.686	0.536	0.643	0.404	0.576
	Mean ± 2.5 STD	0.528 - 1.369	0.751 - 1.551	0.267 - 0.527	0.392 - 0.610	0.170 - 0.414	0.156 - 0.540
Sorghum	**Mean**	0.828	0.741	0.901	0.339	0.559	0.293
	STD	0.083	0.081	0.093	0.032	0.062	0.052
	N	17	19	17	19	17	19
	Min	0.716	0.610	0.697	0.278	0.428	0.217
	Max	1.055	0.899	1.050	0.419	0.649	0.410
	Mean ± 2.5 STD	0.619 - 1.036	0.538 - 0.944	0.669 - 1.133	0.259 - 0.419	0.403 - 0.714	0.163 - 0.423

Table 4: Survey Report of the Grain Nutrient Removal Values for Major Agronomic Crops in Missouri – Year 2008 (only 105 samples completed)

Crop: Corn	N	P	K	Nutrient	Removal	Values
County	%	%	%	lbs N/bu	lbs P_2O_5/bu	lbs K_2O/bu
Albany	1.534	0.373	0.298	0.726	0.401	0.170
Boone	1.150	0.338	0.332	0.544	0.363	0.189
Franklin	1.439	0.273	0.443	0.681	0.294	0.252
Franklin	1.381	0.286	0.361	0.653	0.307	0.206
Franklin	1.604	0.351	0.449	0.759	0.377	0.256
Grundy	1.365	0.373	0.189	0.646	0.402	0.108
Grundy	1.292	0.295	0.300	0.611	0.318	0.171
Hickory	1.621	0.391	0.310	0.767	0.420	0.177
Lafayette	1.396	0.361	0.325	0.661	0.388	0.185
Lafayette	1.396	0.382	0.362	0.661	0.411	0.206
Lafayette	1.367	0.314	0.343	0.647	0.338	0.196
Lafayette	1.342	0.333	0.448	0.635	0.359	0.255
Lafayette	1.379	0.401	0.344	0.653	0.431	0.196
Lafayette	1.285	0.380	0.186	0.608	0.408	0.106
Lamar	1.576	0.335	0.241	0.746	0.361	0.137
Linn	1.460	0.338	0.354	0.691	0.363	0.202
Novelty	1.403	0.295	0.341	0.664	0.317	0.194
Oran	1.468	0.276	0.303	0.695	0.297	0.173
Portageville	1.495	0.434	0.333	0.707	0.467	0.190
Ray	1.353	0.335	0.354	0.640	0.360	0.202
Ray	1.425	0.319	0.325	0.675	0.343	0.185
Saline	1.337	0.386	0.372	0.633	0.415	0.212
Saline	1.371	0.375	0.353	0.649	0.403	0.201
Stoddard	1.586	0.269	0.350	0.750	0.290	0.199
Vernon	1.471	0.221	0.311	0.696	0.238	0.177
Warren	1.450	0.280	0.348	0.686	0.301	0.198
Mean	**1.421**	**0.335**	**0.334**	**0.672**	**0.360**	**0.190**
STD	**0.108**	**0.050**	**0.063**	**0.051**	**0.054**	**0.036**
N	**26**	**26**	**26**	**26**	**26**	**26**
Min	**1.150**	**0.221**	**0.186**	**0.544**	**0.238**	**0.106**
Max	**1.621**	**0.434**	**0.449**	**0.767**	**0.467**	**0.256**
Mean ± 2.5 STD	**1.152 - 1.690**	**0.209 - 0.461**	**0.176 - 0.491**	**0.545 - 0.800**	**0.225 - 0.496**	**0.100 - 0.280**

Crop: Soybean	N	P	K	Nutrient	Removal	Values
County	%	%	%	lbs N/bu	lbs P2O5/bu	lbs K2O/bu
Annada	4.863	0.632	1.864	2.539	0.750	1.172
Audrain	4.759	0.554	1.630	2.484	0.657	1.025
Audrain	4.821	0.542	1.777	2.517	0.644	1.118
Audrain	4.818	0.561	1.825	2.515	0.665	1.148
Audrain	4.942	0.543	1.693	2.580	0.644	1.064
Barton	4.866	0.563	1.760	2.540	0.668	1.107
Boone	4.845	0.613	1.844	2.529	0.727	1.160
Caroll	4.836	0.535	1.734	2.525	0.635	1.090
Caroll	4.875	0.588	1.735	2.545	0.697	1.091
Caroll	4.738	0.520	1.690	2.473	0.617	1.063
Carroll	4.791	0.532	1.712	2.501	0.631	1.077
Chariton	4.780	0.519	1.757	2.495	0.615	1.105
Chariton	4.793	0.538	1.160	2.502	0.638	0.729
Grand Pass	4.822	0.571	1.761	2.517	0.677	1.108
Grundy	4.819	0.514	1.691	2.516	0.610	1.064
Grundy	4.816	0.515	1.690	2.514	0.611	1.063
Lamar	4.832	0.537	1.618	2.522	0.638	1.018
Linn	4.787	0.521	1.673	2.499	0.618	1.052
Novelty	4.767	0.611	1.720	2.488	0.725	1.082
Novelty	4.720	0.625	1.641	2.464	0.742	1.032
Novelty	4.842	0.617	1.786	2.528	0.732	1.123
Saline	4.689	0.539	1.740	2.448	0.640	1.094
Saline	4.822	0.539	1.882	2.517	0.640	1.184
Urich	4.912	0.643	1.685	2.564	0.763	1.060
Warren	4.836	0.556	1.876	2.524	0.659	1.180
Mean	4.816	0.561	1.718	2.514	0.666	1.080
STD	0.056	0.040	0.138	0.029	0.048	0.087
N	25	25	25	25	25	25
MIN	4.689	0.514	1.160	2.448	0.610	0.729
MAX	4.942	0.643	1.882	2.580	0.763	1.184
Mean ± 2.5 STD	4.675 - 4.957	0.461 - 0.662	1.373 - 2.062	2.440 - 2.587	0.546 - 0.785	0.864 - 1.297

Crop: Wheat	N	P	K	Nutrient	Removal	Values
County	%	%	%	lbs N/bu	lbs P_2O_5/bu	lbs K_2O/bu
Barton	2.430	0.400	0.513	1.261	0.472	0.321
Barton	2.385	0.416	0.514	1.238	0.491	0.321
Barton	2.346	0.396	0.446	1.217	0.467	0.279
Barton	2.207	0.374	0.497	1.146	0.441	0.311
Barton	2.473	0.391	0.537	1.283	0.461	0.336
Barton	2.502	0.369	0.477	1.299	0.435	0.298
Barton	2.092	0.365	0.408	1.086	0.431	0.255
Barton	1.866	0.348	0.461	0.968	0.410	0.288
Barton	1.781	0.350	0.417	0.924	0.413	0.261
Barton	1.853	0.375	0.451	0.962	0.442	0.282
Barton	1.920	0.378	0.452	0.997	0.446	0.282
Barton	1.892	0.425	0.510	0.982	0.501	0.319
Boone	2.225	0.398	0.422	1.155	0.470	0.264
Boone	2.280	0.411	0.475	1.183	0.485	0.297
Boone	2.375	0.405	0.482	1.233	0.477	0.301
Boone	2.390	0.457	0.458	1.240	0.539	0.286
Boone	2.198	0.395	0.408	1.141	0.466	0.255
Boone	2.376	0.446	0.401	1.233	0.526	0.251
Boone	2.287	0.417	0.401	1.187	0.492	0.251
Boone	2.433	0.440	0.456	1.262	0.519	0.285
Boone	2.316	0.413	0.410	1.202	0.487	0.256
Boone	2.350	0.453	0.388	1.219	0.534	0.243
Boone	2.298	0.459	0.470	1.193	0.541	0.294
Carroll	2.315	0.403	0.409	1.202	0.475	0.256
Carroll	2.162	0.441	0.451	1.122	0.520	0.282
Carroll	2.227	0.443	0.441	1.156	0.522	0.276
Carroll	2.092	0.390	0.385	1.086	0.460	0.241
Chariton	1.906	0.404	0.489	0.989	0.476	0.306
Chariton	2.201	0.431	0.386	1.142	0.509	0.241

Chariton	2.266	0.410	0.364	1.176	0.484	0.227
Chariton	2.005	0.385	0.436	1.041	0.454	0.273
Franklin	2.137	0.413	0.488	1.109	0.488	0.305
Grundy	2.552	0.429	0.449	1.325	0.506	0.281
Grundy	2.472	0.417	0.485	1.283	0.492	0.303
Grundy	2.499	0.426	0.457	1.297	0.502	0.286
Grundy	2.603	0.448	0.432	1.351	0.529	0.270
Grundy	2.482	0.452	0.501	1.288	0.534	0.314
Grundy	2.329	0.393	0.428	1.209	0.464	0.267
Grundy	2.411	0.430	0.457	1.251	0.508	0.286
Grundy	2.341	0.441	0.451	1.215	0.520	0.282
Grundy	2.586	0.434	0.514	1.342	0.512	0.321
Grundy	2.471	0.475	0.496	1.283	0.560	0.310
Howard	2.321	0.440	0.437	1.205	0.519	0.274
Howard	2.119	0.416	0.423	1.100	0.491	0.265
Jasper	2.179	0.432	0.481	1.131	0.509	0.300
Jasper	1.657	0.358	0.568	0.860	0.423	0.355
Lafayette	2.310	0.438	0.520	1.199	0.517	0.325
Lafayette	2.201	0.453	0.478	1.142	0.534	0.299
Linn	1.971	0.444	0.406	1.023	0.523	0.254
Polk	2.379	0.426	0.447	1.235	0.503	0.280
Saline	2.316	0.445	0.449	1.202	0.525	0.281
Saline	2.322	0.417	0.421	1.205	0.491	0.263
Stoddard	2.142	0.413	0.448	1.112	0.487	0.280
Vernon	2.007	0.398	0.439	1.041	0.470	0.274
Mean	**2.245**	**0.415**	**0.453**	**1.165**	**0.490**	**0.284**
STD	**0.215**	**0.030**	**0.042**	**0.111**	**0.035**	**0.027**
N	**54**	**54**	**54**	**54**	**54**	**54**
MIN	**1.657**	**0.348**	**0.364**	**0.860**	**0.410**	**0.227**
MAX	**2.603**	**0.475**	**0.568**	**1.351**	**0.560**	**0.355**
Mean ± 2.5 STD	**1.708 - 2.783**	**0.340 - 0.490**	**0.348 - 0.558**	**0.886 -1.444**	**0.402 - 0.578**	**0.218 - 0.350**

Table 5: Comparison of Current University of Missouri, Proposed (National Research Council), Phosphate Potash Institute, and Measured Missouri Nutrient Removal Values for 2006 and 2007 for Major Agronomic Crops.

		N removal					P_2O_5 removal					K_2O removal				
				MO Values					MO Values					MO Values		
Crop	Yield Unit	Current	NRC	2006	2007	IPNI	Current	NRC	2006	2007	IPNI	Current	NRC	2006	2007	IPNI
Corn	bushel	0.9	0.74	0.68	0.71	0.75	0.45	0.32	0.48	0.33	0.44	0.3	0.25	0.34	0.27	0.29
Sorghum	pound	0.014	0.018	0.014	0.012	0.015	0.0093	0.0067	0.015	0.006	0.0075	0.006	0.0047	0.0093	0.0048	0.0038
Soybean	bushel	-	3.4	2.55	3.02	4	0.84	0.8	0.53	0.74	0.8	1.44	1.3	1.01	1.18	1.4
Wheat	bushel	1.26	1.18	0.95	1.15	1.5	0.6	0.5	0.4	0.5	0.5	0.3	0.3	0.29	0.35	0.35

Evaluation of Fall Dry Band Application of Phosphorous and Potassium Nutrient Needs for a Corn/Soybean Rotation

Rich Hoormann, Region Agronomy Specialist, Charles Ellis, Region Natural Resources Engineer, Peter Scharf, Associate Professor of Agronomy, University of Missouri Extension

Introduction:

Many Missouri farmers find their profit margins being squeezed by increasing cash rent rates and high fertilizer costs. Land owners are not agreeing to share profit risk with renters, which leaves them at a high business risk. Farmers are looking for alternative methods to reduce fertilizer costs and are reading about information from states where fall band fertilizer research has shown that broadcast rates can be reduced while maintaining yields. While fall and sidedress banding systems in the northern Corn Belt have research data there is little Missouri data on the results of such an approach, where a two year fertilizer recommendation is applied to meet the nutrient needs of a corn-soybean rotation. This is routinely applied broadcast with variable rate equipment or with blanket application equipment.

Field information under Missouri soils and environment would indicate the value of such an approach by Missouri farmers and wither it could be recommended.

The objectives of this study are to determine:

1) The yield influence of fall 2 year band application of a P_20_5/K_20 fertilizer recommendation for a corn and soybean rotation compared to a fall broadcast application.
2) Evaluate crop stand, vigor and yield results from planting directly over fall banded fertilizer using autosteer technology.
3) Evaluate fall strip tillage influence on corn/bean yield.
4) Evaluate the practicality of this approach by farmers to minimizing fertilizer costs, while maintaining or increasing yield environment.

Methods and Materials:

In fall of 2008 four cooperators were with six with low phosphorus and low potassium test sites were identified. GPS referenced soil samples were taken on test sites for determination of composite sample averages and for use in geospatial statistical analysis of treatment interactions.

Composite sample averages were used to determine the broadcast P_20_5/K_20 rate. Treatments consist of 4 replications of 0 P_20_5/K_20 (control), broadcast rate of soil test recommendation of P_20_5/K_20, broadcast rate in a band, and ½ broadcast rate of P_20_5/K_20 in a band. Plots were sized to accommodate harvest equipment of individual cooperators, but will be approximately 0.5 acres in size.

Band application was with a 4 strip till fertilizer bar mounted with a Gandy Orbit-Air box, provided in cooperation Dr. Kelly Nelson and Randy Smoot, Director, of the Greenly Memorial Research Center, Novelty Missouri. Fertilizer bands were on 30” row spacing at 5” depth.

Observations and Results:

Test fields were fall soil sampled. The six fields selected have lower than optimum fertility supplying power based on laboratory analysis. Three of the field sites chosen are rolling loess capped upland sites, one is a river bottom site and the remaining two are poorly drained claypan soil sites.

The plot application was completed at two of the loess upland sites were completed. However, delays in crop harvest due to higher than normal precipitation in East Central Missouri have prevented putting plots at the remaining four test sites.

Objectives for 2009:

During the winter-spring time range the remaining four sites will have plot application completed as site conditions allow.

Plant emergence and harvest populations will be recorded for treatment effect Pest management with cooperators will be monitored during the 2009 cropping season.

Harvest will be with a GIS mapping equipped combine and yield data collected as part of the three-year project.

Evaluation of Dry Band Application of Total Crop Phosphorous and Potassium Nutrient needs for a No-till Corn/Soybean Rotation

Rich Hoormann, Region Agronomy Specialist, Charles Ellis, Region Natural Resources Engineer, Peter Scharf, Associate Professor of Agronomy, University of Missouri Extension

Introduction:

Many Missouri farmers find their profit margins being squeezed by increasing cash rental rates and high fertilizer costs. Summarization of soil samples submitted to the University of Missouri Soil Testing Laboratory by Lincoln County farmers in 2006 document that 34% of samples had low to very low P supplying power and 28% of K samples had low to very low supplying power. With rapidly increasing cash rents and low water holding capacity of claypan soils limiting yields during dry years, farmers are looking to intensively cut input costs.

As a result, farmers are looking for methods to reduce fertilizer costs while maintaining yields. Popular press and extension research publications from northern and high plain states have shown that banding fertilizer can reduce fertilizer application rates while maintaining yields. While banding systems have research data from these production areas, there is little Missouri data on the results of such an approach. Many of the existing studies were conducted on high testing P and K soils with greater water holding capacity than the upland claypan soils in eastern and central Missouri. In addition, with current variable rate technology, it's routine for farmers to broadcast apply two years of P and K fertilizer for a corn-soybean rotation. Missouri farmers and dealers want to continue the practice of a two-year fertilizer application system.

The objectives of this study are:

1. Determine if banded phosphorus and potassium at planting can provide a yield response.
2. Determine if banding phosphorus and potassium can allow for a reduction in fertilizer rates.
3. Evaluate precision farming practices for their usefulness in this type of system.

Methods and Materials:

The 40 acre field selected for this study is typical of east central Missouri, consisting predominately of a gently rolling Mexico silt loam soil. Management of the field has been a no-till rotation of corn and soybeans and broadcast applications of P and K with liquid N applied at planting for corn. The field was grid sampled on one-acre grids in March. Composite data based on GPS reference grid points was used to calculate treatment fertilizer rates. Whole field fertility characteristics consist of soil pH_s 6.7, P1 level of 41lb/A and K level of 274 lb/A. Eighteen acres of the field were selected for replicated plot area. The soil fertility characteristics in the plot area consist of pH_s 6.7, P1 32 lb/A and K 208lb/A.

Taking into account current management techniques and the objectives of the study, four treatments were selected. They are: no application of P or K, broadcast applications of P and K based upon field composite soil test results, banded application of P and K broadcast rate, one-half rate of P and K broadcast rate.

The treatment design is a randomized complete block. Each treatment was twelve rows in size with the middle six rows harvested to insure no influence from neighboring treatments. The harvested six rows were approximately .5 acres in size.

Equipment used for planting soybeans in 2008 was an IH 800 air planter in 30 in. row spacing. Targeted planting rate was 160,000 seed/A of a late group III, planted on June 12 using a no-till system. Soybeans rows were planted in proximity to the fertilizer band established in 2007 when corn was planted. Targeted row location was to be within 4 in. of the initial fertilizer band. This was accomplished, using RTK quality autosteer mounted on the planting tractor. Table 1 is the fertilizer rates applied in 2007, with the 2008 soybeans being the second year of crop removal.

Table 1. Fertilizer amounts applied by treatment in lb/A. 2007.

Treatment	**Nitrogen Sources**			**P_2O_5**	**K_2O**
	UAN	Urea	DAP		
0 P and K	70	45	0	0	0
Broadcast P and K	70	45	0	115	130
1 X Band	70	0	45	115	130
0.5 X Band	92	0	23	58	65

Broadcast fertilizer application was applied the day after planting using a conventional cart with a 40 ft. spread pattern. UAN was applied with a liquid applicator after planting for the 0.5 X band treatment to equalize N rate.

Harvest was conducted on October 20, 2008 with an Ag Leader PF 3000 yield monitor attached to a receiver for yield mapping and data collection. The middle six rows of each twelve row plot were harvested. Prior to harvesting of the plots a calibration load was harvested. The harvested area for the calibration load was similar in yield to the plots, harvested at the same flow rate as the plots. Each treatment was collected as an individual load for analysis.

Observations and Results:

The 2008 growing season for east central Missouri was challenging to a continuous wet period that extended from early spring into early summer. This prevented timely planting of the soybean crop, resulting in a delay in planting until June 12. Planting conditions were damp, with small areas still wet. The plots were scouted during the growing season for weeds, insects and diseases. Minor pest problems were found during the growing season. In August soybean aphids were detected, but were controlled by beneficial insects. Early and season long weed control were excellent. After planting, growing conditions were excellent with mild temperatures and timely rainfalls. Overall the area received over 17 in. above normal rainfall amounts for the year. Harvest conditions were good with little lodging. Harvest population was 105,000 and an average moisture content of plots harvested was12.8%.

The plot treatment yields ranged from 50.9 – 61.8 bu/A, with the mean being 54 bu/A. There was no significant difference in treatments at the 5% probability level. Analysis of yields across different soil pH, P and K levels in the field was also done with no statistical difference detected across the various soil fertility levels measured by the grid soil sampling conducted in 2007.

Table 2. Results of Yield Analysis					
	Replications				
Treatment	1	2	3	4	Trt Mean
0	53.1	51.9	55.3	55.8	54.0
0.5	54.0	53.5	50.6	61.8	55.0
1	54.6	51.2	52.2	54.4	53.1
Broadcast	53.7	50.9	51.6	54.5	53.7
Rep Mean	53.9	51.9	52.4	56.6	54.0
	No significant treatment differences (P=0.05)				

Table 3. K classes across all replications and treatments.		
No. Observations	K Levels	Yield
16	Low	54.9
16	Medium	53.7
13	High	51.1

Table 4. P classes across all replications and treatments.		
No. Observations	P Levels	Yield
16	Low	54.2
16	Medium	53.0
7	High	54.6

Table 5. pH_s classes across all replications and treatments.		
No. Observations	pH Level	Yield
14	Low	52.7
16	High	54.9

Objectives for 2009:

Corn will be planted in 2009 in the same blocks and fertilizer application system as used in 2007. After harvest of 2009, grid soil sampling on one acre grids will be done to measure possible soil fertility changes that may occur due to the different fertilizer strategies used in the study. This data along with yield data will be compiled into a final report addressing the four fertilizer strategies used.

Switchgrass and Sweet Sorghum Fertilization for Bioenergy Feedstocks

Gene Stevens, Roland Holou, David Dunn, and Allen Wrather

Missouri bioenergy processing facilities may require more than one crop species maturing at different times of the year to supply their feedstock needs. Monetary compensation for nutrient crop removal is an important issue for farmers considering growing bioenergy crops. This study is designed to evaluate nitrogen, phosphorus and potassium fertilization in sweet sorghum and switchgrass for bioenergy.

The last six months of 2008 produced wide fluctuations in fuel prices in the world. In July, many stations in Missouri sold gasoline for $4 per gallon. In December, gasoline in Hayti, Missouri dropped to $1.30 per gallon. Does this mean that we need to abandon our plans to produce more biofuel in this country? Unfortunately, that is what we did in the 1970's. Aside from economic issues, our dependence on foreign oil is a growing national security problem. We are currently importing over 60% of our fuel from other countries.

Objectives To determine optimum nitrogen rates, monitor the amount of potassium and phosphorus in stem and leaves throughout growing season, and develop P and K soil test recommendations for sweet sorghum and switchgrass.

Procedures: Switchgrass. Two test sites have been identified for studying switchgrass fertilization. Beginning in 2007, biomass yield and nutrient content was measured from an established stand of switchgrass on the Aubrey Wrather Farm located 3 miles east of Portageville. The switchgrass was planted 10 years ago in strips to provide wind protection from blowing sand for cotton seedlings. In late November 2007, we found tissue content averaged 0.03% P and 0.12% K in leaves and 0.04 % P and 0.54% K in stems. The second switchgrass site is located near Kennett, Missouri. The Missouri Department of Conservation granted us permission to establish research P and K fertilization plots on low testing soil areas in existing switchgrass fields at Little River Conservation Area next to Jerry P. Combs Lake located 5 miles east of Kennett on Highway 412.

At the Little River site, soil samples were collected from several locations in each field to find an area with soil test levels below 45 lb P/acre and/or 250 lb K/acre. A fertilizer response test using seven rates of each nutrient with four replications was conducted to determine critical threshold levels for producing the most economically optimum switchgrass biomass levels. A Troy-Bilt sicklemower was used to harvest biomass yields at mid-summer and in November. At the Wrather Farm, switchgrass biomass was collected from plots in June, July, October, and November. Tissue subsamples will be separated into leaf and upper and lower stem parts, weighed, oven dried, and tested for NPKS content. Root balls were dug, washed, and ground for nutrient analyses to evaluate nutrient remobilization from stems and leaves to roots in the fall.

Sweet Sorghum.

In 2007, an experiment was begun to determine optimum nitrogen fertilizer rates for producing ethanol from corn and sweet sorghum. Tests were conducted on a Tiptonville silt loam with linear move irrigation. Seven N rate treatments per crop are being used with four replications. Corn rates were 0, 50, 100, 150, 200, 250, and 300 lb N/acre. Sweet sorghum rates were 0, 25, 50, 75, 100, 125, and 150 lb N/acre. Ammonium nitrate were broadcast applied. Corn plots were harvested with a plot combine and sweet sorghum plots harvested with a sickle mower. Sugars in the sorghum stalks are being analyzed for sucrose, glucose, and fructose. The bagasse is being tested for acid soluble lignin, acid insoluble lignin, arabinan, xylan, mannan, galactan, and glucan.

Results: In 2008, we learned that the best time to harvest switchgrass may be in October (Figure 1). We had the highest biomass yields at that time and because it was late in the season most of the P and K had translocated back to the roots so there was less nutrient removal than summer cuttings (Figure 2). Almost no regrowth was measured in plots that had been cut earlier in the summer. We learned that in the summer the growing point is 8 to 12 inches above the soil surface (Wayne Bailey, personal communication). Therefore, by setting our cutter 4 to 6 inches high, we had cut off the growing point and stunted the growth. Fortunately by waiting until the fall to harvest, farmers can avoid this problem because the growing point has moved farther down the plant for winter.

Most people associate sweet sorghum with sorghum syrup. But, in this project, we are looking at using the sorghum sugar to make ethanol. We collected biomass yields from the sweet sorghum in 2008 but have not tested the sugar content in the stalk samples that are currently in our lab freezer. In 2007 on a silt loam soil, we found that the sorghum stalks contained sucrose, glucose and fructose which when fermented produced 587 gallons per acre (Table 1-2). Added with 195 gallons gallons possible from converting glucan (cellulose) in the stalks to ethanol, the total potential ethanol was 782 gallons per acre (Tables 3-4). In 2007, corn plots in the same study produced over 200 bushels grain per acre which produced close to the same amount of ethanol as from sweet sorghum sugar (Figure 3). This is assuming a conversion rate of 2.8 gallons of ethanol per bushel of corn grain. The main difference was that we only needed 60 lbs N per acre on the sweet sorghum to produce optimum sugar yields versus 160 lbs N per acre in the corn plots.

In 2008, corn yields plateaued around 175 bushels per acre on our silt loam site but produced less than 100 bushels on the sandy and heavy clay locations (Table 5). The sorghum produced approximately 40 tons fresh weight per acre on the silt loam and clay sites (Figure 4 and Table 5). This indicates to me that maybe we are better off planting corn for food and feed on our most productive silt loam soils and growing sweet sorghum for ethanol in fields with marginal soils.

Table 1. Composition of extractable liquids from sweet sorghum produced with 60 lb N/acre in 2007 on Tiptonville silt loam soil.

Composition	lb per acre	Net weight %
Water	26,030	64
Sucrose	6,454	16
Glucose	414	1
Fructose	345	1
Unknown water extractables	2,348	6
Bagasse	5,199	13

Table 2. Calculations for converting sucrose and fructose to glucose and glucose to ethanol in sorghum stalks from 60 lb N per acre plots in 2007.

Sucrose + H_2O → 2 Glucose
342 18 2 x 180=360 (formula wt)
disaccharide

6,454 lb sucrose = 6,794 lb glucose

Fructose + ½ O_2 → Glucose
164 16 180
isomer invertase

354 lb sucrose = 389 lb glucose

	As lb glucose
Sucrose	6,794
Glucose	414
Fructose	389
Total	7,586 lb glucose/acre

Glucose → 2 Ethanol + 2 CO_2
180 46 44 (formula wt)

Glucose

$$7{,}586 \text{ lb} \times \frac{2(46)}{180} = 3{,}877 \text{ lb ethanol}$$

587 gallons ethanol/acre from sugars based on 6.6 lb ethanol per gallon

Table 3. Composition of bagasse (stalk after extraction) from sweet sorghum produced with 60 lb N/acre in 2007 on Tiptonville silt loam soil.

Composition	lb per acre	Net weight %
Acid soluble lignin	489	9
Acid insoluble lignin	1,092	21
Arabinan	187	4
Xylan	811	16
Mannan	10	>1
Galactan	42	>1
Glucan-chemical name for cellulose	2,293	44
Unknowns	276	5

Table 4. Calculations for converting glucan (chemical name for cellulose) in sweet sorghum bagasse to glucose and ethanol in sweet sorghum stalks from 60 lb N per acre plots in 2007.

Glucan + $H_2O \rightarrow$ Glucose
"cellulose"

180/(180-18) = 1.1 lb glucose/lb glucan

2,293 lb glucan x 1.1 x 0.0774= 195 gallons ethanol/acre

Table 5. Corn and sweet sorghum yields on Sharkey clay and Malden sand in 2008 at the University of Missouri Lee Farm at Portageville and University of Missouri Rhodes Farm at Clarkton, Missouri.

	Corn yield			Sweet sorghum yield	
Lb N/acre	Clay	Sand	Lb N/acre	Clay	Sand
	----bushel/acre----			--fresh wt. ton/acre--	
0	19	33	0	24	18
40	37	59	20	24	16
80	55	74	40	28	21
120	50	93	60	39	18
160	74	85	80	37	22
200	85	98	100	34	26
240	66	91	120	38	21

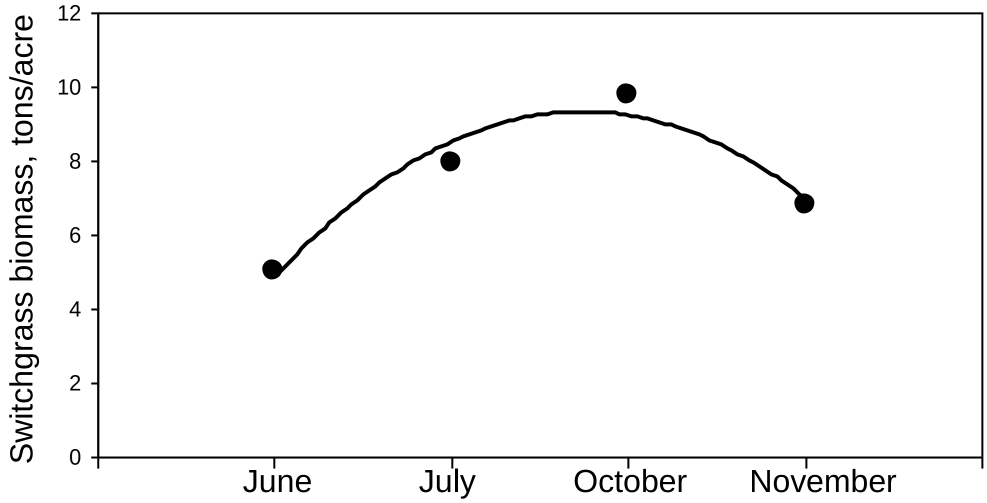

Figure 1. Seasonal biomass yield from switchgrass in the summer and fall at the Aubrey Wrather Farm at Portageville, Missouri in 2008.

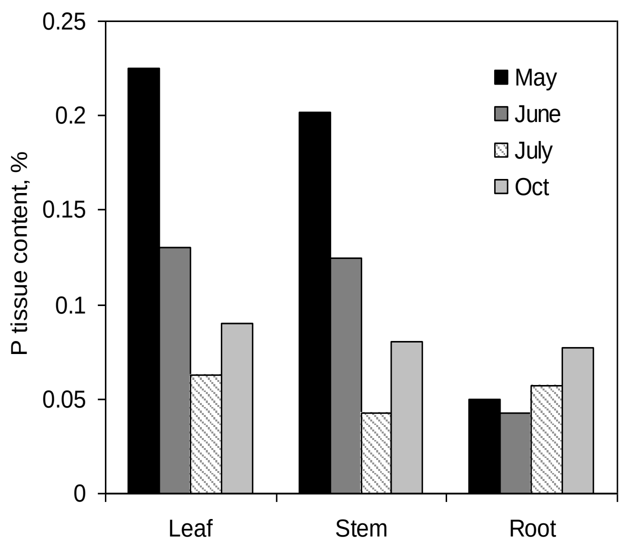

Figure 2. Seasonal phosphorus partitioning in leaf, stem, and root tissue measured in switchgrass in the summer and fall at the Aubrey Wrather Farm at Portageville, Missouri in 2008.

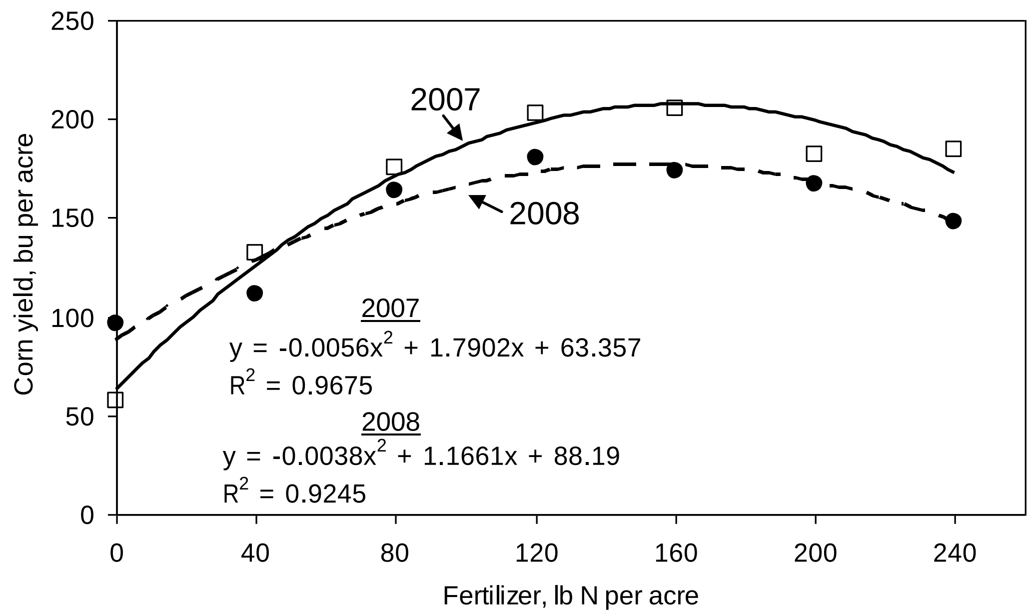

Figure 3. Corn grain yields in 2007 and 2008 on Tiptonville and Reelfoot silt loam soils as affected by nitrogen fertilizer rates applied as ammonium nitrate.

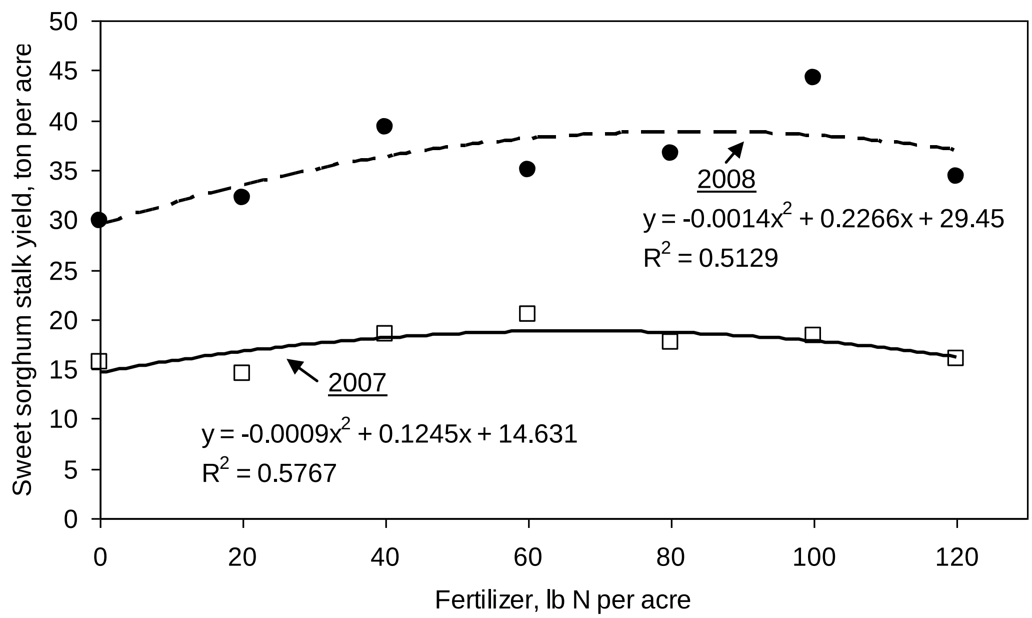

Figure 4. Sweet sorghum stalk fresh weight yields in 2007 and 2008 on Tiptonville and Reelfoot silt loam soils as affected by nitrogen fertilizer rates applied as ammonium nitrate.

Soil Sampling and Fertility Build-up Management

Gene Stevens and David Dunn

University of Missouri (MU) soil test laboratory recommendations for P and K fertilizer are based on three components: target level, crop removal, and build-up. Target level is the amount of extractable nutrient found in a soil at which point applying more fertilizer containing the nutrient will probably not increase crop yields. Crop removal is how much the nutrient is reduced in the soil annually from harvested forage, grain, or fiber. Build-up is the additional fertilizer needed above crop removal to increase low- and medium-testing soil P and K to the target fertility levels for crop production.

Soil P and K build-up can be slow or fast depending on the economic situation of the farmer. Total fertilizer applied in slow and fast build-up programs is about the same amount, but the cost may be spread out over more years in slow build-up periods. The current soil test recommendation system used by MU allows growers to select the number of years over which to build-up soils. This decision has a large effect on the amount of fertilizer that a farmer will purchase and apply in a given year. If a grower does not select a build-up period, the soil test lab uses an 8-year default build-up time to calculate fertilizer recommendations.

Research has not been conducted to determine which build-up strategy is the most profitable to manage crop nutrients in row crop and forage production. Long build-up programs help farmers manage their financial resources by spreading fertilizer costs over several years. However, growers need information concerning the magnitude of yield loss that may occur early in an 8-year build-up as compared to a shorter build-up (1 to 4 years).

The objective of this long-term study is to evaluate the effects of P and K build-up periods on yields of tall fescue hay, cotton, and soybean and rice in rotation and to validate the build-up equations used in the MU fertilizer recommendation program.

Materials and Methods

<u>Rice/Soybean Rotation</u>

An experiment was established in 2004 at the Missouri Rice Research Farm at Qulin, Missouri. Two rice pans were used with soybean and rice rotated between them each year. The experimental design is a randomized complete block with four replications. Permanent markers were placed to help locate research plots in following years. In the spring before fertilizer applications are made, composite soil samples are collected from each plot and analyzed at the MU Delta Center Soil Lab. Yield goals being used to calculate P and K fertilizer recommendations are 45 bu/acre for soybean and 6075 lb/acre (135 bu) for rice. Standard treatments include an untreated check, 1-year, 4-year, and 8-year buildup fertilizer programs. Treatments are included to compare using soybean versus rice soil test target levels. Current MU target soil P buildup for rice is 35 lb Bray-P/acre and soybeans is 45 lb Bray-P/acre. Target ammonium acetate extractable K is 125+(5XCEC) for rice and 220+(5XCEC) for soybeans. Rice receives 150 lb N/acre in a 3-way split application program.

Fescue. A field experiment in a non-renovated fescue hay field was begun in 2004 and is currently mid-way through an eight-year evaluation. The study location is on a Tonti-Hogcreek complex (Typic Fragiudult) soil in the Ozark Highlands near Mountain View, Missouri. The experimental design is a randomized complete block with four replications and permanent markers were installed when the test was established to help locate research plots in following years. Initial soil test levels in the test area averaged 8 lb Bray-1 P/acre and 162 lb ammonium acetate-extractable K/acre. Cation exchange capacity (CEC) was 6.5 meq/100g soil and organic matter content was 1.5%.

Each spring before fertilizer applications are made, 0 to 6-inch composite soil samples are collected from each plot and analyzed for Bray-1 P and ammonium acetate-extractable K at the MU- Delta Center Soil Laboratory at Portageville, Missouri. Hay yield from each plot is determined by harvesting forage (typically two or three cuttings per year) using a lawnmower with a bagging attachment. Forage subsamples are collected from each plot and oven dried to calculate moisture content and analyzed for N, P, and K content, crude protein, and acid and neutral detergent fiber (ADF and NDF, respectively).

Fertilizer treatments used in the experiment were an untreated check, a nitrogen only check, and 1-year, 4-year, and 8-year P and K build-up programs (Table 1). The treatments were designed so that at the end of eight years, the total amount of fertilizer applied to each plot would be close to equal. Triple super phosphate (0-46-0) and muriate of potash (0-0-60) were used as P & K sources. Each plot except the untreated check was fertilized with 80 lbs N/acre as ammonium nitrate and ammonium sulfate each year (50 lb N and 9 lb S/acre in late March, 30 lb N/acre in early September).

Shown below are the equations used at MU to calculate the P and K build-up component of soil test recommendations.

$$\text{Build-up } P_2O_5 = \frac{110(X_d^{1/2} - X_o^{1/2})}{\text{Years}} \qquad \text{Build-up } K_2O = \frac{75.5(X_d^{1/2} - X_o^{1/2})}{\text{Years}}$$

X_d = target soil test level in lb P or K per acre
X_o = observed soil test level in lb P or K per acre
Years = desired time period for build-up

The MU Bray-1 P target for fescue is 40 lb P per acre. Target ammonium acetate-extractable lb K/acre is 160 + (5 x CEC). The soil CEC of the test field was 6.5 so the calculated K target was 193 lb K/acre. When farmers submit soil samples to Missouri labs for testing, they are asked to provide a crop yield goal to be used to calculate additional fertilizer needed to compensate for crop removal. For the test field at Mountain View, the farmer selected a 2-ton/acre yield goal. Current MU recommendations estimate fescue hay nutrient removal at 9 lb P_2O_5 /ton and 34 lb K_2O /ton. Thus, the 2-ton yield goal used for this study resulted in the crop removal fertilizer component in the build-up treatments being 18 lb P_2O_5 and 68 lb K_2O /year (Table 1).

Cotton

Cotton field experiments were begun in 2007 on a Malden fine sand soil (0.8% organic matter, 3.8 meq/100 g soil cation exchange capacity, CEC) at Clarkton, Missouri and a Dundee silt loam (2.3% organic matter, 14.7 meq/100g soil CEC) at Wardell, Missouri.

All plots received equal nitrogen rates. Phosphorus (P) fertilizer was applied to all plots at a rate of 30 lb P2O5 per acre. Standard treatments for K include an untreated check and 1 through 8-yr buildup fertilizer programs. Buildup treatments of 1 to 8 years were applied at rates of 167, 97, 74, 63, 56, 51, 48, and 45 lb K2O per acre. In the following years, each treatment, excluding the 1-yr buildup, will get K fertilizer based on the years of buildup treatment (2 to 8 years). After each buildup has been completed, treatments will receive maintenance K applications based on crop removal of K2O. Plots were mechanically harvested and grab samples were collected to identify crop removal of nitrogen, phosphorus and potassium.

Results and Discussion

Rice/Soybean Rotation

The 2007 growing season was the last buildup year for the four year program. In 2008, we began a maintenance program equivalent to crop removal as we did with the one year buildup beginning in 2005. Generally, yields were lower in 2008 because of poor weather at the Missouri Rice Farm. A tropical storm from Hurricane Ike caused heavy shattering of rice grain before harvest. Averaged across years, the nitrogen only untreated check produced 16 to 24 bushels per acre less rice than buildup programs and 10 to 13 bushels per acre less soybean (Table 2). Initially, we were concerned that using rice target thresholds would decrease soybean yields and that shorter buildup time would produce higher yields than long buildups but that does not appear to be happening.

Fescue

Throughout the fertilizer buildup study we have observed a change in fescue density and weed infestation which was impacted by fertility treatments. In 2008, we recorded the number of broom sedge bluestem and foxtail weeds in each plot on October 16 (Table 3). Applying nitrogen fertilizer without P and K reduced broom sedge 36% but applying P and K reduced infestation by 90% compared to no fertilizer plots. Applying nitrogen fertilizer without P and K reduced foxtail 70% and applying N, P and K reduced infestation by 81% compared to no fertilizer plots.

Cotton

Target K levels are calculated for cotton as 220 + (5 x soil CEC). Target K levels for the loam and sand were 294 and 239 lb K per acre, respectively. One year K buildup on the loam soil was above target levels. However, the 1-yr buildup failed to reach the target level on the fine sand soil. This suggests that either insufficient K was applied or K+ may have leached below 6-inch soil depth. Soil samples collected in April 2008 showed that part of the K had leached to the 18 inch soil layer (Figure 1).

On the silt loam soil, cotton yields decreased during longer buildup programs (Figure 2). One year buildup treatments averaged 220 lb lint per acre more than check plots with no K fertilizer. All treatments longer than one year were not significantly higher than check plots. On the sandy loam soil, we did not observe a consistent response to K fertilizer (Figure 3).

Table 1. Annual fertilizer application rates based on soil tests for soil P and K build-up programs beginning in 2004 (Year 1) in an Ozark Highland hay field near Mountain View, Missouri.

	Year 1		Years 2, 3, 4		Years 5, 6, 7, 8	
Build-up Program	P_2O_5	K_2O	P_2O_5	K_2O	P_2O_5	K_2O
	---------------------------lb/acre---------------------------------					
Untreated check	0	0	0	0	0	0
N only	0	0	0	0	0	0
1-year build	404	156	18†	68†	18†	68†
4-year build	115	90	115	90	18†	68†
8-year build	66	79	66	79	66	79

† Only crop removal P and K applied.

Table 2. Effect of fertilizer build-up programs on third-year rice and soybean yields on a Crowley silt loam soil at Missouri Rice Research Farm, Qulin, Missouri.

Planted Crop	Buildup program Soil crop target	2007 rates P_2O_5	2007 rates K_2O	2004	2005	2006	2007	2008
						Yield		
Rice		---lb/acre---		------------bu/acre------------				
	N only check	0	0	168	142	136	133	122
	1-year/rice target	41†	38†	192	160	133	192	141
	4-year/rice target	41‡	38‡	193	161	136	175	139
	8-year/rice target	45	67	187	159	143	174	136
	1-year/soybean target	41†	38†	172	149	138	189	134
	4-year/soybean target	41‡	38‡	170	161	150	188	138
	8-year/soybean target	56	97	165	155	134	190	150
Soybean	Untreated check	0	0	40	39	53	37	33
	1-year/rice target	38†	65	53	47	63	44	17
	4-year/rice target	38‡	65	53	49	60	45	23
	8-year/rice target	38	65	51	45	62	43	29
	1-year/soybean target	38†	65	58	54	57	49	23
	4-year/soybean target	38‡	65	51	46	55	44	28
	8-year/soybean target	50	65	51	43	57	48	22

† Only crop removal P and K was applied to 1-yr buildup treatment after 2004.

‡ Only crop removal P and K was applied to 4-yr buildup treatment in 2008.

Table 3. Fescue dry matter hay yields from two cuttings in 2008.

Build-up Program	Broom sedge	Yellow foxtail	Dry matter yield June 8	Dry matter yield Oct 16	Dry matter yield Total
	----plants per 50ft^2----		--------------ton/acre------------------		
Check	50	79	0.9	0.9	1.8
N only	32	23	1.2	1.2	2.4
1-year	5	3	1.3	1.2	2.5
4-year	6	15	1.4	1.4	2.8
8-year	4	24	1.3	1.4	2.7

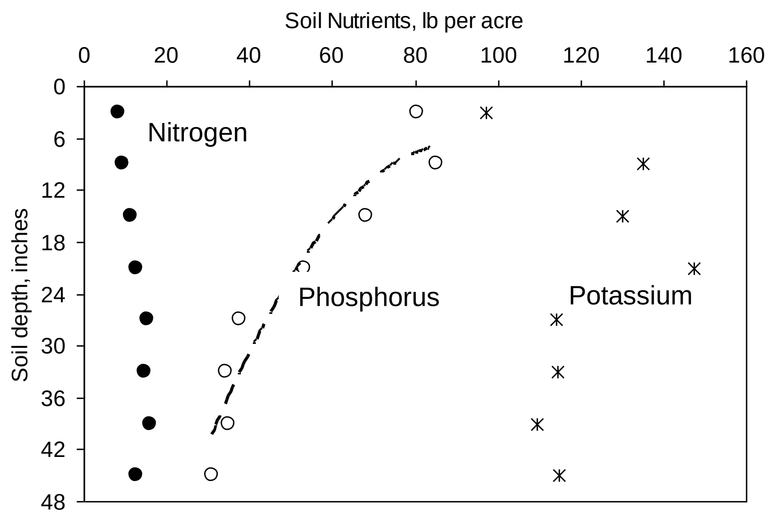

Figure 1. Cotton soil test levels of N, P, and K from 0 to 48 inches collected in 6-inch increments in 2008 at Clarkton, MO from 2-year K buildup treatment on sandy loam soil.

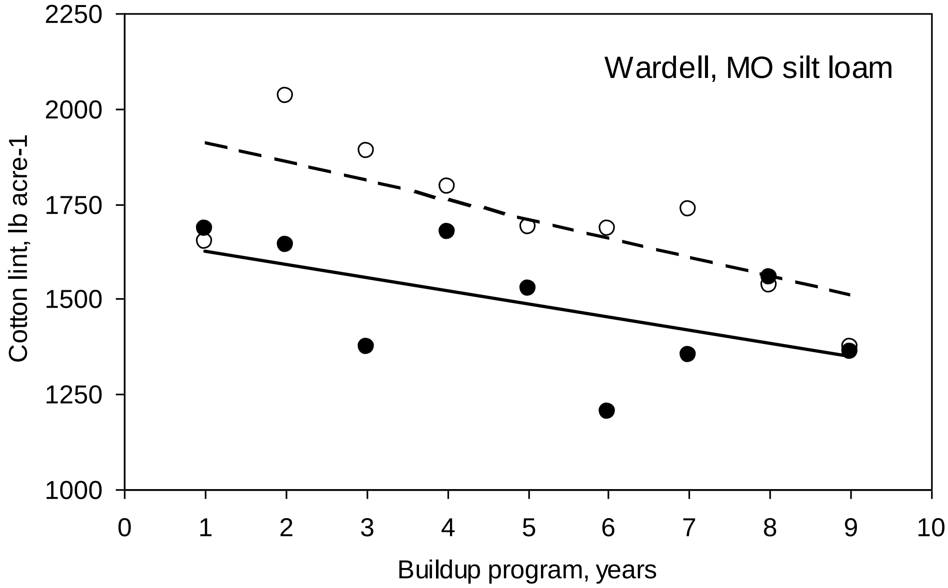

Figure 2. Cotton yields in 2007 (bottom line) and 2008 (top line) after one and two years in buildup programs at Wardell, MO on a Dubbs silt loam soil. The top line is

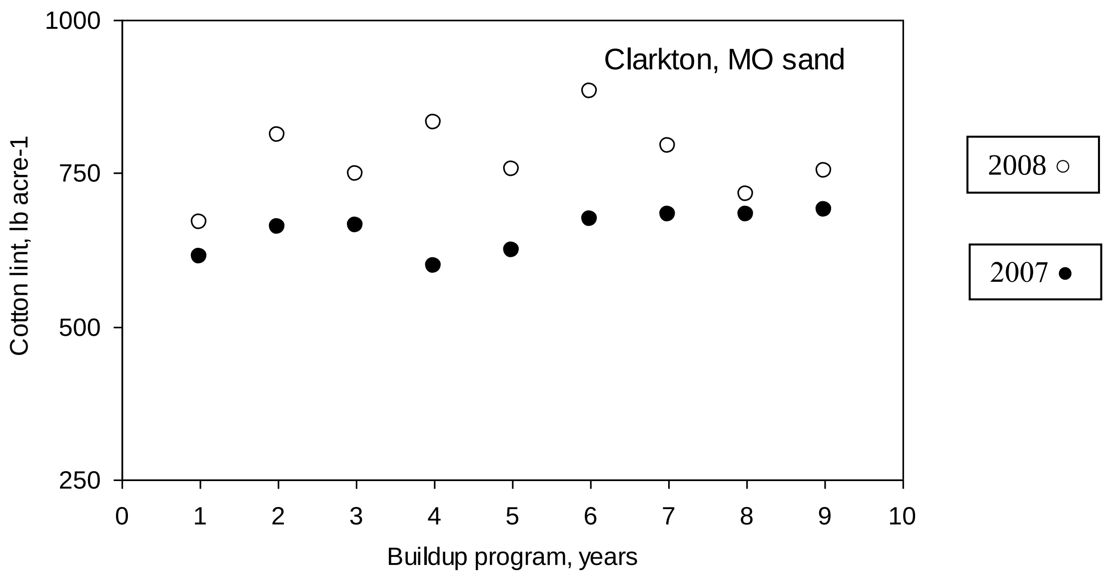

Figure 3. Cotton lint yields in 2007 and 2008 with 1 to 8 year build up programs at the MU Rhodes Farm on a sandy loam soil.

Foliar Fertilizer and Fungicide Interactions on Corn

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Gene Stevens, Div. of Plant Sciences, Univ. of Missouri, Portageville, MO
Bruce Burdick, Div. of Plant Sciences, Univ. of Missouri, Albany, MO
Laura Sweets, Div. of Plant Sciences, Univ. of Missouri, Columbia, MO

INTRODUCTION

Corn acreage increased over 25% in Missouri and total acreage in the U.S. increased nearly 10 million acres from 2006 to 2007. High yield corn production systems have integrated fungicide applications to maximize photosynthetic efficiency of the plant. Over the past four years, median corn yields for 16 site/years increased over 8 bu/acre with a strobilurin fungicide such as pyraclostrobin (Headline®) (Nelson and Smoot, 2007). The greatest yield increases due to fungicide applications have occurred in high yield environments.

Fungal infections decrease the area of photosynthetic tissue which reduces the transfer of assimilates from their source to the ear and diverts assimilates to fungal growth, defense systems, and increased respiration. Growth stimulation with the strobilurin fungicides has been related to a reduction in the incidence of disease as well as increased nitrate uptake and assimilation in small grains (Köhle et al., unpublished). Research has shown that pyraclostrobin was important in stimulating nitric oxide, a key messenger in plants (Conrath et al., 2004). Increased nitrate uptake and assimilation following an application of a strobilurin fungicide would justify additional fertilizer at the time of application. Identifying fertilizer sources that synergistically increase yield with a fungicide treatment would provide opportunities to manage disease, reduce application costs, and provide additional fertilizer when crop demand is greatest.

Research has established a link between plant nutrition and disease incidence including the disease suppressing effects of K, Cl, Mn, B, and P (Fixen et al, 2004). Combining a foliar fertilizer with a fungicide application may reduce application costs, improve disease suppression and nutrient response, and increase flexibility in managing crop response to environmental conditions during the growing season. There was a dramatic increase in the use of strobilurin fungicides in corn in 2007; however, no research has evaluated interactions between fertilizer sources and a fungicide treatment. This research will help Missouri farmers make informed decisions regarding fungicide-fertilizer interactions and how these applications affect productivity and profitability. No published research has evaluated interactions between fungicides and foliar fertilizers on corn. No research has been published on the effects of fungicide treatments on corn plant nutrient levels in the field.

The objective of this research is to evaluate improvements in yield and monitor nutrient uptake of a foliar fertilizer-fungicide management system for corn.

MATERIALS AND METHODS

The first of a two-year field trial was conducted under sprinkler irrigation at Novelty (40.035997 N, 92.243783 W) and Albany (40.251282 N, 94.326977 W) while at Portageville (36.427945 N, 89.700234 W) corn was flood irrigated to assess corn response to fungicide-fertilizer treatments in high yield environments. The soil was a Putnam silt loam (fine, montmorillonitic, mesic Mollic Albaqualf), Grundy silt loam (fine, montmorillonitic, mesic Aquic Argiudolls), and Tiptonville sandy loam (fine-silty, mixed, thermic Typic Argiudolls) at

Novelty, Albany, and Portageville, respectively. Field information about the locations and selected management practices is shown in Table 1.

The study was randomized complete block design with five, four, and three replications at Novelty, Portageville, and Albany, respectively. Treatments consisted of a factorial arrangement of foliar fertilizers combined with and without the fungicide pyraclostrobin (Headline®) at 6 oz/acre plus nonionic surfactant at 0.25% v/v applied at VT. Treatments were applied with a CO_2 propelled hand boom at 3 gallons/acre to simulate an aerial application. The following fertilizer treatments and rates were selected for this research based on previous experience and locally available foliar fertilizers used on corn in combination with fungicide treatments: 3-18-18-0 (%N-%P_2O_5-%K_2O-%S) at 2 gal/acre (NA-CHURS/ALPINE Solutions, Marion, OH), 0-0-30-0 at 2 gal/acre (Double-OK, NA-CHURS/ALPINE Solutions, Marion, OH), potassium thiosulfate (0-0-25-17) at 1 gal/acre (KTS, Tessenderlo Kerley Inc., Phoenix, AZ), potassium thiosulfate plus urea triazone (5-0-20-13) at 1.5 gal/acre (Trisert K+, Tessenderlo Kerley Inc., Phoenix, AZ), potassium chloride (0-0-62-0) at 2.5 lb/acre (PCS, Potash Corp. of Saskatchewan, Northbrook, IL), 25-0-0-0 controlled release nitrogen as methylene urea and diurea with less than 0.01% Cl at 3 gal/acre (CoRoN, Helena Chemical Co., Collierville, TN), 24-0-1-0.6 slow release N with 0.25% B at 3 gal/acre (Pacer N, Crop Production Services, Galesburg, IL), 22-0-2-1 with 0.25% B at 1 gal/acre (Task Force Maize, Crop Production Services, Galesburg, IL), 30-0-0-0 at 1 gal/acre (Nitamin, Georgia-Pacific Chemicals, LLC., Atlanta, GA), boron at 2 pt/acre (NA-CHURS/ALPINE Solutions, Marion, OH), Mn-chelate at 2 pt/acre (NA-CHURS/ALPINE Solutions, Marion, OH), Fe-Mo-Mn-B-Zn (0.3%-0.01%-3.2%-0.2%-2.1%) premix at 1 qt/acre (MAX-IN, Winfield Solutions, LLC., St. Paul, MN), and 6-0-0-0 with 10% Ca at 2.5 gal/acre (Nutri-Cal, CSI Chemical Corp., Bondurant, IA

Corn injury from 0 (no visual crop injury) to 100% (complete crop death) was evaluated 7 to 14 days after treatment based on the combined visual effects of N source on necrosis, chlorosis, and stunting. The incidence of foliar disease was rated on a scale of 0 (no disease) to 100% (complete infestation) 28 days after treatment. Ear leaf tissue status of the fungicide-treated and untreated plants was intensively monitored at each location from the time of application until black layer to build background information to target synergistic foliar nutrient applications. Analysis of corn ear leaf tissue was monitored 7 days after application for all treatments. Leaf tissue samples are currently being analyzed.

The center two rows were harvested for yield and moisture converted to 15% prior to analysis. Grain samples were collected. Grain protein, oil and starch will be determined using NIR spectroscopy from the Portageville and Novelty sites. Data were subjected to an analysis of variance and means separated using Fisher's Protected LSD at $P \leq 0.05$. Main effects were presented in the absence of interactions.

RESULTS

The incidence of disease was less than 5% at Novelty, Portageville, and Albany in 2008 (Tables 2 and 3). There was a slight reduction in the incidence of grey leaf spot at Albany with pyraclostrobin, but no other effects due to the fungicide were detected (Table 2). There was a greater incidence of grey leaf spot when 0-0-30-0 and 0-0-25-17 was applied at Portageville when compared to the non-treated control. Similarly, 24-0-1-0.6 had a greater incidence of common rust at Albany when compared to the non-treated control. In general, there were minimal effects of the fungicide pyraclostrobin or fertilizer treatments on the incidence of diseases at Novelty, Portageville, or Albany in 2008.

The presence of foliar injury was primarily persistent necrosis of leaf tissue caused by fertilizer treatments. Injury was less than 10% for all treatments (Tables 4 and 5). Pyraclostrobin alone did not injure corn (data not presented). Foliar injury increased 0.3 to 0.5% at Novelty and Portageville with pyraclostrobin, but there was no effect of pyraclostrobin on injury at Albany (Table 2). Increased injury with pyraclostrobin was probably due to the presence of surfactant which increased foliar uptake of the fertilizer treatment. Crop injury with 0-0-30-0 ranged from 2 to 7% at all three locations (Table 5). Crop injury was inconsistent with other foliar fertilizers among locations with less than 10% injury with 0-0-25-17 at Novelty, 5-0-20-13 at Novelty, 6-0-0-0 at Portageville, and 22-0-2-1 at Albany.

Grain moisture was 0.3 to 0.4% greater when pyraclostrobin was applied when compared to the non-treated control at Novelty and Albany (Table 4). Fertilizer treatments such as 24-0-1-0.6 and a premix of Fe-Mo-Mn-B-Zn increased grain moisture 0.8 to 1.1% when compared to the non-treated control at Portageville (Table 5).

Pyraclostrobin increased grain yield 11 bu/acre at Novelty and Portageville in high yield environments (Table 4). None of the foliar fertilizer treatments increased grain yield when compared to the non-treated control (Table 5). A reduction in grain yield with 0-0-25-17 at Novelty and 6-0-0-0 at Portageville was related to foliar injury specific to the fertilizer treatments. Albany had a lower grain yield potential and grain yields were reduced with 3-18-18-0, 6-0-0-0, B, and a premix of Fe-Mo-Mn-B-Zn when compared to the non-treated control. Tissue analysis is currently underway.

SUMMARY

- The incidence of disease was less than 5% at all three locations and the effect of pyraclostrobin on disease was minimal.
- The incidence of disease was not affected by fertilizer treatments at Novelty or Albany while there was an inconsistent effect of fertilizer treatments on the incidence of disease at Portageville.
- Pyraclostrobin increased grain moisture 0.3 to 0.4% and yield 11 bu/acre when compared to the non-treated control at 2 of the 3 sites.
- There was no significant increase in grain yield when foliar fertilizers were applied to corn at VT. Some foliar fertilizers reduced grain yield 14 to 24 bu/acre when compared to the non-treated control in 2008.

Timetable:

Feb., 2009-Dec., 2009 Repeat same trial as in 2008

References:

Conrath, U., G. Amoroso, H. Köhle, and D.F. Sultemeyer. 2004. Non-invasive online detection of nitric oxide from plants and other organisms by mass spectroscopy. Plant J. 38:1015-1022.

Fixen, P.E., C.S. Snyder, H.F. Reetz, Jr., T. Yamada, and T. S. Murrell. 2004. Nutrient management of soybeans with the potential for Asian rust infection. Potash & Phosphate Institute, (PPI), Norcross, GA.

Marschner, H. 1995. Functions of mineral nutrients: macronutrients. Mineral nutrition of higher plants. pp. 229-312.

Nelson, K.A., P.P. Motavalli, and M.J. Nathan. 2004. The impact of foliar potassium fertilizer source on crop response and weed control in a no-till “weed and feed” glyphosate-resistant soybean production system. pp. 149-155. Vol. 21. Proceedings of the 2004 Fluid Forum, Scottsdale, AZ.

Nelson, K.A. and R.L. Smoot. 2007. Effect of Quadris and Headline on corn grain yields in Northeast Missouri. Greenley Research Center Field Day Report. 30:14-16.

Budget:

Salaries and fringe benefits 14,000
Presentations, publications, travel, and documentation....................1,000
Supplies....................4,900
Tissue sample processing and analysis....................5,000
2009 Total....................$24,900

Budget narrative:
Salaries and fringe benefits: Funds are requested for partial support of a research technical support and temporary summer workers.
Presentations, publications, and documentation: This will help defray cost of publication and documentation of results and conclusions as well as assist travel and board for one researcher to attend a professional conference for presentation of results.
Supplies: Covers cost of sample containers, fertilizer, seed, plot preparation, planting, weed control harvesting, flags, and other field supplies and operations.
Tissue sample analysis: Ear leaf nutrient analysis.

- *Regular tissue analysis for N, P, K, Ca, and Mg for all treatments and all 3 locations, 7 days after application*
- *Complete tissue analysis + Cl, 3 reps, weekly sampling of the non-treated control and fungicide only treatments*

Table 1. Field information and selected management practices in 2008.

Field information and management practices	Novelty	Portageville	Albany
Previous crop	Corn	Soybean	Soybean
Planting date	May 19	May 1	May 21
Fertilizer rate (N-P-K lbs/acre)	230-70-100	160-0-0	160-60-80
Hybrid	DK63-42	P33N58	DK62-43
Seeding rate (seeds/acre)	35,000	35,000	28,000
Fungicide and foliar fertilizer application date	July 23	July 9-10	July 16
Air temperature (F)	79	76	89
Relative humidity (%)	50	80	70
Height (inches)	96	120	120
Harvest date	October 10	September 22	November 21
Soil test information			
P (lbs/acre)	35	34	62
K (lbs/acre)	288	195	234
pHs	6.0	6.2	5.8
CEC (meq/100g)	14.9	9.7	18.8
Mg (lbs/acre)	367	189	696
Ca (lbs/acre)	3601	3052	5235
OM (%)	2.0	1.3	2.6

Table 2. Incidence of disease at Novelty, Portageville, and Albany 28 days after treatment in 2008. Data were combined over fertilizer treatments.

Fungicide	Novelty			Portageville		Albany	
Treatment	GLS[a]	CR	NCLB	GLS	ANTH	GLS	CR
	%						
Non-treated	1	0.2	0.1	1.2	1	0.2	2.5
Pyraclostrobin[b]	1	0.2	0	1.1	1	0	2.4
LSD (P≤0.05)	NS	NS	NS	NS	NS	0.1	NS

[a]Abbreviations: ANTH, Anthracnose (*Colletotrichum graminicola*); CR, common rust (*Puccinia sorghi*); GLS, grey leaf spot (*Cercospora zeae-maydis*); LSD, least significant difference; NCLB, northern corn leaf blight (*Exserohilum turcicum*); and NS, non-significant.

[b]Headline at 6 oz/acre plus non-ionic surfactant at 0.25% v/v.

Table 3. Incidence of disease at Novelty, Portageville, and Albany 28 days after treatment in 2008. Data were combined over fungicide treatments.

	Novelty			Portageville		Albany	
Fertilizer treatment[a]	GLS[b]	CR	NCLB	GLS	ANTH	GLS	CR
	%						
Non-treated	1	0.3	0	1	1.3	0	2.3
3-18-18-0	1	0.2	0	1	1	0	3
0-0-30-0	1	0.1	0	1.7	1	0.1	2.4
22-0-2-1, 0.25% B	1	0.1	0	1	1	0.3	2.8
24-0-1-0.6, 0.25% B	1	0	0.1	1.2	1	0.2	4.2
25-0-0-0, 0.01% Cl	1	0.6	0	1	1	0.2	2.4
0-0-25-17	1	0.3	0	1.7	1	0.1	1.6
5-0-20-13	1	0.1	0	1.2	1	0.1	2.4
0-0-62-0	1	0.4	0	1	1	0.1	3
30-0-0-0	1	0.2	0	1	1	0.2	2.5
6-0-0-0, 10% Ca	1	0.1	0.1	1	1	0	1.8
Boron	1	0.1	0.1	1.2	1	0	2.1
Fe-Mo-Mn-B-Zn	1	0.1	0.1	1	1	0	1.7
Mn-chelate	1	0.4	0	1	1	0	2.2
LSD (P≤0.05)	NS	NS	NS	0.3	0.2	NS	1.7

[a]3-18-18-0 (%N-%P_2O_5-%K_2O-%S) at 2 gal/acre (NA-CHURS/ALPINE Solutions, Marion, OH), 0-0-30-0 at 2 gal/acre (Double-OK, NA-CHURS/ALPINE Solutions, Marion, OH), potassium thiosulfate (0-0-25-17) at 1 gal/acre (KTS, Tessenderlo Kerley Inc., Phoenix, AZ), potassium thiosulfate plus urea triazone (5-0-20-13) at 1.5 gal/acre (Trisert K+, Tessenderlo Kerley Inc., Phoenix, AZ), potassium chloride (0-0-62-0) at 2.5 lb/acre (PCS, Potash Corp. of Saskatchewan, Northbrook, IL), 25-0-0-0 controlled release nitrogen as methylene urea and diurea with less than 0.01% Cl at 3 gal/acre (CoRoN, Helena Chemical Co., Collierville, TN), 24-0-1-0.6 slow release N with 0.25% B at 3 gal/acre (Pacer N, Crop Production Services, Galesburg, IL), 22-0-2-1 with 0.25% B at 1 gal/acre (Task Force Maize, Crop Production Services, Galesburg, IL), 30-0-0-0 at 1 gal/acre (Nitamin, Georgia-Pacific Chemicals, LLC., Atlanta, GA), boron at 2 pt/acre (NA-CHURS/ALPINE Solutions, Marion, OH), Mn-chelate at 2 pt/acre (NA-CHURS/ALPINE Solutions, Marion, OH), Fe-Mo-Mn-B-Zn (0.3%-0.01%-3.2%-0.2%-2.1%) premix at 1 qt/acre (MAX-IN, Winfield Solutions, LLC., St. Paul, MN), and 6-0-0-0 with 10% Ca at 2.5 gal/acre (Nutri-Cal, CSI Chemical Corp., Bondurant, IA).

[b]Abbreviations: ANTH, Anthracnose (*Colletotrichum graminicola*); Bacterial stalk ; CR, common rust (*Puccinia sorghi*); GLS, grey leaf spot (*Cercospora zeae-maydis*); LSD, least significant difference; NCLB, northern corn leaf blight (*Exserohilum turcicum*); and NS, non-significant.

Table 4. Corn injury 7 to 14 days after treatment, grain moisture, and yield as affected by pyraclostrobin at Novelty, Portageville, and Albany in 2008. Data were combined over fertilizer treatments.

Fungicide	Novelty			Portageville			Albany		
Treatment	Injury	Moisture	Yield	Injury	Moisture	Yield	Injury	Moisture	Yield
	%	%	Bu/a	%	%	Bu/a	%	%	Bu/a
Non-treated	1.7	19.5	216	1.6	17.1	159	0.5	15.9	143
Pyraclostrobin[a]	2.2	19.9	227	1.9	17.2	170	0.5	16.2	143
LSD ($P \leq 0.05$)[b]	0.5	0.2	6	0.2	NS	7	NS	0.2	NS

[a]Headline at 6 oz/acre plus non-ionic surfactant at 0.25% v/v.
[b]Abbreviations: LSD, least significant difference; and NS, non-significant.

Table 5. Corn injury 7 to 14 days after treatment, grain moisture, and yield as affected by fertilizer treatments at Novelty, Portageville, and Albany in 2008. Data were combined over fungicide treatments.

	Novelty			Portageville			Albany		
Fertilizer treatment[a]	Injury	Moisture	Yield	Injury	Moisture	Yield	Injury	Moisture	Yield
	%	%	Bu/a	%	%	Bu/a	%	%	Bu/a
Non-treated	0	19.4	222	0	17.0	170	0	16.0	151
3-18-18-0	0	19.8	226	0	16.9	174	0	16.0	132
0-0-30-0	7	19.6	211	2	17.6	153	5	16.4	144
22-0-2-1, 0.25% B	0	19.5	226	0	16.9	174	2	16.1	151
24-0-1-0.6, 0.25% B	0	19.8	217	0	18.1	158	0	16.1	152
25-0-0-0, 0.01% Cl	0	19.7	223	0	16.7	167	0	16.4	158
0-0-25-17	10	19.6	208	0	16.7	171	0	16.2	147
5-0-20-13	9	19.9	222	0	17.1	182	0	16.0	142
0-0-62-0	0	19.4	220	0	17.3	164	0	15.9	146
30-0-0-0	0	19.6	220	0	17.1	168	0	15.8	142
6-0-0-0, 10% Ca	1	19.6	221	1	17.1	149	0	15.9	136
Boron	0	20.0	234	0	17.1	161	0	16.1	133
Fe-Mo-Mn-B-Zn	0	19.8	226	0	17.8	159	0	15.9	127
Mn-chelate	0	19.6	223	0	17.1	161	0	15.9	139
LSD ($P \leq 0.05$)[b]	1.3	NS	14	0.5	0.5	19	1	NS	13

[a]3-18-18-0 (%N-%P_2O_5-%K_2O-%S) at 2 gal/acre (NA-CHURS/ALPINE Solutions, Marion, OH), 0-0-30-0 at 2 gal/acre (Double-OK, NA-CHURS/ALPINE Solutions, Marion, OH), potassium thiosulfate (0-0-25-17) at 1 gal/acre (KTS, Tessenderlo Kerley Inc., Phoenix, AZ), potassium thiosulfate plus urea triazone (5-0-20-13) at 1.5 gal/acre (Trisert K+, Tessenderlo Kerley Inc., Phoenix, AZ), potassium chloride (0-0-62-0) at 2.5 lb/acre (PCS, Potash Corp. of Saskatchewan, Northbrook, IL), 25-0-0-0 controlled release nitrogen as methylene urea and diurea with less than 0.01% Cl at 3 gal/acre (CoRoN, Helena Chemical Co., Collierville, TN), 24-0-1-0.6 slow release N with 0.25% B at 3 gal/acre (Pacer N, Crop Production Services, Galesburg, IL), 22-0-2-1 with 0.25% B at 1 gal/acre (Task Force Maize, Crop Production Services, Galesburg, IL), 30-0-0-0 at 1 gal/acre (Nitamin, Georgia-Pacific Chemicals, LLC., Atlanta, GA), boron at 2 pt/acre (NA-CHURS/ALPINE Solutions, Marion, OH), Mn-chelate at 2 pt/acre (NA-CHURS/ALPINE Solutions, Marion, OH), Fe-Mo-Mn-B-Zn (0.3%-0.01%-3.2%-0.2%-2.1%) premix at 1 qt/acre (MAX-IN, Winfield Solutions, LLC., St. Paul, MN), and 6-0-0-0 with 10% Ca at 2.5 gal/acre (Nutri-Cal, CSI Chemical Corp., Bondurant, IA).
[b]Abbreviations: LSD, least significant difference; and NS, non-significant.

How Does Kip Grow 150+ bu/acre Soybeans? Is K^+ a Key?

Tim Reinbott, Felix Fritschi, Dale Blevins, Univ. of Missouri-Columbia

Objective:

The overall objective of this proposal is to evaluate the importance of key management practices employed by Mr. Cullers in achieving record soybean yields. Specific objectives include (i) comparisons between the application of N, P, and K nutrients as mineral fertilizer and as poultry litter; (ii) quantification of foliar K application on yield and leaf K concentrations; (iii) determine the effect of foliar micronutrient application on yield; and (iv) evaluate the effects of intensive and moderate irrigation frequency.

Procedures:

A field was selected at the Bradford Research and Extension Center near Columbia, MO and soil samples were collected for standard analyses by the University of Missouri Soil Testing Laboratory. Control treatment fertilization was based on these soil test results and yield goal according to Univ. of Missouri recommendations. Treatments were laid out in a randomized complete block design and were applied as described below. Prior to planting, poultry litter and mineral fertilizer were applied in equivalent amounts for both large applications of poultry litter (9 t/ac) and yield goal based fertilization. Poultry litter and mineral fertilizer was incorporated into the top soil by a single pass with a disc and soybean were planted in 15” rows. Precipitation events following planting caused standing water on large parts of the field over extended time periods and resulted in a patchy stand and weak soybean seedlings. Thus, the field was disked again and replanted. Drip irrigation was installed for the high-frequency irrigation treatments and deployed as needed over the course of the growing season. However, the above-normal rainfall in 2008, resulted in drip irrigation frequency well below expectations. Applications of foliar K were conducted as for even splits of 9 lb/ac. The application of supplemental soil applied K (36 lb/ac; equivalent to the sum of the four foliar applications of K) was conducted on the same day as the first foliar K application. Foliar micronutrients were applied at the time of the first and third foliar K applications. Data collection conducted over the course of the season include root sampling for analyses of nodulation, biomass samples, leaf-let samples, samples for plant mapping, and seed harvest.

Following soybean harvest, the second poultry litter application was made (25 Nov.) at the same rates as in the spring and the entire field was disked.

Results:

Results for soybean nodulation characteristics and yield are presented below with the following treatment assignments:

- FH-I: Fertilizer treatment matching the nutrients applied by 9 tons/ ac of poultry litter; Irrigated
- PH-I: Poultry litter application at 9 tons / ac; Irrigated
- FC-I: Fertilizer control: fertilization based on soil test and yield goal; Irrigated
- PC-I: Poultry litter control: matching nutrient application of fertilizer control; Irrigated
- FH-NI: Fertilizer treatment matching the nutrients applied by 9 tons/ ac of poultry litter; Non-Irrigated

PH-NI: Poultry litter application at 9 tons / ac; Non-Irrigated
FC-NI: Fertilizer control: fertilization based on soil test and yield goal; Non-Irrigated
PC-NI: Poultry litter control: matching nutrient application of fertilizer control; Non-Irrigated
FH: Fertilizer treatment matching the nutrients applied by 9 tons/ ac of poultry litter; averaged across irrigation environments
PH: Poultry litter application at 9 tons / ac; averaged across irrigation environments
FC: Fertilizer control: fertilization based on soil test and yield goal; averaged across irrigation environments
PC: Poultry litter control: matching nutrient application of fertilizer control; averaged across irrigation environments

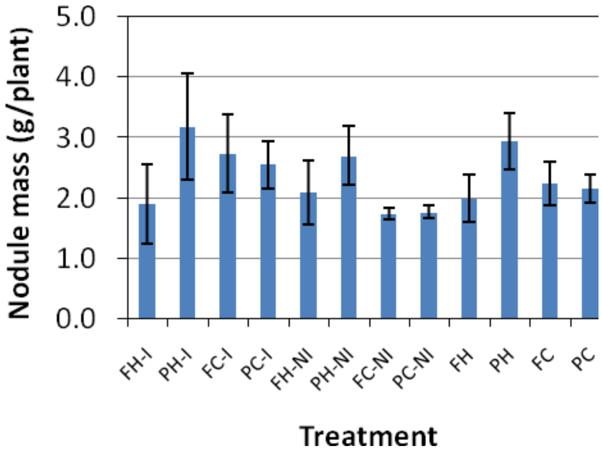

Figure 1. Soybean root nodule mass per plant as affected by fertility treatment.

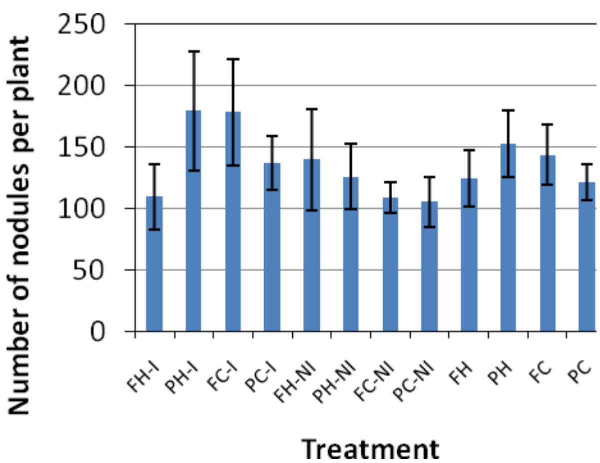

Figure 2. Soybean root nodule number per plant as affected by fertility treatment.

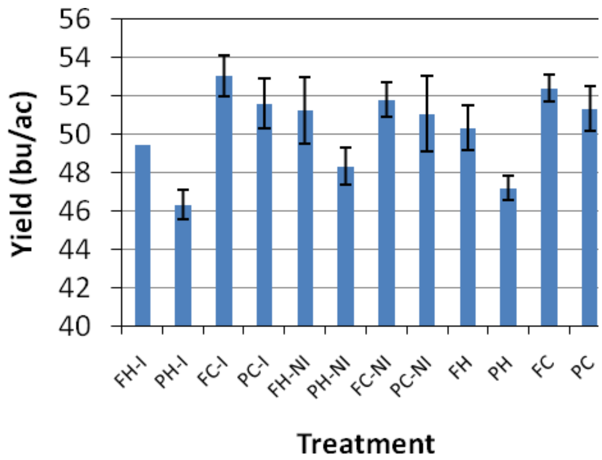

Figure 3. 2008 soybean seed yield as affected by fertility treatment.

Soybean root nodule mass and number both responded to the high poultry litter treatments (Fig. 1 and 2). The highest 2008 seed yield was produced by the high fertilizer treatments (Fig. 3).

2009 Research:

The fall 2008 poultry litter treatments have already been applied and worked in. In the spring of 2009, soybeans will be planted, treated, grown and harvested as in 2008. Hopefully, 2009 will be a "normal" year!

Budget for 2009:

Category	**2009**
Personnel	
Graduate Research Assistant (50%)	$14,500
Benefits	$2,030
Laboratory analyses (soil and plant spls)	$3,840
Field Supplies*	$3,500
Travel (professional meeting)	$1,200
Total	**$25,070**

*fertilizer, irrigation expenses (fuel and riser repair), seed, pesticides, machinery repair

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