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University of Missouri

Thank You
Missouri Fertilizer and Ag Lime Distributors

The contributors to this report wish to express their sincere thanks for the willingness of the Missouri Fertilizer and Ag Lime Distributors of the state who provide funding, through their annual permit fees, for the research which is reported in this publication. These research projects would not be possible without this funding source.

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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Agricultural Lime

Final Reports

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

Kevin Bradley and Peter Scharf

Investigators: Dr. Kevin Bradley and Dr. Peter Scharf

Objectives: To determine if variations in soil pH have an influence on the carryover of the triketone herbicides Callisto (mesotrione), Impact (topramezone), and Laudis (tembotrione) to soybeans the season following treatment.

Procedures: The experiment was arranged in a split block design with 4 replications of 4 herbicide treatments and 5 pH levels. Whole plots were herbicide treatments while subplots were individual pH levels. Five soil pH levels were maintained on existing variable pH plots located at the Bradford Research and Extension Center near Columbia, Missouri. Each year, soil samples were taken in each plot to determine amounts of lime and iron sulfate needed to adjust pH levels prior to the initiation of the experiments. This resulted in the following five average pH levels: 4.5, 5.4, 6.7, 7.0, and 7.2. The soil type was a Mexico silt loam with 2.5% organic matter. The year prior to soybean, herbicide treatments applied to corn consisted of Callisto at 3 fl ozs/A, Impact at 0.75 fl ozs/A, Laudis at 3 fl ozs/A, and an untreated, weed-free check. In both years, these treatments were applied to corn that was 75 cm in height. Herbicide applications were made on June 21 in 2008 and June 17 in 2009. All herbicide treatments were applied across each of the five average soil pH levels resulting in a total of 20 treatment comparisons. In both corn and soybeans, all plots were kept weed-free throughout the experiments through applications of glyphosate and hand weeding. MorSoy 3738 and Asgrow 4005 soybeans were planted at 160,000 seed/A on June 2, 2009 and May 28, 2010, respectively. Visual soybean injury and height (2 measurements per plot) were recorded each year at 14 and 28 days after emergence. Soybeans were harvested from the two center rows in each plot with a small plot combine and yields were adjusted to 13% moisture content. All data were analyzed using the PROC MIXED procedure in SAS and means were separated using Fisher's protected LSD (0.05). Soybean heights at both the 14 and 28 day after emergence assessment intervals were significantly different between years and therefore the data were analyzed separately. There were no differences in soybean yields between years, therefore 2009 and 2010 data were pooled for analysis.

Results: Rainfall totals received in all 3 years of the experiment were significantly greater than the 30-year average, especially in April, June and July (Figure 1). This likely had a dramatic impact on the degree of triketone herbicide carryover observed in these experiments. Under drier conditions and years with a more "normal" rainfall pattern, carryover of these herbicides is more likely and the results of these experiments may have differed.

There were no differences in soybean height at either assessment timing in 2009 (data not shown). However, there were slight differences observed in 2010 and these are recorded in Tables 1 and 2. When compared to the untreated control, soybean heights 14 days after emergence in 2010 were significantly lower in response to Callisto applications made the

previous season in plots with the most acidic soil pH values (Table 1). However, there were no reductions in soybean height at 14 days after emergence in response to Impact or Laudis applications made to corn the previous season, regardless of soil pH. By 28 days after emergence, however, the soybeans had recovered and there were no reductions in soybean height in response to applications of Callisto made the previous season (Table 2). Also at 28 days after emergence, soybean heights were reduced in response to Impact applications made the previous season in plots with the most acidic soil pH values (Table 2). Within all plots that had an average soil pH of 4.5, Impact applications made the previous season also reduced soybean height more than either Callisto or the untreated control.

Across all soil pH values, soybean yields in plots that received a triketone herbicide the year prior to soybean planting were not reduced compared to plots not receiving a triketone herbicide application (Table 3). However, soybean yields in the most acidic plots that received Impact were significantly lower than all other plots that received Impact.

Summary and Conclusions: In this research, none of the triketone herbicides reduced soybean yields the season following treatment compared to the untreated control, regardless of soil pH. However, results from this research also indicated that Impact applied on acidic soils (~pH 4.5) in corn has the potential to cause height and yield reductions to soybeans the season following treatment. Although some initial stunting occurred on acidic soils in response to Callisto applications made the previous season, soybeans recovered by 28 days after emergence and no yield reductions were observed. Another interesting finding from this research is that no visual symptoms of triketone herbicide carryover injury were observed in response to any treatment during either growing season (data not shown), yet some height and yield responses were observed. Above-average rainfall amounts received throughout these experiments are likely to have played a major role in the persistence of triketone herbicides in the soil and the results of these experiments.

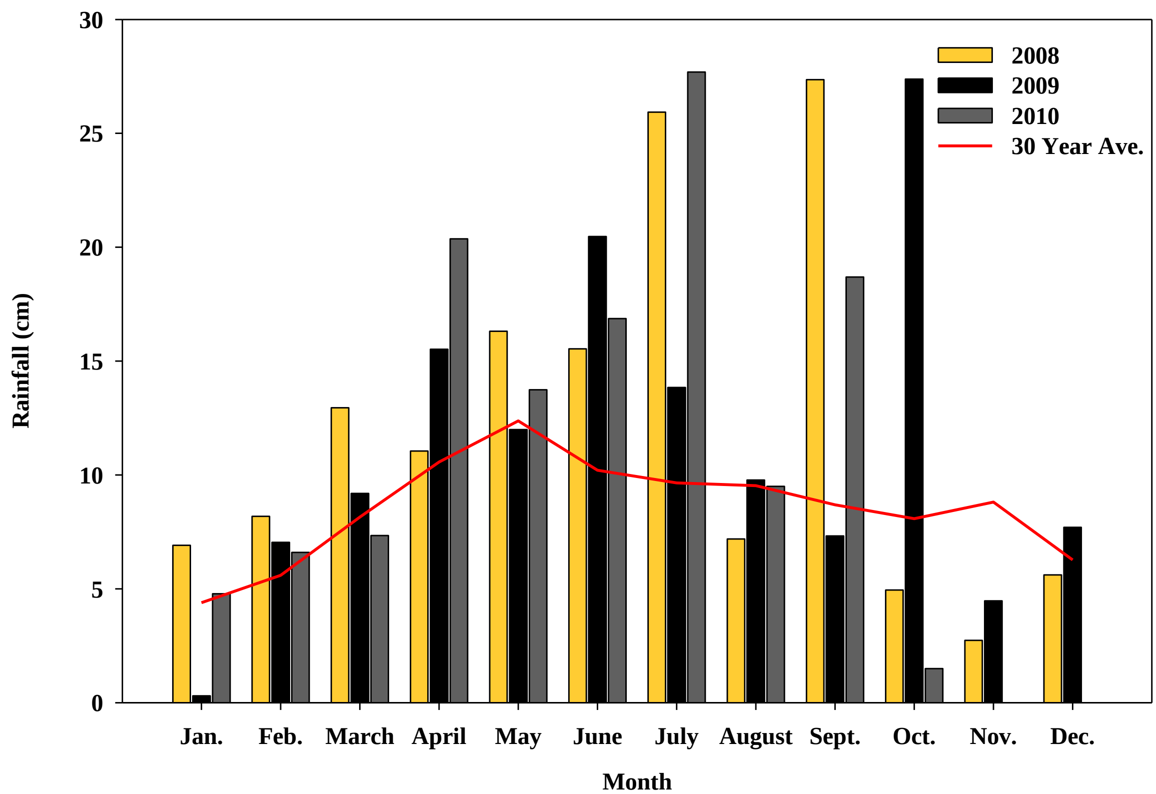

Figure 1. Monthly rainfall totals in Columbia, Missouri throughout the experiment as compared to the 30-year average.

Table 1. Soybean heights 14 days after emergence in response to soil pH and triketone herbicide applications made to the 2009 corn crop.

	Average Soil pH				
Treatment[a]	4.5	5.4	6.7	7.0	7.2
	---------2010 Soybean Heights 14 Days after Emergence (cm)[bc]----------				
Callisto	12.9 B b	14.3 A ab	15.1 AB a	13.3 B ab	13.0 A b
Impact	14.3 AB b	14.1 A b	16.0 A a	15.2 A ab	14.0 A b
Laudis	13.2 AB a	14.6 A a	13.2 B a	13.5 B a	13.1 A a
Untreated	14.5 A a	14.1 A a	13.8 B a	13.7 AB a	14.3 A a

[a] Treatments applied to 75-cm corn the growing season prior to soybean planting.
[b] Means within a column followed by same uppercase letters are not different (P≤0.05).
[c] Means within a row followed by same lowercase letters are not different (P≤0.05).

Table 2. Soybean heights 28 days after emergence in response to soil pH and triketone herbicide applications made to the 2009 corn crop.

	Average Soil pH				
Treatment[a]	4.5	5.4	6.7	7.0	7.2
	---------2010 Soybean Heights 28 Days after Emergence (cm)[bc]----------				
Callisto	39.7 A a	39.7 A a	40.5 A a	39.5 A a	40.0 A a
Impact	34.3 B c	38.1 A b	40.8 A a	38.4 A ab	40.6 A ab
Laudis	36.4 AB b	40.0 A ab	41.0 A a	40.3 A a	38.9 A ab
Untreated	38.4 A b	38.7 A ab	41.1 A a	40.0 A ab	41.0 A a

[a] Treatments applied to 75-cm corn the growing season prior to soybean planting.
[b] Means within a column followed by same uppercase letters are not different (P≤0.05).
[c] Means within a row followed by same lowercase letters are not different (P≤0.05).

Table 3. Soybean yield response to soil pH and triketone herbicide applications made the previous growing season (2009 and 2010 combined data).

	Average Soil pH				
Treatment[a]	4.5	5.4	6.7	7.0	7.2
	----------------------------- Soybean Yield (Bu/A)[bc] ----------------------------				
Callisto	53 A a	52 B a	54 AB a	52 A a	53 AB a
Impact	51 A b	57 A a	56 A a	54 A a	56 A a
Laudis	50 A b	55 AB a	54 AB ab	53 A ab	54 AB ab
Untreated	49 A a	49 C a	52 B a	51 A a	51 B a

[a] Treatments applied to 75-cm corn the growing season prior to soybean planting.
[b] Means within a column followed by same uppercase letters are not different (P≤0.05).
[c] Means within a row followed by same lowercase letters are not different (P≤0.05).

Progress Reports

Liming in a Rice/Soybean Rotation

David Dunn and Gene Stevens
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Objective: The objective of this study is to determine the correct lime rates and application timings for a rice/soybean rotation. It will also investigate the economics of lime applications in the rice-soybean rotation.

Current Status/Importance of Research Area: Rotating rice with soybeans is a common practice in Southeast Missouri. These crops have different soil pH requirements with soybeans requiring a higher pH than rice to achieve maximum yields. Current University of Missouri soil test recommendations for lime treat rice and soybeans as separate crops. In 1999 a liming study was funded by the Rice Council. This study found that one ton of lime increased soybean yields 25%, however rice yields were lowered by 9 bu/acre. In the first year of this study the increased value of the soybean crop was approximately equal to the lost value in the rice crop. This study was not continued in 2000 due to funding cuts and the relative values of the subsequent years crops could not be determined. However, a news release from the University of AR indicated similar results on the soybean side but indicated that rice yields generally were increased with lime applications.

Procedure: This study investigates the lime requirements of both crops in the rice-soybean rotation. It is being conducted on a Crowley silt loam soil located at the Missouri Rice Research Farm located near Qulin, MO. Here the initial soil pH was 5.6 and the lime recommendation was 755 ENM/acre or 1 ½ ton of lime. The experimental design is a complete block design with four replications. Plots representing six lime treatments were established for both rice and soybeans. The following lime treatments were applied 1) control, no lime applied, 2) 0.4 ton lime, 3) 0.8 ton lime, 4) 1.2 lime, 5) 1.6 lime, and 6) pell lime at 200 lbs/a. These lime recommendations cover a three-year time frame, consequently, no lime will be added to the plots in 2011 or 2012. However as pell lime is recommended annually this product will be added in both subsequent years. All methods of N, P, and K fertilization, weed & insect control and irrigation were the standard practices for a drill seeded rice and soybean rotation in Southeast Missouri. Each plot will be harvested and the yield measured. Net returns to producers will then be calculated using current grain and lime costs.

Project accomplishments: Plots were established in 2010 for both rice and soybeans. The rice crop was successfully established, brought to harvest and yield measured. Protracted drought conditions in May through September of 2010 resulted in a failure to establish a consistent stand for the soybean crop. Consequently these plots had to be abandoned for 2010 and no yield measurement was possible. It is hoped that favorable rainfall conditions will return in 2011. Crop yields for 2010 are presented as Table 1.

Table 1. Rice and soybean yields for lime treatments at Qulin, MO 2010.

Trt#	Lime Rate	2010 rice yield	2010 soybean yield
1	check	141	---------
2	0.4 ton (200 ENM)	141	---------
3	0.8 ton (400 ENM)	149	---------
4	1.2 ton (600 ENM)	140	---------
5	1.6 ton (800 ENM)	144	---------
6	200 lb pel lime (60 ENM)	142	---------

Proposed budget:

Expenses	2010	**2011**	2012
Labor	$8,000	**$8,255**	$8,518
Fringe benefits	$2,582	**$2,660**	$2,740
Supplies	$1,000	**$1,000**	$1,000
Travel	$850	**$850**	$850
Lab analysis	$1,500	**$1,500**	$1,500
Total	$13,932	**$14,265**	$14,608

Field Calibration of Woodruff, Mehlich and Sikora Buffer Tests for Determining Lime Requirement for Missouri soils

Manjula Nathan, Rob Kallenbach, Kelly Nelson, David Dunn, Tim Reinbott and Bruce Burdick

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Tim Reinbott, Bradford Research and Extension Center, University of Missouri
Bruce Burdick, Hundley-Whaley Research and Extension Center, University of Missouri

Objectives:

1. To determine whether the Modified Woodruff Buffer test is accurately predicting the lime requirement for Missouri soils.
2. To calibrate the Modified Woodruff Buffer, Sikora and Mehlich buffer tests for Missouri soils.
3. To determine lime recommendations Equations for Sikora and Mehlich Buffers on Missouri soils the pH rages of 5.5 to 6.0; 6.0 to 6.5 and 6.5 to7.0.
4. Compare field calibration results with incubation study results for the buffer tests.

Procedures:

- A Field calibration study was established at Bradford, Greenley, Southwest, Delta and Hundley Whaley University of Missouri Research and Extension Centers. The Bradford, Delta, Greenley, and Hundley-Whaley sites were planted with corn-soybean rotations. The Southwest Center site was planted with forages. The Delta and Hundley-Whaley sites were plowed and the Bradford and Greenley sites were under No-till systems.
- Each experimental field sites received seven lime treatments (0, 250, 500, 1000, 1500, 2000 and 2500 ENM/ac to cover a wide range from low, recommended, and double the recommended lime rates. The Southwest Center site was limed at 0, 250, 500, 750, 1000, 1500, and 2000 ENM/ac. The liming material used in the study had an ENM of 680. The experiment was laid out in a randomized complete block design with four replicates. All the plots received University of Missouri recommended levels of N, P and K based on soil test.
- Soil samples were collected at 0-6" and 6-12" depths to measure top soil and subsoil pHs at the beginning of the study. Results are presented in Tables 1-5. Soil samples were collected at 45, 90, and 120 days after lime applications at the 0-6" depth. Soil samples were analyzed for pHs, and buffer pH using Woodruff, Mehlich, and Sikora buffers.
- Crop yield data was collected at all five sites. The yield data was correlated with the response received from lime requirement estimated by the three different buffer tests and was compared with the incubation studies results.

Progress Report for 2010:

A field calibration study was established at University of Missouri at Bradford (BF), Delta (DE), Greenley (GR), Huntley-Whaley (HW) and South West (SW) Research and Extension Centers in 2009. The initial soil pH_s for the BR, DE, GR, HW and SW were 5.1, 5.2, 5.3, 5.8 and 5.6 respectively. The BR, DE, GR, HW sites were planted with corn-soybean rotations and SW site with tall-fescue. The BR, GR, SW sites were under no-till and the DE and HW were under conventional tillage systems. . Each site received seven lime treatments to cover a wide range from low, recommended LR, and 2xLR rates. The experiment was a randomized complete block design with four replicates. Soil samples were collected (0 to 15-cm) at the beginning and at 45, 90, 120, and 365-d after lime applications and analyzed for pH_s, and for buffer pH using MWB, MMB, and SBs. The yield data was collected at all five sites.

Results:

a. Lab incubation study:

The incubation study conducted by Nathan and Sun (2009) comparing Sikora and Mehlich buffers to the Woodruff buffer test for Missouri soils had promising results. The Sikora and Mehlich buffers were found to be well correlated with the Woodruff buffer test suggesting these buffers could be used as an alternative to Woodruff buffer for Missouri soils.

Lime requirements(LR) for soils selected for the incubation study were estimated and the relationship between the buffer pH and lime requirement for Modified Woodruff Buffer (MWB), Modified Mehlich Buffer (MMB) and Sikora Buffer (SB)for soils to achieve target pHs of 5.8, 6.3 and 6.8 are presented in Fig 1.a, 1.b, and 1.c. There was a linear relationship between the buffer pH values for MWB, MMB and SB tests and the lime requirement to target pH_s 5.8, 6.3 and 6.8. The MMB and SB were found to be slightly better predictors of LR than MWB at target pH_s of 5.8, as demonstrated by the slightly higher R^2 values than MWB (Fig. 1.a). At target pH_s of 6.3 and 6.8 the MMB was found to be a better predictor of LR, followed by SB and MWB (Fig 1.b and 1.c). The findings from the lab incubation study led to the field calibration of these buffers with yield response to evaluate these buffer tests for Missouri soils.

b. Field Calibration Study:

Lime requirement based on the field calibration study was estimated and the relationship between the buffer pH and lime requirement for MWB, MMB and SB for soils to achieve target pHs of 5.8, 6.3 and 6.8 are presented in Fig 2.a, 2.b, and 2.c. There was a linear relationship between the buffer pH values for MWB, MMB and SB tests and the lime requirement to achieve target pH_s 5.8, 6.3 and 6.8. The LR estimated for different target pHs based on the three buffer pHs from the field study was not consistent. At the target pHs of 5.8, the MWB was a better predictor of LR than MMB and SBs (Fig. 2.a). At target pHs of 6.3 the MMB was a better predictor of LR than MWB and SBs. (Fig. 2.b). At target pH_s of 6.8 the SB was found to be a better predictor of LR, followed by MMB and MWB (Fig 2.c)

The LR predictions based on lab incubation and the field calibrations were different. In the lab study, the lime was thoroughly mixed with ground, sieved, homogenized soil, and temperature and moisture conditions were kept at constant levels. Conversely, in the field study lime was not as uniformly mixed with the soil and there were natural variations in soil temperature and moisture. These conditions likely explain the different LR estimations for each study.

The yield response for the lime treatments at the BR, DE, GR and HW locations are presented in Table 1.a (metric units) and 1.b (English units). The yield response to lime treatments was not consistent. However, the yield response for lime treatments was high enough to be economic in most cases.

The field calibration results were inconsistent in estimating LR for different target pHs due to the variability that existed in the field (tillage, surface application vs. mixing), the findings from the first two years of the field calibration study prompted the need for an in-situ field incubation study in the field sites. The findings from the lab and in-situ field incubation studies and the field calibration studies will help selecting the most suitable lime requirement method and in developing the most efficient lime recommendations for Missouri soils.

Brief summary of the proposed in-situ field incubation study in 2011:

Lime incubations have been conducted for Missouri soils with laboratory and field application. The lime requirement estimates from the field study and the lab incubation were remarkably different. The field study includes control plots without lime addition. These control plots provide an excellent opportunity to address questions on various methods of measuring soil pHs after lime incubation and to obtain a better understanding of the mechanisms involved with differences in lime requirement from field studies versus laboratory incubations.

Methodology

Soil from the control plots in the field study will be incubated with lime under four methods. Three of the methods will involve incubation of lime with soil in the control plots in six-inch diameter PVC pipes placed vertically in soil at six-inch depth. To simulate thorough mixing of lime and soil in conventional tillage, Method A will involve mixing lime with all the soil placed in the pipe. The bottom of the pipe will have a screen to contain the soil in the pipe when removed at the end of the incubation and to allow water to leach as normally occurs in the field. Method B will be the same as Method A but has a solid bottom to prevent water leaching. A comparison of Methods A and B will determine the importance of salt leaching on soil pH buffer capacity. Method C will simulate application of lime in no-till field management with surface application of lime and an open bottom with a screen to allow water to leach. This treatment will have another screen at the three inch depth in the PVC pipe so soil can be sampled at 0-3 inches and 3-6 inches at the end of incubation to evaluate the translocation of lime into the soil. Method D is a laboratory incubation where soil water is maintained at field capacity or slightly less.

Table 1. Description of treatments

	Location	Bottom of PVC pipe	Mixing of lime
Method A	Field incubation in PVC pipe	Open bottom	Thorough mixing
Method B	Field incubation in PVC pipe	Closed bottom	Thorough mixing
Method C	Field incubation in PVC pipe	Open bottom	Surface applied
Method D	Laboratory incubation		

Four rates of ag lime are recommended at 0, 0.5x, 1.0 x, and 2x where x is the amount of ag lime required to reach a target pH. Ag lime will be used to simulate actual lime application as occurs in the field. An ag lime source will be chosen with a good quality (ENM greater than 700) and the amount of lime to add will be based on the ENM value of lime. The ag lime will be analyzed to verify the ENM value. The ag lime will be thoroughly mixed before use in the in-situ field incubation study treatments.

Soils for the incubations will be collected from a 0 to 6 inch depth in the control plots of the field lime studies. The soil will be air-dried. The soil will not be pulverized in order to maintain as much of the original soil structure as possible. After adding lime to the soils, the soil will be placed in the PVC pipe in Methods A, B, and C or in plastic bags with open top for Method D. The soils will be incubated in-situ with lime for a period of 6 months in the field. At the end of incubation, soil will be collected from each treatment, air-dried, and ground to pass a 2-mm screen. The samples will be analyzed for pHw, pHs, and 3 buffer tests (MWB, MMB, and SB).

Data Analysis: Lime response curves will be determined for the various measured of soil pH (water, 0.01 M $CaCl_2$, and 1 M CaCl2). Soil pH buffer capacity will be determined from each of the lime response curves as the inverse slope (delta pH/mg ENM/kg soil) and compared amongst the various method of lime incubation. Lime requirements curves will be developed based on the field in-situ incubation study. Results from this study will be used with the lab incubation and field calibration studies in developing appropriate lime recommendations equations for Missouri soils using the three lime requirement methods. This study is timely to develop the lime recommendations equations and use it fine tune University of Missouri lime recommendations. Additional funds are being requested to complete this study in year 2011.

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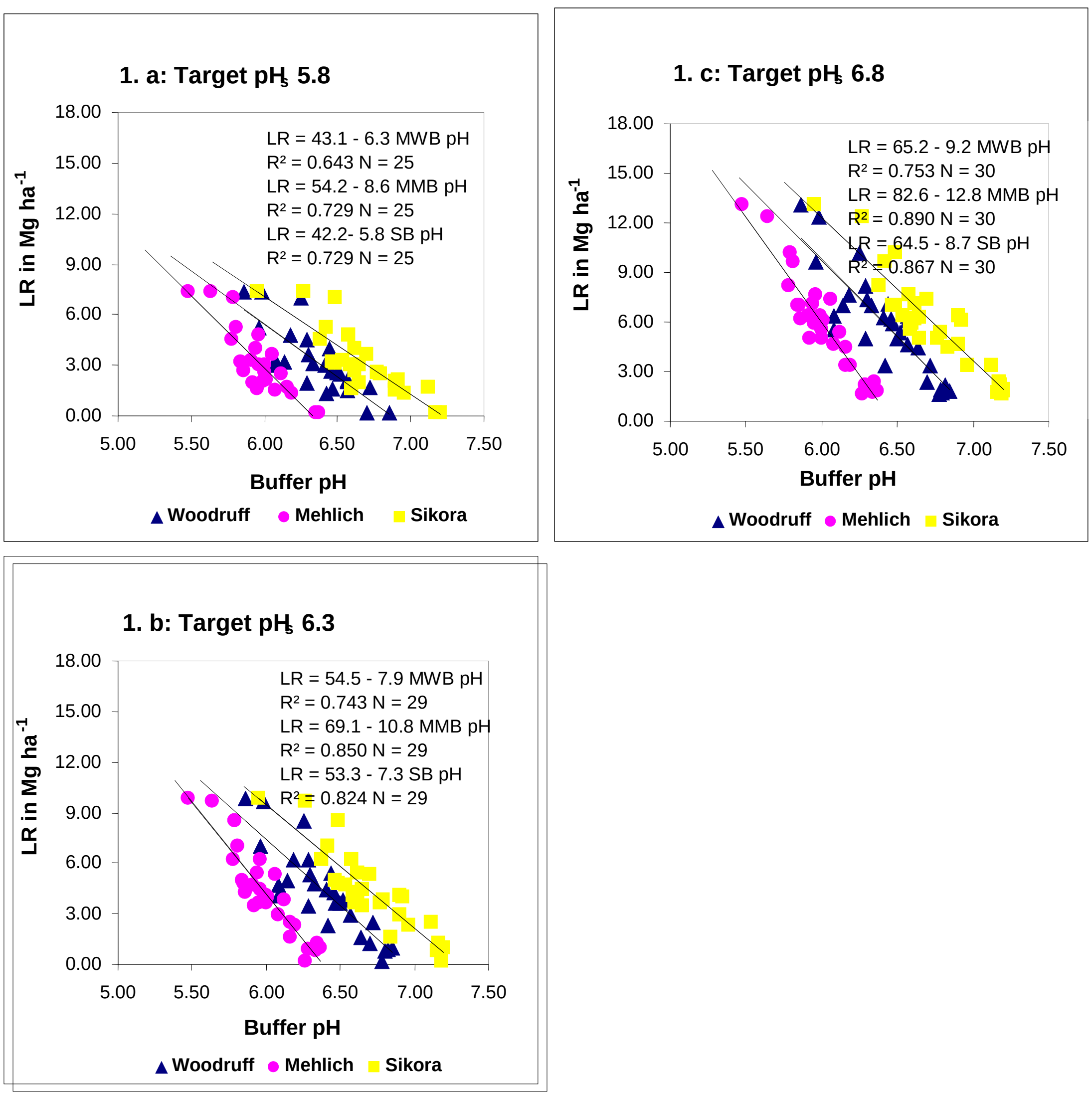


Fig. 1. Buffer pH vs lime requirement for (2a) target pHs 5.8, (2b) target pHs 6.3, and (2c) target pHs 6.8 based on lab incubation study.

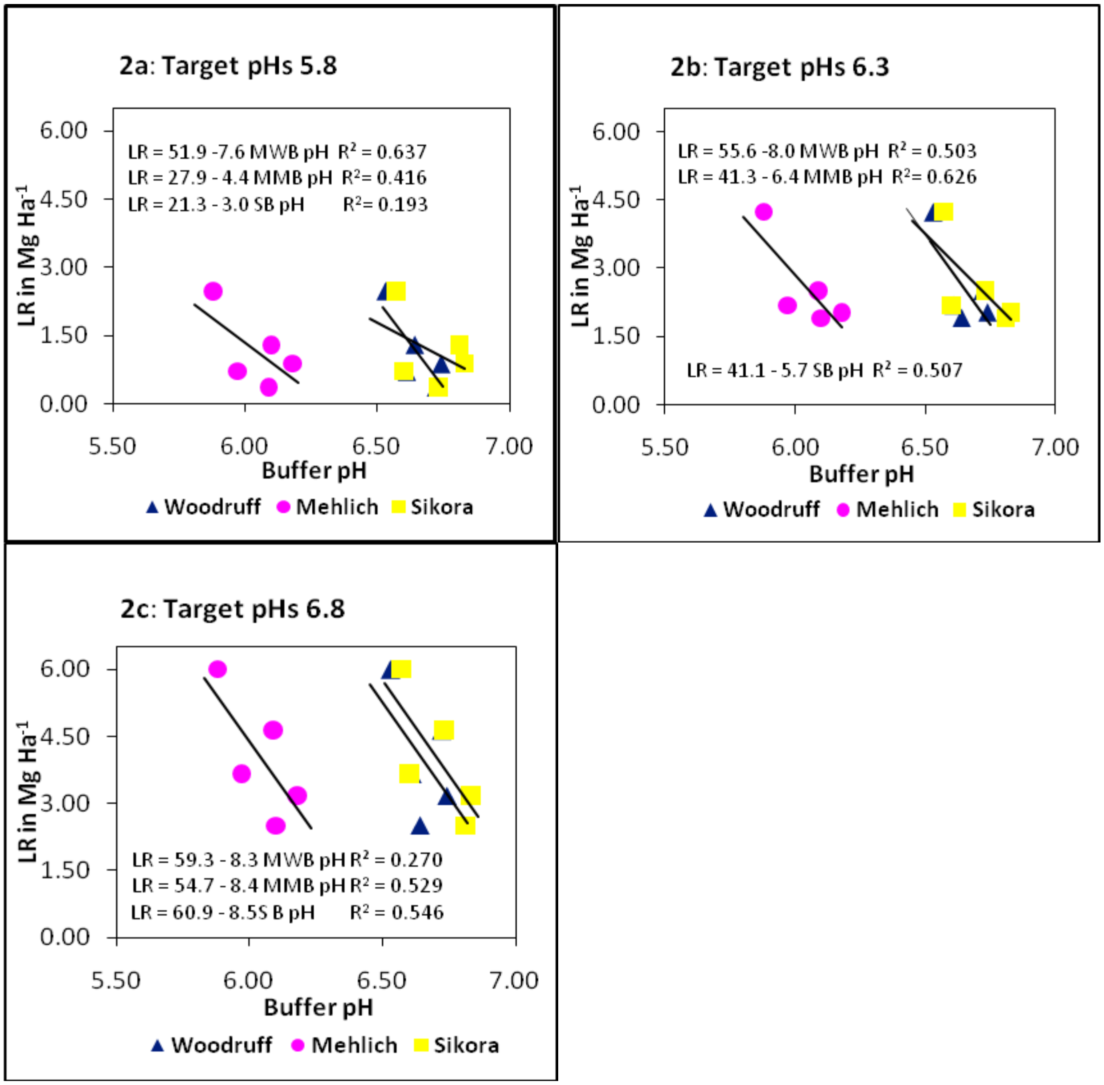


Fig. 2. Buffer pH vs lime requirement for (2a) target pHs 5.8, (2b) target pHs 6.3, and (2c) target pHs 6.8 based on field calibration study at 365 days after application.

Table 1.a: Yield response (Mg/ha) to lime treatments (ENM Mg/ha) at the field sites for 2009 and 2010

Lime Mg/ha ENM	BR corn Mg/ha 2009	BR beans Mg/ha 2010	DE corn Mg/ha 2009	DE beans Mg/ha 2010	HW corn Mg/ha 2009	HW beans Mg/ha 2010	GR corn Mg/ha 2009	GR beans Mg/ha 2010
0	5.66 ab	3.48 ab	9.16 b	1.464 d	12.83 b	3.45 ab	7.65 c	4.43 a
0.28	5.48 ab	3.86 a	9.93 ab	2.244 c	13.83 ab	3.31 b	8.53 bc	4.37 a
0.56	5.61 ab	3.08 b	10.13 a	2.342 c	14.26 ab	3.16 b	9.94 ab	4.63 a
1.12	5.41 ab	3.43 ab	10.43 a	3.220 a	14.34 ab	3.38 ab	10.54 a	4.43 a
1.68	6.30 a	3.40 ab	10.23 a	2.439 c	14.52 a	3.45 ab	10.69 a	4.36 a
2.24	4.84 ab	3.42 ab	10.13 a	3.090 ab	14.50 a	3.44 ab	9.37 abc	4.42 a
2.80	4.50 b	3.23 b	10.56 a	2.569 bc	14.61 a	3.61 a	8.59 bc	4.33 a

Table 1.b Yield response (bu/ac) to lime treatments (ENM lb/ac) at the field sites for 2009 and 2010

Lime	BR- corn	BR-beans	DE -corn	DE-beans	HW -corn	HW -beans	GR –corn	GR-beans
ENM lbs/ac	bu/ac	bu/ac	bu/ac	bu/ac	bu/ac	bu/ac	bu/ac	bu/ac
	2009	2010	2009	2010	2009	2010	2009	2010
0	90.25	51.83	146.12	21.78	204.50	51.31	122.00	65.95
250	87.33	57.42	158.40	33.40	220.50	49.21	136.00	65.08
500	89.50	45.90	161.57	34.85	227.25	47.04	158.50	68.88
1000	86.33	51.10	166.32	47.92	229.25	50.31	168.00	65.98
1500	100.50	50.59	163.15	36.30	231.50	51.27	170.50	64.95
2000	77.25	50.92	161.57	45.98	231.25	51.20	149.50	65.78
2500	71.75	48.05	168.30	38.24	233.00	53.71	137.00	64.45

Plan of work for 2011

March, 2011	Initial soil sampling of all 28 plots at 0-6” and 6-12” depths to measure surface and subsoil acidity.
April – May, 2011	Fertilizer applications, and planting of field calibration studies. Installing field incubation equipment in check plots and applying lime treatments and start the in-situ field incubation study.
July – September, 2011	Field observations, measurements and management of experimental plots. Collecting soil samples from the field incubation units and analyze them for pHs and buffer pH by the three methods (MWB, MMB, and SB).
October- November, 2011	Harvesting, yield measurements, end of season soil sampling, soil analysis.
December, 2011	Statistical analysis, data summary and report writing Final report and a manuscript will be submitted for Soil Science Society of America Journal.

This is the second year of the field calibration studies and study will be continued until 2011. Three years of field calibration data will be summarized with the lab and in-situ field incubation and a manuscript will be written for publication in Soil Science Society or Agronomy Journal.

Budget:

CATEGORIES	Year 2011
A. Salaries	
Senior Lab Technician (20%)	$5,842
General Labor for help with field work at the rate of $9:00 per hour 1600 man hours	$14,400
B. Fringe Benefits	
Fringe for Lab Technician (25%)	$1,753
TOTAL SALARIES AND FRINGE BENEFITS	$21,995
C. Travel	
Travel to five field sites	$1,500
To present research findings at Field days & National Meetings	$600
TOTAL TRAVEL COSTS	$2,100
D. Equipment	
TOTAL EQUIPMENT use and maintenance COSTS	$2,000
E. Other Direct Costs	
Soil analysis	$6,100
Field and lab supplies	$2,000
Publication cost	$800
TOTAL OTHER DIRECT COSTS	$8,900
TOTAL REQUEST	**$34,995**

Note: The above budget is for competing the third year of field calibration and for completing the in-situ field incubation study.

***J**ustification:*

Salaries and Fringe Benefits: Funds are requested support of a senior lab technician for 2.5 months based on an annual salary of $29,210, 30% fringe benefits.

Travel: Covers cost of travel to the five field sites located in through out the state of Missouri. For soil and plant samples collections, setting up of field incubation study, field measurements, and harvesting. Funds will be required to travel for field day presentations and to present the research work in the regional and national meetings.

Field and lab supplies: Seeds, fertilizer, lime, soil samplers, sample bags, making field incubation units, and other field and lab supplies.

Can “quarter minus” materials be used as a liming source in a special situation?

David Dunn and Gene Stevens
MU-Delta Center, Portageville, MO,

Objective: This study will investigate the possibility of using “quarter minus” materials as lime sources. A possible use will be evaluated, low pH sandy alluvial soils..

Current Status/Importance of Research Area:
The quality of liming materials in Missouri is given in pounds of Effective Neutralizing Material (ENM) per ton. This number is calculated to represent the amount of soil acidity that a given material will neutralize over the course of a three-year period. The effectiveness of liming materials is controlled by two factors, chemical composition and a fineness factor. “Quarter minus” material is what remains from a lime crushing run after the course fraction (greater than ¼ inch diameter) has been removed for other uses. Depending on the source rock and final product of the “quarter plus” material the “quarter minus” fraction can represent 15-35% of the original material. A local lime producer indicated that their inventory of “quarter minus” material is currently over 400,000 tons.

As the Missouri Lime Standards are based on size consists and do not consider material greater than 8 mesh as contributing to ENM , “quarter minus” materials generally contain low ENM and are not suited for most agricultural situations. A special situation has been identified for possible use of “quarter minus” materials. The University of Missouri lime recommendations are for three years, but in sandy alluvial soils with high potential for leaching, a lime application often will begin to lose its effectiveness in two years. This is one situation where a larger size consist material may be more cost effective than traditional materials.

Procedure: This study compares “quarter minus” material with traditional ag lime derived from the Delta Companies quarry located near Poplar Buff, MO The traditional ag lime from this source was found to contain 495 ENM per ton, while the quarter minus material was found to contain 284 ENM per ton. The details of this analysis are found in Table 1. Two low pH research areas were identified. One at the University of Missouri Marsh Farm where the soil type is a Tiptonville silt loam, here soybeans were cultivated. The initial soil pH at this location was 5.2. The other research area is located at the University of Missouri Rhodes farm, here cotton was cultivated. At this location the soil type is a Bosket loamy sand and the initial soil pH was 5.4. Prior to planting plots representing seven lime treatments were established at each location. The treatments used at each location are listed in Table 2. The corresponding amount of specified product was applied to each plot and incorporated with tillage prior to planting. All methods of N, P and K fertilization, weed & insect control and irrigation were the standard practices for Southeast Missouri. At the end of the season all plots were harvested and the yield measured. Soil samples were collected monthly from each plot during the growing season. These samples were analyzed for pH.

Project accomplishments: Crop yields for both locations are presented in Table 3. At both locations all lime treatments numerically increased crop yields relative to the untreated check. At the Marsh Farm where soybeans were cultivated all plots that received either aglime or ¼ minus lime had yields that were statistically equivalent. Yields for treatments receiving less than 1000 ENM were also statistically equivalent to but numerically greater than the untreated check. The treatment which received 1136 ENM as ¼ minus lime produced the greatest numerical yields. At the Rhodes Farm where cotton was cultivated all plots that received either aglime or ¼ minus lime had yields that were statistically equivalent. Yields for treatments receiving less than 600 ENM were also equivalent but numerical greater than the untreated check. The treatment which received 1420 ENM as ¼ minus lime produced the greatest numerical yields. The data indicates that ¼ minus materials are equivalent in producing yield increases to traditional aglime when applied on an equivalent ENM basis.

The seasonal pH data is presented as Figures 1 and 2. For all sampling times addition of lime as either traditional aglime or ¼ minus produced soil pH levels significantly greater than the untreated check. However, at both locations the aglime produced a greater pH change in a shorter time than corresponding rates of ¼ minus material. At the Marsh Farm, where soybeans were cultivated only treatments where more than 1000 ENM from either aglime or ¼ minus lime was applied did the pH levels raise into the desired range for row crop production (6.1). This pH level was produced for the July sampling date for the aglime (1485 ENM) compared to the August sampling data for the ¼ minus (1136 ENM). At the Rhodes Farm where cotton was cultivated the pH increase was steeper for all treatments. All treatments except the ¼ minus (568 ENM) raised soil pH above the target level within 2 months of application. This may be due to the lower buffering capacity offered by the Bosket loamy sand. The data indicates that ¼ minus materials are equivalent in producing soil pH increases to traditional aglime when applied on an equivalent ENM basis.

Summary

- The ¼ minus lime material studied was found to be equivalent to traditional aglime for increasing soil pH and crop yields when compared on an ENM vrs. ENM basis.
- It takes approximately 2 tons of ¼ minus to equal 1 ton of traditional aglime in terms of ENM content.
- Transportation costs may be significant when comparing the economics of these two products.

Budget:

Expenses	2010	**2011**	2012
Labor	$4,000	**$4,255**	$4,518
Fringe benefits	$1,000	**$1,064**	$1,130
Supplies	$1,000	**$1,000**	$1,000
Travel	$350	**$350**	$350
Lab analysis	$1,500	**$1,500**	$1,500
Total	$7,850	**$8,169**	$8,498

Table 1. Physical and chemical parameters for materials used in this experiment, 2010.

Parameter	aglime	¼ minus lime
ENM / ton	495	284
Mg %	11.5	11.4
CCE %	91.8	90.4
Fineness factor	67.4	39.3
Sieve profile		
% retained #8	0.6	36.2
% between #8 and #40	35.9	29.0
% between #40 and #60	12.8	6.8
% passing #60	50.7	28.0

Table 2. Lime treatments used for each experiment location 2010.

Trt #	Marsh Farm Tiptonville silt loam Soybeans (950 ENM recommended)	Rhodes farm Bosket loamy sand Cotton (805 ENM recommended)
	Tons material/acre	
1	Check	Check
2	1 ton aglime (495 ENM)	1 ton aglime (495 ENM)
3	2 ton aglime (990 ENM)	2 ton aglime (990 ENM)
4	2 ½ ton aglime (1485 ENM)	2 ton ¼ minus (568 ENM)
5	2 ½ ton ¼ minus (710 ENM)	3 ton ¼ minus (852 ENM)
6	3 ton ¼ minus (852 ENM)	4 ton ¼ minus (1136 ENM)
7	4 ton ¼ minus (1136 ENM)	5 ton ¼ minus (1420 ENM)

Table 3. Crop yields for lime treatments 2010.

Trt#	Soybeans		Cotton	
	Material	Yield (bu/a)	Material	Yield (lb/a)
1	Check	24.7 b	Check	854 b
2	Aglime (495 ENM)	30.0 ab	Aglime (495 ENM)	935 ab
3	Aglime (990 ENM)	31.5 ab	Aglime (990 ENM)	1010 a
4	Aglime (1485 ENM)	37.3 a	¼ minus (568 ENM)	922 ab
5	¼ minus (710 ENM)	32.0 ab	¼ minus (852 ENM)	992 a
6	¼ minus (852 ENM)	36.8 a	¼ minus (1136 ENM)	968 a
7	¼ minus (1136 ENM)	38.2 a	¼ minus (1420 ENM)	1016 a
lsd 0.05		5.9		77
CV %		12.0		5.4

Figure 1 pH change with time for liming materials on a low pH soil at the University of Missouri Marsh Farm Portageville, MO 2010.

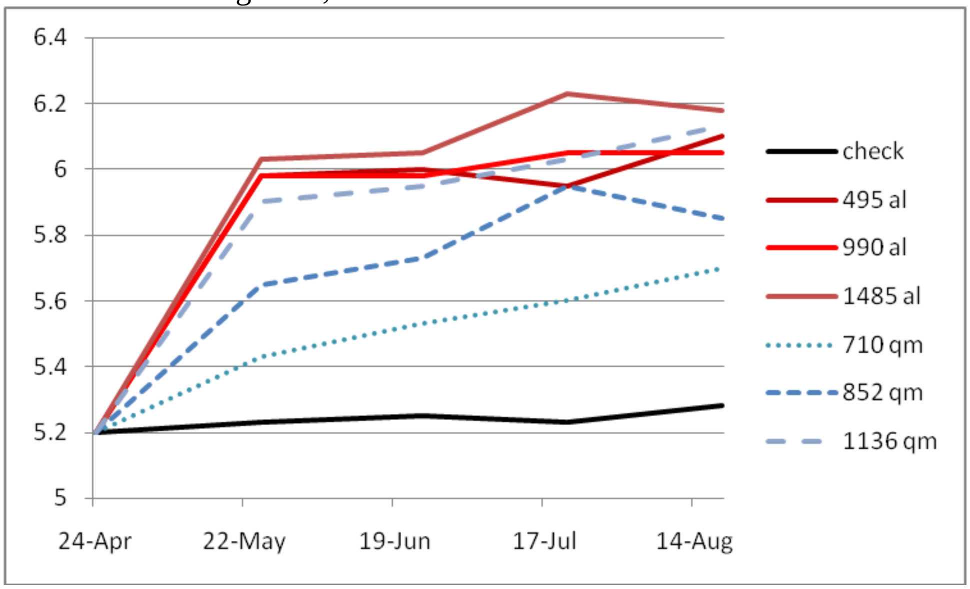
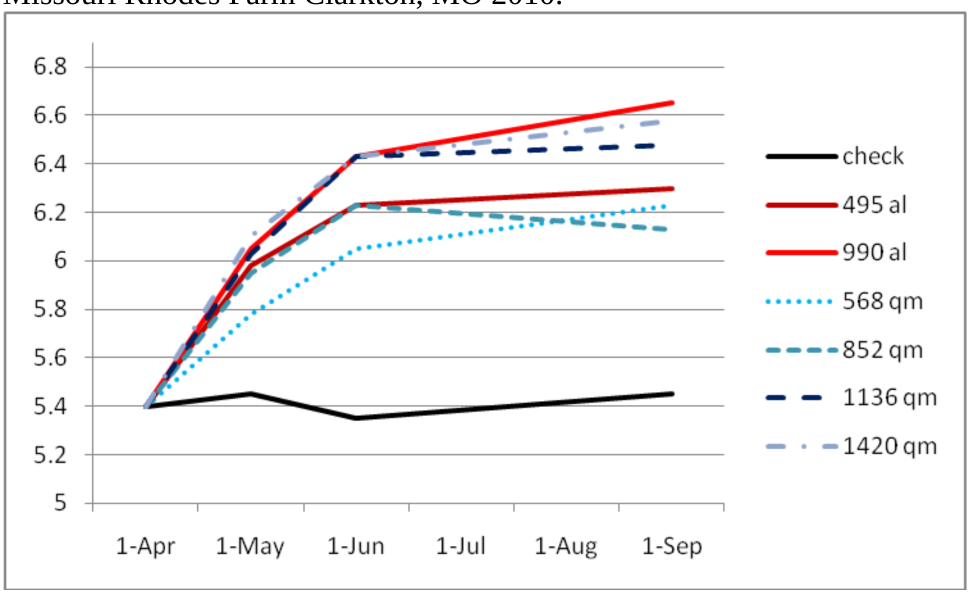


Figure 2. pH change with time for liming materials on a low pH soil at the University of Missouri Rhodes Farm Clarkton, MO 2010.



Nitrogen Management

Final Report

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

Peter Motavalli, Kelly Nelson, and Pat Nash

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INTRODUCTION

Nitrogen management for corn and wheat production in poorly-drained soils, such as found with claypan soils in northeastern Missouri, can be challenging due to the large potential for low N use efficiency due to wet soil conditions. In addition, climate factors, such as wet spring weather, warm winter temperatures or above-average rainfall seasons, can further complicate N fertilizer management since these conditions may enhance N loss depending on N fertilizer management practices. Among the management strategies that have been examined to improve crop production and reduce soil N loss include improved timing of N fertilizer applications (Medeiros et al., 2005; Nelson and Motavalli, 2007a), application of different enhanced efficiency N fertilizer sources (Noellsch et al., 2009; Scharf and Mueller, 2010), and use of different tillage/N placement methods (e.g., strip till, deep banding fertilizer applications) (Nelson and Motavalli, 2007b).

One of the major gaseous N loss processes in wet soils is denitrification which can cause gaseous N losses between 2 to 5% of nitrate-N per day for soils that are saturated (Sawyer, 2008). Nitrous oxide (N_2O) gas, which can be produced during denitrification, is both a greenhouse and ozone-depleting gas and estimates are that crop and soil management practices contribute approximately 41% of the anthropogenic emissions of N_2O in the United States (Massey and Ulmer, 2010). This gas has a global warming potential about 300 times that of carbon dioxide (Massey and Ulmer, 2010). Increasing emphasis is being placed on determining the relative losses of N_2O under different agricultural practices and environmental conditions and identifying agricultural practices that may minimize soil N_2O loss while also maintaining or increasing agricultural production.

The objectives of this research were to: 1) evaluate yield response of fall-applied polymer-coated urea (PCU) compared with non-coated urea and anhydrous ammonia with and without a nitrification inhibitor 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. An additional objective which was initiated in 2009 was to determine the relative cumulative soil N_2O loss with treatments of different pre-plant N fertilizer sources and fertilizer application/tillage methods.

MATERIALS AND METHODS

Research was conducted at the Greenley Research Center in northeastern Missouri for three growing seasons from 2008 to 2010. For the corn studies, two field trials with three replications at each trial were established at the Greenley Research Center in plots 10 by 70 ft on a Putnam silt loam (fine, smectitic, mesic, Vertic Albaqualfs). 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.

Soil nitrous oxide N flux was determined periodically during the growing season using a vented PVC collection chamber (5 inches high and 8 inch inside diameter) based on the GRACEnet standard protocol recommended by the USDA-Agricultural Research Service (Baker et al., 2003). Head space gas samples were taken using a 10 ml syringe at 0, 30 and 60 minutes after capping to determine gas flux. The gas samples were then injected into pre-evacuated 5 mL serum bottles for storage and transport to the laboratory. Soil temperature was measured in triplicate around each chamber during the gas collection process with a digital thermometer at the 2 inch depth. Soil samples to a 2 inch depth were also taken in triplicate within 20 inches from the center of the chamber for determination of gravimetric soil water content and soil inorganic N (NH_4^+-N + NO_3^--N). Gas samples were analyzed using a gas chromatograph (GC) (Buck Scientific Inc., East Norwalk, CT, USA) fitted with an electron capture detector (ECD). The ECD temperature was 300°C, and the standing current was 350 milliamps. The make-up gas was ultra-high purity dinitrogen. Carrier gas (high purity helium) flow rate (through a 1.8 m Porapak Q column at 50°C) was 18 mL min^{-1}. The concentration of the sub-sampled gas was determined based on a standard curve using incremental aliquots of a 10 µL L^{-1} N_2O standard gas (Scott Specialty Gases, Plumsteadville, PA, USA).

The soybean residue study was planted to corn hybrid 'DK 63-42 VT3' at 30,000 seeds/acre on 29 May 2008, 23 Apr. 2009, and 14 Apr. 2010. In the clover residue study, 'DK 61-69 VT3' was planted at 30,000 seeds/acre on 6 May 2008, 23 Apr. 2009, and 14 Apr. 2010. 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.

The wheat studies were initiated in the fall of 2007 and included three consecutive wheat-double-crop soybean growing seasons (approximately Oct. through Sept.) on a Kilwinning silt loam (fine, smectitic, mesic, Vertic Epiqualfs) with approximately 2 to 5% slope in 2008 and 2009 and on a Putnam silt loam (fine, smectitic, mesic, Vertic Albaqualfs) with approximately 0 to 1% slope in 2010. The experimental design was a 2 x 7 x 5 factorial in a completely randomized block design, with five replications and a non-treated control. Plots were 10 by 30 ft. Fertilized treatments consisted of two N application rates (75 and 100 lb N/acre), seven application timings (day 5 through 30 in Oct., and 12 through 18 in Nov., Dec., Jan., Feb., Mar., and Apr.), and five dry fertilizer source/blend(s) (100% AN, 100% PCU, 100% NCU, 75% PCU:25% NCU, and 50% PCU:50% NCU). Polymer-coated urea used in this study was ESN

(Agrium Advanced Technology, Denver, CO). All N fertilizers were broadcast applied to the soil surface using a hand spreader.

Soft red winter wheat variety ‘Pioneer 25R56’ was no-till seeded in September to October at 120 lb/acre in 7.5 in. rows. Soybean cultivars (‘Asgrow 3602’ in 2008, ‘Pioneer 94Y01’ in 2009, and ‘Asgrow 3539’ in 2010) were planted in July following wheat harvest in 7.5 in. rows at 200,000 seeds ha^{-1}. Grain yields were determined with a small-plot combine (Wintersteiger Inc., Salt Lake City, Utah) and grain moisture adjusted to 13% prior to analysis.

Urea release rates were obtained by placing a known weight of PCU (approximately 10 g) on the soil surface in heat sealed standard mesh, fiberglass insect screen. For each timing application, an individual bag was removed after each subsequent month up to June, washed in iced water, dried, and weighed to determine the percent of urea-N release. Weather data was collected on-site using an automated Campbell weather station, which included daily rainfall, soil temperature taken at a depth of 2 in with corn residue, and air temperature. All data were subjected to analysis of variance and means separated using Fisher’s Protected LSD (P = 0.05).

RESULTS

All three years (2008 to 2010) of the field trials had above average rainfall during the growing seasons resulting in wet soil conditions (Fig. 1). These conditions would also be expected to affect plant growth and promote environmental N loss.

Corn Trials

Strip till practices may improve corn seed germination and emergence compared to no-till because of faster soil warming during the spring within the tilled strips. However, this effect of strip till versus no-till practices was only observed in 2010 possibly due to greater rainfall in the spring during that year (Fig. 2). Significantly higher ear leaf N content was also observed in 2008 and 2009 with strip till and deep banded N fertilizer compared to no-till surface broadcast N fertilizer application (Fig. 3). Polymer-coated urea had higher ear leaf N compared to conventional non-coated urea only in 2009 in the no-till/surface broadcasted treatment (Fig. 3).

These differences in plant populations and ear leaf N may explain some of the differences observed in corn grain yields (Fig. 4). In all three years in field following soybean, strip till and deep banding N fertilizer had 25 to 86 bu/acre greater corn grain yields than plots that had no-till and surface N fertilizer application (Fig. 4). Fall versus spring pre-plant applications of fertilizer had no significant differences in yields (data not shown) and the use of NCU versus PCU did not make a significant difference in yield (Fig. 4). These results suggest that the deep banding of the N fertilizer may have been an effective strategy to limit N loss and increase N availability in moderately wet years and the use of strip till was effective in increasing yields in the excessively wet year due to improved plant populations. Among all the three years, 2010 had the lowest corn grain yields (Fig. 4)

Soil Nitrous Oxide Emissions

Soil nitrous oxide flux was measured intensively during the 2009 and 2010 growing seasons in the corn trials to determine cumulative soil nitrous oxide losses over the growing season caused by use of different N fertilizer sources and tillage/N placement practices. These measurements were only conducted in the treatments in which N fertilizer was spring pre-plant applied. Soil nitrous oxide flux was characterized by high spatial variation with initial increases in flux among the treatments occurring between 20 to 30 days after N fertilizer application and lasting to until approximately 70 days after N fertilization (Fig. 5). Calculating cumulative soil nitrous oxide emissions over the growing season indicated that this form of N loss accounted for between 2.4 to 3.8% of the fertilizer N applied over the two growing seasons when soil nitrous oxide flux was measured (Fig. 6). Compared to several reported research studies from Colorado and Minnesota, this percentage loss of fertilizer N as nitrous oxide is relatively high indicating that the poor drainage of the claypan soil and the relatively high rainfall experienced during 2009 and 2010 in northeastern Missouri probably promoted high levels of soil nitrous oxide loss. No significant effects of N fertilizer source (NCU versus PCU) or tillage/N placement were observed for cumulative nitrous oxide emissions, possibly due to the high spatial variation in gas flux measured in the field (Figs. 5 & 6).

Calculation of the amount of cumulative soil nitrous oxide emissions per unit of grain production is an important way to evaluate different management practices for their effects on reducing emissions of nitrous oxide in relation to grain production (Table 1). Producer adoption of these alternative agricultural practices will probably not be based solely on their effects on lowering soil nitrous oxide emissions but also on their impacts on grain production. Based on this statistic, use of strip till and deep banding of N fertilizer significantly lowered the cumulative soil nitrous oxide loss per bushel corn grain compared to that of no-till and surface fertilizer application. Use of PCU or NCU fertilizer did not result in any statistical differences in soil nitrous oxide loss per unit of grain production (Table 1).

Wheat Trials

The percentage release of urea from PCU applied to the soil surface at different application timings varied considerably due to seasonal variability of rainfall (Figure 7). Rainfall distribution was similar in 2007-2008 and 2008-2009 with the majority of the rainfall occurring after Apr.; however, 2009-2010 had an abnormally wet fall which accounted for a greater percentage of urea-N released from PCU fertilizers applied in the fall and early winter. Urea release with Oct. applications was approximately 10 to 35% greater ($P < 0.05$) than Feb. to Apr. applications in 2007-2008 and 2009-2010. In 2008-2009, applications in Oct. had approximately 15 to 65% greater urea release than all other application timings. Applications in Oct. released less than 10% urea after one month in 2007-2008 and 2008-2009. However, 45% of the urea released in 2009-2010 was likely due to higher fall rainfall. Midseason N applications in Feb. averaged 64% release of urea-N which was similar to that released in Nov. and Jan. in 2007-2008, Nov. to Jan. in 2008-2009, and only Jan. in 2009-2010. Significant variation in urea released from PCU applied in Feb. or earlier between seasons may have been due to variation in weather among the seasons. Applications of PCU in Mar. to June averaged 54% or less urea released. This surface-applied PCU release data indicates that PCU fertilizer N may require the addition of a fast-release fertilizer source when applied after February in order to supply adequate plant available N during high wheat demand in Mar. and April.

In 2008 and 2010, wheat yields significantly ($P < 0.05$) increased with increasing N rates (0, 75, and 100 lb N/acre) at each application timing (Oct. to Apr.) (Table 2). Comparing Oct. to Apr. N fertilizer applications, N source treatments increased yield by 7 to 10 bu/acre (AN and NCU), decreased yield by 8 bu/acre (100% PCU), and were similar (75/25 and 50/50 bends of PCU and NCU) over this period. Treatments of 100% PCU in Nov. produced similar yields compared to NCU applications in Mar. and Apr., and an Apr. application of AN.

Double-cropped soybean yields generally increased with lower N rates and earlier applications, and were positively correlated with winter wheat yields (Data not shown). Yields increased by 0.6 to 0.9 bu/acre with 100% PCU applications prior to soybean planting (Oct. to Apr.) compared to 100% NCU and PCU/NCU ratio of 75%/25% (Fig. 8). Polymer-coated urea maximized double-crop soybean yields in 2008 and 2009 compared to other N sources (Fig. 8).

SUMMARY

Corn

- In wet years, deep banding NCU or PCU under strip tillage has shown more consistent advantages in crop performance due to its possible effect on reducing N loss and improving plant stands.
- Timing (fall vs. pre-plant) of strip tillage N fertilization had no consistent effect on grain yields.
- Significantly higher soil N_2O emissions occurred with the fertilized treatments compared to untreated soil between approximately 30 to 60 days after N application in three growing seasons of above average rainfall.
- Cumulative losses of N_2O over the growing season represented between 2.4 to 3.8% of fertilizer N applied which is small compared to other potential N losses (e.g., total N loss from denitrification, NH_3 volatilization), but is relatively high compared to losses observed at other locations in the United States. This is possibly due to the poor drainage of claypan soils and the relatively wet conditions experienced from 2008 to 2010 in northeastern Missouri.
- Strip tillage with N fertilizer banded at depth significantly reduced the amount of N_2O-N emitted per bushel of corn grain produced compared to that of the no-till/surface broadcast treatments.

Wheat/Soybeans

- Polymer-coated urea is a viable N fertilizer source for fall applications, and may even increase grain yields over NCU fertilizers in seasons with high rainfall and N loss potential. Potential yield benefits from blending of PCU and NCU fertilizers compared to 100% PCU treatments were the greatest when applied in Mar. or April.

- Nitrogen management practices which increased winter wheat yields were positively correlated with soybean yields and negatively correlated with soybean population and height. Contrary to our hypotheses, higher N rates and later application timings, which may have increased fertilizer N carry over and residual soil N from winter wheat production, did not increase soybean yields. However, greater soybean yields following winter wheat were observed with PCU applications compared to N sources more susceptible to loss may have be due to increased early soybean growth which could have reduced yield reductions associated with late planting of soybean (July).

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Table 1. Cumulative growing season soil N_2O emissions, corn grain yields, and N_2O-N emitted per yield produced, analyzed by the main effect of N fertilizer source, tillage/placement, and year.

	N Fertilizer Source			Tillage / Placement		Year
				No-till	Strip-till	
Year	PCU	NCU	Non-Treated	Surface Broadcast	Deep Banding	Average
	lbs N_2O-N $acre^{-1}$					
2009	5.46	4.26	1.00	4.06	3.09	4.58a
2010	4.32	5.02	1.37	3.68	3.45	4.57a
Average	4.89a	4.65a	1.18b	3.87a	3.27a	
	bu corn grain $acre^{-1}$					
2009	176	144	92	120	154	137a
2010	95	88	49	69	86	77b
Average	136a	116b	70c	94a	120b	
	lbs N_2O-N bu-corn $grain^{-1}$					
2009	0.031	0.030	0.011	0.034	0.020	0.033b
2010	0.045	0.057	0.028	0.053	0.040	0.059a
Average	0.038a	0.044a	0.020b	0.044a	0.030b	

† Letters following averages of N fertilizer source, tillage / placement, and year for cumulative growing season N_2O emissions, corn grain yield, and N_2O / yield indicate least significant differences $P < 0.05$ among treatments.

Table 2. Soft red winter wheat grain yields by N rate and application timing or fertilizer source(s) from the 2008, 2009 and 2010 growing seasons.

		N application timing†							N fertilizer source‡				
									100%	100%	100%	75/25%	50/50%
Year	Rate	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	AN	NCU	PCU	PCU / NCU	
lbs acre^{-1}		bu acre^{-1}							bu acre^{-1}				
2008	0	53	53	53	53	53	53	53	53	53	53	53	53
	75	73	77	70	72	67	76	76	73	71	75	74	73
	100	79	84	76	78	70	79	80	76	76	79	80	79
	LSD	2							2				
2009	0	32	32	32	32	32	32	32	32	32	32	32	32
	75	50	51	45	52	52	48	50	51	48	52	52	46
	100	52	50	47	51	51	49	51	51	50	46	51	52
	LSD	5							3				
2010	0	28	28	28	28	28	28	28	28	28	28	28	28
	75	36	37	42	45	42	46	46	42	40	44	42	41
	100	39	42	49	47	48	51	46	47	44	48	45	45
	LSD	3							2				

† Fisher's Least Significant Difference at $P < 0.05$.
‡ Fisher's Least Significant Difference at $P < 0.10$.
Abbreviations: AN = ammonium nitrate; NCU = non-coated urea; PCU = polymer-coated urea.

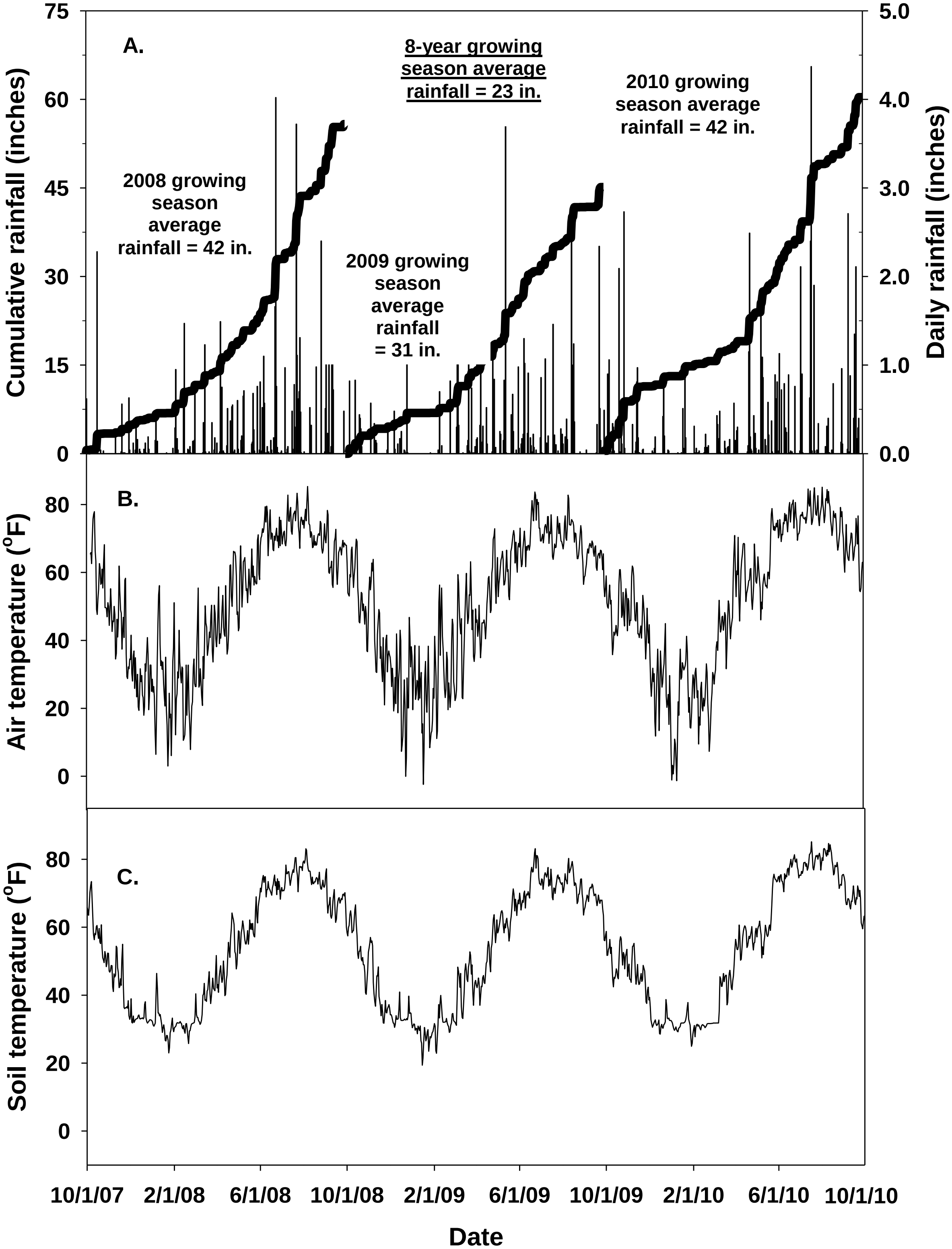

Figure 1. Climatic information for the Greenley Experiment Station with (A) Daily (bars) and cumulative rainfall (lines) (B), daily average air temperature and (C), soil temperature at the 2 in depth with soybean residue from fall 2007 to fall 2010. Text indicates average growing season rainfall and 8-year overall growing season average for the Greenley Experiment Station.

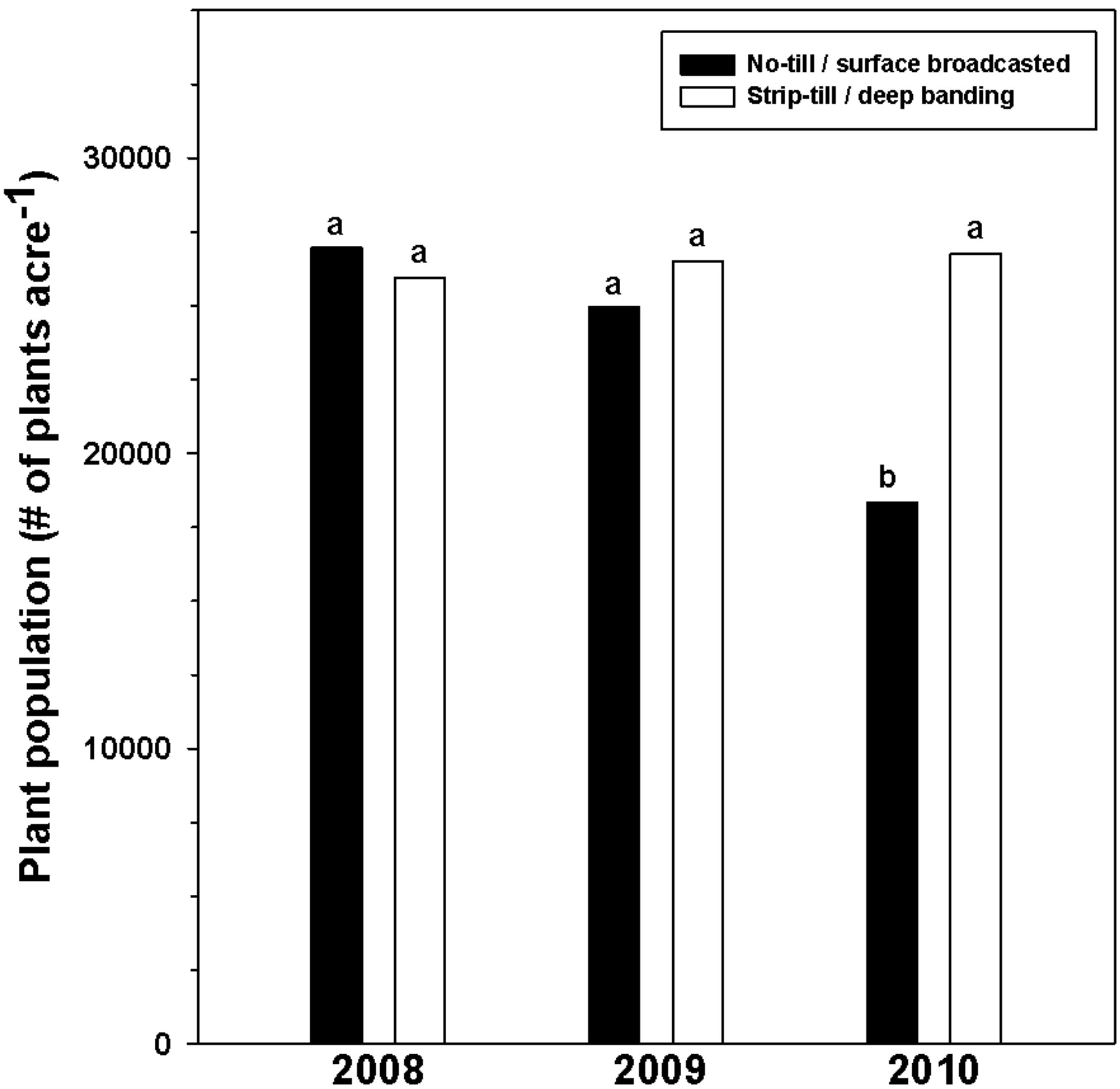

Figure 2. Corn plant population following soybean production due to tillage / N placement for 2008, 2009, and 2010. Letters over bars indicate differences among treatments within a given year using Fisher's Protected LSD (P < 0.05)

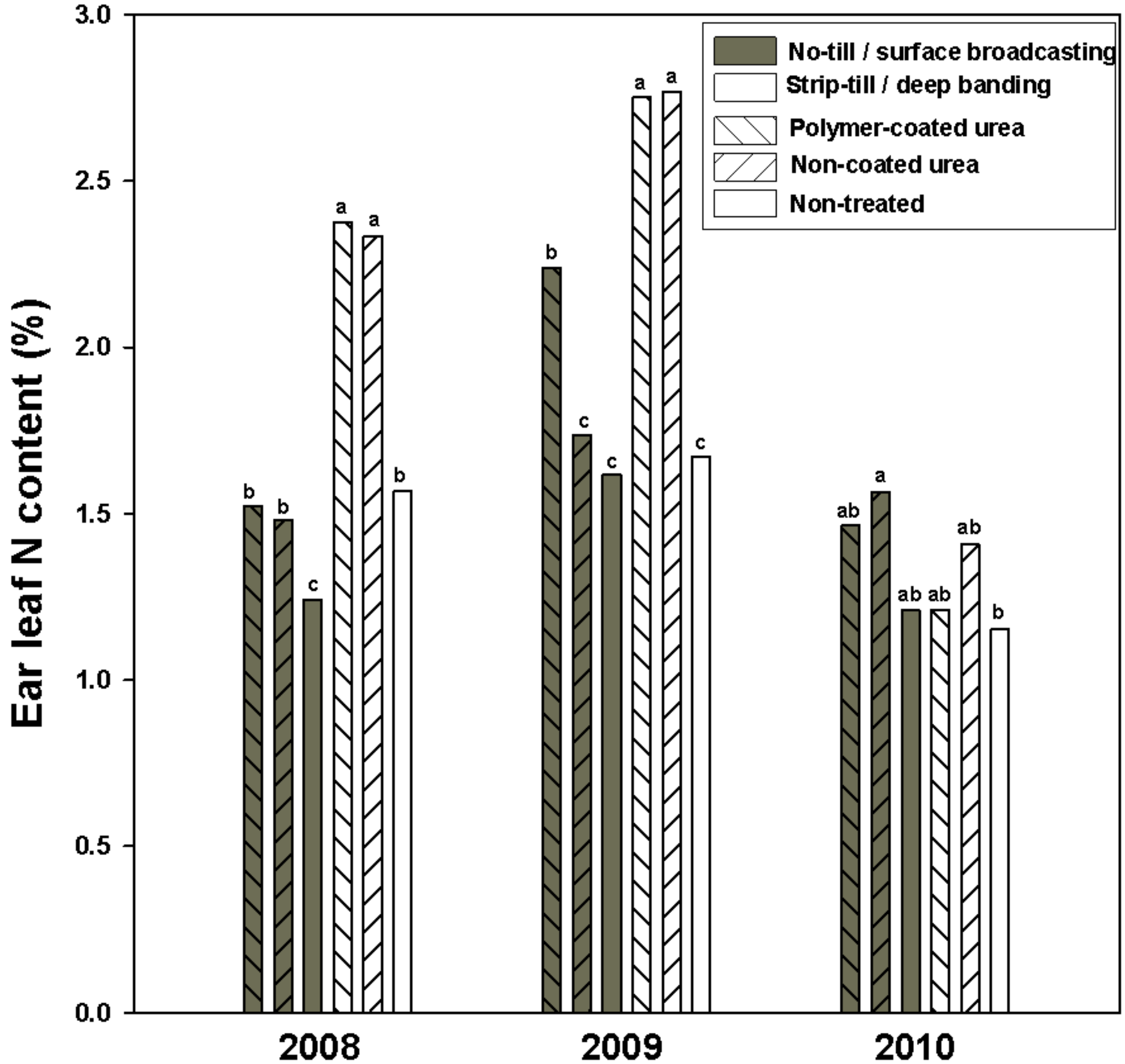

Figure 3. Ear leaf N content following soybean production due to the interaction of tillage/N placement and N fertilizer source for 2008, 2009, and 2010. Ear leaf samples were taken between the R3 and R5 growth stage. Letters over bars indicate differences among treatments within a given year using Fisher's Protected LSD ($P <$ 0.10).

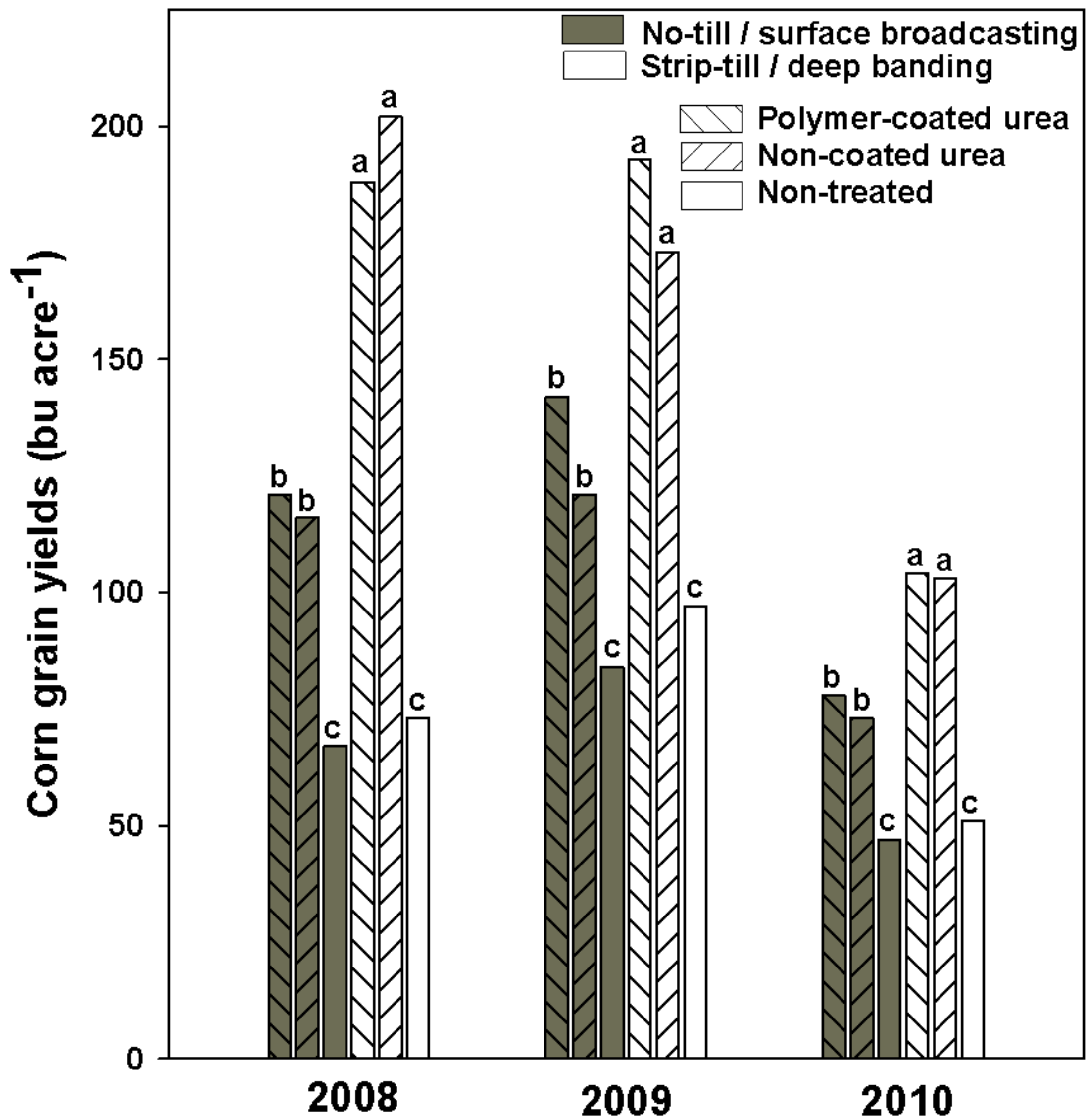

Figure 4. Corn grain yield following soybean production due to the interaction of tillage/N placement and N fertilizer sources in 2008, 2009, and 2010. Letters over bars indicate differences among treatments within a given year using Fisher's Protected LSD (P < 0.05).

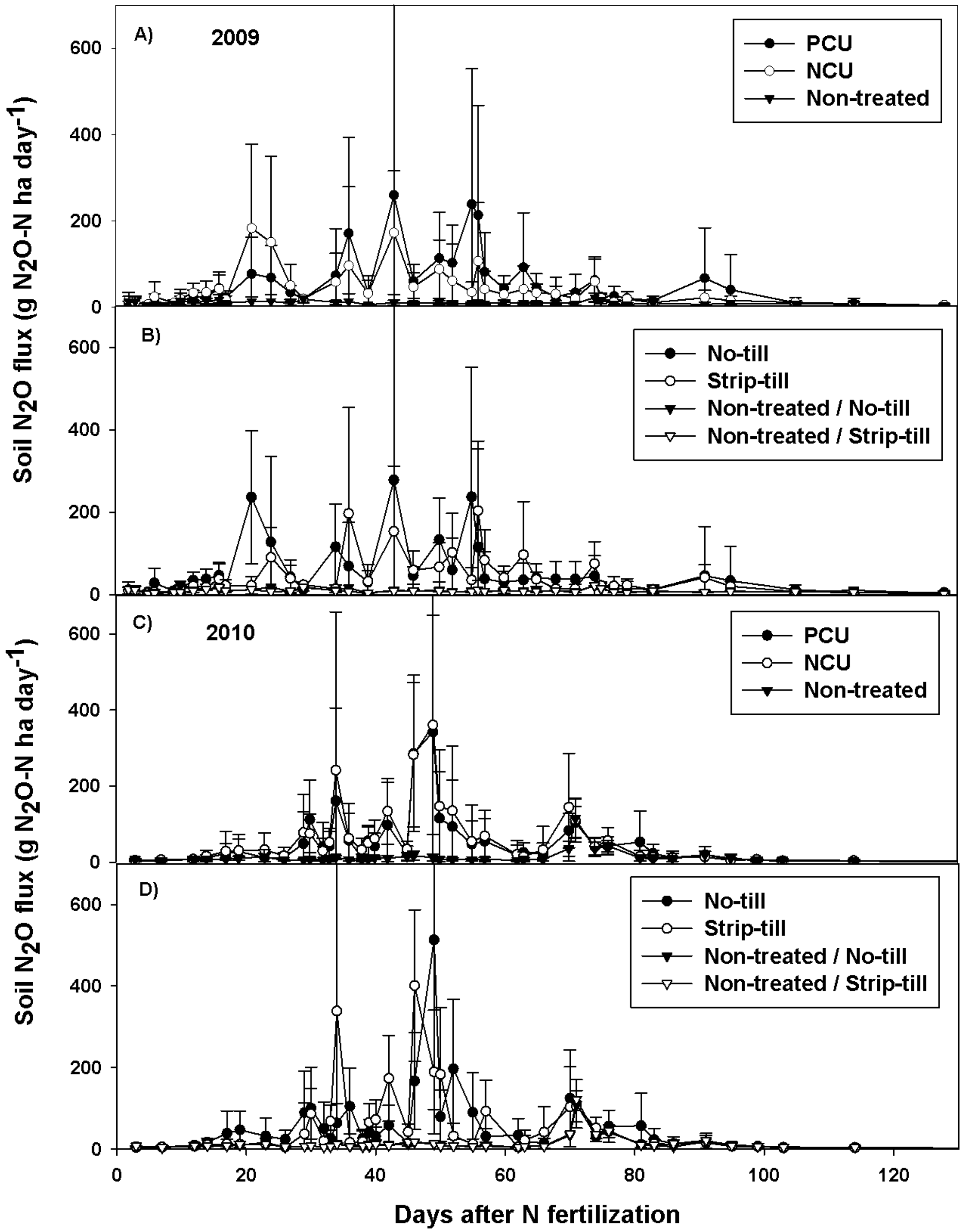

Figure 5. Nitrogen fertilizer source and tillage managements effect on soil N_2O flux over the 2009 and 2010 growing season (n = 12). Symbols are means with standard deviations. A) N fertilizer source (2009). B) Tillage / N placement (2009). C) N fertilizer source (2010). D) Tillage / N placement (2010).

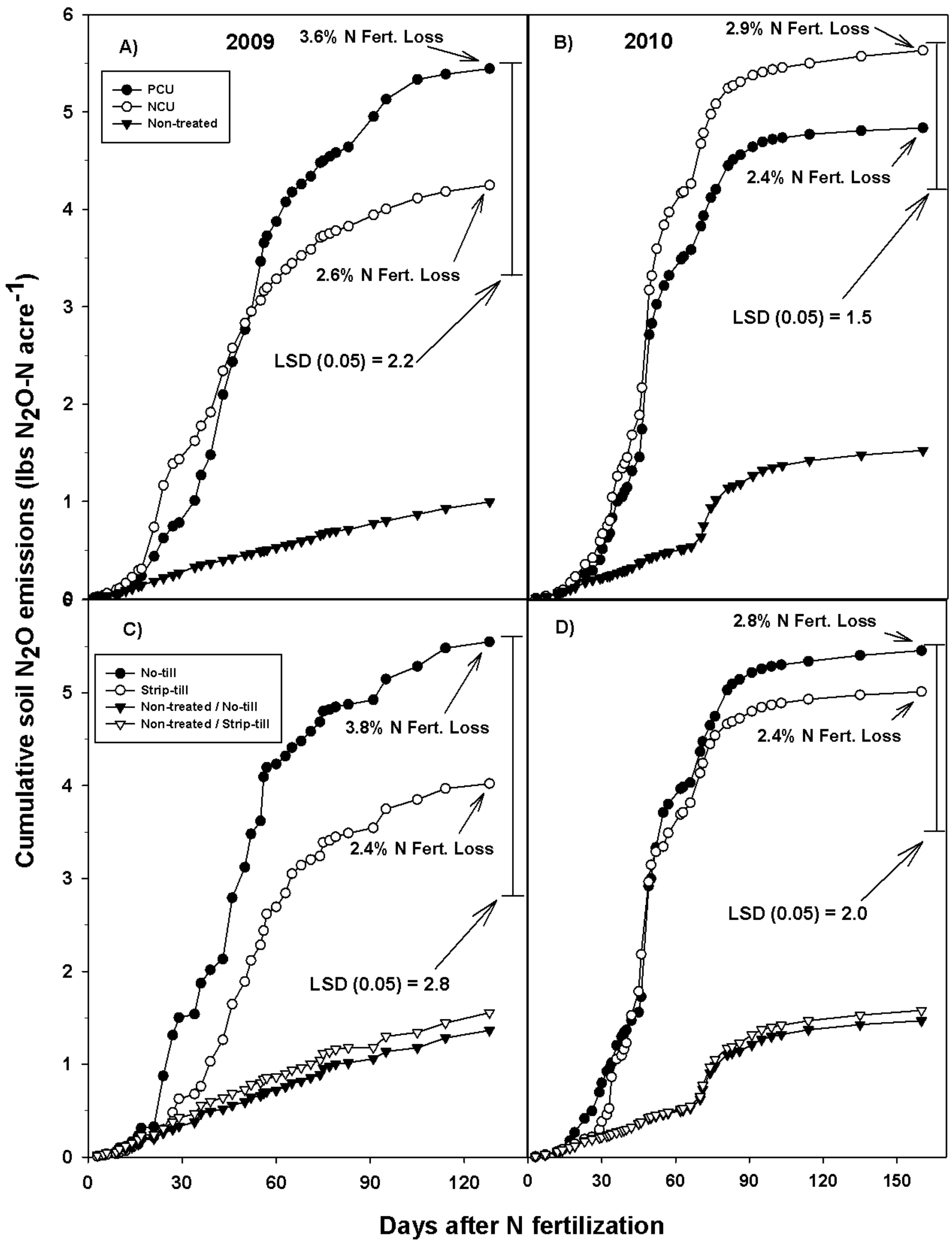

Figure 6. Nitrogen fertilizer source and tillage management effects on the cumulative soil N_2O emissions over the 2009 and 2010 growing season, including the % N fertilizer loss and LSD (0.05) for the last sampling date. A) Nitrogen fertilizer source (2009). B) Nitrogen fertilizer source (2010). C) Tillage / N placement (2009). D) Tillage / N placement (2010).

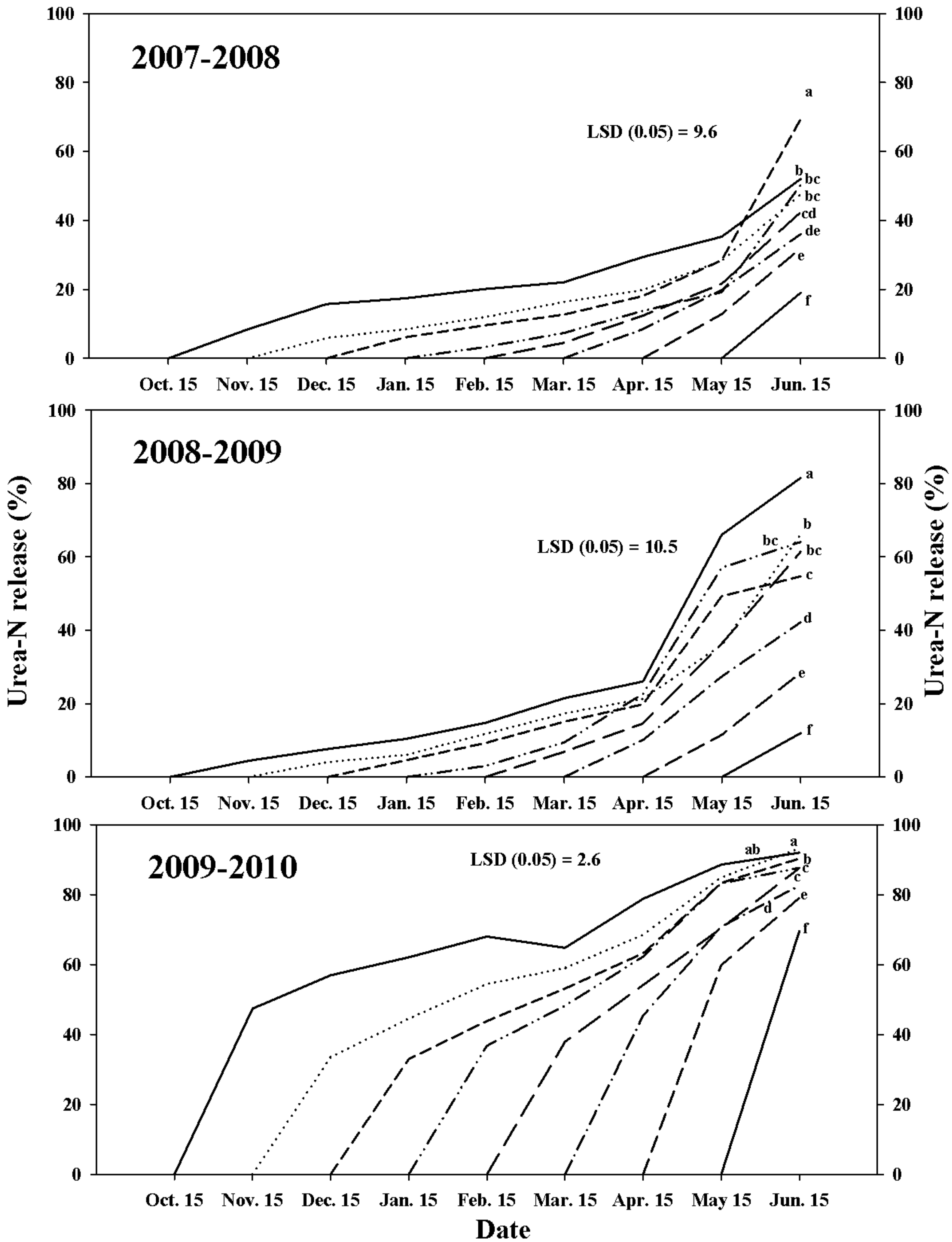

Figure 7. In-field study of the percent urea released from PCU fertilizer applied to the soil surface at different timings with applications starting 15 Oct. to 15 May.

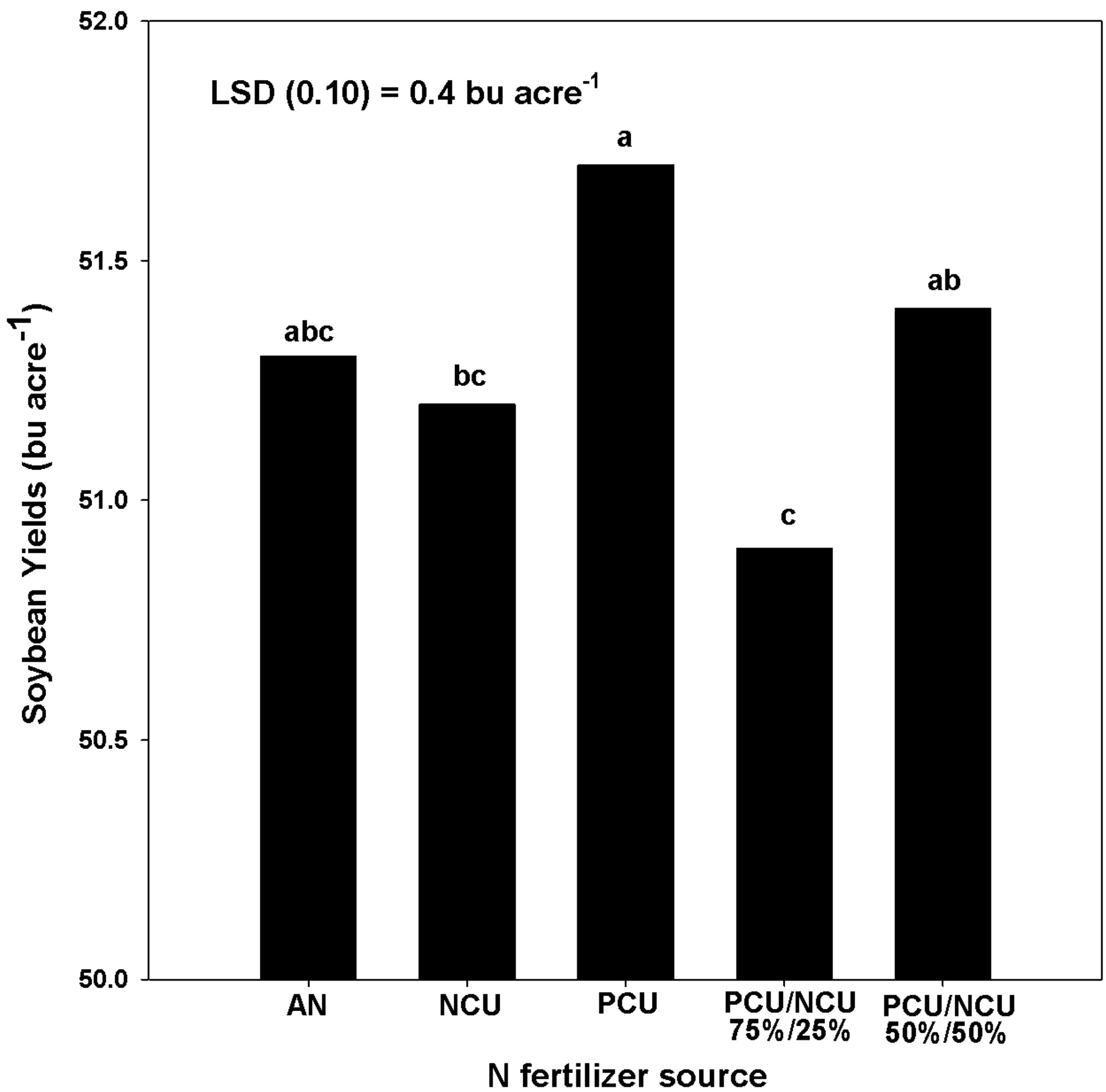

Figure 8. Double-crop soybean yield as impacted by N fertilizer source applications from Oct. to Apr. for wheat averaged over 2007-2008 and 2008-2009.

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 over multiple years?
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 2010:

- 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.

<u>Long-term nitrogen rate recommendation systems experiment</u>

- 2010 was, like 2009 and 2008, a very wet year, especially Apriland May.
- Pre-plant nitrogen treatments were applied on April 29 as broadcast ammonium nitrate. Planting was delayed until May 28 due to wet weather. Sidedress treatments were applied July 2 as surface between-row ammonium nitrate when corn was in the V7 stage.
- This experiment received 4.8 inches of rainfall between pre-plant treatments and planting and3.3 inches more rainfall was received from planting to the time of sidedress. The pre-plant nitrogen was exposed to total of 8.1 inches more rainfall than the sidedress nitrogen.
- This wet weather apparently caused loss of much of the soil &pre-plant nitrogen. By early August, all of the treatments with pre-plant nitrogen appeared severely nitrogen-deficient over the entire plant (Fig.1). We observed the classic V-shaped nitrogen deficiency burn up the midrib on all plants in these treatments, usually up to the leaf below the ear.

FIG. 2

- All sidedress nitrogen treatments had much better leaf color (Fig. 2). In early August these treatments were green right down to their lowest leaves.

- **Nitrogen timing had a large effect on yield in this experiment.**
  - Plots receiving pre-plant N had an average yield of 38bu/acre (see table next page).
  - Plots receiving sidedress N had an average yield of 119bu/acre, an advantage of more than80 bu/acre.
  - All yields were surprisingly low given the good moisture availability throughout the season. Some anthracnose and diplodia were observed, but not enough to expect a major yield impact. No weed or insect problems were observed. One possibility is that the corn was never able to fully recover from the effects of the extended waterlogging early in the season.
  - This is the third year in a row with an unusually wet spring and a large yield advantage to sidedress N timing.
  - This experiment is continuous no-till corn. High levels of corn residue on the surface lead to wetter soil conditions than in other rotations and tillage systems. In wet years, this system will be more vulnerable to N loss than other systems.
  - Part of the yield advantage to sidedress N timing is due to the fairly high N rates recommended by all three sidedress recommendation systems in this wet year. Even so, thelowest sidedressrate(147 lb N/acre) out-yielded the highest pre-plant N rate (180 lb N/acre) by 59 bushels.
  - Nitrogen timing appeared to influence the number of kernels on an ear. We did not collect data on kernel number, but many of the ears in plots receiving pre-plant N could be seen to have low kernel number. This could have been due to poor pollination or to kernel abortion.
  - The large yield advantage to sidedressN timing is in agreement with the appearance of the plants as shown in the photos (Figures 1 and 2).

- **After four years, the most profitable systems are the two systems in which in-season N rate is based on corn color** (Minolta chlorophyll meter andCrop Circle sensor).
  - These systems gave profits $195/acre/year above the profits given by the most profitable pre-plant N management system.
    - ✓ This is due to the poor yields with pre-plant N in 2008, 2009 and 2010. These years all had excessive spring rainfall.
  - The color-based systems also out-performed sidedress N management based on asidedresssoil nitrate test (Iowa State Universityinterpretations) by about $30/acre/year.
    - ✓ This is probably due to the higher N rates recommended by the color-based systems, which appeared to more successfully compensate for high losses of soil N.
    - ✓ Profit was higher with color-based management than soil-nitrate-based management in 3 out of 4 years. All sidedress treatments were within a few dollars of one another in2009.
  - The chlorophyll meter system recommended an average of 22 lb N/acre more than the reflectance sensor system, and yielded an average of 4 bu/acre higher, resulting in virtually identical estimates of profitability.

- Among pre-plant treatments, the high-rate treatment (180 lb N/acre) gave the highest yields and highest profits both in 2010 and over a four-year span.
  - With adverse weather causing N loss, all preplant treatments were N-deficient, and the high rate treatment was the least deficient.
  - Yield of the high-rate preplant treatment in 2010 was still 80 bushels below the average of the two color-based sidedress treatments.

- The check treatment that received no N fertilizer yielded only 8 bu/acre. This shows how severely depleted the soil N supply was, both by N loss due to wet weather and by four years of removal without replenishment by fertilizer.

Table 1. Nitrogen rates recommended and corn yields produced by eight different recommendation systems in 2010 and 2007-2010.

Nitrogen Recommendation System	Nitrogen Application Timing[1]	2010 Nitrogen Rates (lb/ac)	2010 Yield (bu/ac)[3]	2007-2010 Ave. N rate (lb/ac)	2007-2010 Ave. yield (bu/ac)	2007-2010 Ave. gross (Yield-N) ($/ac/year)[4]
Chlorophyll meter	**V7**	**197**	**130**	**171**	**146**	**481**
Crop Circle sensor	**V7**	**220,182,168 219,202,203[2] avg. rate = 199**	**122**	**149**	**142**	**479**
Sidedress soil test	**V7**	**147**	**105**	**123**	**131**	**450**
High	**Pre-plant**	**180**	**46**	**180**	**98**	**284**
Yield goal/ MRTN	**Pre-plant**	**140**	**39**	**140**	**86**	**260**
Pre-plant soil test	**Pre-plant**	**124**	**38**	**134**	**84**	**256**
Low	**Pre-plant**	**100**	**27**	**100**	**76**	**244**
Check	**Pre-plant**	**0**	**8**	**0**	**47**	**188**

[1] Growth stage V7 is about knee high corn

[2] A different N rate was applied in each of 6 replications for this treatment. It is feasibleto use this sensor to change N rate automatically while fertilizing a field, and we felt that this ability would be most accurately reflected by diagnosing N rate for each plot separately.

[3] 2010 yields are different from each other (95% confidence) if they are more than 19 bushels apart

[4] Gross calculated using $4/bu corn, $0.60/lb N as estimates of average corn price and N cost during these four years.

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, 40 lb N preplant and two in-season applications of 20 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 when serious N deficiency occurs.
  - Initially we chose 50lb N/acre, divided into two applications to reduce burn, as a rate that could address serious N deficiency.
  - In the first year of the study this approach produced marginally unacceptable leaf burn.
  - For subsequent years we have reduced the in-season N applications to 40 lb N/acre, divided into two applications, and increased the preplant rate to keep the total the same.
- All treatments received a broadcast application of preplant N at a rate of 40 lb N/acre.
- All treatments except the check received two equal in-season applications of N.Applications were made on June16 (stage V10, waist high) and again on June24 (V13, shoulder high).
- In-season nitrogen treatments were:
  - foliar CoRoN, study rate (8 gal/ac)
  - foliar CoRoN, manufacture's rate (3 gal/ac)
  - foliar UAN
  - foliar urea
  - dribbled UAN (between rows)
  - broadcast ammonium nitrate
  - broadcast urea with Agrotain
  - check (no in-season N)

- Average yield response to 40 lb in-season N/acre was 24bu/acre. This shows that in-season N applications can produce good yield response in N-deficient corn.
  - However, yield response to in-season N was much lower than in 2008, when 50 lb/acre of in-season N produced an average yield response of 54 bu/acre.
  - N stress was less in the check treatment this year(94bu/acre) than in 2008 (69 bu/acre).
  - Top-side yield potential was also less this year, as reflected in state-average yields, although the reasons for this are not clear.
- **Foliar treatments did not show superior ability to deliver in-season N to a corn crop relative to soil-applied treatments.**See Table 3.
  - Average yield with foliar N (excluding the lower-rate CoRoN treatment) was 115bu/acre, with soil-applied N was 121bu/acre.

- A similar pattern was seen in 2008.
- 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.
- Foliar UAN gave the highest burn rating (see photo in Figure 3) and lowest yield among treatments receiving a total of 80 lb N/acre, as it also did in 2008. UAN solution is not an ideal N source for foliar applications.

Table 3. Corn yields with foliar or dry N sources. All treatments were applied at a rate of 20 lb N/acre at V10 and again at V13 except for the check and manufacturer rec rate CoRoN treatments. Urea-ammonium nitrate solution was broadcast on all plots preplantat a rate of 40 lb N/acre and incorporated with light tillage.

In-season source	2010 Ave. Yield (Bu/ac)[1]	2010 Ave. Burn Rating[2]	2008 Yield Bu./ac	2008 Ave. Burn Rating[2]	2 yr Yield Bu./ac	2 yr. Ave.Burn Rating[2]
Urea with Agrotain(dry)	128	0.75	133	1	131	0.9
Foliar Urea	118	4.4	130	7.5	124	6.0
Ammonium Nitrate(dry)	119	1.8	126	4.5	123	3.2
UAN dribbled	117	0.0[3]	122	0.0[3]	120	0.0
Foliar CoRoN Study rate	115	3.6	116	4.0	116	3.8
Foliar UAN	111	8.3	112	8.5	112	8.4
Foliar CoRoN 3 gal/acre (Manufacturer recommended rate)	107	1.0	---	1.0	---	1.0
No in-season N	94		69	0	82	0

[1] Yields are different than each other if they are 9 or more bushels apart. (95% confidence)

[2]Burn rating shown is the average of ratings 7 days after each application (V10 and V13). (10 = Severe, 0 = None) I

3 Leaf burn = 0, Some cosmetic burn on plant stalk from application splash

- Broadcast dry urea with Agrotain gave significantly higher yield than any other N source/placement.
  - In both years, this treatment gave the lowest burn rating except for the dribbled UAN treatment. This agrees with our earlier research showing lower burn potential for urea than for other N sources.
- Other N sources gave yields that were not statistically different than each other when applied at the full study rate (total 80 lb N/acre).
- The lower (manufacturer's recommended) rate of CoRoN gave a significant yield

response (applied twice), but still yielded 11 bushels less than foliar urea (with 95% confidence). It also yielded less, statistically, than all three soil-applied N treatments.
  - The beneficial properties of CoRoN are not enough to compensate for low N rates.
  - Claims that CoRoN is more effective per lb of N than other N sources were not supported by this study. These claims also go against established scientific principles.

Due to the loss of our 2009 foliar N experiment (farm crew accidentally harvested it as bulk corn), we will continue this experiment for one more year. The final report for the whole project will be completed at the end of 2011.

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

- This experiment was designed to test the new N products ESN, Calcium Ammonium Nitrate, and Nurea, the new N-enhancement product Nutrisphere, and the established N-enhancement product Agrotain. All treatments are dry surface applied N products.
- Soybean was the previous crop. This field received some light tillage to level seedbed as a damp soybean harvest had left some tire tracks.
- Corn was planted on April 21.
- A nitrogen rate of 140 lb N/acre was used for all treatments.
- Emergence was slow and vigor weak as over 4.5" of rainfall was received within days of planting and treatment application was delayed. Over 8" rainfall had been received since planting when treatments were applied to V3-4 corn on May 26.
- Effectiveness of N delivery was not tested well this year. The check treatment with no N yielded 110 bu/acre, and the highest-yield N treatment yielded 133. This is a yield response of only 23 bu/acre to 140 lb N/acre applied. Clearly another factor other than

N availability was limiting yield, but we don't know what it was. We did not observe any pest or crop growth problems that could explain the modest yields despite plentiful soil water.

- Thus it is likely that the observed 'treatment differences' are not real, since even a very poor-performing treatment should have been able to deliver enough N to support a 23 bu/ac yield response.
- **Over the three years of this study, ESN stands out as the new N product that performed most successfully.** Average yield with ESN was 20 bushels higher than with normal urea. This was partly a product of the wet spring weather during all three years. ESN is a coated urea product and releases the urea slowly from the coating; while still inside the coating, the N is protected from loss processes.
- Agrotain is a volatilization inhibitor that has been shown for decades to reduce loss of ammonia from surface-applied urea products. Its application to dry urea gave an average yield benefit of 9 bushels/acre over the three study years.
- Nutrisphere may have also given a yield increase of 7 bushels/acre during the study period. The mode of action of this product appears to be unknown, so I would recommend interpreting these results with caution.
- The new N products Nurea and calcium ammonium nitrate performed adequately but not well enough to justify using them in place of standard N sources.

Table 2. Yields with new N sources or N additives compared to standard dry N products.
[1]Yields are different from each other if they are 11 or more bushels apart.

Nitrogen source	2010 yield[1]	2009 yield	2008 yield	3-yr ave. yield
ESN	132	140	124	132
Urea + Agrotain	131	126	107	121
Urea + Nutrisphere	128	126	104	119
Ammonium nitrate	133	115	102	117
Urea	122	120	93	112
Calcium ammonium nitrate	119	108	106	111
Nurea	127	122	84	111
Check (0 N)	110	74	----[2]	----[2]

(95%confidence)
[2]Check treatment omitted in 2008.

Table 3. Details of experimental procedures for the three experiments in this project.			
Description	Long Term N	Foliar N	New Sources of Dry N
Previous Crop	Corn 70-75% Residue cover	Soybean 20-25% Residue cover	
Pre-plant Soil Sampling	4/7/2010	none	
Tillage	No-till	Pre-plant tillage - light field cultivation and mulcher to remove harvest tracks	
Weed Control Broadcast Herbicide Application	Burn down Round-up 32 oz./ac Residual Lexar 3.0 qts/ac Nonionic surfactant 2 pt /100/gal 4/19/2010	Residual Lexar 3.0 qts/ac Nonionic surfactant 2 pt /100/gal 4/20/2010	Residual Lexar 3.0 qts/ac Nonionic surfactant 2 pt /100/gal 4/20/2010
Early Nitrogen Application	3 Fixed rate treatments & MO pre-plant soil test treatment 4/29/2010	All plots, 40 lbs/ac N UAN added to above herbicidemix, incorporated with mulcher 4/20/2010	All treatments applied 5/26/2010
Plant Plots	Planter: JD 7000 w/finger pickup Variety: Pioneer P1395XR RR2 Herculexxtra Liberty Link, Cruiser Seed drop: 31,300 Depth: 1.25" – 1.50" Conditions: Good Emergence – Good 5/28/2010	Planter: JD 7000 w/finger pickup Variety: Pioneer P1395XR RR2 Herculexxtra Liberty Link, Cruiser Seed drop: 31,300 Depth: 1.25" – 1.50" Conditions: Good Emergence – Slow 4/21/2010	Planter: JD 7000 w/finger pickup Variety: Pioneer P1395XR RR2 Herculexxtra Liberty Link, Cruiser Seed drop: 31,300 Depth: 1.25" – 1.50" Conditions: Good Emergence – Slow 4/21/2010
Weed Control Clean – up Broadcast Herbicide Application	Round-up32 oz./ac+ AMS 20 gal water/ac 6/16/2010	none	none
Sidedress Treatment Applications	Spad, Holland &Soil nitrate test Sidedress treatment applied 7/2/2010	1st foliar application 20 lbs./ac N 6/16/2010 2nd foliar application 20 lbs./ac N 6/24/2010	none
Harvest	10/4/2010	9/29-30/2010	9/29/2010

Progress Reports

Nitrogen dynamics of standard and enhanced urea in corn

James H. Houx III and Felix B. Fritschi

INTRODUCTION:

Concerns about illegal uses of anhydrous ammonia and ammonium nitrate may make urea a more suitable N fertilizer choice in the future. Urea is more concentrated than most N sources and thus may be more economical to apply. However, urea is subject to volatilization losses that in extreme circumstances can be as much as 50% (Harrison and Webb, 2001). To combat N losses from urea, manufacturers have developed additives and specialty N fertilizer products designed to inhibit N losses and prolong the N release period. These characteristics may reduce leaching and nitrate runoff, and may reduce emissions of N-containing greenhouse gases. Further, they may offer producers some flexibility in their N management decisions.

OBJECTIVE:

The overall objective of this project is to evaluate different Urea-N management products on the fate of fertilizer N and corn yields.

Specifically, we will:

1) Evaluate corn yield response to fertilization with standard urea and enhanced N-urea (Agrotain, Nutrisphere, and ESN).
2) Examine timing and quantity of corn fertilizer N uptake, fertilizer N use efficiency, and recovery in the soil base for these product classes using ^{15}N tracer techniques.

2010 ACCOMPLISHMENTS AND UPDATE:

- This year (2010) was the second year of a 3-year project evaluating urea-N management products on corn yield and nitrogen uptake, nitrogen use efficiency, and recovery of soil nitrogen following corn harvest.
- The following treatments were randomly applied to 30’ x 80’ plots and replicated four times at the Bradford Research and Extension Center. Four, square-meter microplots were embedded in each plot receiving treatments 2, 3, and 4 in which ^{15}N-enriched urea at 2%

atom excess was supplanted for standard urea. This year, we added another urea product, SuperU from Agrotain LLC, to the study.

Main Treatments*: (6 treatments to evaluate product effect on yield)*

1) Zero fertilizer N
2) Urea (^{15}N microplot)
3) Agrotain treated Urea (^{15}N microplot)
4) PCU (Polymer coated Urea—Duration 75) (^{15}N microplot)
5) Nutrisphere treated Urea
6) ESN urea
7) 28% UAN (as a growers standard)
8) SuperU urea

- International Fertilizer Development Corporation (IFDC) in Mussel Shoals, AL manufactured the ^{15}N urea and we received the material in April 2009. The pellet size was consistent with bagged urea purchased from MFA.
- Pioneer hybrid 33M16 (corn) was no-till planted into good soil conditions on May 24, 2010 and established a uniform population of approximately 32,000 plants/acre.
- The N treatments were broadcast surface-applied (except injected UAN) at a rate equivalent to 150 lbs N/acre the day of planting.
- Soil and plant tissue samples were taken periodically in the main plots and ^{15}N microplots during the growing season and following harvest—these samples are being processed and analyzed with the 2009 samples and we expect analysis to be completed in early 2011.
- Once soil and tissue samples have been analyzed, full-season fertilizer use efficiency, amount of plant N derived from fertilizer, amount of fertilizer N removed from the field with the grain, and ^{15}N remaining in the soil will be determined to construct a fertilizer N balance.

2009 and 2010 PRELIMINARY RESULTS:

- Yields of all treatments, except UAN, were significantly less in 2010 than in 2009 (Fig. 1).
- The highest yielding treatment in 2009 (PCU) was the second highest yielding treatment in 2010. UAN yields were similar in 2009 to PCU but greater in 2010 than PCU.
- In 2010, like in 2009, there were no differences in yield between Agrotain-treated urea,

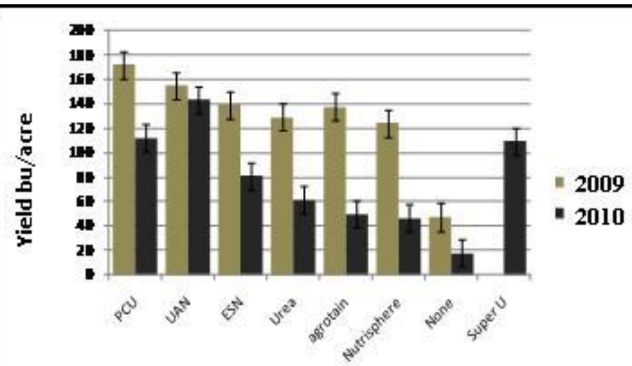

Figure 1. 2009 and 2010 corn yield from plots receiving different urea-N management products.

untreated urea, and Nutrisphere-treated urea. Yields from these products were less than that from ESN, UAN, and PCU.

- SuperU, which was evaluated for the first time in 2010, resulted in yields that were similar to PCU and greater than all other treatments, except UAN.
- Yield differences corresponded to differences in kernel weight in 2009 (Fig. 2) with PCU applications resulting in the highest kernel weight of 36.3 grams/100 kernels and the zero N fertilizer resulting in the lowest kernel weight of 27.1 grams/100 kernels. In 2010, yield differences did not correspond to kernel weight, but the highest kernel weights did correspond to the highest yielding treatments, UAN and PCU (29.2 and 28.5 grams/100 kernels, respectively).

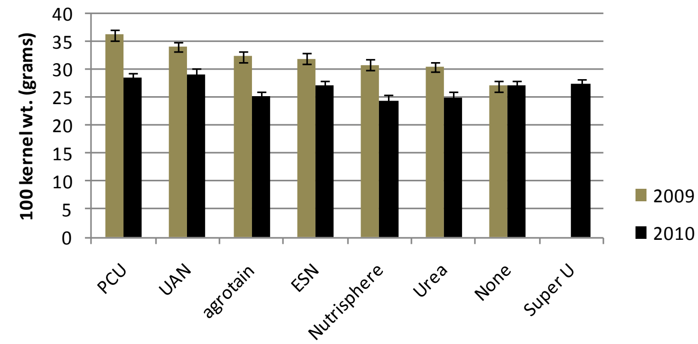

Figure 2. 2009 and 2010 kernel weights for corn receiving different urea management products.

- In 2009, there were no statistically significant differences in kernel weight between Agrotain- treated urea, ESN, Nutrisphere-treated urea, and untreated urea. These treatmtents resulted in 100 kernel weights of 32.4, 31.9, 30.8, and 30.5 grams, respectively. In 2010, there were no differences in kernel weight between Agrotain-treated urea, untreated urea, and Nutrisphere-treated urea (25.3, 25.1, and 24.5 grams/100 kernels, respectively), but these products resulted in lower kernel weights than no urea or ESN (27.1 and 27.2 grams/100 kernels, respectively) which were similar to each other.
- In 2009, rainfall events soon after application likely incorporated much of the surface applied urea. In 2010, urea applied at planting remained at the soil surface for 8 days before rainfall could incorporate the fertilizer on June 2. This may partly explain the poor yields in 2010 from the urea and urea products.

OBJECTIVES FOR YEAR 3 (2011):

The third field season of this 3-year experiment will be repeated in 2011 using a similar planting and experimental layout as in 2009 and 2010. Following are the planting and experimental layout for 2011.

Cultural Practices: This study will be conducted as the third season of a 3-yr field study at the Bradford Research and Extension Center in Columbia, MO. The experiment was initiated in spring 2009. Fertilization of P and K will be conducted according to soil test results and N fertilization will be uniform across all main treatments as surface-applied urea at planting. N will be applied at rates equivalent to 150 lbs N/acre. This rate should allow for differences in N release, uptake, and loss to affect yield. Higher N rates may not allow us to delineate treatment differences due to N source. Microplots will be embedded in the larger plots and standard urea will be substituted with ^{15}N- enriched urea.

Design: Each treatment will be replicated four times in a randomized complete block design. Each main treatment will be applied to 30'x 80' plots to allow for destructive plant sampling throughout the study. From these plots, tissue N analysis, final yield, and soil N samples will be taken. Within the 30'x80' plot of treatments 2, 3, and 4 outlined above, a microplot will be delineated for fertilizer tracing. Microplots are standard research units and are necessary due to costs of ^{15}N-enriched fertilizer. We propose to apply ^{15}N-enriched urea (1.0 atom% excess) to 4-m^2 microplots within the main treatment plots. Thus, we will be able to determine corn fertilizer uptake efficiency, residual soil fertilizer N, and N loss.

Measurements: Corn yield will be determined for every treatment in 30'x80'plots. Crop growth and development will be measured 5 times over the course of each growing season and plant samples will be collected at selected time points for determination of tissue N levels. Plants will be sampled in all treatments in the main plots (not labeled with ^{15}N) as well as the microplots where applicable. Samples collected at harvest will allow us to determine full season fertilizer use efficiency, amount of plant N derived from fertilizer, and amount of fertilizer N removed from the field with the grain. Soil samples will be taken to determine ^{15}N remaining in the soil, and construct a fertilizer N balance.

PROPOSED BUDGET FOR YEAR 3 (2011)

Category	**Year 3**
Personnel	
Research Associate (40%)	$14,710
Benefits	$4,859
Analytical cost (soil and plant N and ^{15}N analysis)	$3,000
^{15}N fertilizer purchase, formulation, and field supplies	$4,500
Travel	$1,000
Total	**$28,069**

Enhanced Efficiency Liquid N Applications for Corn

Kelly Nelson, John Shetley, Peter Motavalli, and Bruce Burdick

Investigators:
Kelly Nelson, Div. of Plant Sciences, Univ. of Missouri, Novelty, MO; John Shetley, Dept. of Soil, Environ., and Atmos. Sci., Univ. of Missouri, Columbia, MO; Peter Motavalli, Dept. of Soil, Environ., and Atmos. Sci., Univ. of Missouri, Columbia, MO; and Bruce Burdick, Div. of Plant Sciences, Univ. of Missouri, Albany, MO.

Objectives and Relevance:

Corn production in Missouri has averaged approximately 2.9 million acres since 2004 with a value of $1.2 billion in total production (NASS, 2009). High yield corn production systems have integrated fungicide applications to maximize photosynthetic efficiency of the plant to meet the growing food, fuel, and fiber demands. Plant 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., 2002). Research has shown that pyraclostrobin (Headline®) 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 nitrogen fertilizer at the time of application to corn. 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.

Chlorophyll meters have been used to diagnose N deficiency and provide recommendations for N rates and yield responses (Scharf et al., 2006). Relative chlorophyll meter readings were the best predictor of yield response to N applications and required a high N reference, but absolute chlorophyll meter values were good predictors of grain yield from V10-R1. Farmers planning a fungicide application could utilize a chlorophyll meter as a decision aid to determine if an enhanced efficiency liquid N fertilizer should be combined with the fungicide.

In 2008, 2009, and 2010, N loss limited grain production in several production fields in upstate Missouri. Research in 2004 and 2005 evaluated rescue N applications for corn (Nelson et al., 2011). Late applications were beneficial for restoring yield; however, liquid N applications reduced yield when broadcast applied at 150 lbs N/acre from 2 to 4 ft tall corn. Over the past two years, commercially available liquid fertilizers were evaluated for corn grain yield response when applied at VT in the presence and absence of Headline (Nelson et al., 2009). Products were identified that consistently increased corn grain yield. Nitamin (30-0-0), slowly available N from triazone and methylene urea, at 1 gallon/acre increased yields 28 bu/acre at four of the six site years. When Nitamin was combined with pyraclostrobin at 6 oz/a, there were inconsistent yield responses. Other research evaluated rates of Nitamin up to 4 gallon/acre with and without Headline in 2008 and 2009 (Figure 1) (Nelson and Meinhardt, 2009). Combinations with Headline at 6 oz/acre were similar to this research; however, a reduced rate of Headline (3 oz/acre) with Nitamin at 1 gal/acre synergistically increased yield 26 bu/acre particularly when Headline was added to the spray mixture first followed by Nitamin. A rate response to Nitamin alone increased yield 2 bu/lb of applied N. Research is needed to confirm the effect of reduced rates of Nitamin and Headline as well as the efficiency of this N source for late applications in corn. If grain yield response and recommended rates could be related to SPAD leaf readings at the time of application, this would be a great tool to help farmers and custom applicators make informed decisions on what products to recommend at a VT application timing.

The objectives of this research were to:

1. Validate the effect of mixing order of an enhanced efficiency liquid N rates with a preventative fungicide, and
2. Provide foliar liquid fertilizer recommendations based on SPAD readings at VT.

Procedures:

Field research was established at the Greenley Research Center near Novelty and Hundley-Whaley Center near Albany. Corn followed soybean and conventional tillage was used at both sites. Plots were 10 by 50 ft and arranged in a randomized complete block design with six replications at each site. This study was arranged as a three-factor factorial including soil applied ammonium nitrate at three rates (75, 150, and 300 lbs N/a), three enhanced efficiency liquid N rates (Nitamin at 0, 1, and 3 gal/acre), and four pyraclostrobin (Headline) treatments (non-treated control, Headline applied at 3 oz/acre plus nonionic surfactant added first or following the addition of Nitamin, and Headline at 6 oz/a added first followed by nonionic surfactant and Nitamin). Foliar treatments were applied on 12 July and 13 July at Novelty and Albany, respectively, when corn was at the VT stage of development (Ritchie et al., 1993). Foliar fertilizer and fungicide treatments were applied with a CO_2 propelled hand boom at 3 gal/acre. Field and management information is reported in Table 1. Supplemental irrigation was scheduled using the Woodruff chart to ensure optimal growing conditions.

Corn injury from 0 (no visual crop injury) to 100% (complete crop death) was evaluated 7 and 14 days after treatment (DAT) based on the combined visual effects of foliar treatments on necrosis, chlorosis, and stunting. The severity of common rust (*Puccinia sorghi*), northern corn leaf blight (*Exserohilum turcicum*), and grey leaf spot (*Cercospora zeae-maydis*) was rated on a scale of 0 (no disease) to 100% (complete infestation) 0, 28, and 42 DAT. A Minolta chlorophyll meter (SPAD-502, Konica Minolta, Hong Kong) was used determine absolute ear leaf greenness differences among treatments at the time of application and 28 DAT in order to help determine if an enhanced efficiency liquid N fertilizer would be beneficial in the presence or absence of a fungicide treatment, and determine if an enhanced efficiency fertilizer rate could be recommended based on leaf greenness. The center two rows were harvested for yield and converted to 15% moisture prior to analysis. All data were subjected to ANOVA and means separated using Fisher's protected LSD at $P = 0.05$ or 0.1. Data were combined over factors and locations when appropriate as indicated by the analysis of variance (data not presented).

Results:

Corn plant population at harvest was approximately 27,000/acre at both locations (data not presented). Rainfall at both locations was extensive in 2010. Ammonium nitrate was soil applied approximately 1 month after planting to increase efficiency of this factor (Table 1). However, conditions throughout the season were favorable for extensive N loss. The severity of disease was less than 1% at VT. Chlorophyll meter readings indicated differences among soil applied N rates as expected at the time of the foliar VT applications (Table 2, Figure 1). The Albany site was greener than Novelty indicating less N loss at Albany (Table 2). We expected the 300 lb N/acre rate would be in the low response range to additional N (Scharf et al., 2006), and N would not have been limiting. Based upon previous research from V10 to R1 (Scharf et al., 2006), absolute chlorophyll meter readings at VT indicated that an addition of 130 to 180 lbs N/acre, 100 to 130 lbs N/acre, and

45 to 90 lbs N/acre was recommended for the soil applied rates of 75 lbs N/acre, 150 lbs N/acre, and 300 lbs N/acre, respectively. The Nitamin rates evaluated in this research were applied at 3.1 and 9.3 lbs N/acre for the 1 and 3 gal/acre rates, respectively.

Absolute chlorophyll meter readings at VT generally remain similar or decrease slightly over time in the absence of additional N (Scharf et al., 2006). Chlorophyll meter values 28 DAT indicated an increase in greenness with Nitamin at 3 gal/acre compared to the readings 0 DAT in some instances, while limited differences between the 0 and 28 DAT readings were observed when Nitamin was applied at 0 or 1 gal/acre (Figure 1). Based on the chlorophyll meter values, we expected yield differences for the 3 gal/acre rate of Nitamin; however, this was not the case (Figure 2).

The low rates of soil applied N (75 and 150 lbs N/acre) were not responsive to Nitamin at 1 or 3 gal/acre in 2010. It appears that corn with chlorophyll meter readings less than 45 (Figure 1) should not use a 1 to 3 gal/acre rate of Nitamin or fungicide treatment because N was yield limiting and an insufficient level of N was supplied to the crop. This could explain why some fungicide and foliar fertilizer research was non-responsive under some conditions. Nitamin at 1 gal/acre increased grain yield 11 bu/acre following the 300 lb/acre soil applied N treatment when data were averaged over Headline treatments. Further analysis of soil applied N at 300 lbs/acre indicated Headline at 6 oz/acre plus Nitamin at 1 gal/acre increased yield 21 bu/acre compared to Headline at 3 oz/acre plus Nitamin at 1 gal/acre (Figure 3). This research indicated no significant effect of mixing order on corn response when Nitamin was applied at 1 gal/acre and Headline at 3 oz/acre. In previous research (Nelson et al., 2009), there was a lower overall severity of disease and grain yield potential was higher when a synergistic increase in grain yield was observed with Headline at 3 oz/acre plus Nitamin at 1 gal/acre, which indicated a possible physiological response to this combination.

Rescue N applications of liquid UAN that were broadcast applied at 150 lbs N/acre caused extensive injury to corn reduced yield and should not be recommended (Nelson et al., 2011). However, crop injury due to Nitamin at 1 or 3 gal/acre was 1% or less 7 and 14 DAT (data not presented). Therefore, crop response differences in 2010 were probably related to the higher severity of disease observed during this year and N fertility. Soil and foliar applied N affected the severity of foliar disease. The severity of grey leaf spot and northern corn leaf blight increased as soil applied N increased at Novelty, but no differences were observed at Albany (Table 3). An interaction between soil applied N rates and Nitamin rates at Albany and Novelty indicated a slight increase in the severity of common rust at Novelty as the soil and foliar N rates increased. However, the severity of common rust was greater at low soil applied N rates and a high rate (3 gal/a) of Nitamin. Similarly, the severity of grey leaf spot and northern corn leaf blight increased as the Nitamin rate increased at Novelty and Albany (Table 4). These differences were probably due to improved growth and increased greenness with Nitamin at 3 gal/acre (Figure 1).

Headline at 6 oz/acre reduced the severity of grey leaf spot at Novelty, while no differences among fungicide treatments were observed for grey leaf spot at Albany or northern corn leaf blight at Novelty or Albany (Table 5). An interaction between Headline treatments, Nitamin rates, and locations was observed for the severity of common rust (Table 6). In general, the severity of common rust was greater as the Nitamin rate increased. Headline at 6 oz/acre reduced the severity of common rust at the 3 gal/acre rate of Nitamin compared to the non-treated control.

In summary, Nitamin at 1 gal/acre increased grain yields 11 bu/acre when chlorophyll meter readings at VT were greater than 45. Headline at 6 oz/acre plus Nitamin at 1 gal/acre increased grain yields 21 bu/acre compared to Headline at 3 oz/acre plus Nitamin, but this treatment was similar to Nitamin applied alone. Decisions to apply Nitamin alone, Headline alone, or a combination of Headline and Nitamin may need to be based on the yield potential of the corn crop using an absolute chlorophyll meter reading near VT which can help identify sites that are non-responsive and aid in better understanding sites that are responsive to foliar fertilizer and/or fungicide applications. In 2010, the severity of disease was affected by N fertility and was affected by the rate of a foliar fertilizer especially in a year with a high risk of foliar disease. This research will be repeated in 2011.

Timetable:

Feb., 2011:	Assemble products for treatments
April, 2011:	Plant research trial and apply response treatments at both locations
July, 2011:	Apply foliar fertilizer and fungicide treatments, SPAD readings, rate severity of disease.
Sept.-Dec., 2011:	Harvest experiments, analyze results, and submit final report.

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Table 1. Field and management information at Novelty and Albany in 2010.

Management information	Novelty	Albany
Previous crop	Soybean	Soybean
Hybrid or cultivar	DK 63-42 VT3	DK 63-42 VT3
Planting date	13 Apr.	26 Apr.
Seeding rate (seeds/acre)	32,000	29,500
Harvest date	30 Sept.	19 Oct.
Maintenance fertilizer	13 Apr., MAP 32-160-300 (N-P-K)	15 Apr., 18-46-80 (N-P-K)
Ammonium nitrate	7 May, Between-row at 75, 150, or 300 lbs N/acre	26 May, Between-row at 75, 150, or 300 lbs N/acre
Weed management		
Burndown	NA	NA
Preemergence	15 Apr., Atrazine (2 qt/acre) + Outlook (21 oz/acre)	27 Apr., Lumax (3.2 qt/acre)
Postemergence	22 June, Roundup PowerMAX (30 oz/acre) + DAS (17 lbs/100 gal)	
Insect management	NA	NA
Disease management	Pyraclostrobin +/- Nitamin	Pyraclostrobin +/- Nitamin
Date & Time	12 July, 1700 to 2100 h	13 July, 1100 to 1600 h
Relative humidity (%)	74	60
Wind speed (MPH, direction)	1-3, E	3-4, S
Height (inches)	72-96	84-108
Leaf moisture	Dry	Dry

†Abbreviations: DAS, diammonium sulfate; MAP, monoammonium phosphate; NA, None applied.

Table 2. Chlorophyll meter readings at Novelty and Albany, and severity of disease for preplant N rates at VT. Data were combined over foliar fertilizer and fungicide treatments.

	Chlorophyll meter		Severity of disease†		
Preplant N rates	Novelty	Albany	Grey leaf spot	Common rust	Northern corn leaf blight
lbs N/acre	--- SPAD units ---		----------------------------- % -----------------------------		
75	32.5	36.6	< 1	0	< 1
150	37.3	44.2	< 1	0	< 1
300	43.2	50.3	< 1	0	< 1
LSD (P = 0.01)	1.4		NS	NS	NS

†Common rust (*Puccinia sorghi*); grey leaf spot (*Cercospora zeae-maydis*); northern corn leaf blight (*Exserohilum turcicum*).

Table 3. Severity of grey leaf spot and Northern corn leaf blight 42 d after treatment as affected by preplant N and location, and severity of common rust as affected by preplant N, location, and Nitamin rate.

	Grey leaf spot		Northern corn leaf blight		Common rust					
					Novelty			Albany		
Preplant N	Novelty	Albany	Novelty	Albany	0 gal/a	1 gal/a	3 gal/a	0 gal/a	1 gal/a	3 gal/a
(lbs N/acre)										
75	3	1	0	1	1	1	1	2	3	7
150	5	1	1	1	1	1	2	2	2	4
300	7	1	1	1	2	2	2	2	2	2
LSD (P = 0.1)	----- 1 -----		---------- 1 ----------		------------------------ 1 ------------------------					

Table 4. Severity of grey leaf spot and northern corn leaf blight 42 d after treatment as affected by Nitamin application rate. Data were averaged over location, fungicide treatment, and soil applied N rates.

Nitamin rate	Grey leaf spot	Northern corn leaf blight
(gal/acre)	---------------------------- Severity of disease (%)	----------------------------
0	2.7	0.6
1	2.6	0.8
3	3.3	1.1
LSD (*P* = 0.1)	0.3	0.2

Table 5. Effect of pyraclostrobin (Headline) treatment and location on the severity of grey leaf spot and northern corn leaf blight.

	Grey leaf spot		Northern corn leaf blight	
Fungicide treatment	Novelty	Albany	Novelty	Albany
	------------- Severity of disease (%) -------------			
Non-treated	6	1	1	1
Headline at 3 oz/acre + NIS fb Nitamin	5	1	1	1
Nitamin fb Headline at 3 oz/a + NIS	5	1	1	1
Headline at 6 oz/acre + NIS fb Nitamin	4	1	1	1
LSD (*P* = 0.1)	----- 1 -----		--------- NS --------	

†Mixing order for fungicide treatments.
‡Abbreviations: fb, followed by; NIS, non-ionic surfactant.

Table 6. Severity of common rust at Novelty and Albany as affected by Nitamin rate and pyraclostrobin (Headline) treatment.

	Novelty			Albany		
Fungicide treatment	0 gal/acre	1 gal/acre	3 gal/acre	0 gal/acre	1 gal/acre	3 gal/acre
	----------------------------------- % --------------------------------------					
Non-treated	2	2	2	3	3	7
Headline at 3 oz/acre + NIS fb Nitamin	1	1	2	2	2	4
Nitamin fb Headline at 3 oz/a + NIS	1	1	2	2	2	4
Headline at 6 oz/acre + NIS fb Nitamin	1	1	2	2	2	3
LSD (*P* = 0.1)	----------------------------------- 1 --------------------------------------					

†Mixing order for fungicide treatments.
‡Abbreviations: fb, followed by; NIS, non-ionic surfactant.

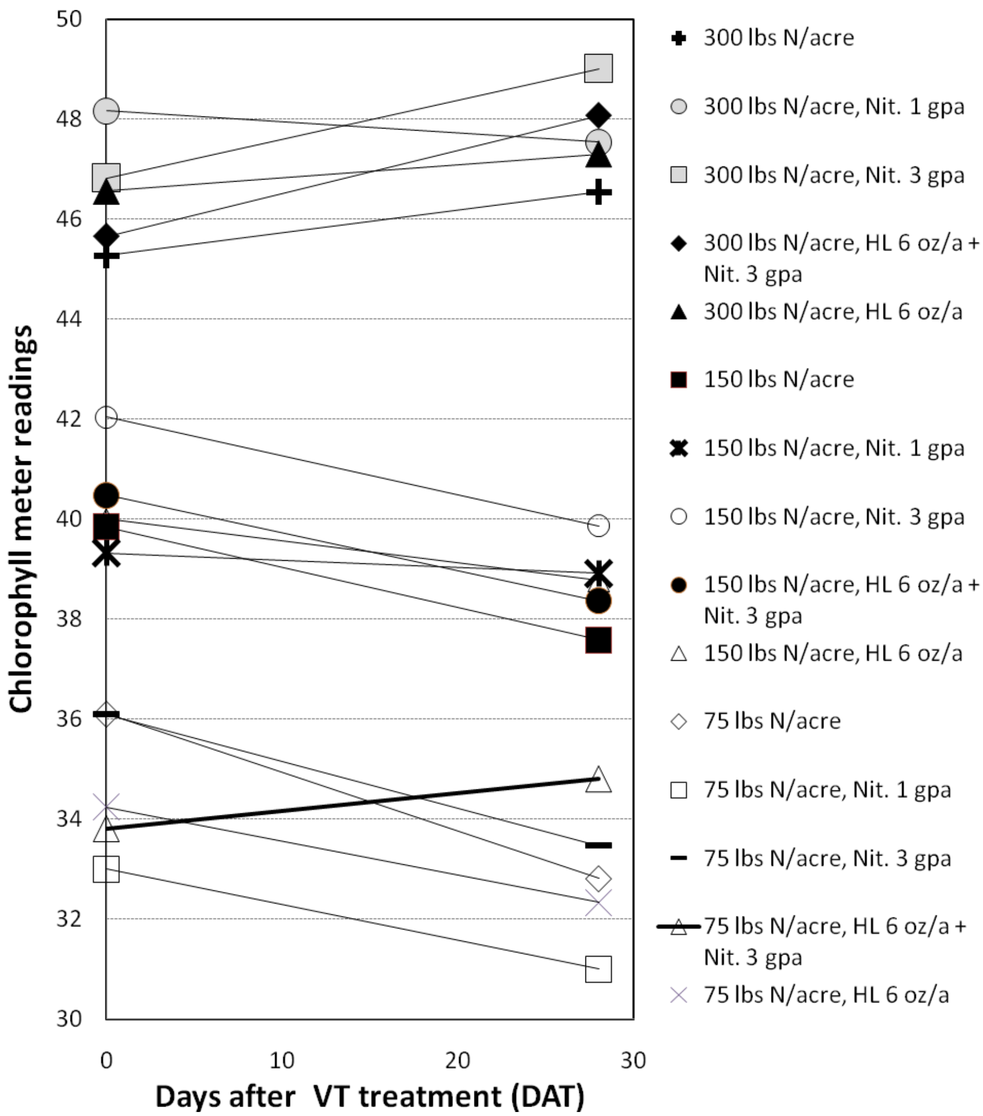

Figure 1. Chlorophyll meter readings at the time of application (VT) and 28 days after treatment (DAT) for selected soil applied N treatments (75, 150, or 300 lbs N/acre), Nitamin (Nit.) rates (0, 1 or 3 gallons per acre = gpa), and pyraclostrobin (Headline = HL) at 6 oz/acre. Data were combined over Novelty and Albany locations.

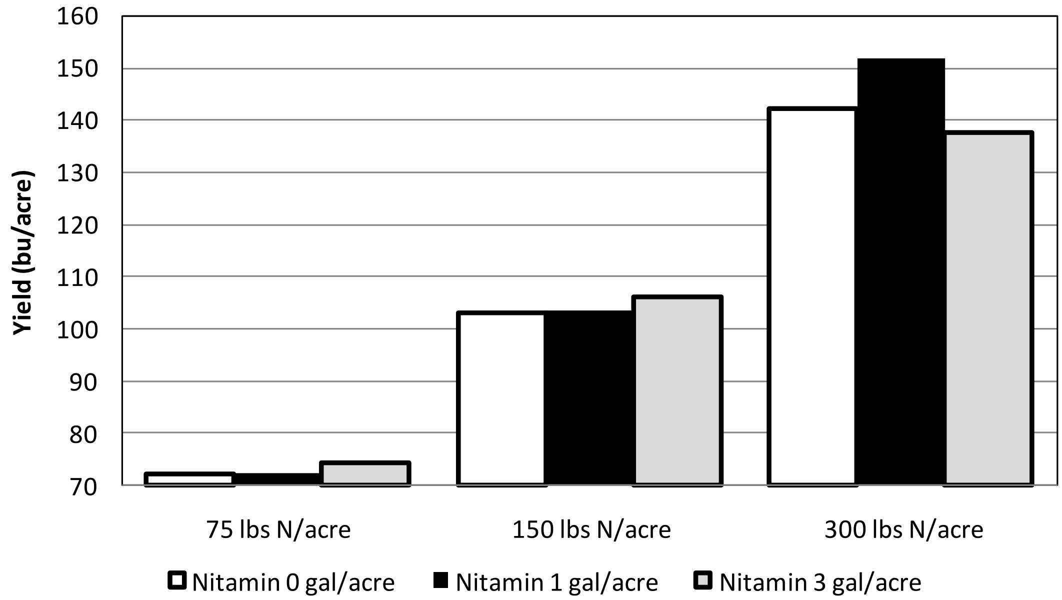

Figure 2. Corn grain yield as affected by soil applied N (75, 150, and 300 lbs N/acre) and foliar Nitamin rate (0, 1, and 3 gal/acre) at VT. LSD (P = 0.05) was 10 bu/acre. Data were combined over locations and pyraclostrobin treatments.

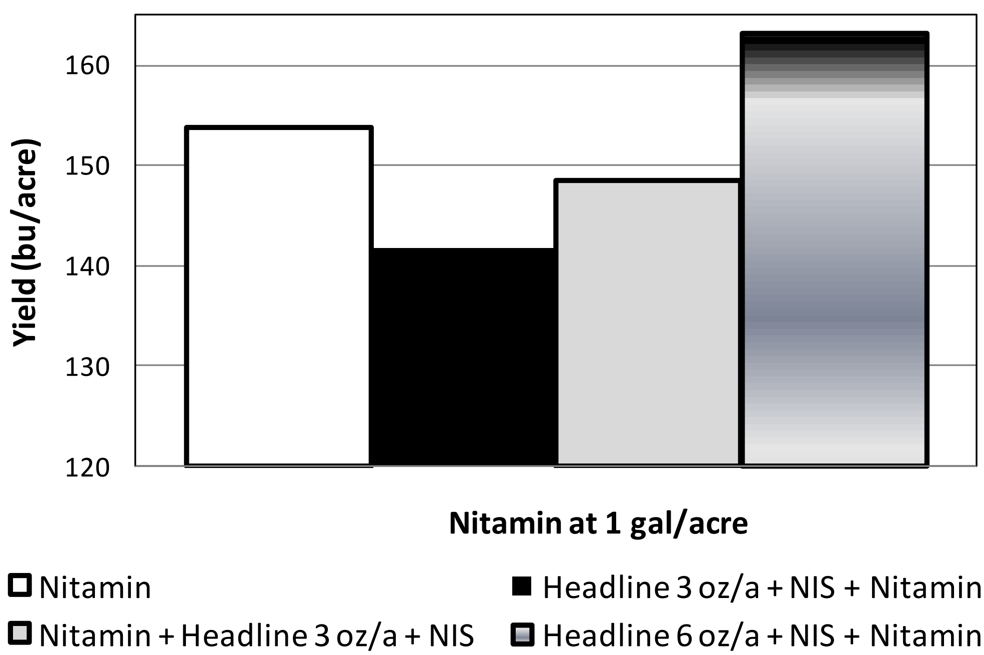

Figure 3. Corn grain yield as affected by Nitamin at 1 gal/acre applied alone and with pyraclostrobin (Headline) fungicide rates. LSD (P = 0.1) was 15 bu/acre. The order listed in the legend was the spray mixing order.

Budget:

CATEGORIES	Year 2011	Total*
A. Salaries Technical assistance or graduate research assistant (50%)	$14,382	$28,205
B. Fringe Benefits Fringe for graduate student	$1,995	$3,985
TOTAL SALARIES AND FRINGE BENEFITS	$16,377	$32,190
C. Travel Travel to field site To present research findings at National Meetings	 $500 $800	 $1000 $800
TOTAL TRAVEL COSTS	$1300	$1800
D. Equipment	$0	$0
TOTAL EQUIPMENT use and maintenance COSTS	$1200	$2400
E. Other Direct Costs Soil analysis Field supplies Publication cost Off-site PI	 $200 $500 $1,000 $5,000	 $400 $1000 $1000 $10,000
TOTAL OTHER DIRECT COSTS	$6,700	$12,400
TOTAL REQUEST	**$25,577**	**$48,790**

*Included the 2010 (Year 1) budget.

Budget narrative:
Salaries and fringe benefit funds are requested for partial support of a research technical support and/or graduate research assistant.

Presentations, publications, and documentation will help defray cost of publication and documentation of results and conclusions as well as assist travel and board for presentation of results.

Equipment use and maintenance will help defray machinery use and maintenance costs associated with field research.

Other Direct Costs: Covers cost of analysis, sample containers, fertilizer, seed, plot preparation, planting, weed control harvesting, flags, and other field supplies and operations.

Sensor-based variable rate N: Long-term performance in corn and cotton

Peter Scharf, Andrea Jones, David Dunn, Vicky Hubbard, Larry Mueller, and David Kleinsorge

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Objective:

The objective of this project is to evaluate long-term performance of sensor-based variable N rate recommendations for corn and cotton. Sensor-based N will be compared with typical producer N management and with other N rate decision systems.

Accomplishments for 2010:

- Two small-plot corn experiments were conducted as planned at Bradford Farm near Columbia.
- One small-plot cotton experiment was conducted as planned at the Delta Center near Portageville.

Sensor-based variable rate N: Long-term performance in corn

Experiment 1: Long-term impact of nitrogen rate recommendation systems

- This experiment uses the following systems to evaluate corn nitrogen need.

  Pre-Plant Systems
  1. Fixed Rate
     A. 0 lbs.N/acre
     B. 100 lbs.N/acre
     C. 140 lbs.N/acre
     D. 180 lbs.N/acre
  2. Missouri Pre-plant Soil N Test

  In-Season Systems
  3. Sensor Based
     A. Crop Circle Sensor (Variable Rate)
     B. Chlorophyll meter
  4. Iowa Side-dress Soil Test

- 2010 is the fourth year of this study. It has been previously funded by the Fertilizer & Lime grants program as part of the project 'Addressing Nitrogen Controversies'. Reports on years 1 to 3 are available under this title.
- Part of the reason for focusing this project on long-term performance of sensor-based N management is that it was the most profitable system (of eight tested) after three years of study in corn.

- Continuous no-till corn is grown in this study, and N timing and rate decision systems remain the same on each plot every year. This tests the cumulative effect of using these different N rate and timing systems.
- 2010 was, like 2009 and 2008, a very wet year, especially April and May.
- Pre-plant nitrogen treatments were applied on April 29 as surface broadcast ammonium nitrate. Planting was delayed until May 28 due to wet weather. Side-dress treatments were applied July 2 when corn was in the V7 stage as surface in-row ammonium nitrate.
- This experiment received 4.8” of rainfall between pre-plant treatments and planting and 3.3” more rainfall was received from planting to the time of side-dress. The pre-plant nitrogen was exposed to total of 8.1” more of rainfall than the side-dress nitrogen.
- The wet weather apparently caused loss of much of the pre-plant nitrogen. By early August, all of the treatments with pre-plant nitrogen appeared severely nitrogen-deficient over the entire plant (see Fig.1). We observed the classic V-shaped nitrogen deficiency burn up the midrib on all plants in these treatments, usually up to the leaf below the ear.

- All side-dress nitrogen treatments had much better leaf color (see Fig. 2). In early August these treatments were green right down to their lowest leaves.

Table 1.
Nitrogen rates recommended and corn yields produced by eight different recommendation systems in 2010 and 2007-2010.

Nitrogen Recommendation System	Nitrogen Application Timing[1]	2010 Nitrogen Rates lbs./ac[2]	2010 Yields bu./ac[3]	2007-2010 Ave. rate lbs N/ac	2007-2010 Ave. yield bu/ac	Gross (Yield-N) $/ac[4]
Chlorophyll meter	V7	197	130	171	146	481
Crop Circle sensor	V7	[220,182,168 219,202,203] avg. rate = 199	122	149	142	479
Side-dress soil test	V7	147	105	123	131	450
High	Pre-plant	180	46	180	98	284
Yield goal/ MRTN	Pre-plant	140	39	140	86	260
Pre-plant soil test	Pre-plant	124	38	134	84	256
Low	Pre-plant	100	27	100	76	244
Check	Pre-plant	0	8	0	47	188

[1] Growth stage V7 is about knee high corn
[2] 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 automatically while fertilizing a field, and we felt that this ability would be most accurately reflected by diagnosing N rate for each plot Separately.
[3] 2010 yields are different from each other (95% confidence) if they are more than 19 bushels apart
[4] Gross calculated using $4/bu. corn price, $0.60/lb. N cost as estimates of average corn Prices and N cost during these years.

- **In 2010, the N rate systems based on corn color again gave the highest yields (Table 1). This had also been true for the combined 2007-2009 results.**
  - Average yield for these two systems was 88 bushels more than the average of the four preplant N treatments, and 19 bushels more than sidedress N rate based on a soil nitrate test.
  - The Crop Circle sensor is designed to support variable-rate N applications based on crop color measured during fertilizer application.
  - The Minolta chlorophyll meter is hand-held and can diagnose N rate for whole fields or zones before fertilizer application begins.

- **The color-based N rate recommendation systems are also the most profitable systems after four years of testing (Table 1).**
  - These systems gave profits $195/acre/year above the profits given by the most profitable pre-plant N management system.
    - ✓ This is due to the poor yields with pre-plant N in 2008, 2009 and 2010. These years all had excessive spring rainfall.
  - The color-based systems also out-performed sidedress N management based on a sidedress soil nitrate test (Iowa State University interpretations) by about $30/acre/year.
    - ✓ This is probably due to the higher N rates recommended by the color-based systems, which appeared to more successfully compensate for high losses of soil N.
    - ✓ Profit was higher with color-based management than soil-nitrate-based management in 3 out of 4 years. All sidedress treatments were within a few dollars of one another in 2009.
  - The chlorophyll meter system recommended an average of 22 lb N/acre more than the reflectance sensor system, and yielded an average of 4 bu/acre higher, resulting in virtually identical estimates of profitability.

- **Crop sensors appear to be a feasible long-term nitrogen management option for corn based on results to date.**
  - Yields have been maintained at higher levels than all other N rate and timing systems tested except the chlorophyll meter-based system.
    - ✓ This has been accomplished while applying only 149 lb N/acre
      - This rate is just slightly above the MRTN (Maximum Return to Nitrogen) N rate of 140 lb N/acre for Missouri.
      - Environmentally this is preferable to making the same profit while applying 22 extra lb N/acre, as happened with chlorophyll meter-based N rates.

- **Nitrogen timing had a large effect on yield in this experiment.**
  - Plots receiving pre-plant N had an average yield of 38 bu/acre (Table 1).
  - Plots receiving sidedress N had an average yield of 119 bu/acre, an advantage of 81 bu/acre.
  - This large yield difference suggests that a large proportion of N applied pre-plant was lost.
  - All yields were surprisingly low given the good moisture availability throughout the season. Some anthracnose and diplodia were observed, but not enough to expect a major yield impact. No weed or insect problems were observed. One possibility is that the corn was never able to fully recover from the effects of the extended waterlogging early in the season.
    - Nitrogen loss even with sidedress N application could potentially explain the limited yields, but no deficiency symptoms were visible in mid-August to support this idea (Figure 2).
  - This is the third year in a row with an unusually wet spring and a large yield advantage to sidedress N timing.
  - This experiment is continuous no-till corn. High levels of corn residue on the surface lead to wetter soil conditions than in other rotations and tillage systems. In wet years, this system will be more vulnerable to N loss than other systems.
  - Part of the yield advantage to sidedress N timing is due to the fairly high N rates recommended by all three sidedress recommendation systems in this wet year. Even so, the lowest sidedress rate (147 lb N/acre) out-yielded the highest pre-plant N rate (180 lb N/acre) by 59 bushels.
  - Nitrogen timing appeared to influence the number of kernels on an ear. We did not collect data on kernel number, but many of the ears in plots receiving pre-plant N could be seen to have low kernel number. This could have been due to poor pollination or to kernel abortion.
  - The large yield advantage to sidedress N timing is in agreement with the appearance of the plants as shown in the photos (Figures 1 and 2).

- The check treatment that received no N fertilizer yielded only 8 bu/acre. This shows how severely depleted the soil N supply was, both by N loss due to wet weather and by four years of removal without replenishment by fertilizer.

<u>Experiment 2: Effect of pre-plant nitrogen on sensor-based N rate performance</u>

- One concern that arose with sensor-based N recommendations and the design of Experiment 1 was the potential for early-season N deficiency.
  - Sidedress treatments in Experiment 1 receive no pre-plant N.
  - N stress experienced before sidedress could potentially reduce yield.
  - Various members of the agricultural community have expressed concern about whether sensor-based sidedressing with no N applied pre-plant is a viable system.

- Experiment 2 is designed to express that concern.
  - 2010 is the first year for Experiment 2.
  - The key treatment is 50 lb N/ac applied pre-plant, followed by sidedress N at rates diagnosed by the Crop Circle sensor.
    - ✓ Results from this treatment can be compared to pre-plant N management (140 and 180 lb N rates) and sensor-based sidedress with no N pre-plant to evaluate its relative performance.
    - ✓ Any N stress experienced with the sidedress-only treatments should be avoided.
  - Experiment 2 is designed to complement experiment 1 and is therefore as similar as possible.
    - ✓ It is right next to Experiment 1, so soils and weather are very similar.
      - However, in this first year of the study, previous crop is sweet corn instead of corn. Residue cover was lower than in experiment 1 (Table 3).
    - ✓ Same seed, same herbicide, same planting date, same application dates.
    - ✓ Three of the four treatments are the same as in Experiment 1.

- All corn in this experiment was taller and greener than the corn in Experiment 1 early in the season.
  - This is likely due to a previous crop of sweet corn, resulting in lower residue cover, warmer soil temperatures, and greater nitrogen availability.

- Experiment 2 corn did show the same growing pattern as experiment 1:
  - Pre-plant N treatments were taller and greener than sidedress treatments early in the season
  - Sidedress treatments were greener than preplant treatments later in the season.
  - However, the visual N stress symptoms in preplant N treatments of experiment 2 were far less severe than in experiment 1.
  - This again ties to greater soil N availability (compared to Experiment 1) resulting from a previous crop of sweet corn.
  - Experiment 2 will, like Experiment 1, be cropped continuously to corn from now on.

- **Early-season N stress did not appear to be a problem when all N was sidedressed on knee-high corn at rates recommended by crop sensors.**
  - Yield was 4 bushels higher with sensor-based sidedressing when 50 lb N/acre was applied preplant than when none was applied (Table 2).
  - Statistically, there is only a 24% likelihood that this yield difference is real. There is a 76% chance that it is due to random experimental error.
  - Even if it is real, it barely covers the cost of the higher total N rate applied (an extra 23 lb N/acre).
  - We will continue to evaluate whether using a modest pre-plant N rate enhances the performance of sensor-based N management.

Table 2. Nitrogen rates and yields for four N rate/timing systems in Experiment 2 in corn.

Nitrogen Recommendation System	Nitrogen Application Timing[1]	Nitrogen Rates[2] lbs N/ac	Yield bu/ac	Gross (Yield-N)[3] $/ac
50 lbs N/ac preplant + Crop Circle sensor	Pre-plant + V8	50 pre + [60,74,60 157,160,96] avg. rate = 151	139	$465
Crop Circle sensor	V8	[135,113,108 84,163,167] avg. rate = 128	135	$463
High	Pre-plant	180	107	$320
Yield goal/ MRTN	Pre-plant	140	104	$332

[1] Stage V8 is usually knee- to thigh-high corn
[2] 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 automatically while fertilizing a field, and we felt that this ability would be most accurately reflected by diagnosing N rate for each plot separately.
[3] Prices used were $4/bushel and $0.60/lb N

- As in Experiment 1, sensor-based sidedress N treatments out-yielded pre-plant treatments by a considerable margin.
  - In Experiment 2, this margin was about 30 bu/ac (Table 2).
  - In Experiment 1, it was about 80 bu/ac.
  - This agrees with the much milder N deficiency symptoms seen in the pre-plant treatments in Experiment 2.
    - ✓ Three wet years with continuous corn have depleted the N soil reserves in Experiment 1.
    - ✓ A previous crop of sweet corn in this first year of Experiment 2 also contributed lower cover, higher temperatures, and higher soil N release. This area had been in fertilized sweet corn or fallow during the last three years.

- Experiment 2 also had greater variability in soil N supply as indicated by the wider range of N rates recommended by the sensors.
  - The highest and lowest N rates based on sensors were only 51 lb N/acre apart in Experiment 1.
  - In experiment 2, the range of N rates was 100 lb N/acre in one sensor treatment, and 83 lb N/acre in the other.
  - This variability is caused in part by landscape position. This plot area is a summit position and tends to drain poorly and has areas where water pools, affecting N availability. (Fig. 3)

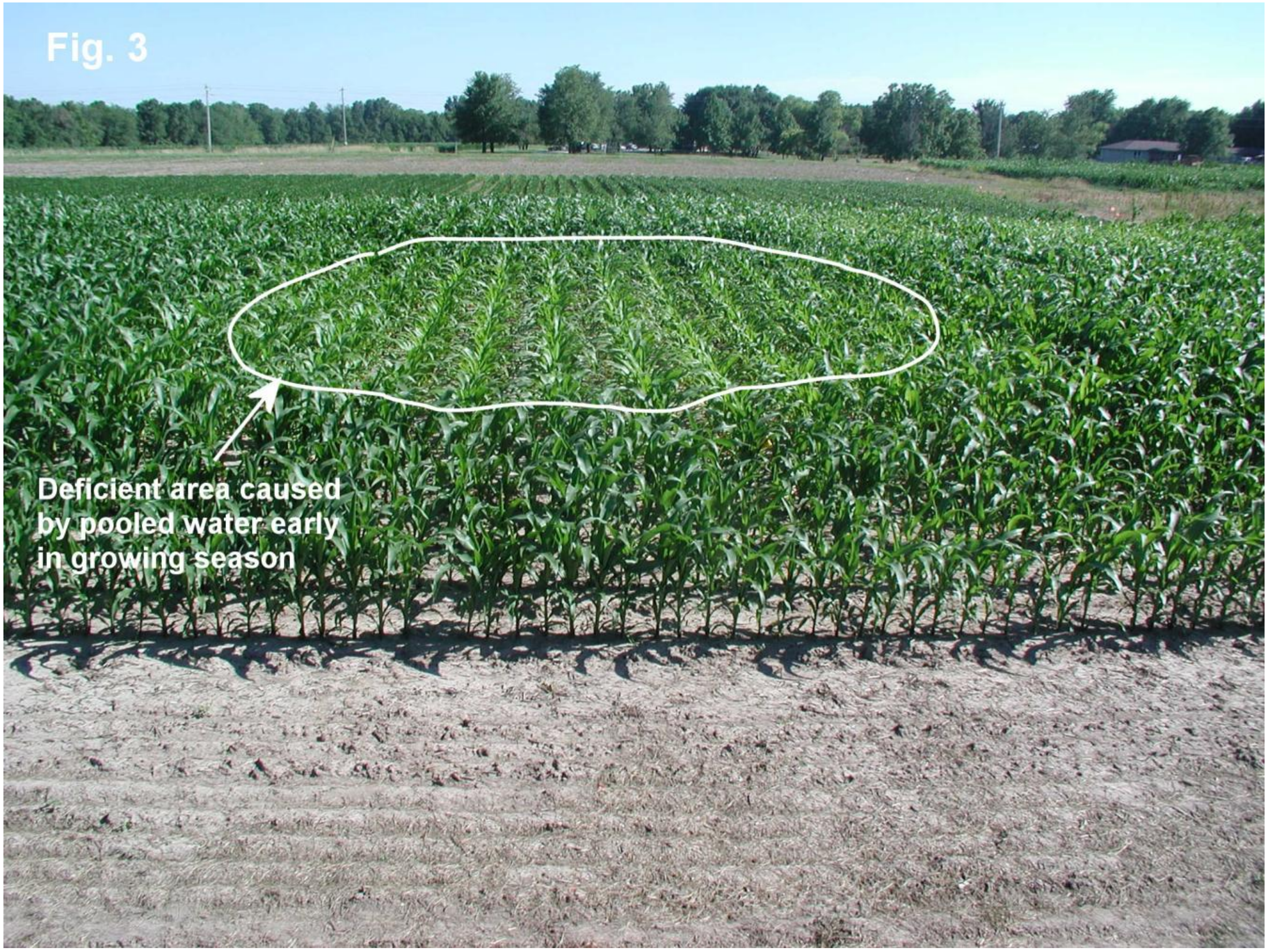
Fig. 3
Deficient area caused
by pooled water early
in growing season

Table 3. Procedures for long-term corn sensor N experiments		
Description	Experiment 1	Experiment 2
Previous Crop	Corn 70-75% Residue cover	Sweet Corn, 150 lbs.N/ac 50-55% Residue cover
Pre-plant Soil Sampling	4/08/10	none
Tillage	No-till	No-till
Weed Control Broadcast Herbicide Application	Burn down Round-up 32 oz./ac Residual Lexar 3.0 qts/ac Nonionic surfactant 2 pt /100/gal 4/19/2010	Burn down Round-up 32 oz./ac Residual Lexar 3.0 qts/ac Nonionic surfactant 2 pt /100/gal 4/19/2010
Early Nitrogen Application	3 Fixed rate treatments & Mo pre-plant soil test treatment 4/29/2010	2 Fixed rate treatments & 1 Fixed rate treatment Pre-plant for sensor based 4/29/2010
Plant Plots	Planter: JD 7000 w/finger pickup Variety: Pioneer P1395XR RR2 Herculex xtra Liberty Link, Cruiser Seed drop: 31,300 Depth: 1.25" – 1.50" Conditions: Good Emergence – Good 5/28/2010	Planter: JD 7000 w/finger pickup Variety: Pioneer P1395XR RR2 Herculex xtra Liberty Link, Cruiser Seed drop: 31,300 Depth: 1.25" – 1.50" Conditions: Good Emergence – Good 5/28/2010
In-Season Soil Sampling	6/24/20/10	none
WeedControl Clean – up Broadcast Herbicide Application	Round-up 32 oz./ac+ AMS 20 gal water/ac 6/16/2010	Round-up 32 oz./ac+ AMS 20 gal water/ac 6/16/2010
Sidedress Treatment Applications	Chlorophyll meter, sensor, & sidedress soil nitrate test treatments applied 7/02/2010	sensor sidedress treatment applied 7/02/2010
Harvest	10/4/2010	10/4/2010

Sensor-based variable rate N: Long-term performance in cotton

- Recent experiments in Missouri and other states have shown that:
  - Optimal N rate for cotton varies widely from field to field
  - Crop sensors can provide relatively reliable estimates of optimal N rate

- This has created a need to evaluate how sensor-based N rates perform when used routinely and on the same land over an extended period.

- We initiated this experiment in 2010 to meet that need.

- This experiment is designed to look at sensor-based N performance both with and without N applied preplant. Treatments used include:
  - Sensor-based N applied at mid-square stage
  - 30 lb N/acre applied pre-plant, then sensor-based N applied at mid-square stage
  - Standard N management: 50 lb N/acre preplant, 50 lb N/acre early square
  - Standard N management with credit for soil nitrate test
  - 50 lb N/acre preplant, followed by additional N if petiole nitrate is below critical value
  - High rate: 50 lb N/acre preplant + 80 lb N/acre early square
  - Low rate: 20 lb N/acre preplant + 50 lb N/acre early square
  - Check treatment: no N applied

- Yields have not yet been analyzed for spatial trends and are not ready to present until this step is completed. However, a few points emerge from the initial yield analysis that will probably hold true in the final analysis:
  - Yield in the zero-N (check) treatment was 1230 lb lint/acre. This is a very good yield and indicates that the soil supplied a substantial amount of N to the crop.
  - Yield in the fertilized treatments averaged 1320 lb lint/acre, an average yield response of only 90 lb lint/acre.
    - ✓ Any of the N treatments should have been able to supply enough N to the crop to support a 90 lb response
    - ✓ Differences in yield from plot to plot under these conditions are probably due mostly to spatial variability in the soil where the experiment is planted, rather than to the effectiveness of the treatments.
  - In this situation there is potential for N applications to hurt yields, quality, or harvestability.
  - The best treatment under these conditions will probably be the one with the lowest N rate applied, partly due to savings on N and partly due to reduced risk that excess N will cause yield, quality, or harvestability problems.
  - By this criterion, the sensor-based N (with no N applied pre-plant) treatment is the best treatment, since only 22 lb N/acre was applied.
  - **The sensors correctly diagnosed that the soil was supplying a high level of N and that minimal fertilization was needed.**
  - However, fiber strength was significantly lower with the sensor-only treatment (33.6) than with standard N management (34.8) in the preliminary analysis. This is a disadvantage.

Objectives for 2011

Our objective for 2011 is to repeat these three experiments in the same locations, and with the same treatments on the same plots. This will help us to assess the long-term effects of sensor-based N management relative to other N rate and timing approaches.

Budget for 2011

Labor & benefits, corn experiment	$8,000
Labor & benefits, cotton experiment	$8,000
Labor & benefits, data & website	$ 500
Soil & petiole sample analyses	$ 500
Field supplies & fuel	$ 500
Total	**$17,500**

Sensor-based Topdressing for Winter Wheat

Peter Scharf and Larry Mueller

Objective:

- Develop reliable sensor interpretations as a basis for on-the-go variable-rate N topdressing of winter wheat.

Accomplishments for 2010:

- Three nitrogen rate experiments were planted in early October 2009.
- After receiving about a foot of rain in central Missouri in October 2009, stands were terrible.
- Experiments were re-planted in early November 2009.
- Fall growth was poor in all three experiments.
- The condition of the wheat was poor in all three experiments in mid-March 2009. We decided to abandon all three experiments. Many producers in the region made the same decision in their production fields and killed out wheat to plant corn or soybeans.
- Our plan is to continue this project for an extra year using only the funding in the original grant request.

Budget for 2011:

All work for 2011 experiments will be carried out with money allocated for the aborted 2010 experiments. We plan to continue experiments into 2012 with the third year of funding as originally budgeted (but delayed by one year).

Nitrogen & Phosphorus Management

Progress Reports

2010 Second Year (18 month) Report

Optimum Timing of Nitrogen and Phosphorus Applications for Improved Tall Fescue Seed Production

Dale G. Blevins
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Division of Plant Sciences
University of Missouri

Objective and Relevance – **The Problem:** Missouri produces large quantities of tall fescue seed, but average yields are very low. **The Hypothesis:** Optimal timing of nitrogen (N) and phosphorus (P) fertilization, along with the strip-kill production method, will greatly increase tall fescue seed yields in Missouri. **The Objective:** to determine the optimum timing of N and P applications for maximum tall fescue seed production in Missouri.

Procedures – A low phosphorus site (Bray I P 14-17 lbs P/acre) was selected at the Agronomy Research Center near Columbia in August 2009. The site selected was along the eastern edge of Bradford Farm just north of the east Lake. The steps taken to setup this study are shown in the Timetable below (Table 1).

Table 1. Timetable used to start this tall fescue seed production experiment in 2009.
Late Aug 2009 identified tall fescue sites at Bradford Farm and collected soil samples
Early Sept – Selected plot area that had low Bray I P level and a good fescue stand
Sept 3 Bushhog was used to mow the fescue
Sept 7 Raked the dried hay off the plot area
Sept 15 Plot areas were measured and flagged (10' x 25'with 5' borders
Sept 17 Specific plots were strip-killed by treating with Roundup (2oz/acre) + a surfactant and a blue tracking dye. Strips were approximately 7.5" wide. Dr. Will McClain did the spraying. A blue tracking dye was added to ensure the width and location of the sprayed areas (See Fig. x).
Sept 30 Strips were visible, and plots were treated with triple super phosphate or urea-N as shown in Fig.1 with treatments randomly assigned. See treatments listed below.
Oct 2 Photographs of strips were taken (Figs. 3-5)
Dec 18 Plots were treated with their second application of P and N fertilizer
June 22 2010 Seed was harvested with a plot combine, air-dried and cleaned
June 28 Seeds were weighted and yields were calculated
July 15 Data were analyzed and graphs were drawn
September 15 N and P were applied based on treatments
December 20 N and P were applied based on treatments

Plots were randomly assigned with the following treatments and replications:

N treatment splits: a) 0 lbs N late Sept + 100 lbs N in mid-Dec
b) 50 lbs N late Sept + 50 lbs N in mid-Dec
c) 100 lbs N late Sept + 0 lbs N in mid-Dec
P treatment splits: a) 0 lbs P in late Sept + 50 lbs P in mid-Dec
b) 25 lbs P in late Sept + 25 lbs P in mid-Dec
c) 50 lbs P in late Sept + 0 lbs P in mid-Dec

Production system: Conventional pasture or Stripkill
Replications: Five replications of each treatment
Total plots = 90 (10' x 25') plots with 5' borders
(3 Ntrtmts x 3 Ptrtmts x 2 ProdSystems x 5 reps = 90 plots total)

Ammonium nitrate was used as the N source and triple super phosphate (0-46-0) was used as the P source. Seed will be harvested with a plot combine around June 18, 2011.
After combining, seed will be screened to remove any stems and other trash prior to weighing and moisture determination for final seed yield determination. Total forage fresh weight will be determined at harvest time and weights of sub-samples will be determined before and after drying for dry weight determination. This will allow determination of total plant biomass production from each treatment and calculation of % seed vs % biomass for each plot.

2011 Budget: No additional funds requested for June harvest, data collection, graph and final report preparation

2010 Results

Tall fescue seed yields were very good in 2010. The winter and spring weather was favorable for seed production. One interesting result for this year was that for the first time in about seven years of tall fescue seed production experiments conventional production out yielded strip-kill. One possible explanation was the robust growth caused extensive lodging in the plots. In fact, this was demonstrated in plots where all of the N was applied in September. In June, the tall fescue plants in these plots clearly lodged and seed yield suffered as a result of the extensive vegetative growth. It should be noted that unlike farmer's fields, these research plots were not grazed in the fall or winter months. The highest seed yields were from conventional plots treated with the N and P treatments split between September and December (Figures 2, 3 & 4). This is the first year in about seven years that conventional plots have out yielded strip-kill plots. One of the conventional plots with split N & P treatments produced over 1000 lbs seed/acre.

Figure 1. A view of the conventional (left) and strip-kill (right) tall fescue plots about one month after spraying with Roundup in late September 2009 at Bradford Farm.

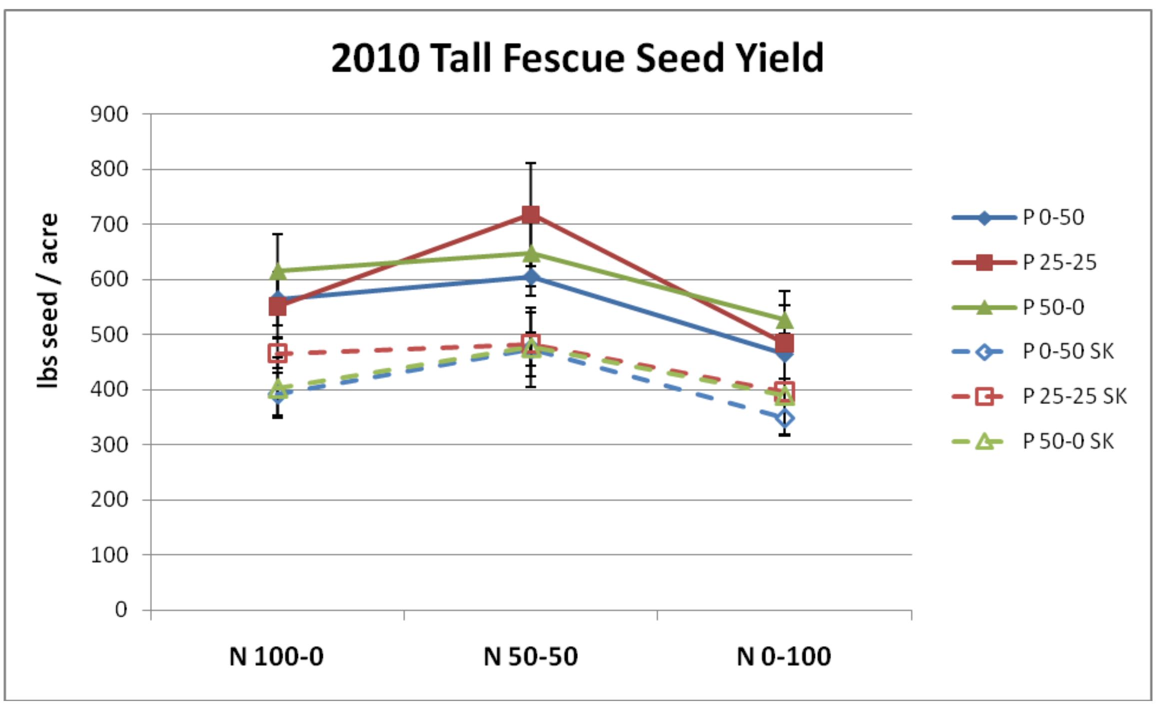

Figure 2. The June 2010 tall fescue seed yield from strip-kill and conventional plots treated with N and/or P in either September or December of 2009.

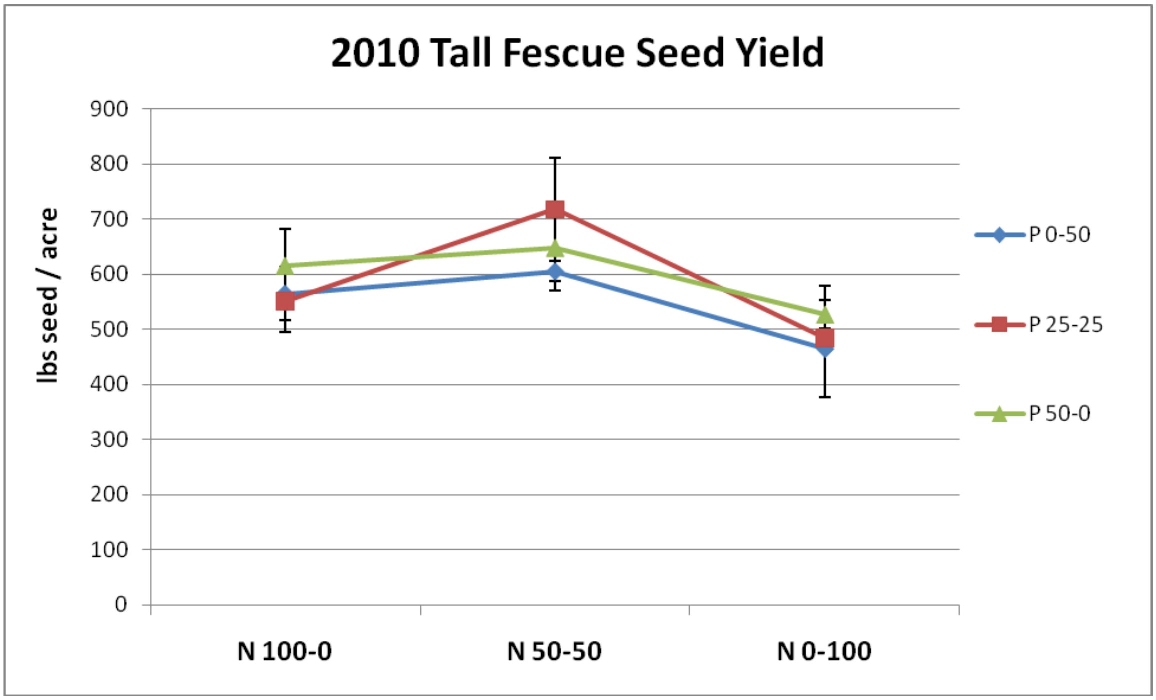

Figure 3. 2010 tall fescue seed yield from conventional plots treated with N and /or P in September and/or December 2009.

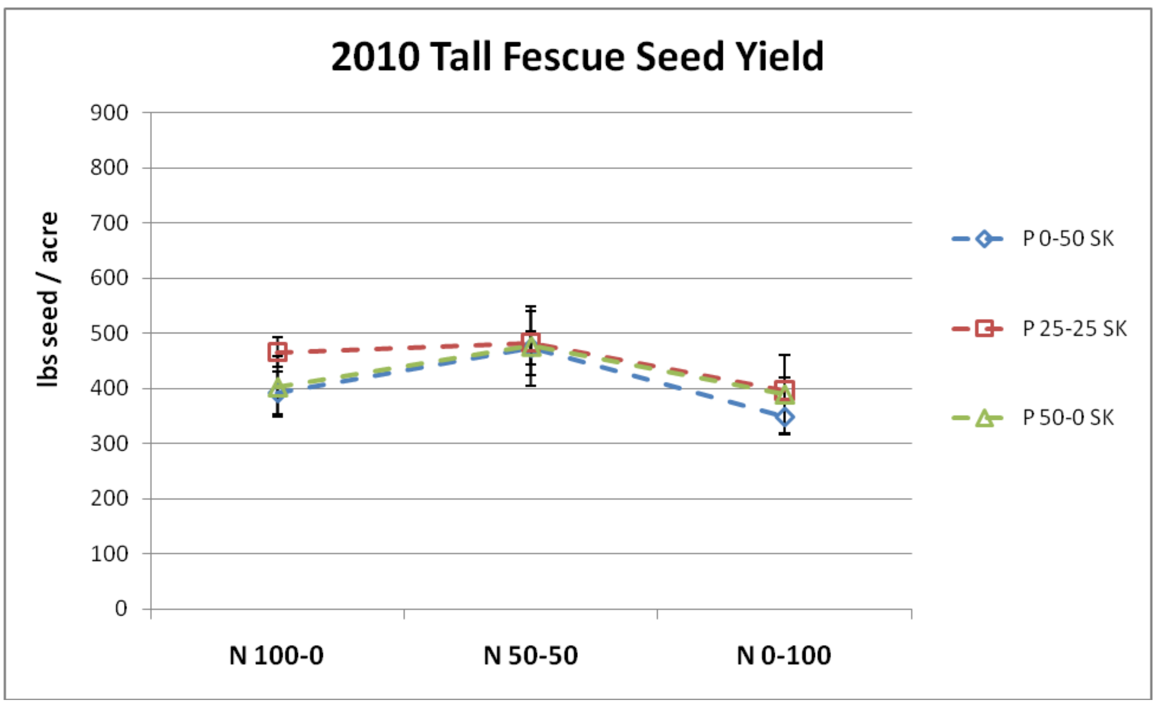

Figure 4. 2010 tall fescue seed yield from strip-kill (SK) plots treated with N and /or P in September and/or December 2009.

Phosphorus Management

Enhanced Efficiency Phosphorus Application for a Corn-Soybean Rotation

Kelly Nelson, Chris Dudenhoeffer, Bruce Burdick, David Dunn, Peter Motavalli, Manjula Nathan, Peter Scharf and Gene Stevens

Investigators:

Kelly Nelson, Div. of Plant Sci., Univ. of MO, Novelty; Chris Dudenhoeffer, Dep. of Soil, Environ., and Atmos. Sci., Univ. of MO, Columbia; Bruce Burdick, Div. of Plant Sci., Univ. of MO, Albany; David Dunn, Div. of Plant Sci. Univ. of MO, Portageville; Peter Motavalli, Dep. of Soil, Environ., and Atmos. Sci., Univ. of MO, Columbia; Manjula Nathan, Div. of Plant Sci. Univ. of MO, Columbia; Peter Scharf, Div. of Plant Sci., Univ. of MO, Columbia; and Gene Stevens, Div. of Plant Sci. Univ. of MO, Portageville.

Objectives and Relevance:

Phosphorus (P) is an essential plant nutrient that is taken up by plants as inorganic ions ($H_2PO_4^-$ and HPO_4^{-2}) found in soil solution. Phosphorus in plants is an important structural element in nucleic acids (RNA and DNA), serves as an energy transfer element (ATP), and has a critical role in cellular regulation, and carbon partitioning. Soluble forms of P or P bound to clay particles can be lost from agricultural land through runoff and surface erosion. Unless the soil is coarse-textured, has a shallow depth to bedrock, has preferential flow paths, has high initial soil test P, or artificial drainage is present, the potential for P leaching is generally considered very low. Soil P sorption reactions (i.e., adsorption and precipitation) reduce plant available P in the soil solution and the relative capacity of a soil for P sorption is dependent on such soil properties as the type and proportion of clay in the soil, the soil pH, and the amount of soil organic matter (Pierzynski et al., 2005)

With high fertilizer costs, farmers are evaluating application rates and considering enhanced efficiency P applications or treatments. This project was expanded to include additional P-enhancing products. AVAIL® (Specialty Fertilizer Products, Leawood, KS), NutriLife MAX® (Advanced Microbial Solutions, Pilot Point, TX), and P_2O_5 Max® (P-Max, Rosen's Inc., Fairmont, MN) are three new products that may enhance the efficiency of P-based fertilizers. AVAIL is a P enhancing product for granular phosphate fertilizers including DAP, MAP, and other phosphate fertilizers. It was designed to reduce the impact of metals in the soil around the fertilizer granule on plant uptake, and P sorption, and allow P to be more available to the plant. This product primarily binds with calcium, iron, manganese, and aluminum to prevent precipitation of P. When applied to single crops, Blevins (2009) reported a 19 to 22 bu/acre increase in corn grain yields when AVAIL was added to MAP at 20 lbs P_2O_5/acre and applied as a broadcast or banded treatment. Dunn (2009) reported increased Bray-P1 soil test P availability and a 4 bu/acre yield increase in soybean yield after applying 50 lbs P_2O_5/acre with AVAIL. Similarly, rice yields increased 8 bu/acre when reduced rates of triple super phosphate were applied (25 lbs P_2O_5/acre) with AVAIL. P-Max increases P uptake and improves root surface area resulting in better nutrient absorption and higher yields (Rosen's Diversified Inc, 2010). NutriLife MAX improves fertilizer uptake, thus contributing to overall plant vigor and quality (Advanced Microbial Solutions, 2005). In addition, banded applications of P may also increase P efficiency (Minor et al., 1993). Phosphate placement in the rooting zone of moist soil was suggested to improve efficiency if farmers desired to apply reduced rates. Strip-till applications may also limit P loss if soil particles were eroded into surface waters.

The objectives of this research were to:

1. evaluate the effect of P placement, rate, and P enhanced efficiency products on grain yield and P uptake in a corn-soybean rotation, and
2. determine the effect of P source, P enhancer, and ag lime on grain yield and P uptake in a corn-soybean rotation.

Procedures:

General. A two-year rotational crop study utilizing P fertilizer applications for corn was initiated in 2010, and will evaluate the subsequent impact on soybean yield and/or uptake. Research trials were established at the Greenley Memorial Research Center near Novelty, Delta Center near Portageville, and Hundley-Whaley Center near Albany. Each site was arranged as a randomized complete block design with four replications. Soils were initially characterized for soil organic C, pH (0.01 M $CaCl_2$), and exchangeable K, Ca and Mg at each site (data not presented). Soil test P (Bray P1) concentrations were determined prior to application from each replication at each site. Soil test P will be determined following soybean harvest for each treatment. Grain yields were determined and grain collected (Novelty and Albany) to evaluate for starch, protein, and oil concentration (Foss Infratec, Eden Prairie, MN). Grain moisture was adjusted to 15% prior to analysis. All data were subjected to analysis of variance and means separated using Fisher's Protected LSD (P = 0.05). Data were combined over factors and locations when appropriate as indicated by the analysis of variance (data not presented).

P placement, rate, and enhancer. Sites to accomplish objective 1 included Novelty and Albany. Treatments included a factorial arrangement of application placement (i.e., surface broadcast of strip-till), MAP rate (0, half the recommended rate, and recommended rate), and the presence and absence of two enhanced phosphorus efficiency products [AVAIL®(Specialty Fertilizer Products, Leawood, KS) at 0.5 gal/ton and P_2O_5 Max® (P-Max, Rosen's Inc., Fairmont, MN) at 1 gal/ton]. Plots were 10 to 15 by 70 ft. Phosphorus treatments were deep banded using a Yetter® 2984 strip-till system equipped with high residue Maverick® units (Yetter Manufacturing, Inc., Colchester, IL) with a rolling basket and dry fertilizer application tubes at the Novelty site. Phosphorus treatments were deep banded using a Yetter® 2984 strip-till system equipped with residue manager wheels (Yetter Manufacturing, Inc., Colchester, IL), B-33 mole knife, and opposing closing wheel disks at the Albany site. A Gandy Orbit Air (Gandy Company, Owatonna, MN) fertilizer applicator was used to deliver fertilizer behind the applicator knife in the strip till system. Phosphorus was broadcast applied with a hand spreader. Ammonium nitrate fertilizer was broadcast applied for the appropriate treatments to balance the N contribution of MAP as the rate was reduced. The planter was equipped with Shark-tooth® (Yetter Manufacturing, Inc., Colchester, IL) 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 strip-tilled plots. Management information is available in Table 1. Tissue and grain samples were collected to determine crop P uptake due to the effects of the treatments at both locations and are currently being analyzed by the University of Missouri Soil and Plant Testing Laboratory.

P source, P enhancer, and ag lime. Research to accomplish objective 2 was conducted at Novelty and Portageville. Treatments include a factorial arrangement of a P source [non-treated control and a broadcast application of DAP (diammonium phosphate) or TSP (triple superphosphate], presence or absence of the phosphorus efficiency products [AVAIL®(Specialty Fertilizer Products, Leawood, KS) at 0.5 gal/ton, NutriLife MAX® at the Novelty location only (Advanced Microbial Solutions, Pilot Point, TX) at 1 gal/ton, and P_2O_5 Max® (P-Max, Rosen's Inc., Fairmont, MN) at 1 gal/ton], and broadcast surface application of ag lime (0 and recommended rate). Plots were 10 by 40 ft. The Novelty site was no-till and rain fed, while the Portageville was conventional tillage with furrow irrigation. Management information is available in Table 2. Tissue (Novelty and Portageville) and grain (Novelty) samples were collected to determine crop P uptake and are currently being analyzed by the University of Missouri Soil and Plant Testing Laboratory.

Results:

P placement, rate, and enhancer. Corn was planted early at Novelty and replanted due to a poor overall stand at Albany. Harvested plant population was 9,400 plants/acre greater with strip-till than no-till at Novelty, while there was no difference among tillage systems at Albany (Table 3). Tillage system had no effect on silage dry weight. Grain moisture was slightly greater (0.5 %) with no-till corn at both locations, but test weight was 0.3 lbs/bu greater with strip-till at Novelty. There was no effect of P enhancer or rate on plant population, silage dry weight, grain moisture, test weight at Novelty, or grain yield (Table 4). However, there was an interaction between P placement and enhancer (Figure 1). There was no effect of P enhancer on grain yield when broadcast applied in a no-till system, but AVAIL increased yield 8 bu/acre when applied in a strip-tilled band compared to P without an enhancer.

P source, P enhancer, and ag lime. AVAIL and P-Max P enhancers were evaluated at Portageville, and AVAIL, P-Max, and NutriLife MAX were evaluated at Novelty in 2010. Phosphorus enhancer had no effect on plant population, test weight at Novelty, moisture at Novelty, or grain yield (Table 5). Silage yields were greater at Novelty than Portageville. At Novelty, AVAIL increased silage yield 1.2 tons/acre when compared to the absence of a P enhancer. Silage yields were ranked non-treated control = AVAIL $\geq$ P-Max at Portageville. NutriLife MAX was added at the Novelty location, but there was no significant difference (P = 0.91) between P enhancer treatments and the non-treated control (Figure 2).

Lime was applied at 3.6 and 2 ton/acre at Novelty and Portageville, respectively. Both sites were corn following corn, and the harvested plant population was approximately 20,000 plants/acre (Table 6). Plant population was similar among P sources in the absence of lime, but was 2,600 and 3,200 plants/acre lower where TSP and DAP were applied, respectively. There was no effect of P source and lime application on silage yield at Novelty or Portageville, and there was no effect of P source or lime on test weight or moisture at Novelty. Grain yields were 7 bu/acre greater with TSP compared to DAP. Ammonium nitrate was added to TSP to balance the N present in DAP. This readily available N source with TSP may have contributed to the yield differences between the P sources. The recommended lime rate increased silage yields 1.1 tons/acre at Novelty, but grain yields were similar between lime treatments. However, recommended lime had no effect on silage yields at Portageville, but grain yields increased 11 bu/acre compared to the non-treated control.

Summary:

- Strip-till increased plant population 9,400 plants/acre and test weight 0.3 lbs/bu compared to no-till at Novelty.
- AVAIL increased corn grain yield 8 bu/acre when applied with P in a strip-till band at Novelty and Albany.
- There was no effect of P enhancer on grain yield when broadcast applied in a no-till system at Novelty and Albany. Similarly, there was no difference in grain yield among P enhancers at Novelty and Portageville.
- Grain yields were 7 bu/acre greater with TSP compared to DAP.
- Lime increase silage yields 1.1 tons/acre when compared to the non-treated control at Novelty, but grain yields were similar among lime treatments. However, lime had no effect on silage yields at Portageville, but grain yields increased 11 bu/acre.
- The corn plots will rotate into soybean and another location will be identified to repeat this research in 2011.

Timetable:

2011

March	Soil sampling
April	Corn planting for the 2011/2012 trials
April/May	Soybean planting in 2010 trial
July	Tissue sampling
September	Harvest and grain sample P for corn and soybean
Oct/Nov	Soil sample from all treatments following soybean harvest
December	Submission of annual report

2012

March	Soil sampling
April/May	Soybean planting in 2011 trial
July	Tissue sampling
September	Harvest and grain sample P for soybean
Oct/Nov	Soil sample from all treatments following soybean harvest
December	Submission of final report

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Table 1. Field and management information for the P placement, rate, and enhancer experiment at Novelty and Albany in 2010.

	Novelty	Albany
Management information	Corn 2010†	Corn 2010
Previous crop	soybean	oybean
Plot size	10 by 75 ft	15 by 75 ft
Hybrid or cultivar	DK 62-54	DK 63-84
Planting date	14 Apr.	30 May
Seeding rate	30,000 seeds/acre	30,000 seeds/acre
Tissue harvest date	7 Sep.	9 Sep.
Harvest date	30 Oct.	15 Oct.
Fertilizer		
P application (date & 1x rate)	13 Apr. 100 lbs P_2O_5/acre	15 Apr., 100 lbs P_2O_5/acre
Additional fertilizer (date, source, & rate)	6 May, Urea (180 lbs N/acre) + Agrotain (1 gal/ton)	19 Apr., urea (150 lbs N/acre) + Agrotain (1 gal/ton)
Weed management		
Burndown	NA	NA
Preemergence	16 Apr., Lumax (3 qt/acre) + Banvel (1 pt/acre)	15 Apr., Lumax (3.2 qt/acre); 30 May, Balance Pro (4 oz/acre)
Postemergence	22 June, Roundup PowerMAX (30 oz/acre) + AMS (17 lbs/100 gal)	21 June, Roundup PowerMAX (24 oz/acre)
Insect management	16 Apr., Warrior (1.5 oz/acre)	NA
Disease management	NA	NA

†Abbreviations: NA, None applied.

Table 2. Field and management information for the P source, P enhancer, and ag lime experiment at Novelty and Portageville in 2010.

	Novelty	Portageville
Management information	Corn 2010†	Corn 2010
Previous crop	Corn	Corn
Plot size	10 by 45 ft	10 by 45 ft
Hybrid or cultivar	DK 61-69 VT3	Croplan Genetics 68-31
Planting date	26 May	7 Apr.
Seeding rate	30,000 seeds/acre	30,000 seeds/acre
Tissue harvest date	7 Sep.	16 Aug.
Harvest date	1 Oct.	8-9 Sep.
Fertilizer		
P application (date & rate)	27 Apr. 105 lbs P_2O_5/acre	6 Apr.50 lbs P_2O_5/acre
Lime application (date & rate)	1 Apr., 3.6 ton/acre	1 Apr., 2 ton/acre
Additional fertilizer (date, source, & rate)	12 Apr., Anhydrous ammonia (235 lbs N/acre)	7 Apr., Urea (50 lbs N/acre) + Agrotain (1 gal/ton)
Sidedress N	11 June, 32% UAN (150 lbs N/acre)	5 May, Urea (150 lbs N/acre) + Agrotain (1 gal/ton)
Weed management		
Burndown	21 Apr. Roundup PowerMAX (15 oz/acre)	5 Apr., Cornerstone 32 oz/acre
Preemergence	21 Apr., Bicep II Magnum (1.65 qt/acre)	9 Apr., Bicep II Magnum (1.5 qt/acre) + Atrazine (2 qt/acre)
Postemergence	22 June, Roundup PowerMAX (22 oz/acre)	8 May, Atrazine (1 qt/acre) + Glyphosate (32 oz/acre)
Insect management	NA	NA
Disease management	NA	NA

†Abbreviations: NA, None applied.

Table 3. The effect of P placement on harvested corn population, silage dry weight, grain moisture, and test weight at Novelty and Albany in 2010. Data were combined over P enhancer, rate, and location unless otherwise denoted below.

P placement	Population		Silage dry weight	Grain moisture	Test weight†
	Novelty	Albany			
	----- no./acre -----		lbs/acre	%	lbs/bu
No-till broadcasted	18,000	19,000	12,100	16.8	55.1
Strip-till banded	27,400	21,900	11,700	16.3	55.4
LSD‡ (*P* = 0.05)	----- 2,400 -----		-- NS --	0.3	0.1

†Novelty location only.
‡Abbreviations: LSD, least significant difference; NS, non-significant.

Table 4. The effect of P rate and enhancer on harvested corn population, silage dry weight, grain moisture, test weight, and yield at Novelty and Albany in 2010. Data were combined over P placement and location.

P enhancer	Rate	Population	Silage dry weight	Grain moisture	Test weight†	Yield
	lbs P_2O_5/acre	no./acre	lbs/acre	%	lbs/bu	bu/acre
None	0	21,700	12,200	16.6	55.3	100
	50	23,200	11,800	16.9	55.3	94
	100	21,800	12,200	16.7	55.3	98
AVAIL	0	21,200	12,900	16.5	55.3	100
	50	20,400	10,900	16.7	55.3	98
	100	20,900	11,600	16.7	55.3	98
P-Max	0	21,400	12,800	16.6	55.3	103
	50	21,200	11,600	16.3	55.3	94
	100	21,400	11,400	16.3	55.4	96
LSD (*P* = 0.1)		-- NS --	-- NS --	-- NS --	-- NS --	-- NS --

†Novelty location only.

Table 5. The effect of P enhancer on harvested population, silage dry weight, test weight, moisture, and grain yield at Novelty and Portageville in 2010. Data were combined over lime treatment and location when appropriate.

P enhancer	Population	Silage dry weight		Test weight†	Moisture†	Yield
		Novelty	Portageville			
	no./acre	---------- lbs/acre ----------		lbs/bu	%	bu/acre
Non-treated	19,600	15,100	14,000	51.1	26.4	135
AVAIL	20,400	17,500	13,000	51.2	25.8	135
P-Max	19,100	15,400	12,700	51.2	25.7	136
LSD (*P* = 0.1)	-- NS --	----------- 1,100 -----------		-- NS --	-- NS --	-- NS --

†Novelty location only.

Table 6. The effect of P source and lime application on harvested plant population, silage dry weight, and grain yield at Novelty and Portageville in 2010. Data were combined over P enhancer, location, and lime treatment when appropriate.

	Harvested population		Silage dry weight				
	-------- Lime --------		-------- Lime --------		Test		
P source[†]	None	Recommended	None	Recommended	weight[‡]	Moisture[‡]	Yield
	-------- no./acre --------		-------- lbs/acre --------		lbs/bu	%	bu/acre
Non-treated	19,600	21,900	13,400	15,700	51.1	26.2	132
TSP	20,400	19,300	15,200	14,800	51.2	25.8	139
DAP	19,400	18,700	13,500	15,000	51.1	26.0	135
LSD (P = 0.1)	---------- 1,300 ----------		---------- NS ----------		-- NS --	-- NS --	6

[†]Abbreviations: DAP, diammonium phosphate; LSD = least significant difference; NS = non-significant; TSP, triple super phosphate.
[‡]Novelty location only.

Table 7. The effect of lime on silage and grain yields at Novelty and Portageville in 2010. Data were combined over P source and enhancer.

	Silage yield		Grain yield	
Lime application	Novelty	Portageville	Novelty	Portageville
	------- lbs/acre -------		------- bu/acre -------	
Non-treated	14,900	13,100	160	105
Recommended	17,100	13,200	159	116
LSD (P = 0.1)	---------- 900 ----------		---------- 5 ----------	

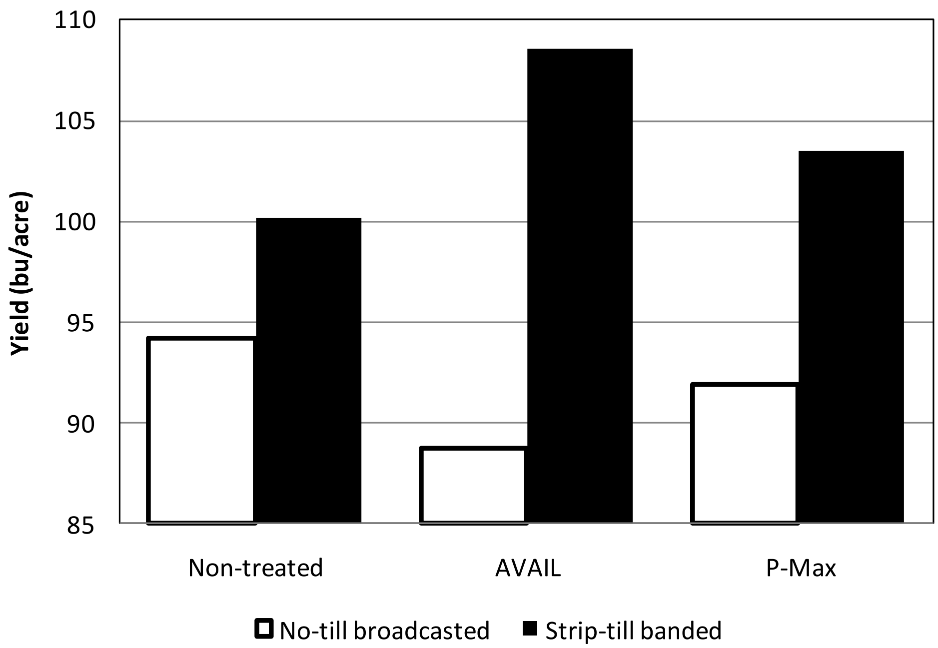


Figure 4. The effect of P placement (no-till surface broadcasted and strip-till banded) and enhancer (non-treated control, AVAIL, and P-Max) on grain yield at Novelty and Albany in 2010. LSD (P = 0.1) was 8 bu/acre.

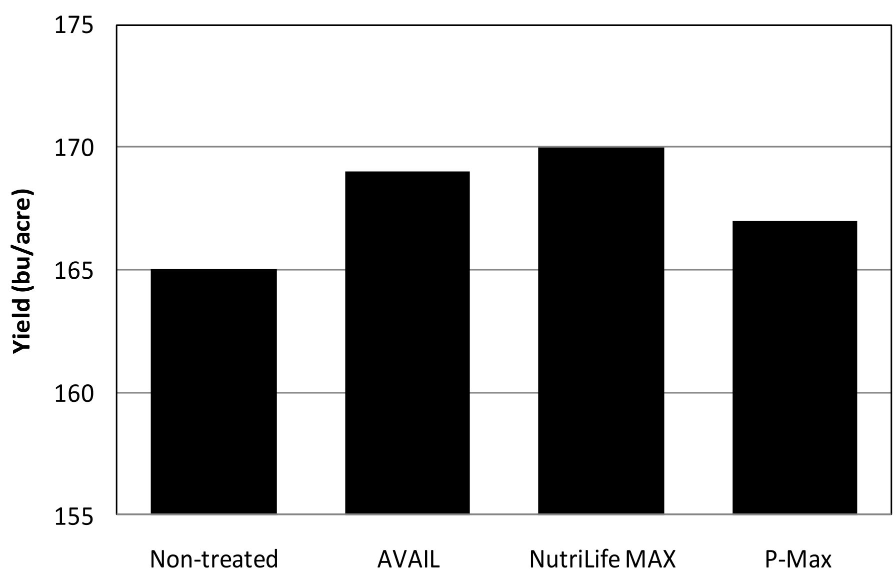


Figure 5. Corn grain yield response to P enhancers at Novelty in 2010. There was no significant (P = 0.91) yield difference among treatments. Data were averaged over lime treatments and P sources.

Budget:

CATEGORIES	Year 2011	Year 2012	Total*
A. Salaries Technical assistance or graduate research assistant (50%)	$14,382	$14,670	$42,875
B. Fringe Benefits Fringe for graduate student	$1,995	$2,095	$6,080
TOTAL SALARIES AND FRINGE BENEFITS	$16,377	$16,765	$48,955
C. Travel			
Travel to field site	$0	$0	$0
To present research findings at National Meetings	$0	$1000	$1000
TOTAL TRAVEL COSTS	$0	$1000	$1000
D. Equipment	$0	$0	$0
TOTAL EQUIPMENT use and maintenance COSTS	$0	$0	$0
E. Other Direct Costs			
Soil analysis	$1680	$1020	$4080
Grain analysis	$2560	$2560	$7680
Tissue analysis	$2560	$2560	$7680
Field supplies	$500	$500	$1500
Publication cost	$0	$500	$500
Off-site PI’s (2)	$6,000	$6,000	$18,000
TOTAL OTHER DIRECT COSTS	$13,300	$13,140	$39,440
TOTAL REQUEST	**$29,677**	**$30,905**	**$89,395**

*Included the 2010 (Year 1) budget.

Budget narrative:
Salaries and fringe benefits: Funds are requested for partial support of a research technical support and/or graduate research assistant.
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 presentation of results
Other Direct Costs: Covers cost of analysis, sample containers, fertilizer, seed, plot preparation, planting, weed control harvesting, flags, and other field supplies and operations.

Phosphorus & Potassium Management

Progress Reports

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

Rich Hoormann, Charles Ellis, Kent Shannon and Peter Scharf

Rich Hoormann, Region Agronomy Specialist, Charles Ellis, Region Natural Resources Engineer, Kent Shannon, 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. 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 minimize fertilizer costs, while maintaining or increasing yields.

Methods and Materials:

In fall of 2008 cooperators 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. Due to heavy rainfall in the fall 2009, strip tillage was not conducted until the spring of 2010.

Composite sample averages were used to determine the broadcast P_20_5/K_20 rate. Treatments consisted of four replications of 0 P205/K20 (control), broadcast rate of soil test recommendation of P205/K20, and ½ broadcast rate of P205/K20 in a band. Recommendations called for 80 lbs. phosphorus and 100 lbs. potassium for a two rotation of corn at 150 bu./ac. and soybean at 45 bu./ac. Nitrogen applications were: 40 lbs./ac at planting with Urea and DAP with 30 gal./ac. of 32% (141 lbs. N) side dressed at V7. Plots were sized to accommodate harvest equipment of eight rows with plot size being approximately 0.2 acres.

2010 band application was with a 4 row strip-till fertilizer bar mounted with a Gandy Spread-Air box. Strip-till units were Yetter Maverick model units. Fertilizer bands were on 30" row spacing at 5" depth. Plot tillage and fertilizer application was completed at one site on April 21, 2010. Planting was conducted the same day as strip-tillage. Planting rate was 29000 seeds per acre of LG Seed 2614VT3 variety. Below is the plot layout.

Rep 1			Rep 2			Rep 3			Rep 4		
0.5X	0X	BX	0X	0.5X	BX	0.5X	0X	BX	0.5X	BX	0X

Observations and Results:
The 2010 crop growing season provided excellent planting conditions, rapid seedling emergence, and adequate growing season moisture with a late season dry period providing quick dry down. Harvest was conducted on September 30, 2010. Treatment yields ranged from 196 - 220 bu./ac. with the mean being 208.6 bu./ac. There were no significant yield differences between treatments at the 5% probability level. Stand and emergence were uniform with no significant population differences between treatments. The high yields raise questions about possible tillage benefits that will be addressed in 2011.

Objectives for 2011:

1. Two sites were completed on November 18 with banded and broadcast fertilizer.
2. A tillage interaction plot was completed on November 18.
3. Plant soybeans on the rows of 2010 corn plots.
4. Additional sites are under consideration with weather permitting.

Results of Corn Yield 2010 Analysis					
	Replication 1	**Replication 2**	**Replication 3**	**Replicatio n 4**	**Treatment Mean**
Treatment	**------------------------------Bu/A------------------------------**				
0X	**210.0**	**219.2**	**206.8**	**220.4**	**214.1**
0.5X	**213.1**	**207.4**	**196.2**	**212.2**	**207.2**
B 1X	**210.9**	**207.0**	**198.7**	**201.5**	**204.6**
Block Mean	**211.3**	**211.2**	**200.6**	**211.4**	**208.6**

No significant treatment differences (P=0.05)	LSD 8.6

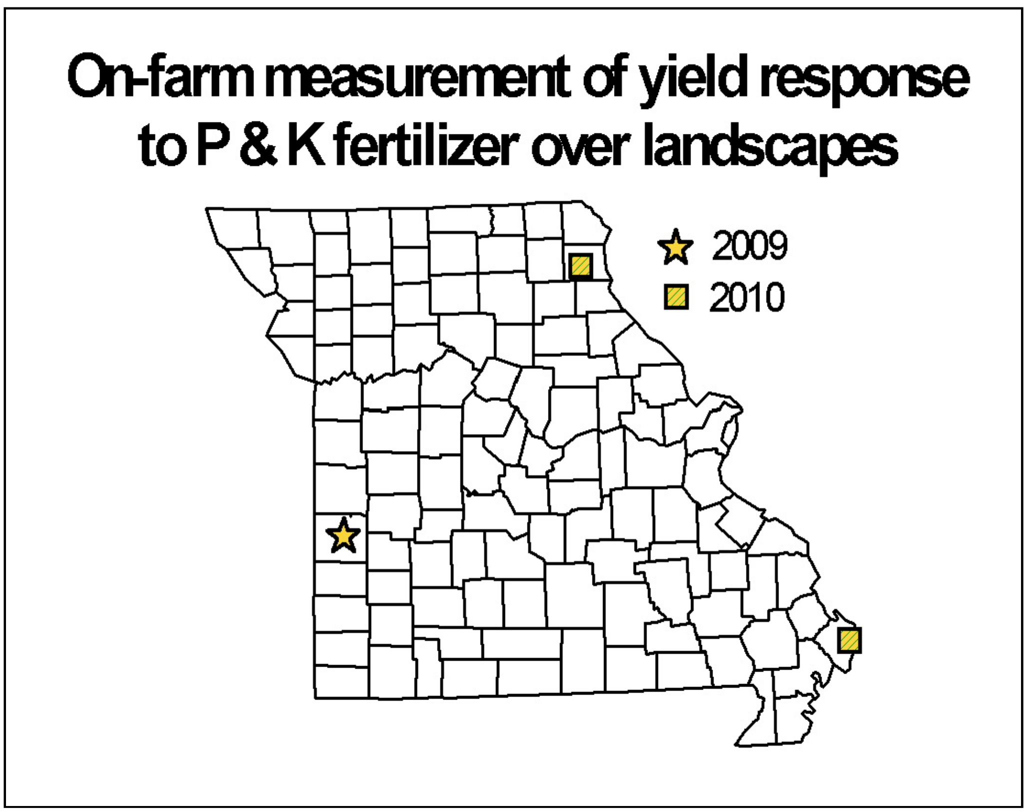
Yield response to P & K fertilizers over landscapes

Peter Scharf, Kent Shannon, Vicky Hubbard, and Larry Mueller
University of Missouri, Plant Sciences Division and MU Extension

Objective:
The objective of this project is to measure grain crop yield response to P and K over landscapes and identify factors that favor response. Soil tests are currently used as nearly the only tool to predict response, but we know that many other factors are involved.

Accomplishments for 2010:
- We set up on-farm, field-scale P and K response tests with producers in three different regions of Missouri.
  - All tests involved spring-applied treatments since funding began in Febraury 2010.
  - This was feasible because fall 2009 field conditions prevented P & K applications in most fields.
  - Spring 2010 field conditions were also wet, making it difficult to get field work done and causing one producer to withdraw from the study.
  - This report will report on the other two fields, and will also report on the field that we studied as a pilot project in 2009.
  - Field locations are shown in Figure 1.

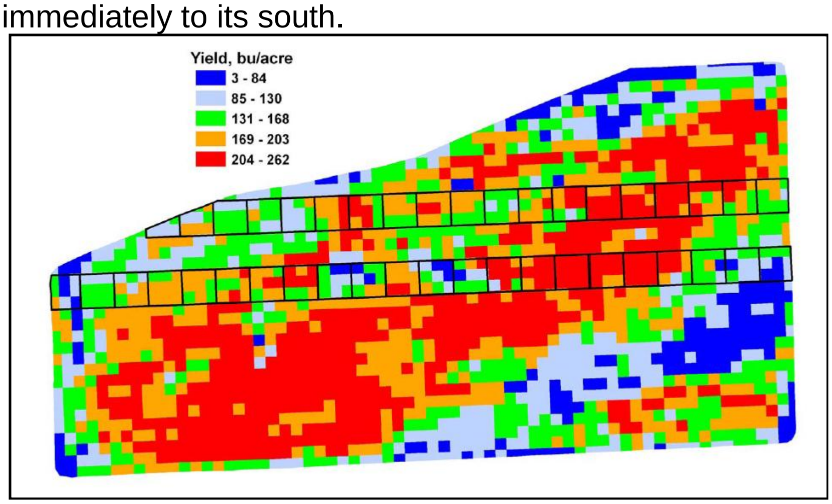
1. Locations of on-farm field-scale trials measuring yield response to P and K across landscapes.



Mississippi County field

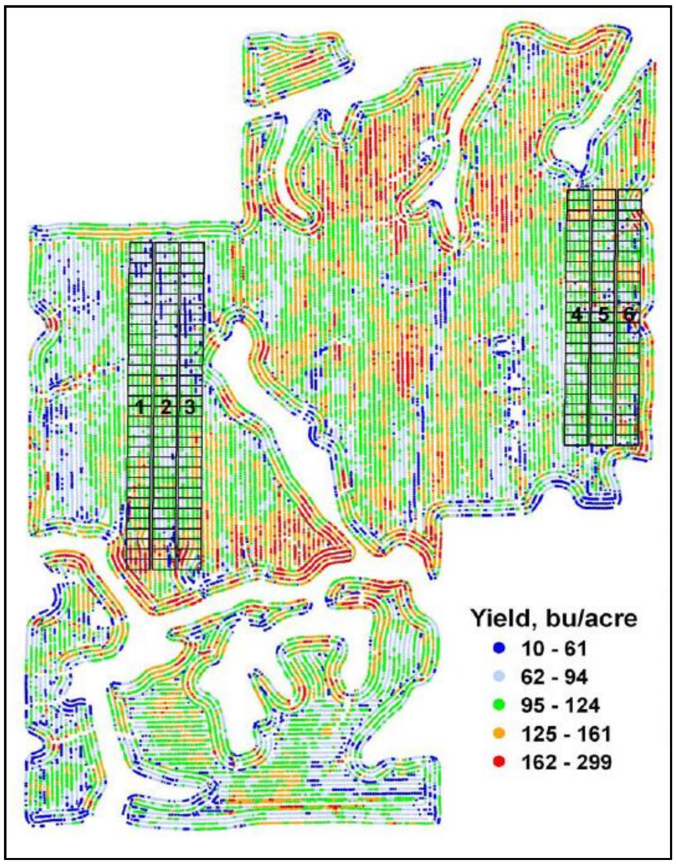
- The smoothed yield map with the treatment areas overlaid is shown in Figure 2 for this 108-acre field.
  - The squares show areas where no P or K was applied.
  - The rest of the field received a broadcast variable-rate P & K application based on grid soil sampling.
  - Yield effect of P & K application was estimated by calculating the average yield for each full square, then comparing it with the average yield for the same-size square immediately to the south.
  - Each square is approximately six combine passes wide.
- Spatial variability in yield was wide in this field (Figure 2), leading to wide variability in estimated yield response to P & K.
- Yield response was seen mostly in the middle of the south strip. Soil in this location appears to be a Malden loamy fine sand. Soils in other parts of the field are Dundee silt loam and Sharkey silty clam loam.
- We have not completed Geographic Information Systems analysis of soil effects on yield response. This analysis will give us better information about the possibility that the yield response is located mainly in the Malden soil.
- The Malden soil map unit makes up much of the high-yield zone in this field.
- Regression analysis shows that high yields when P and K were applied predicts large yield responses ($R^2 = 0.64$). This should be interpreted cautiously, since yield response is calculated from yield with P & K applied. However, it's possible that the high-yielding areas have greater response to P & K due to increased demand.
- We have not yet received soil-test data for this field, but we did receive rate recommendations for P and K for each square (Figure 2) based on grid soil sampling. These rates are inversely related to soil test values (higher soil test gives lower rate recommendation). There was no relationship between yield response to P/K and recommended P rate, nor between yield response and recommended K rate. This suggests that there would also be no relationship between yield response and soil test P or K. It appears that factors other than soil test levels controlled yield response to P and K in this field.
- We will also use GIS to test the relationship between color of bare-soil aerial

Figure 2. Squares (black outline) show locations of test strips receiving no P or K in the Mississippi County field. Colors show the smoothed corn yield map for this field. Response to P and K was estimated by calculating average yield for each full square, then subtracting it from the average yield for a square of the same size immediately to its south.



photos and:
  - yield response to P & K
  - yield
  - these photos may reflect soil variability and boundaries better than the soil map
- The overall average yield response to P and K in this field is only 3 bushels
  - The area of large positive yield response in the middle of the south strip is counter-balanced by large negative 'yield response' values at the east end of the south strip and the west-central part of the north strip.
  - The negative values are not believable as a yield penalty to P and K.
  - Therefore they must reflect factors other than P & K that created yield differences between adjacent squares. This is not too surprising, since soils can vary widely over short distances in Mississippi County.
  - Some of the large positive 'yield responses' in the center of the south strip may also be due to yield-controlling factors other than P & K.

Figure 3. Strips 2 and 5 in this Lewis County field did not receive any P or K for the 2010 season. Strips 1, 3, 4, and 6 received an application of 25-120-100 in spring 2010. Comparisons of yields from these strips was used to map yield response to P and K. Corn yields for 2010 are indicated by color for yield monitor data.



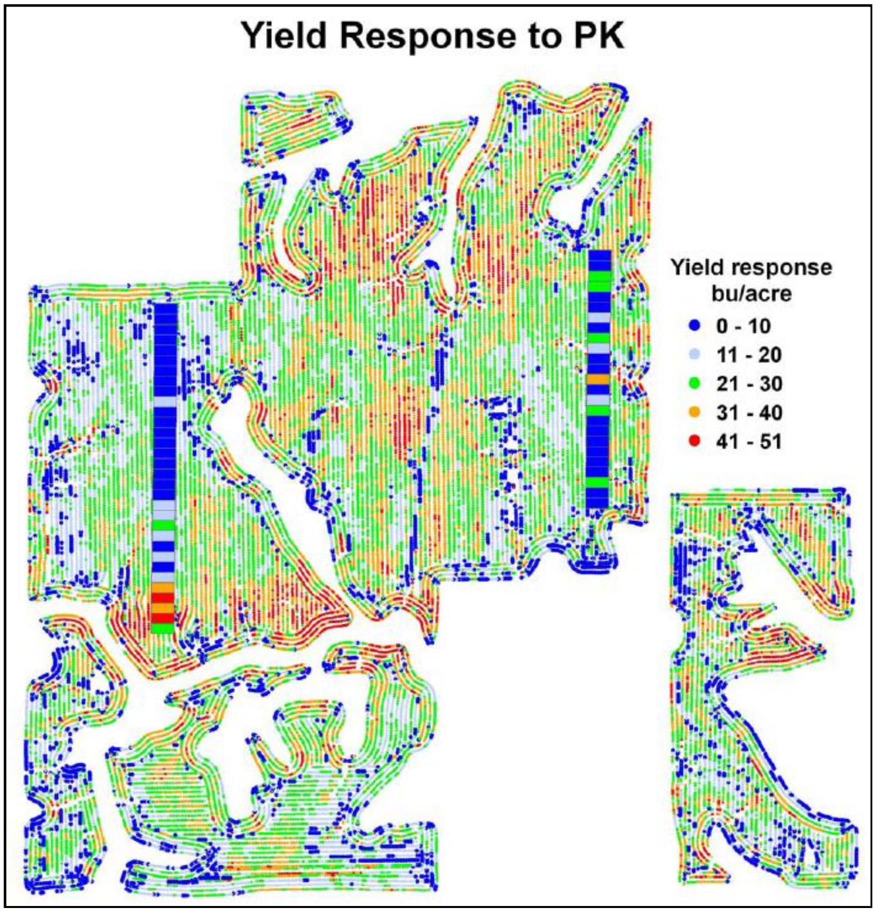
<u>Lewis County field</u>

- The unfertilized strips in this field are shown as strips 2 and 5 overlaid on the corn yield map (Figure 3).
- The remainder of the field received a uniform application of 25-120-100 broadcast in the spring of 2010 before planting.
  - Strips 1 and 3 received this application and are used for comparison to strip 2.
  - Strips 4 and 6 received this application and are used for comparison to strip 5.
- Yield response to P & K was calculated from these comparisons.
  - For each rectangle in strip 2, we averaged the yield of the adjacent rectangles in strips 1 and 3, then subtracted the yield from strip 2.
  - For each rectangle in strip 5, we averaged the yield of the adjacent rectangles in strips 4 and 6, then subtracted the yield from strip 5.
- Yield response to P & K for this field is shown in Figure 4.
- More than half (36 of 57) of the rectangles had a yield response of less than 10 bushels

per acre.

- Average yield response to P & K over the entire test area was 7.5 bushels/acre.
- The greatest yield response to P and K was seen at the south end of the western strip. This was one of the highest-yielding areas in the field. However, the statistical connection between high yield and high yield response to P & K is weak when analyzed over the whole field.
    - This area is mapped mostly as an eroded Armstrong loam, with Westerville silt loam mapped at the southern end.
    - Neither of these soils is represented elsewhere in the test strip area, so it's possible that something about these soils makes them more P- and K-responsive than other soils in the field.
    - Again, we need to follow up with GIS analysis to clarify how well this idea holds up.
- In the east strip, a good yield response is seen near the north end approximately where the strips cross some eroded Keswick clay loam soil. We will check how well these line up using GIS analysis. Other than that, there are only a smattering of locations in this strip with good yield response.
- This field was grid soil sampled within the past year or two. However, we do not yet have the soil test data from this sampling. When we do, we will analyze the relationship between soil test value and yield response.

Figure 4. Yield response to P and K is color coded in the rectangles of strips 2 and 5. See Figure 3 for a description of how yield response was calculated. Response is greatest at the south end of the western strip, which is a high yielding area with an Armstrong loam soil.



Vernon County field

- In this field, P and K were placed in a subsoil band in February, but four strips were left with no P or K (Figure 5). Colored areas show where P & K were applied, and the four white strips are the ones left without P & K. Strips were 16 rows wide. Corn yields in this field were excellent for Vernon County, averaging over 160 bushels/acre.
- By subtracting yield with P & K from yield in the adjacent strip(s) without P & K, we measured yield response to P & K. Numbers on the field map indicate corn yield response to P & K (in bushels/acre).
- Responsive areas at the north end of the field were not different in yield, pH, or soil test P or K from non-responsive areas.
- A soils map shows that the soils in the responsive areas were derived from sandstone, while soils in the rest of the field were derived from shale.
- An area in the southeastern part of the field with higher cation exchange capacity (CEC), as shown in the grid soil samples, was also relatively responsive.
- Yield, soil test P, and soil test K levels were not significant predictors of yield response to P & K in this field, nor was soil pH.
- Soil drainage class was the best single predictor of yield response, with well-drained soils giving the largest response.

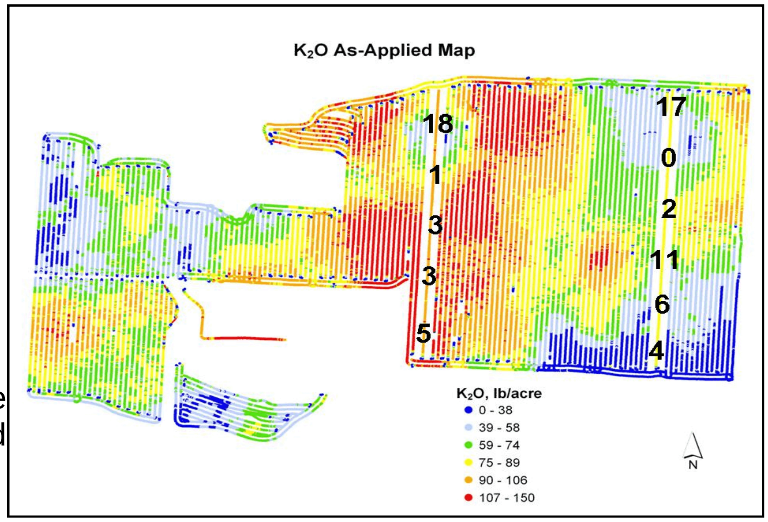


Figure 5. White strips in this field were left unfertilized during a February strip-till and variable-rate fertilizer injection operation. Yield response was greatest at the north end of each test strip. These locations were mapped as sandstone-derived Barco soils, while the rest of the field is made up of soils derived from shale.

Budget request for 2011:

Category	Amount budgeted in:	
	2010	2011
labor and benefits for setup and scouting	$6000	$6000
labor and benefits for data analysis	8000	8000
field supplies and fuel	1000	1000
TOTAL	$15,000	$15,000

Request for 2011: $15,000

Potassium Management

Final Reports

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 project was to evaluate the importance of key management practices employed by Kip 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:

The study was conducted at the Bradford Research and Extension Center near Columbia, MO in the same field and the same plots with the same treatments in all three years. Control fertilization treatments were based on soil test results and yield goal according to Univ. of Missouri recommendations. Depending on weather conditions poultry litter applications were made either in the fall or in the spring before planting (Table 2) and base mineral fertilizers applications were conducted pre-plant in the spring each year (Table 2). Poultry litter and base mineral fertilizers were applied at two rates: a high rate based on 9 tons/A of poultry litter and a low rate based on yield goal. Poultry litter and mineral fertilizer were incorporated into the top soil with a disc and soybeans (cv. Pioneer 94Y01) were planted in 15" rows at 200,000 seeds/acre. Drip irrigation was installed for the high-frequency irrigation treatments and deployed as needed over the course of the growing season. Applications of foliar K were conducted as splits of 8 lbs/A in the first year and as splits of 4 lbs/A in the second (8 applications) and third (6 applications) year. The application of supplemental soil applied K (36 lbs/A; equivalent to the sum of the foliar applications of K) were in season at the time the second foliar K application was conducted. Micronutrients were applied at the time of the first foliar K application or shortly before. Data collection conducted over the course of the season included root sampling for analyses of nodulation, biomass samples, leaf-let samples, samples for plant mapping, and seed harvest.

An overview of the management employed over the course of the three-year project is provided in Table 1. The summary of the amounts of nutrients applied for each of the the three years can be found in Table 2.

Table 1. Task Completion for 2008-2010.

	2008	2009	2010
Poultry Litter Spread	5/19-21	11/25/2008	4/14
Mineral Fertilizer Applied	5/19-21	5/20-21	4/14-15
Planting	6/19	5/22	4/20 & 5/23
Micronutrients Applied	8/19		7/2
Irrigation Started	8/1	5/22	6/18
Foliar Applications			
	8/19-22	8/5	7/15
	8/28	8/14	8/4
	9/8	8/24	8/12
	9/23	8/30	8/26
	-	9/3	9/7
	-	9/9	9/16
	-	9/14	-
	-	9/21	-
Nodule Collection	9/8	8/17	8/31 & 9/2
Harvest	11/3	11/8-9	10/7

Table 2. Fertilizer applications and nutrients added for 2008-2010.

2008	**N**	**P**	**K**	**Fertilizer**
		Lbs/A		
Low				
Poultry	40.3	12.1	28.2	2014.7
Mineral	41.0	26.0	32.8	201.5
High				
Poultry	360.0	108.0	252.0	18000.0
Mineral	365.4	101.1	242.8	1796.9
2009	**N**	**P**	**K**	**Fertilizer**
		Lbs/A		
Low				
Poultry	29.2	20.4	23.3	1470.0
Mineral	29.5	20.4	24.7	185.1
High				
Poultry	357.7	249.5	284.9	18000.0
Mineral	360.2	249.3	301.9	2264.2
2010	**N**	**P**	**K**	**Fertilizer**
		Lbs/A		
Low				
Poultry	26.9	28.9	31.6	1851.9
Mineral	26.7	28.6	31.4	225.4
High				
Poultry	261.0	280.0	308.2	18000.0
Mineral	260.0	278.2	305.0	2188.9

Results:

Weather conditions

Weather conditions over the duration of this project significantly differed from long-term average conditions. All three years were characterized by higher than normal precipitation (Table 3). Unusually high precipitation amounts during the growing seasons influenced the timing of various management practices in each year. Depending on year, precipitation pattern influenced the timing of poultry and base mineral fertilizer applications, planting, foliar K applications, as well as harvest. Further, above normal precipitation significantly influenced irrigation management and impact of irrigation on crop growth and yield.

Table 3. Precipitation amounts during the growing season and irrigation events. Irrigation was manually set for a percentage of full capacity, based on soil moisture.

	Precipitation	**Irrigation**
	inches	*days applied*
2008	28.16	43
2009	37.15	87
2010	32.72	11

Irrigation was conducted less frequently in 2010 than in the two previous years. Early season rains made irrigation unnecessary and rainfall remained fairly consistent until the R5-R7 stages.

Grain yield

Grain yields within each of the three years were not significantly influenced by the imposed treatments (Figs. 1 and 2; and Table 4). However, differences among years were observed with 2009 and 2010 yields being considerably greater than in 2008. The high poultry application may be increasing yield over the three years, perhaps a result of the cumulative effect of the poultry litter decomposition.

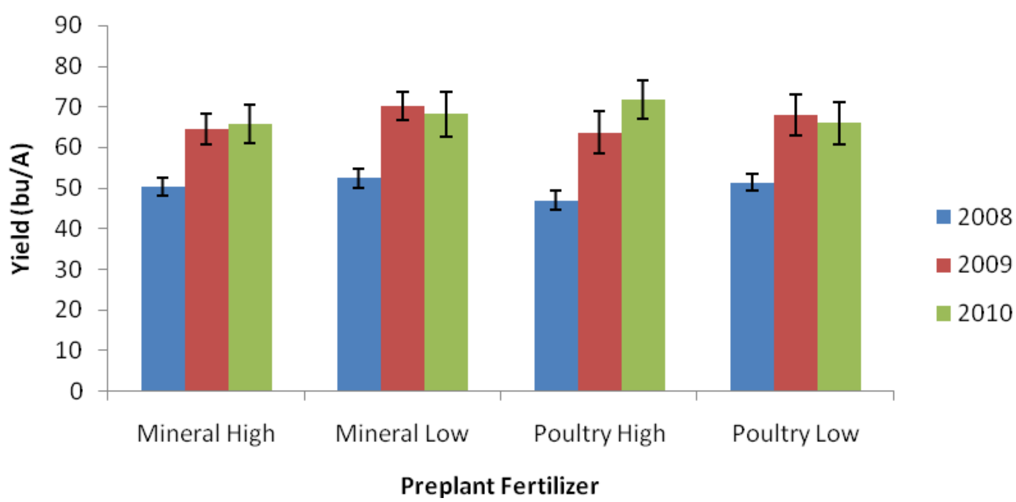


Fig. 1. Grain yields of base nutrient treatments for 2008, 2009, and 2010.

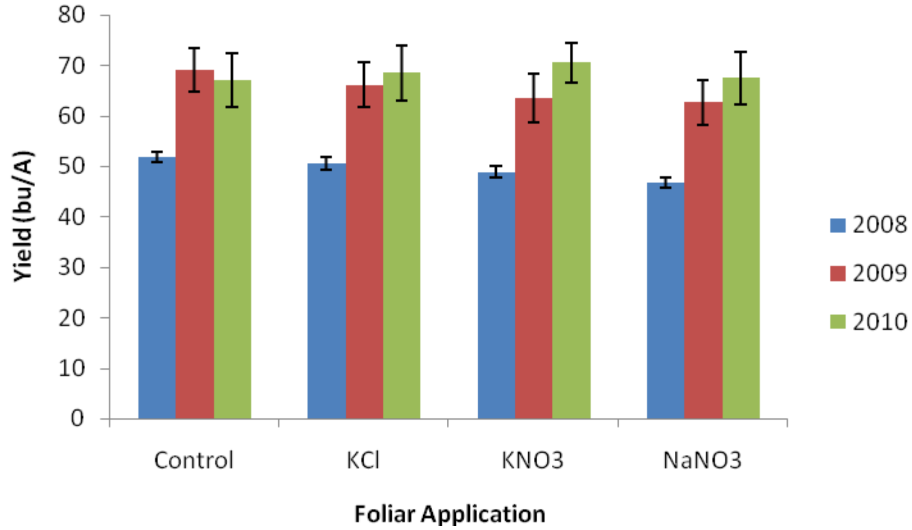


Fig. 1. Grain yields in response to foliar K applications for 2008, 2009, and 2010.

Table 4. 2008 – 2010 Yield summary including standard errors.

Treatment:	**2008**	**2009**	**2010**
		Yield (bu/A)	
Mineral High	50.3 ± 2.2	64.5 ± 3.8	65.8 ± 4.7
Poultry High	47.0 ± 2.3	63.7 ± 5.3	71.9 ± 4.7
Mineral Low	52.4 ± 2.3	70.2 ± 3.4	68.2 ± 5.4
Poultry Low	51.3 ± 2.0	68.1 ± 5.0	65.9 ± 5.2
KCl	50.5 ± 2.4	66.1 ± 4.4	68.5 ± 5.4
NaNO3	46.7 ± 2.0	62.7 ± 4.4	67.5 ± 5.2
KNO3	48.8 ± 2.3	63.4 ± 4.8	70.5 ± 4.0
Control	51.9± 2.1	69.2 ± 4.3	67.1 ± 5.3
Irrigation	48.8 ± 2.5	65.6 ± 4.8	68.4 ± 5.2
No irrigation	50.2 ± 2.3	65.1 ± 4.4	68.4 ± 4.9
Micronutrients	49.8 ± 2.6	66.8 ± 5.1	67.3 ± 4.9
No Micronutrients	49.2 ± 2.2	63.9 ± 4.0	69.5 ± 5.1

Nodulation

In light of the large amounts of poultry litter and mineral fertilizer applied at the beginning of the season, nodulation of soybean roots was greater than expected (Figs. 4 and 5). Interestingly, fertilizer treatments did not appear to significantly influence nodulation. This is a surprising result since high N is reported to suppress nodulation. However, it is similar to observations on Mr. Kip Culler's soybean plants, which are also reported to be highly nodulated. Significantly lower nodule numbers and nodule weights were observed in 2010 as compared to 2008 and 2009 (Figs. 4 and 5).

In 2010, root nodules were picked at a later stage of soybean development, which may partially explain these differences.

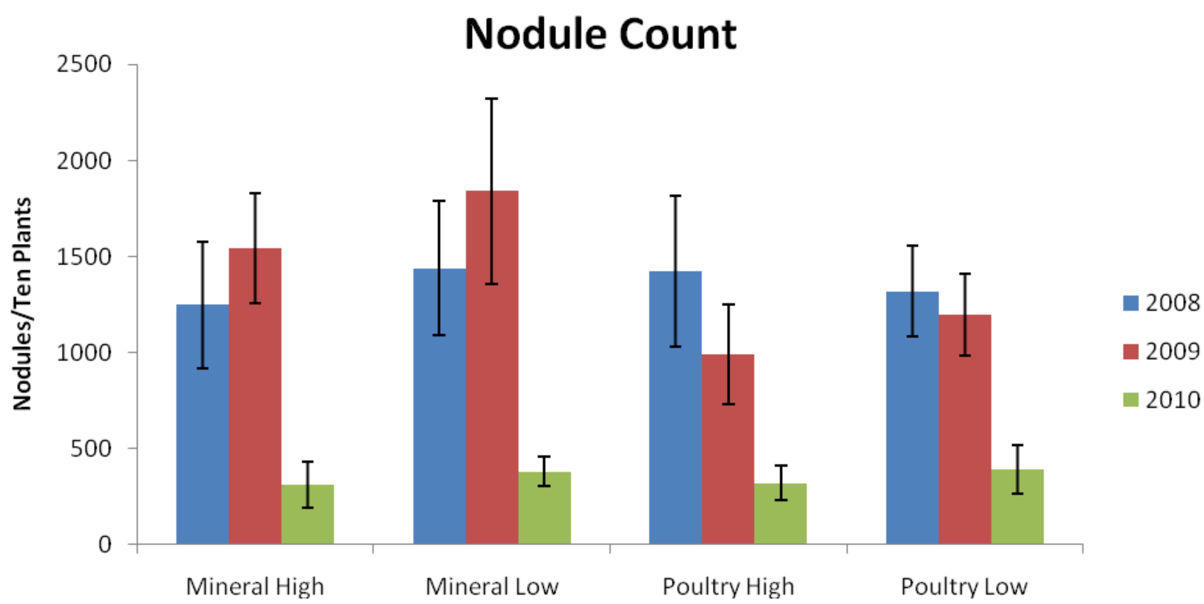


Fig. 4. Number of root nodules found on 10 plants. In 2010, nodulation was assessed later in development than in 2008 and 2009.

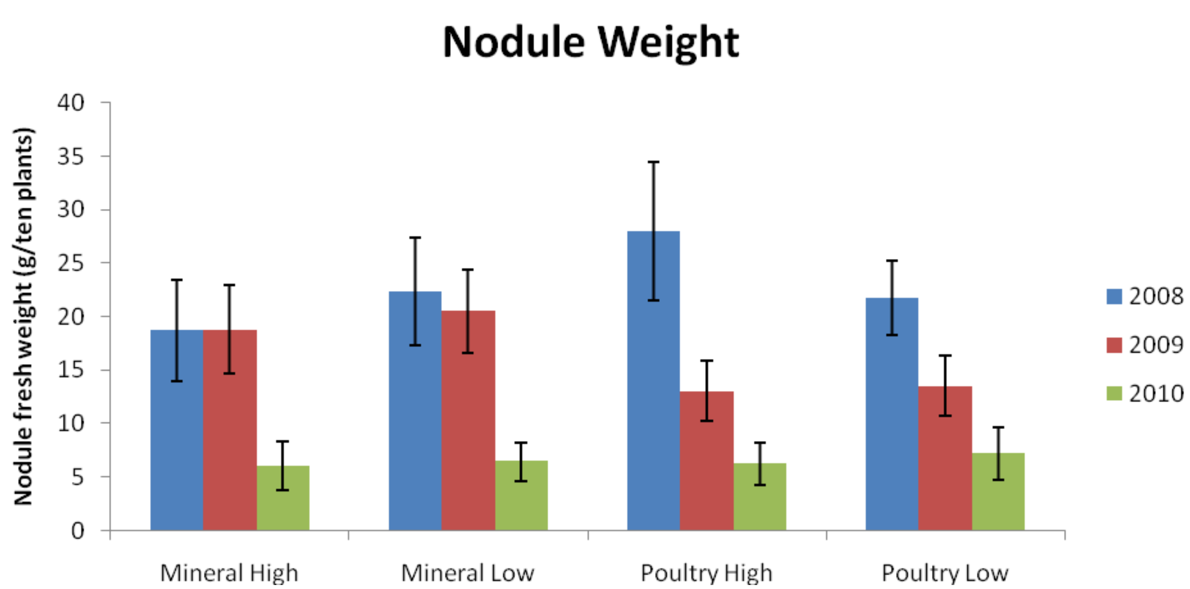


Fig. 5. Fresh weight of root nodules found on 10 plants. In 2010, nodulation was assessed later in development than in 2008 and 2009.

Summary and Conclusions:

The above average precipation in each year and cool summers in 2008 and 2009 greatly reduced soybean response to irrigation treatment. Although soybean yield in 2009 and 2010 were above 60 bu/acre they were less than half of what was found at Kip Cullers fields. A major factor explaining the yield differences maybe that the soils of Kip Cullers, Newtonia Silt Loam are extremely well drained whereas the Mexico Silt loam in this study is a clay pan soil with severe internal drainage issues during wet years. These prolonged wet soil conditions reduced yield potential as compared to the relatively dry 2007 where soybean yield in irrigated treatments (three times per week with a ½ inch each time) were 87 bu/acre compared to 40 bu/acre of controls. At yield levels observed in this three study it is obvious that extra fertilizer NPK and micronutrients is not going to result in a yield advantage. However, it was encouraging that after three years of manure application there was a small increase in soybean yield. It still remains to be seen whether under 100 plus soybean yield environments that additional soil applied NPK regardless source or additional K and micronutrients as foliar treatments will increase yield. It is our plan for 2011 to simplify the project to only irrigation and fertilizer treatments in corn and then go back to soybean in 2012.

Miscellaneous Projects

Final Reports

Title:

Environmentally Sound High Impact Forage Management Research Based Demonstrations for Increased Livestock Profitability by Increasing Forage Production and Quality

Investigators:

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

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

Livestock producers and landowners read about 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 allowing 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 have been 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. 2009 was also an extremely cool and wet year which may have impacted yields and forage quality.

Forage was harvested with a mechanical forage harvester during May, August, and October in 2007 and May, August, and November in 2008 and 2009. 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.

Weighted 3-year averages were calculated and analyzed to determine the effect of fertilizer treatment on forage yield and percentages of crude protein (CP), acid detergent fiber (ADF), total digestible nutrients (TDN), calcium (Ca), phosphorus (P), potassium (K) and magnesium (Mg).

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

Yield: As expected, fertilizer application based on University of Missouri soil test results for a yield goal of 3 tons of hay per acre produced the most forage during the project (Table 2). The red clover (rcl) treatment was second highest yielding and had higher yield than all other treatments except the 50-30-30 treatment. The 50-30-30 treatment only out yielded the 0-0-0 and 0-0-30 treatments. 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?

Nutrient Analysis: In addition to yield, the production of nutrients, especially energy and protein, are important to beef cattle producers. Average percent CP was higher for the 100-65-60 and 0-65-60 rcl treatments than for the 0-0-0, 50-30-30 and 50-0-0 treatments (Table 3). Total digestible nutrient values, calculated from ADF analysis, were higher for 100-65-60, 0-0-0 and 0-65-60 lespedeza (lesp) treatments than for the 0-30-0 treatment (Table 4).

Nutrient requirements for selected animals common to Missouri beef cattle production settings are listed in Table 9. Crude protein requirements are met by all fertilizer treatments for all selected animals except growing calves with estimated average daily gain (adg) of 2.0 pounds or higher. Total digestible nutrient requirements are met by forage alone for 1,200 pound dry beef cows, 1,200 pound medium milk producing cows at peak lactation and 600 pound steer calves gaining 1.0 lb adg or less. The full fertility treatment met the TDN requirement for 600 pound steer calves gaining 1.5 lbs adg, meaning additional energy from grain or grain by-product feed sources would not need to be fed in order to achieve that level of performance. All other fertilizer treatments would require at least a small amount of energy supplementation to meet gain goals of 1.5 lbs adg. All fertilizer treatments require additional energy supplementation to achieve 2.0 lbs adg for growing calves. Due to the high quality of forage produced in this study, supplementation levels of grain or grain by-products would not be excessive in order to meet production goals of the selected animals listed in Table 9.

The high forage quality achieved in this study is also due to the timing of the first harvest of the year. The first cutting was taken early enough in the growing season to ensure high quality plus provide adequate time in mid- to late-spring for ample re-growth so a second harvest could be made in August. This also contributed to the high yields achieved in this study.

Following the full MU fertilizer recommendations resulted in more yield and produced more pounds of CP and TDN compared to the other fertilizer treatments used in this study.

While forage levels of Ca, Mg and K were statistically different between fertilizer treatments, there was no apparent forage response in these minerals due to differing levels of P or K fertilization (Tables 5, 6 and 7). Phosphorus was the exception in that higher P fertilization rates resulted in higher forage P levels (Table 8). All treatments exceeded animal requirements listed in Table 9 for Ca, Mg and K. Only the 100-65-60 and 0-65-60 lesp treatments met the highest animal requirement for P. Four treatments, 0-30-0, 0-0-0, 50-0-0 and 0-0-30 did not meet the lowest animal P requirement.

Economic Analysis:

The 3-year average budget is found in Table 13. Hay price is based on $36 per 1,200 pound round bale at 85% dry matter, resulting in a price of $70.59 per ton of dry matter. Fertilizer prices are averaged for the three years of the study. Annual fertilizer prices are listed in Table 10. Operating and ownership costs are averaged from budgets prepared by FAPRI for large round bales of fescue / red clover mixed hay for the years of 2007 - 2009.

In Table 11, the 3-year averages for yield and income and treatment ranking of yield and income are shown. Based on these results and cost estimates, it appears producers should fertilize according to soil test, incorporate a high percentage of red clover, or fertilize using minimal amounts of the most limiting nutrient in order to achieve the most profit from a hay production system. Moderate levels of fertilization increased cost over lower fertilization treatments but did not increase forage yield sufficiently to warrant the increased cost of fertilizer application.

As the study progressed, the 50-30-0 and the 0-30-0 treatments improved in yield and income rank while the 50-30-30 and 0-0-30 treatments declined in yield and income rank (see Table 12). This is most likely due to soil nutrient profiles. Initial soil tests taken in the spring of 2007 showed P at 6 pounds per acre (very low) while K was 148 pounds per acre (Medium to High). We are seeing yield responses to P fertilization, but not K fertilization, due to the increased probability of a fertilization response with decreasing soil test nutrient level. Moderate (50 pounds per acre) applications of nitrogen (N) did not improve yield sufficiently to overcome the additional cost of the fertilizer.

It is important for producers to understand that if yield losses occur due to lack of fertilizer application, additional feed resources must be acquired. This can be accomplished by either renting or leasing more acres for hay harvest, purchasing additional hay, protein, or energy supplements, or reducing livestock numbers to reduce feed needs. The cost of additional hay land may vary from costs used in this analysis and must be accounted for by each producer. This relationship between production capability due to fertilization and land costs may be more important in future years as land costs rise and hay and pasture land availability shrink.

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.

Our fourth workshop was held on August 12, 2009. Eighty-four percent of survey respondents agreed or strongly agreed that greater attention to forage quality is needed in order to be profitable. Sixty-seven percent would like to see more information about variable rate fertilizer technology. Eight-six percent said they would consider attending future Extension field days. Ninety-five percent agreed or strongly agreed that it is important that Extension continues local field days and research plot work.

Forty-six percent of those in attendance had attended previous field days at the research site. Of these, 64 percent agreed or strongly agreed that their forage management changed because of attending the field day. Fifty-five percent agreed or strongly agreed that information from the last field day helped them change their pasture fertilization management and cope with high 2008 and 2009 fertilizer prices.

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.

Producers in central Missouri have readily accepted this multi-disciplinary, local research/education approach. To date, over 200 producers from eight counties have attended four on-site workshops. Extension agronomy specialists present plot data on yield and discuss fertilizer management. Nutrient yield and quality differences between fertility treatments as they apply to beef cattle feeding programs are discussed by Extension livestock specialists. Extension agriculture business specialists highlight the economics of forage production. Producers see the impact of a particular fertilizer program by comparing plots. They learn to incorporate forage quality information into economical beef cattle feeding programs. Producer survey responses include: “You brought up points I hadn’t thought about,” and “You guys always hit the nail on the head.”

Summary points from this research/demonstration project to date are:

- Aggressive harvest management can lead to high yields and high forage quality.
- Producers must decide how to deal with potential reduced yields if the forage fertility program is reduced.
- Producers may need to change fertilizer strategies and target-apply fertilizer when forage is needed and can be harvested in a timely manner, rather than blanket fertilizer applications over all their acres.
- Producers need to consider and compare the costs of supplemental feeds with the cost of fertilizer application to increase tons of hay and pounds of nutrients produced on the farm.
- Producers have changed their forage management as a result attending a project field day.
- Producers have changed their forage fertilizer practices as a result of this project.
- A vast majority of producers attending our field days feel it is important Extension specialists continue doing local research and demonstration projects.

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. Three-Year Weighted Yield Results, lbs dry matter per acre.

Treatment	Yield, lbs DM/acre
100-65-60	12,360[a]
0-65-60 rcl	10,068[b]
50-30-30	9,092[bc]
0-65-60 lesp	8,737[cd]
50-30-0	8,485[cd]
0-30-0	8,431[cd]
50-0-0	8,101[cd]
0-0-0	7,655[d]
0-0-30	7,627[d]

Means in columns with different superscripts are different ($P<.05$)

Table 3. Three-Year Weighted Average CP %.

Treatment	% CP
100-65-60	12.4[a]
0-65-60 rcl	12.4[a]
0-30-0	12.0[ab]
0-0-30	11.7[abc]
0-65-60 lesp	11.4[abc]
50-30-0	11.3[abc]
0-0-0	11.0[bc]
50-30-30	10.8[c]
50-0-0	10.6[c]

Means in columns with different superscripts are different ($P<.05$)

Table 4. Three-Year Weighted Average TDN %.

Treatment	% TDN
100-65-60	63.5[a]
0-0-0	62.7[ab]
0-65-60 lesp	62.6[ab]
0-65-60 rcl	62.1[bc]
50-30-30	62.1[bc]
50-30-0	61.9[bc]
0-0-30	61.8[bc]
50-0-0	61.4[bc]
0-30-0	60.9[c]

Means in columns with different superscripts are different ($P<.05$)

Table 5. Three-Year Weighted Average Ca %.

Treatment	% Ca
0-30-0	1.02^{a}
0-65-60 rcl	$.91^{b}$
0-0-0	$.88^{bc}$
0-0-30	$.86^{bcd}$
50-30-0	$.80^{cde}$
50-30-30	$.77^{de}$
0-65-60 lesp	$.77^{de}$
50-0-0	$.74^{ef}$
100-65-60	$.65^{f}$

Means in columns with different superscripts are different (P<.05)

Table 6. Three-Year Weighted Average Mg %.

Treatment	% Mg
0-0-0	$.33^{a}$
0-65-60 rcl	$.31^{ab}$
0-30-0	$.30^{abc}$
0-0-30	$.29^{abc}$
100-65-60	$.29^{abc}$
50-30-30	$.28^{bc}$
0-65-60 lesp	$.28^{bc}$
50-30-0	$.27^{cd}$
50-0-0	$.24^{d}$

Means in columns with different superscripts are different (P<.05)

Table 7. Three-Year Weighted Average K %.

Treatment	% K
50-30-0	1.95^{a}
50-0-0	1.94^{a}
0-65-60 lesp	1.88^{ab}
0-65-60 rcl	1.81^{abc}
0-0-30	1.76^{abc}
50-30-30	1.73^{bc}
100-65-60	1.68^{c}
0-30-0	1.67^{c}
0-0-0	1.63^{c}

Means in columns with different superscripts are different (P<.05)

Table 8. Three-Year Weighted Average P %.

Treatment	% P
100-65-60	.23[a]
0-65-60 lesp	.23[a]
0-65-60 rcl	.22[ab]
50-30-0	.19[bc]
50-30-30	.18[cd]
0-30-0	.16[cde]
0-0-0	.16[cde]
50-0-0	.15[de]
0-0-30	.14[e]

Means in columns with different superscripts are different (P<.05)

Table 9. Nutrient Requirements of Selected Classes of Beef Cattle.

Animal Description	CP, %	TDN, %	Ca, %	P, %	K, %	Mg, %
1200 lb. dry cow, mid 1/3 gestation	7.9	54	.26	.17	.60	.12
1200 lb. lactating cow @ 20 pounds of milk	9.8	58	.28	.19	.70	.20
600 lb steer, 1.00 lbs adg	9.3	58	.31	.17	.60	.10
600 lb steer, 1.50 lbs adg	10.6	63	.38	.20	.60	.10
600 lb steer, 2.00 lbs adg	12.1	68	.46	.23	.60	.10

Table 10. Fertilizer Prices by Year, $/lb.

	2007	2008	2009
N	$0.50	$0.90	$0.45
P	$0.34	$1.01	$0.48
K	$0.23	$0.75	$0.67

Table 11. 3-Year Average Yield, Income and Ranking.

Treatment	Yield, lbs. DM / Acre	Yield Rank	Income, $ per Acre	Income Rank
100-65-60	12,630[a]	1	202.46	1
0-65-60 rcl	10,068[b]	2	183.26	2
50-30-30	9,092[bc]	3	155.81	5
0-65-60 lesp	8,737[cd]	4	136.28	9
50-30-0	8,485[cd]	5	150.89	8
0-30-0	8,431[cd]	6	179.83	3
50-0-0	8,101[cd]	7	155.63	6
0-0-0	7,655[d]	8	175.74	4
0-0-30	7,627[d]	9	153.25	7

Table 12. Yield and Income Ranking by Year.

	2007	2007	2008	2008	2009	2009
Treatment	Yield Rank	Income Rank	Yield Rank	Income Rank	Yield Rank	Income Rank
100-65-60	1	1	1	7	1	5
0-65-60 rcl	2	3	2	1	3	4
0-0-0	3	2	9	4	9	3
50-30-30	4	4	3	5	6	8
0-65-60 lesp	5	6	4	8	5	9
50-0-0	6	7	7	9	7	6
0-0-30	7	5	8	6	8	7
50-30-0	8	9	5	3	4	2
0-30-0	9	8	6	2	2	1

Table 13. 3-Year Average 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										
Total yield	lbs/acre	8101	8485	8431	7627	9092	7655	12,360	10,068	8737
Income/acre	$70.59 per ton*	**$285.92**	**$299.48**	**$297.57**	**$269.19**	**$320.90**	**$270.18**	**$436.25**	**$355.35**	**$308.37**
Fertilizer costs/acre**										
N - Urea (46% N)	$0.617	30.85	30.85	0.00	0.00	30.85	0.00	61.70	0.00	0.00
P - Phosphate	$0.610	0.00	18.30	18.30	0.00	18.30	0.00	39.65	39.65	39.65
K - Potash	$0.550	0.00	0.00	0.00	16.50	16.50	0.00	33.00	33.00	33.00
Application charge	$5.00/acre	5.00	5.00	5.00	5.00	5.00	0.00	5.00	5.00	5.00
Total Fertilizer cost/Acre		***$35.85***	***$54.15***	***$23.30***	***$21.50***	***$70.65***	***$0.00***	***$139.35***	***$77.65***	***$77.65***
Operating costs/acre***										
Crop supplies		5.48	5.48	5.48	5.48	5.48	5.48	5.48	5.48	5.48
Custom hire & rental		13.96	13.96	13.96	13.96	13.96	13.96	13.96	13.96	13.96
Machinery fuel		5.42	5.42	5.42	5.42	5.42	5.42	5.42	5.42	5.42
Machinery repairs & maintenance		5.04	5.04	5.04	5.04	5.04	5.04	5.04	5.04	5.04
Operator & hired labor		8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00
Operating interest @ 8.42% x 1/2 year		4.92	4.92	4.92	4.92	4.92	4.92	4.92	4.92	4.92
Total Operating costs/acre		***$42.82***	***$42.82***	***$42.82***	***$42.82***	***$42.82***	***$42.82***	***$42.82***	***$42.82***	***$42.82***
Total Fert. & Operating Costs/Acre		**$78.67**	**$96.97**	**$66.12**	**$64.32**	**$113.47**	**$42.82**	**$182.17**	**$120.47**	**$120.47**
Income Over Fert. & Op. Cost/Acre		**$207.25**	**$202.51**	**$231.45**	**$204.87**	**$207.43**	**$227.36**	**$254.08**	**$234.88**	**$187.90**
Ownership Costs/Acre***										
Farm business overhead		2.68	2.68	2.68	2.68	2.68	2.68	2.68	2.68	2.68
Machinery overhead		8.36	8.36	8.36	8.36	8.36	8.36	8.36	8.36	8.36
Machinery depreciation		9.20	9.20	9.20	9.20	9.20	9.20	9.20	9.20	9.20
Real estate charge		31.38	31.38	31.38	31.38	31.38	31.38	31.38	31.38	31.38
Total Ownership Cost/Acre		**$51.62**	**$51.62**	**$51.62**	**$51.62**	**$51.62**	**$51.62**	**$51.62**	**$51.62**	**$51.62**
Total Cost/Acre		**$130.29**	**$148.59**	**$117.74**	**$115.94**	**$165.09**	**$94.44**	**$233.79**	**$172.09**	**$172.09**
Income Over Total Cost/Acre		**$155.63**	**$150.89**	**$179.83**	**$153.25**	**$155.81**	**$175.74**	**$202.46**	**$183.26**	**$136.28**

* = Hay price is on a 100% dry matter basis; based on hay price of $36 per 1200 pound round bale at 85% dry matter.
** = 3-year average of actual fertilizer costs
*** = 3-year average from 2007, 2008 and 2009 FAPRI Fescue/RedClover Hay, Large Round Bale budgets.

Environmentally Sound High Impact Forage Management Research Based Demonstrations for Increased Livestock Profitability by Increasing Forage Production and Quality - Supplemental

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 was over-seeded with legumes again in 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 allowed us to add this supplemental experiment that included 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 were harvested three times annually to follow annual forage response to management changes and long term economic impact from increased productivity and quality. Forage analysis was conducted on each of the treatments during each harvest to measure forage quality variations in a year round forage production system. Field days were conducted to provide demonstrations of proven research based concepts. These concepts included: 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 total was 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 (10,849 pounds per acre vs. 10,430 pounds per acre respectively). Even with this separation in the year of application, we expect this variation to widen with more reaction time in 2009.

2009 Results

There appears to be no differences in measured parameters in 2008 and 2009. Treatment means do not show large differences in yield or forage quality parameters that would make us believe there were statistical differences. We did not analyze for trace minerals in 2009. Data for 2008 and 2009 are listed in Table 14 and Table 15 below.

Table 14. Yield and Quality Differences Between Waste Lime and Agricultural Lime, 2008 and 2009.

Year	2008							2009					
Harvest date	5-13		8-5		11-4			5-21		8-10		11-2	
Treatment	Waste Lime	Ag Lime	Waste Lime	Ag Lime	Waste Lime	Ag Lime		Waste Lime	Ag Lime	Waste Lime	Ag Lime	Waste Lime	Ag Lime
DM Yield, lbs/acre	4815	5206	3883	3737	1732	1906		5698	5461	3772	3707	2231	2201
CP,%	16.8	16.4	11.1	11.3	9.2	10.1		10.0	9.9	9.3	8.1	9.4	9.2
TDN, %	67.9	66.8	61.7	62.2	67.9	67.6		58.2	58.4	59.1	59.8	63.5	62.1
Ca, %	.68	.66	.67	.70	.71	.83		.41	.40	.80	.66	.63	.59
P, %	.38	.37	.67	.70	.22	.23		.24	.24	.19	.21	.24	.23
Mg,%	.19	.19	.34	.33	.33	.28		.19	.18	.26	.23	.23	.21
K,%	2.59	2.53	1.25	1.25	1.01	1.34		1.95	1.88	1.20	1.44	1.17	1.10
Zn, ppm	23	23	24	29	22	23							
Cu, ppm	9	8	10	13	8	8							
Fe, ppm	117	210	83	91	77	137							
Mn, ppm	79	72	91	63	133	97							

Table 15. Yield and Weighted Average Forage Quality for Waste Lime and Agricultural Lime, 2008 and 2009.

Year	2008		2009	
Treatment	Waste Lime	Ag Lime	Waste Lime	Ag Lime
DM Yield, lbs/acre	10,430	10,849	11,701	11,369
CP, %, wt. avg.	13.4	13.5	9.7	9.2
TDN, %, wt. avg.	65.6	65.4	59.5	59.6
Ca, %, wt. avg.	0.68	0.70	0.58	0.52
P, %, wt. avg.	0.46	0.46	0.22	0.23
Mg, %, wt. avg.	0.27	0.25	0.22	0.20
K, %, wt. avg.	1.83	1.88	1.56	1.59
Zn, ppm, wt. avg.	23	25		
Cu, ppm, wt. avg.	9	10		
Fe, ppm, wt. avg.	98	156		
Mn, ppm, wt. avg.	92	73		

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 was 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 nearing the end of 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).

Results and Discussion

Fescue

Hay yields were higher with P and K fertilizer programs than N only and the untreated check (Table 2). On average, P and K increased fescue hay yields 0.7 tons per acre compared to N only. Throughout the fertilizer buildup study we have observed a change in fescue density and weed infestation which was impacted by fertility treatments. In 2009, when the orchardgrass and fescue seed heads were present in early June, we recorded the amounts in each plot (Table 3). Orchardgrass stands increased relative to fescue with P and K fertilizer compared to untreated check. Untreated check plots had the most broomsedge, foxtail, and greasegrass infestations (Table 4).

Rice/Soybean Rotation

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 (Table 5). All of the fertilizer programs produced more rice and soybean yields than the untreated check (N only for rice). But there does not appear to be a yield advantage to bringing up P and K levels faster than 8 years.

Summary

On low fertility soils, fescue hay, soybean, and rice yields were consistently by P and K fertilizer applications. In fescue plots, P and K promoted shifts in plant types. Fertilizer increased orchardgrass levels and decreased undesireable species such as broomsedge and foxtails. Yield averages over the seven year life of the study showed that crops on 1 year, 4 year, and 8 year PK buildup programs produced the same amount of yield. Since the current default buildup in MU recommendations is 8 years, we found no evidence that this should be changed.

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. Annual dry matter fescue hay yields from P and K buildup programs on an Ozark Highland hay field near Mountain View, Missouri.

Buildup	2004	2005	2006	2007	2008	2009	2010	Average
	------------------------------ton/acre--------------------------							
Check	1.5	0.9	2.2	1.0	1.7	1.9	1.6	1.5
N only	2.1	1.3	1.6	1.4	2.5	2.7	2.4	2.0
1-year	3.0	2.0	2.2	1.8	2.5	3.8	3.3	2.7
4-year	2.8	2.0	2.2	2.1	2.8	3.8	3.2	2.7
8-year	2.6	1.9	2.3	2.1	2.7	3.7	3.3	2.7

Table 3. Spring estimate of orchardgrass and fescue distribution, soil test levels and dry matter hay yields from two cuttings in 2009.

Build-up Program	Orchard † grass	Fescue	Soil test results K	Soil test results P	Dry matter yield June 6	Dry matter yield Nov 20	Dry matter yield Total
	----% of plot area----		---lb/acre---		----------ton/acre------------		
Check	13	69	183	16	1.8	2.5	4.2
N only	32	59	126	16	3.1	3.0	6.2
1-year	58	41	173	41	5.1	3.6	8.7
4-year	57	40	172	61	5.0	3.6	8.6
8-year	63	34	191	42	5.3	5.0	10.2

† Cool season grasses were identified by their seed heads on June 6.

Table 4. Plants identified growing in fescue hay plots in September 4, 2009.

Program	CoolG†	BrmS	Foxt	GreG	Plum	Mint	HsNt	Lesp	Forb
	------------------------------% of plot area--------------------------------------								
Check	46	19	21	6	3	0	1	4	0
N only	81	9	6	1	1	0	1	0	0
1 yr bldup	88	3	0	4	0	0	0	4	0
4 yr bldup	75	0	3	4	5	10	0	0	1
8 yr bldup	86	1	8	3	0	0	1	0	0

† Abbreviations for plants are CoolG=coolseason grasses; BrmS=broomsedge; Foxt=foxtail; GreG= grease grass; Plum= plum tree; Mint= mint; HsNt= horsenettle; Lesp= lespedeza clover

Table 5. 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 Yield	2007	2008	2009	2010	Average
Rice		---lb/acre---				-----------------------bushels/acre-----------------------					
	N only check	0	0	168	142	136	133	122	138	168	144
	1-yr/rice target	41†	38†	192	160	133	192	141	146	197	166
	4-year/rice target	41†	38†	193	161	136	175	139	149	198	164
	8-year/rice target	45	67	187	159	143	174	136	146	213	165
	1-year/soybean target	41†	38†	172	149	138	189	134	159	164	158
	4-year/soybean target	41†	38†	170	161	150	188	138	161	158	161
	8-year/soybean target	56	97	165	155	134	190	150	161	146	157
Soybean	Untreated check	0	0	40	39	53	37	33	60	-‡	44
	1-year/rice target	38†	65	53	47	63	44	17	69	-	49
	4-year/rice target	38‡	65	53	49	60	45	23	61	-	49
	8-year/rice target	38	65	51	45	62	43	29	62	-	49
	1-year/soybean target	38†	65	58	54	57	49	23	60	-	50
	4-year/soybean target	38‡	65	51	46	55	44	28	73	-	50
	8-year/soybean target	50	65	51	43	57	48	22	67	-	48

† 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 and 2009.

‡ Hot weather in 2010 cause soybean pod shattering before harvest.

Switchgrass and Sweet Sorghum Fertilization for Bioenergy Feedstocks

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

Nutrient uptake and crop removal from sweet sorghum and switchgrass was studied in model biofuel production systems in Missouri. Although both crops are relatively efficient users of fertilizer, farmers should consider the cost to replenish nutrients being "mined" from their fields in biofuel systems. Sugars in sweet sorghum juice are readily fermented by yeast into ethanol. The remaining biomass material after juice is extracted is called bagasse. Bagasse can be feed to livestock or the cellulose broken down into sugars by enzymes. Sweet sorghum can be harvested with a silage cutter which removes all leaves and stalks from the field or with a modified sugar cane harvester which strips the leaves and only removes the stalks. Prototype sweet sorghum harvest machines have been tested that squeeze the juice in the field and leave stalks and leaves on the soil. One potential advantage from this system to farmers is the nutrients in the leaves and bagasse are not removed from the field. In a switchgrass ethanol system, all the nutrients in the biomass are removed from the field because the cellulose is treated with enzymes to make sugars for fermentation. Preliminary tissue test showed that nutrient content in switchgrass harvested varied by the time of year biomass was harvested. This study measured nutrient content in switchgrass biomass from summer and fall harvest dates to find a time that the least amount of fertilizer would be needed to offset crop removal.

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. 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.

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. In 2008 and 2009, we expanded the sites to include a Sharkey clay and Malden fine sandy loam. Atrazine and metolachor gave good grass and broadleaf weed control. Before planting, sweet sorghum seed was treated with fluxofenin herbicide seed safener to minimize crop injury. 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 was broadcast applied. Corn plots were harvested with a plot combine and sweet sorghum plots harvested with a sickle mower. Sugars in the sorghum stalks were analyzed for sucrose, glucose, and fructose.

Results:

Switchgrass. The overall goal of the switchgrass research is to determine the best time of the growing season to harvest the biomass in order to minimize nutrient removal and sustain the system. This experiment was conducted on a 10-year old switchgrass stand near Portageville, Missouri. Four plots were delimited and at different time of the year, biomass was harvested within these plots. Using an atomic absorption spectrometer, nutrient content was determined in the biomass. The maximum feedstock yield was obtained in October (9.8 tons/acre); while a slight loss of biomass was encountered from October to November due to the fall of seed and the wind that cut some dried leaves off the plants (Table 1). The big challenge for Missouri farmers harvesting in late fall is the potential onset of winter rains and poor hay drying conditions. Phosphorus and potassium removal was lowest in the November harvest, but the magnitude of change was greatest with potassium. The least decrease was observed with the micronutrients such as Zn, Cu, Mn, and Fe. November was the optimum time to harvest in order to maximize the yield and minimize nutrient removal. Using conversion factors in the literature, more than 7500 liters/ha of ethanol could be produced from switchgrass biomass. Until cellulose enzymes can be produced economically switchgrass may be more used for biofuel in pellets for burning in heating and electricity generating.

Sweet sorghum was an efficient user of nitrogen fertilizer. Averaged across years, sweet sorghum yields Tiptonville silt loam increased with N fertilization to 60 lb N per acre (Table 2). The seed heads on sweet sorghum are located on the top of the stalks. A significant effect of soil type was found for the fresh and the dried biomass yield of sweet sorghum ($P<.0001$). In 2009, the silt loam site followed corn. In the same experiment, corn yields increased to 120 to 160 lb N per acre (Table 3). As the plant matures carbohydrates are translocated from the stalks to the head to make starch in the seeds. To maintain high sugar content in the stems we removed the seed heads at "when the seed is in the milk stage. We found that the juice in sweet sorghum contained almost one-half of the P_2O_5 and two thirds of the K_2O in the biomass (Table 4).

Summary

The practical implications of this research are that sweet sorghum is more efficient in producing maximum yields from nitrogen than corn. Harvesting sweet sorghum with a silage cutter would remove more nutrients than a sugar cane harvester. However, since most of the P and K are in the juice there was not as much difference as we expected. If the ethanol producing facility is close to production fields, growers should consider returning the vinasse material to the field after juice fermentation and distillation to replenish the soil with nutrients. The least amount of P, and K was removed from October and November switchgrass harvests, but growers need to access the risk of rainfall as the fall progresses in Missouri.

Table 1. Phosphorus and potassium removed with switchgrass biomass harvest at different times of the year in 2008 and 2009.

Harvest	Removed Phosphorus			Removed Potassium		
	-----lb P_2O_5 per acre------			---------lb K_2O per acre----------		
	2008	2009	Average	2008	2009	Average
May	16	23	20	105	260	183
June	29	31	30	251	395	323
July	23	45	34	188	379	283
October	41	31	36	171	258	215
November	12	23	17	64	110	87

Table 2. Fresh weight yield of sweet sorghum produced on Tiptonville silt loam.

Nitrogen	2007	2008	2009	2010	Average
lb N/acre	-----------------tons fresh wt per acre----------------				
0	15.7	25.9	13.0	33.4	22.0
20	14.6	23.5	15.2	29.7	20.8
40	18.4	36.7	16.4	30.7	25.6
60	20.4	44.3	21.9	31.7	29.6
80	17.6	47.1	21.0	36.5	30.6
100	18.3	38.6	21.1	40.7	29.7
120	16.0	40.1	23.1	29.4	27.2

Table 3. Grain yield of corn produced on Tiptonville silt loam.

Nitrogen	2007	2008	2009	2010	Average
lb N/acre	-----------------bushels per acre---------------				
0	57	96	20	65	60
40	132	90	46	88	89
80	175	128	87	109	125
120	203	169	95	118	146
160	205	163	102	116	147
200	182	134	104	126	137
240	184	139	102	131	139

Table 4. Average phosphorus and potassium removed in processing sweet sorghum for ethanol production.

Nutrient	Juice	Leaves	Bagasse ǂ	Total
removed	--------------------	lb nutrient per acre	---------------------	
P_2O_5	10	6	7	24
K_2O	123	40	26	189

ǂ Bagasse is the remaining stalk material after juice has been squeezed.

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Progress Reports

Title:
A Long-Term Study to Further Enhance Variable Rate Fertility Management

Investigator(s):
Kent Shannon, Todd Lorenz, Joni Harper, Peter Scharf, and Gene Schmitz

Objectives:

The objectives of this project are:

1) To evaluate proposed changes in University of Missouri fertilizer recommendations in variable rate fertility management of P and K as relates to soil test critical values.

2) To gain a better understanding of how yield map data can be used to fine tune removal rates of P and K in a variable rate fertility system.

3) Provide producers and service providers the production and economic information necessary to make more informed variable rate fertility management decisions.

The main goal of the project is to better understand how producers can further improve the efficiency of variable rate fertility management of P and K while maintaining or improving crop yields. With the volatility of P and K prices, being able to further improve fertilizer use efficiency is important in today's production system. The result of the project also has the potential to further increase the adoption of variable rate technologies which not only effects profitability but in the end it also protects the environment.

Procedures:

In the spring of 2010, three crop fields were chosen for the project. Fields ranged in size from 63 to 108 acres. Each of the fields selected were highly visibility and will be utilized for upcoming field days throughout the remainder of the project. The fields selected will be in a corn-soybean rotation for the duration of the project. All three fields have been grid soil sampled on a 1 acre grid. Two of the fields received fertility treatments in the spring of 2010. The third field chosen was in wheat followed by double crop soybeans and was soil sampled after harvest in the fall of 2010 and will receive its first fertilizer treatments in the spring of 2011.

There were four treatments applied to be used to evaluate the effectiveness and economics of furthering enhancing variable rate fertility management. These treatments included:

1) A control which receives no fertilizer.
2) Whole field management of P and K fertilizer.
3) Variable rate fertility management of P and K based on grid soil sampling using current University of Missouri fertilizer recommendations.
4) Variable rate fertility management of P and K based on grid soil sampling using proposed University of Missouri fertilizer recommendations using soil test critical values of 30 lbs/acre for P and 200 lbs/acre for K.

The four treatments were laid out to minimize any differences in soil type and terrain within the field. Each treatment was replicated at 12 times in each of the two fields where treatments were applied in the spring of 2010. Plots were 80' x 300' in size. The 80' width was chosen because of the width of fertilizer application equipment and the 300' length to assure quality as-applied fertilizer rate data and yield map data for analysis. Plot layout for the two fields implemented can be seen in Figures 1 and 2. Plots were embedded in a variable rate application map and applied with standard variable rate fertilizer application equipment. Plots were harvested with a yield mapping equipped combine collecting data using a one second time interval.

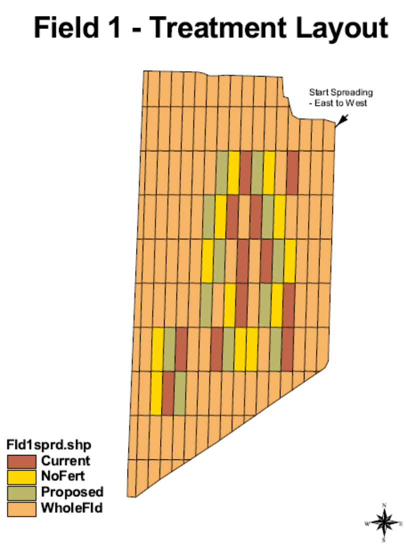

Figure 6. Plot Layout for Field 1

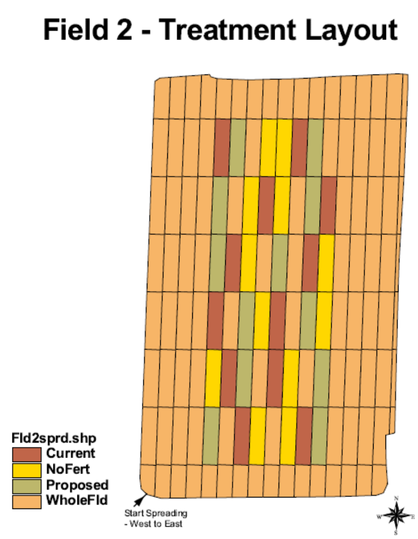

Figure 7. Plot Layout for Field 2

Results for 2010:

Yield data was processed utilizing GIS software to analyze treatment differences. At the time of this report only yield has been analyzed. Further analysis will be conducted to estimate P and K removal rates utilizing grain yield data and post harvest soil sampling information. The post harvest soil sampling information will also give an indication of the performance of the fertilizer recommendations at the completion of the study.

Plot yields ranged from 143 to 195 bu/acre with the mean being 163 bu/acre for Field 1. Field 2 had plot yield ranging from 92 to 171 bu/acre with a mean of 122 bu/acre. There were no significant yield differences between treatments at the 5% probability level. Though there were significant yield differences between replications which needs to be further explored. A detailed summary of each field can be found in the following tables. It should be noted only 5 replications were analyzed for Fields 1 and 2. This was due to the quality of as-applied fertilizer rate data and yield data.

Yield Results for Field 1

	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5	Treatment Mean
Treatment	---- bu/acre ----					
No Fertilizer	163.4	172.3	155.2	188.2	146.2	164.8
Whole Field	149.2	150.7	142.6	190.8	148.9	156.1
Current Recommendations	150.8	180.2	153.0	182.3	151.3	163.0
Proposed Recommendations	156.4	171.7	153.5	194.8	165.4	169.1
Block Mean	154.9	170.4	150.6	189.2	152.8	163.1
No significant treatment differences (P=0.05)						LSD 9.9

Yield Results for Field 2

	Rep 1	Rep 2	Rep 3	Rep 4	Rep 5	Treatment Mean
Treatment	---- bu/acre ----					
No Fertilizer	134.5	126.7	102.8	121.1	92.3	116.8
Whole Field	171.3	101.4	99.6	110.4	126.3	118.6
Current Recommendations	145.1	137.2	98.9	139.2	135.0	133.0
Proposed Recommendations	153.4	106.8	125.1	107.0	134.8	120.9
Block Mean	150.5	116.6	106.7	116.6	124.3	122.2
No significant treatment differences (P=0.05)						LSD 22.7

Also included are tables summarizing fertilizer recommendations for P and K for the two fields by treatment. It should be noted by using the proposed University of Missouri fertilizer recommendations decreased fertilizer requirements of both P and K in both Fields 1 and 2. These differences were considerably less than current University of

Missouri recommendations. In Field 1, the P recommendation was 2624 lbs less and the K recommendation was 4048 lbs less. Field 2 shows the same trend. The P recommendation was 6179 lbs less and the K recommendation was 4147 lbs/acre less.

Fertilizer Recommendations for P and K by Treatment for Field 1

Treatment	Total Pounds of P	Total Pounds of K
Whole Field	**3920**	**6770**
Current Recommendations	**3607**	**5810**
Proposed Recommendations	**983**	**1762**

Fertilizer Recommendations for P and K by Treatment for Field 2

Treatment	Total Pounds of P	Total Pounds of K
Whole Field	**10766**	**5700**
Current Recommendations	**11099**	**6220**
Proposed Recommendations	**4920**	**2073**

Objectives for 2011:

1. Apply fertilizer treatments to the three fields in the spring of 2011. Field 1 and 2 will in planted to soybeans and Field 3 will be planted to corn.
2. Further analyze post harvest soil samples and yield data for P and K crop removal and soil test trends by treatment.
3. Conduct a field day in the summer of 2011 to discuss results from 2010.

BUDGET for 2010 and 2011

Item	Description	2010	2011
Soil Tests			
800 pre and post @ $10.00		4,000	0
Plot Specific Soil Tests		200	0
Soil Sampling Equipment			
Computer Hardware/Software/Sampling Equipment		4125	0
Supplies		125	0
Field Days		500	500
Publication		300	300
Travel		780	520
Sub total	by year	$10,030	$1,320
Support Salary	25% of the above total	$2,508	$530
Grant Total	by year total	$12,538	$1,850

Budget Request for 2011 $1,850

Nutrient Management for Biofuel Crop Production

Tim Reinbott, Manjula Nathan, Kelly Nelson and Bob Kremer

Tim Reinbott, Manjula Nathan, Kelly Nelson of Division of Plant Sciences and Robert Kremer, USDA-ARS, Department of Soils, Environmental, and Atmospheric Sciences

Objectives:

1. To determine the optimum nutrient management practices for environmentally safe and economically viable biofuel crop production.
2. To evaluate long-term effects of biofuel crop production on selected chemical, physical and microbiological properties of crop land

Procedures:

- Experimental plots established for research on biofuel crops production and management practices at Bradford and Greenley Research and Extension Centers near Columbia and Novelty are used in this study. The experimental design is an 8x3 factorial laid out in a split-plot design with three replications at Greenley and four replications at Bradford.
- The main plots consisted of eight bio-fuel cropping systems as listed below:
    - Continuous Corn for grain only
    - Continuous Corn for grain and stover removal
    - Corn-soybean rotation for grain only
    - Soybean-corn rotation for grain only
    - Sweet Sorghum /Wheat double crop
    - Miscanthus
    - Switchgrass
    - Tall Fescue
- The subplots received the following three fertilizer treatments:
    1. University of Missouri Fertilizer and lime recommendations with a 4 year P and K Buildup
    2. Fertilizer recommendations based on annual crop removal values with one year P and K buildup
    3. Control- 0 P, 0K
- The following soil chemical, physical and microbiological measurements collected each year.
    - Initial Soil fertility measurements (pH, NA, P, K, Ca, Mg, OM, CEC)
    - Organic C and total N measurements
    - Wet aggregate stability measurements to determine structural changes
    - Carbon and Nitrogen mineralization using selected soil enzyme assays
    - End of season soil fertility measurements
- Plant measurements:
    1. Dry matter production (Treatments 2, 5-8)
    2. Grain yield (Treatments 1-4)
    3. Nutrient uptake (based on dry matter production and grain yield)

Experimental plots for research on bio-fuel crops production were established in 2008 at the Bradford and Greenley Research and Extension Centers. The experimental design was an 8x3 factorial laid out in a split plot design. The main plots were eight bio-fuel cropping systems: 1)continuous corn for grain (CCG), 2) continuous corn for grain and stover removal (CCGS), 3) corn-soybean rotation for grain (CSG), 4)soybean-corn rotation for grain (SCG), 5) sweet sorghum-wheat double crop (SSW), 6) miscanthus (MIS), 7) switch grass (SWI) and 8) tall fescue (TF). Subplots received the fertilizer treatments: 1) MU recommended P and K with a 4 year buildup 2) fertilizer recommendations based on annual crop removal values and 3) control without P and K. Soil samples were collected for soil fertility analysis (pH, P, K, Ca, Mg, OM and CEC), and soil quality measurements. The total organic carbon (TOC) and total N (TN) by dry combustion, and C:N ratios were calculated. A wet sieving method was used to determine stability of aggregates (WSA; >250 um diameter). Soil microbial activity was assessed by measuring dehydrogenase (DEHYD) and glucosaminidase (GLUCO) enzyme activities using in vitro assays. Grain yield, and dry matter production and nutrient uptake measurements were made. Statistical analysis was performed on TOC, TN, C:N, DEHYD, and GLUCO using SAS analysis..

Fertilizer Treatments 2010:

Fertilizer treatments for 2010 were determined by either spring 2010 soil test measurements based upon University of Missouri Soil Test Recommendations (Tables 1 and 2) or based upon removal from 2009 grain, stover, and dry matter yield (Tables 3 and 4). Each rep of each treatment was measured individually and fertilizer treatments were applied based upon those individual measurements. A summary of the mean fertilizer amounts across all replications applied at Bradford is listed in Table 5. Generally, fertilizer rates were greater when based upon maintenance and buildup rather than removal with the exceptions of tall fescue and sweet sorghum.

Table 1. Grain and biomass nutrient concentration, and nutrient removal based on 2009 harvest grain, stover, and biomass at Greenley.

Cropping Systems	Fertilizer	N %	P %	K %	P_2O_5 lb/acre	K_2O lb/acre
Continuous Corn (Grain only)	0 P and K	1.460	0.271	0.275	53.7	29.1
	Buildup	1.456	0.299	0.308	71.2	39.2
	Removal	1.385	0.301	0.306	83.8	45.2
Continuous Corn (Stover removed)	0 P and K	1.362	0.315	0.304	117.2	103.8
	Buildup	1.392	0.308	0.305	132.9	123.3
	Removal	1.514	0.325	0.307	128.4	107.0
Corn/Soybean Rotation	0 P and K	1.535	0.272	0.266	81.1	41.5
	Buildup	1.521	0.293	0.288	86.5	44.5
	Removal	1.507	0.300	0.288	91.3	45.6
Miscanthus	0 P and K	0.616	0.146	0.241	0.3	0.3
	Buildup	0.659	0.160	0.325	0.3	0.4
	Removal	0.549	0.120	0.259	0.4	0.4
Soybean/Corn Rotation	0 P and K	5.361	0.594	1.701	46.0	69.2
	Buildup	5.346	0.614	1.716	39.5	57.8
	Removal	5.346	0.630	1.754	35.4	51.4
Sweet Sorghum	0 P and K	1.182	0.236	0.876	61.4	119.0
	Buildup	1.275	0.243	0.963	72.1	148.6
	Removal	1.197	0.241	1.162	76.5	196.3
Switchgrass	0 P and K	0.792	0.136	0.400	27.9	41.5
	Buildup	0.818	0.124	0.356	13.7	20.4
	Removal	0.693	0.142	0.428	20.7	35.5
Tall Fescue	0 P and K	1.537	0.263	1.854	34.5	107.5
	Buildup	1.458	0.279	1.940	40.3	130.9
	Removal	1.851	0.333	2.209	44.2	139.3

By Cropping System:

Cropping Systems	N %	P %	K %	P_2O_5 lb/acre	K_2O lb/acre
Continuous Corn (Grain only)	1.434	0.290	0.296	69.5	37.8
Continuous Corn (Stover removed)	1.422	0.316	0.306	126.2	111.3
Corn/Soybean Rotation	1.521	0.288	0.280	86.3	43.9
Miscanthus	0.608	0.142	0.275	0.4	0.4
Soybean/Corn Rotation	5.351	0.613	1.724	40.3	59.5
Sweet Sorghum	1.218	0.240	1.000	70.0	154.6
Switchgrass	0.768	0.134	0.395	20.8	32.5
Tall Fescue	1.615	0.292	2.001	39.7	125.9

Table 2. Grain and biomass nutrient concentration, and nutrient removal based on 2009 grain, stover, and dry matter yield at Bradford.

Cropping Systems	Fertilizer	N %	P %	K %	P_2O_5 lb/acre	K_2O lb/acre
Continuous Corn (Grain only)	0 P and K	1.329	0.303	0.314	34.7	18.9
	Buildup	1.275	0.311	0.320	51.3	27.5
	Removal	1.445	0.296	0.315	53.3	29.6
Continuous Corn (Stover removed)	0 P and K	1.328	0.321	0.341	60.0	57.6
	Buildup	1.363	0.327	0.308	72.9	72.4
	Removal	1.421	0.338	0.292	74.8	72.2
Corn/Soybean Rotation	0 P and K	1.520	0.337	0.288	30.2	13.6
	Buildup	1.488	0.327	0.282	44.0	19.9
	Removal	1.552	0.338	0.294	45.5	20.7
Miscanthus	0 P and K	0.366	0.097	0.345	30.0	56.6
	Buildup	0.343	0.100	0.304	27.8	44.3
	Removal	0.387	0.097	0.393	34.5	73.7
Soybean/Corn Rotation	0 P and K	6.858	0.640	1.231	26.4	26.6
	Buildup	6.636	0.636	1.210	26.2	26.2
	Removal	6.764	0.637	1.468	26.3	31.8
Sweet Sorghum	0 P and K	0.635	0.193	0.692	41.8	80.8
	Buildup	0.724	0.208	0.854	64.9	137.4
	Removal	0.623	0.209	0.866	52.6	124.5
Switchgrass	0 P and K	0.213	0.131	0.281	27.3	30.4
	Buildup	0.207	0.126	0.267	26.5	29.9
	Removal	0.216	0.154	0.371	24.8	32.9
Tall Fescue	0 P and K	1.444	0.285	1.439	35.6	94.8
	Buildup	1.674	0.285	1.740	42.6	138.2
	Removal	1.461	0.294	1.636	38.8	114.9

By Cropping Systems

Cropping Systems	N %	P %	K %	P_2O_5 lb/acre	K_2O lb/acre
Continuous Corn (Grain only)	1.350	0.303	0.316	46.4	25.3
Continuous Corn (Stover removed)	1.370	0.329	0.313	69.2	67.4
Corn/Soybean Rotation	1.520	0.334	0.288	39.9	18.1
Miscanthus	0.365	0.098	0.347	30.8	58.2
Soybean/Corn Rotation	6.752	0.637	1.303	26.3	28.2
Sweet Sorghum	0.661	0.203	0.804	53.1	114.2
Switchgrass	0.212	0.137	0.306	26.2	31.1
Tall Fescue	1.527	0.288	1.605	39.0	115.9

Table 3. Soil test characteristics at Bradford in spring, 2010.

Cropping Systems	Fertilizer	pHs	P lb/acre	K lb/acre	OM %	CEC
Continuous Corn (Grain only)	0 P and K	6.0	26	146	2.70	13.2
	Buildup	5.9	36	153	2.60	13.2
	Removal	5.8	39	201	2.83	12.8
Continuous Corn (Stover removed)	0 P and K	6.1	30	148	2.88	13.1
	Buildup	5.9	32	161	2.95	12.7
	Removal	5.9	44	197	2.88	12.6
Corn/Soybean Rotation	0 P and K	5.9	22	152	2.88	13.7
	Buildup	5.8	35	187	2.93	13.9
	Removal	5.8	37	228	2.98	13.7
Miscanthus	0 P and K	6.0	29	148	3.00	12.9
	Buildup	5.8	35	184	3.00	12.5
	Removal	5.9	35	193	3.00	13.3
Soybean/Corn Rotation	0 P and K	5.8	24	133	2.70	12.5
	Buildup	5.7	36	189	2.80	12.9
	Removal	5.8	41	181	2.70	12.2
Sweet Sorghum	0 P and K	5.9	30	159	3.00	12.6
	Buildup	5.8	41	174	3.00	12.8
	Removal	5.9	42	192	2.98	13.1
Switchgrass	0 P and K	5.8	32	149	2.98	13.3
	Buildup	5.9	29	173	2.88	13.3
	Removal	5.9	29	177	2.95	13.4
Tall Fescue	0 P and K	6.0	31	186	2.88	13.0
	Buildup	5.9	30	211	2.90	13.5
	Removal	6.0	37	236	2.88	13.1

Cropping Systems	pHs	P lb/acre	K lb/acre	OM %	CEC
Continuous Corn (Grain only)	5.9	34	167	2.71	13.0
Continuous Corn (Stover removed)	5.9	35	169	2.90	12.8
Corn/Soybean Rotation	5.8	31	189	2.93	13.8
Miscanthus	5.9	33	175	3.00	12.9
Soybean/Corn Rotation	5.8	34	167	2.73	12.5
Sweet Sorghum	5.9	38	175	2.99	12.8
Switchgrass	5.9	30	166	2.93	13.3
Tall Fescue	5.9	33	211	2.88	13.1

Table 4. Soil test characteristics at Greenley in spring, 2010

Cropping Systems	Fertilizer	pHs	P lb/acre	K lb/acre	OM %	CEC
Continuous Corn (Grain only)	0 P and K	5.9	25	170	3.13	15.5
	Buildup	5.8	26	154	3.07	15.4
	Removal	6.0	30	188	2.97	15.2
Continuous Corn (Stover removed)	0 P and K	6.2	31	165	3.33	16.2
	Buildup	6.2	40	173	3.20	15.7
	Removal	6.3	37	215	3.07	16.3
Corn/Soybean Rotation	0 P and K	5.9	23	157	3.03	15.4
	Buildup	5.9	23	164	2.97	15.0
	Removal	6.1	33	159	2.80	14.7
Miscanthus	0 P and K	5.9	21	191	2.83	14.7
	Buildup	5.8	24	181	2.80	14.1
	Removal	6.2	25	192	2.80	14.7
Soybean/Corn Rotation	0 P and K	6.0	23	167	2.80	13.4
	Buildup	5.9	27	153	3.20	14.3
	Removal	6.2	32	163	2.97	13.8
Sweet Sorghum	0 P and K	5.7	29	142	3.03	15.1
	Buildup	5.8	32	129	3.03	14.8
	Removal	6.1	39	166	3.00	15.0
Switchgrass	0 P and K	6.2	34	205	2.87	15.3
	Buildup	6.0	29	215	3.00	15.6
	Removal	6.0	33	222	2.87	15.2
Tall Fescue	0 P and K	5.9	17	150	3.33	15.0
	Buildup	5.9	25	144	3.10	14.5
	Removal	6.1	36	158	3.07	15.1

Cropping Systems	pHs	P lb/acre	K lb/acre	OM %	CEC
Continuous Corn (Grain only)	5.9	27	171	3.06	15.4
Continuous Corn (Stover removed)	6.2	36	184	3.20	16.1
Corn/Soybean Rotation	6.0	26	160	2.93	15.0
Miscanthus	6.0	24	188	2.81	14.5
Soybean/Corn Rotation	6.0	27	161	2.99	13.8
Sweet Sorghum	5.9	33	146	3.02	15.0
Switchgrass	6.1	32	214	2.91	15.4
Tall Fescue	6.0	26	151	3.17	14.9

Table 5. Average fertility treatments at Bradford in spring ,2010

Cropping Systems	Fertilizer	N lb/acre	P lb/acre	K lb/acre
Continuous Corn (Grain only)	0 P and K	240	0	0
	Buildup	240	108	146
	Removal	240	58	40
Continuous Corn (Stover removed)	0 P and K	240	0	0
	Buildup	240	119	140
	Removal	240	58	40
Corn/Soybean Rotation	0 P and K	240	0	0
	Buildup	240	111	123
	Removal	240	40	40
Miscanthus	0 P and K	60	0	0
	Buildup	60	20	142
	Removal	60	45	84
Soybean/Corn Rotation	0 P and K	0	0	0
	Buildup	0	85	153
	Removal	0	50	40
Sweet Sorghum	0 P and K	120	0	0
	Buildup	120	56	98
	Removal	120	58	130
Switchgrass	0 P and K	60	0	0
	Buildup	60	25	109
	Removal	60	28	35
Tall Fescue	0 P and K	120	0	0
	Buildup	120	54	128
	Removal	120	45	122

Results:

Soil Quality Analysis

The TOC, TN and C:N ratio measured at initial sampling (spring) date were not significantly different for different cropping systems at both sites (Table 6). The same trend was observed at the end of the growing season (fall) samples at Bradford. However, there were significant differences in the TOC and C:N ratios at Greenley in fall samples at the end of the growing season (Table 6). The CCGS, SCG, SSW and MIS cropping systems had significantly higher levels of TOC than SWI (Table 6). In general soils at the Greenley site appeared to have about 14% more TOC than at the Bradford site. At both sites, there is drop in TOC from spring to fall in most of the bio-fuel cropping systems.

Table 6: Total organic carbon, total N and C: N ratios for soils for Bradford and Greenley sites in different bio-fuel cropping systems, spring and fall, 2009. Different letters indicate significant differences within a column.

Cropping Systems	TOC g kg^{-1}Soil	TN g kg^{-1}Soil	C:N	TOC g kg^{-1}Soil	TN g kg^{-1}Soil	C:N
			Bradford			
		Spring			Fall	
CCG	18.9a	2.00a	9.83a	16.3a	1.64a	9.94ab
CCGS	17.0a	1.73a	9.77a	17.2a	1.70a	10.15ab
CSG	16.6a	1.71a	9.81a	16.8a	1.74a	9.70b
SCG				16.5a	1.62a	10.22ab
SSW	15.6a	1.59a	10.11a	16.6a	1.61a	10.35a
MIS	17.8a	1.61a	10.96a	16.8a	1.63a	10.31a
SWI	17.9a	1.80a	10.03a	16.0a	1.61a	9.93ab
TF				16.6a	1.69a	9.81ab
Pr>F	*0.602*	*0.629*	*0.635*	*0.923*	*0.645*	*0.187*
			Greenley			
		Spring			Fall	
CCG	20.9ab	1.95ab	10.77a	17.6bc	1.79ab	9.83ab
CCGS	22.6a	2.02a	11.16a	19.4a	1.89ab	10.30a
CSG	19.2b	1.72ab	11.22a	17.7abc	1.91a	9.26b
SCG	18.4b	1.70b	10.85a	18.0ab	1.89ab	9.55b
SSW	20.4ab	1.84ab	11.07a	18.7ab	1.93a	9.65b
MIS	18.5b	1.69b	10.97a	18ab	1.83ab	9.82ab
SWI	19.5b	1.67b	11.89a	16.1c	1.72b	9.34b
TF	19.9ab	1.85ab	10.82a	18.4ab	1.9ab	9.73b
Pr>F	*0.114*	*0.212*	*0.769*	*0.033*	*0.248*	*0.027*

During the initial sampling time (spring), WSA seemed to be higher at Bradford (Avg. 26.1%) than at Greenley site (Avg. 18.9%). Even though there were no significant differences amongst cropping systems at Bradford site, there were significant differences amongst cropping systems at Greenley (Table 7). The TF, CCGS and MIS plots had significantly higher WSA than CSG, SCG, SSW and SWI plots. At the end of growing season (fall) there were significant differences between cropping systems in WSA at both sites and the values were higher in fall than spring (Avg. Bradford 31%, Greenley 31.2%). At Bradford, the WSA was highest at the TF plots (34.4%) was lowest at the CSG (26.1%). At Greenley, WSA was highest at the MIS plots and lowest at CSG and SCG plots. DEHYD and GLUCO decreased from spring to fall at both sites suggesting possible seasonal effects (Table 7). More importantly, high enzyme activities in fall 2009 were generally associated with perennial crops (SSW, MIS, TF) which was likely due to persistent viable roots facilitating continuous soil biological activity. Associated increases in WSA support the overall benefit of the perennial crops to increase soil quality compared with most of the annual cropping systems in this study.

Conclusions:

1. Although only two sampling dates are reported, the initial trend for improved soil quality based on WSA and enzyme activity analyses is becoming evident in perennial crops.
2. Increases in enzyme activities agree with previous reports, suggesting their highly sensitive ability to detect rapid changes in soil quality due to changes in management.
3. Few changes in TOC, TN, and C:N are evident at this early stage; however, we expect differences to evolve due to management as this long-term field study progresses.

In summary, the organic and biological properties measured suggest the plot locations selected for each site are relatively uniform and changes resulting from response of these properties to bio-fuel crop and imposed management should be detected within the study timeframe. The initial differences between the two sites, primarily in soil C content and glucosamindase activity, may require separate analyses for the sites as the project progresses.

Table 7: Water-stable aggregates (WSA) and enzyme activity for soils for Bradford and Greenley sites in different bio-fuel cropping systems, spring and fall, 2009

Cropping Systems	WSA %	DEHYD µg TPF g^{-1} soi	GLUCO µg PNP g^{-1} soil	WSA %	DEHYD µg TPF g^{-1} soi	GLUCO µg PNP g^{-1} soil
			Bradford			
		Spring			Fall	
CCG	26.5a	276.5a	1072.1a	30.8ab	185.9bcd	928.0bc
CCGS	30.3a	237.9a	1095.4a	31.2ab	157.2d	868.8c
CSG	24.3a	243.9a	1077.6a	26.1c	157.9d	969.1ab
SCG				30.6ab	192.5abc	991.8ab
SSW	26.2a	248.0a	1119.9a	32.9ab	198.2ab	987.2ab
MIS	25.2a	217.9a	1066.6a	32.7ab	223.1a	1047.5a
SWI	24.3a	235.3a	974.3a	29.3bc	175.7bcd	995.0ab
TF				34.4a	166.5cd	1037.5a
Pr>F	*0.710*	*0.691*	*0.437*	*0.014*	*0.001*	*0.003*
			Greenley			
		Spring			Fall	
CCG	20.7bc	225.3ab	660.0a	29.5c	156.5d	573.5ab
CCGS	25.0ab	174.2c	729.8a	32.3bc	175.7d	481.9dc
CSG	10.5c	175.7c	733.4a	23.9d	189.7cd	517.9bc
SCG	12.9bc	136.2d	694.7a	19.9d	167.5d	438.1dc
SSW	18.3bc	205.8bc	717.4a	36.3ab	245.1b	547.9ab
MIS	22.6abc	184.9c	651.8a	38.7a	288.6a	599.4a
SWI	13.5bc	184.2c	705.8a	32.5bc	218.4bc	595.5a
TF	34.6a	249.0a	754.8a	36.3ab	320.4a	485.4dc
Pr>F	*0.026*	*0.001*	*0.514*	*0.001*	*0.001*	*0.001*

Dehydrogenase (DEHYD) activity expressed as concentration of product, triphenyl formazam (TPF), formed during enzyme assay.
Glucosaminidase (GLUCO) activity expressed as concentration of product, *p*-nitrophenol (PNP), formed during enzyme assay.

Grain and Biomass Yield:

Continuous corn yield responded to P and K fertilizer at both locations especially when stover was removed (Table 8). However, there was no response to P and K fertilizer applications when corn was rotated with soybean. This lack of response may indicate soybean were over fertilized although there was a slight increase in soybean yield with the P and K treatment. At both locations with the continuous corn treatment (grain only), there was a yield advantage of applying maintenance + buildup rather than based upon removal. However, when stover was removed, the greatest yield response occurred when P and K treatment was based upon removal. This indicated that when continuous corn was grown that P and K uptake and corn yield was dependent upon P and K availability from the previous year's corn stover. Corn responded differently to P and K fertilizer application in the soybean/corn rotation in 2010 at Bradford and Greenley which may have been related to poor soybean yields at Bradford in 2009 when little P and K was removed.

Corn stover yield response was similar to that of grain with a response to increasing P and K applications (Table 9). Biomass response to P and K treatment was different at each location which was partially due to the age and variety of the crop. The Miscanthus plots at Bradford are one year older than Greenley which at this stage makes a tremendous difference in dry matter yield. However, it seems that highest Miscanthus yield was not related to P and K fertilization. Switchgrass yield was much higher, 2 tons/acre, at Greenley than Bradford and responded to P and K fertilization although it did not make a difference whether it was maintenance and build up or removal. The higher yield at Greenley may have been a result of the difference in variety Blackwell at Greenley and Cave in Rock at Bradford. In general, there was not a response to P and K applications for tall fescue or sweet sorghum-wheat system.

Nutrient Uptake:

In 2009, luxury uptake of P and K in corn or soybean was limited regardless of treatment. There was more removal of P and K, but this was based on higher yields in response to P and K treatments. Nutrient removal was also based upon yield due to P and K treatments in corn stover, miscanthus, and switchgrass; however, there was luxury update of P and K in tall fescue and sweet sorghum plots. Since these two crop production systems were harvested in the vegetative stage they did not have an opportunity to remobilize nutrients out of the leaves and stems into the roots as the other crops did. It was surprising that corn stover did not remove more P and K that was reported. Apparently some P and K had been mobilized into the soil before harvest.

Table 8: Grain yield at the Bradford and Greenley Research Centers, 2010

Cropping Systems	Fertilizer Treatments	Yield bu/ac	Means bu/ac	Yield bu/ac	Means bu/ac
		Bradford		Greenley	
Continuous Corn (Grain only)	0 P and K	84b	107a	85a	97b
	Maint+Build	124a		112a	
	Removal	113ab		93a	
Continuous Corn (Stover removed)	0 P and K	99a	111a	83b	117ab
	Maint+Build	112a		125ab	
	Removal	121a		142a	
Soybean 2009/Corn 2010 Rotation	0 P and K	132a	121a	145a	149a
	Maint+Build	116a		142a	
	Removal	115a		161a	
Corn 2009/Soybean 2010 Rotation	0 P and K	61	64	68	70
	Maint+Build	64		70	
	Removal	67		72	

Different letters indicate significant differences ($P = 0.05$) within a column.

Table 9: Biomass yield at the Bradford and Greenley Research Centers, 2010

Cropping Systems	Fertilizer Treatments	Biomass tons/ac	Means tons/ac	Biomass tons/ac	Means tons/ac
		Bradford		Greenley	
Continuous Corn (Stover removed)	0 P and K	2.90a	3.35c	3.03a	2.94c
	Maint+Build	4.03a		2.24a	
	Removal	3.00a		3.56a	
Miscanthus	0 P and K	8.29ab	3.97a	1.67a	2.65c
	Maint+Build	6.62b		4.08a	
	Removal	9.00a		2.21a	
Sweet sorghum-wheat	0 P and K	2.08a	1.83d	5.02a	5.02b
	Maint+Build	1.69a		4.64a	
	Removal	1.72a		5.40a	
Switchgrass	0 P and K	3.84a	3.60c	5.65a	6.98a
	Maint+Build	3.48a		7.52a	
	Removal	3.49a		7.76a	
Tall Fescue	0 P and K	6.45a	6.80b	5.91a	5.95ab
	Maint+Build	7.17a		6.06a	
	Removal	6.79a		5.88a	

Summary:

Continuous corn responded to P and K applications with grain only responding best with maintenance and buildup whereas, stover responded best when based upon removal. In 2009, there was luxury consumption and removal of P and K with sweet sorghum and tall fescue. It will be interesting to see how if this was repeated in 2010 with a different yield environment. Biomass response to P and K application is somewhat variable and depends on total yield. In the first two years of this study, it is apparent that in order to maximize dry matter and grain yield in a monoculture system P and K levels will need to be closely monitored.

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Updating University of Missouri Soil Test Recommendations

John A. Lory, Peter Scharf, Manjula Nathan, Peter Motavalli, David Dunn, Gene Stevens and Newell Kitchen

Principal Investigator: John A. Lory Co-investigators: Peter Scharf, Manjula Nathan, Peter Motavalli, David Dunn, Gene Stevens, Newell Kitchen

The objectives of this project are to:

- Update and revise University of Missouri Soil Test Recommendations and the supporting publication "Soil Test Interpretations and Recommendations Handbook."

This project supports a part-time position to provide support to faculty developing proposals for changes to MU soil test and fertilizer recommendations. The proposal stated the work of the research specialist will include performing literature reviews, summarizing data from completed experiments and editing proposals. The funds were not to be used to undertake new lab or field research.

2010 Accomplishments

- Initial approval of new soil test P and K buildup equations by the soil fertility working group.
- Preliminary proposal and discussion of reduced critical values for soil test P and K on fields with site-specific management of fertilizers.
- Presentation of approved changes in crop nutrient removal values and proposed new soil P and K buildup equations at the 2010 MU Crop Management Conference.
- Supplemental work on completing nutrient removal values for agronomic crops including a chapter in the 2010 Missouri Soil Fertility and Fertilizers Research Update.

Remaining Objectives

1. Finalize changes to the equation used to calculate soil test build rates for P and K.
2. Finalize proposed changes to the critical values used for P and K for row and forage crops.
3. Develop and approve proposal for update to row crop nitrogen recommendations.
4. Finalize and approve proposal for update to forage nitrogen recommendations.
5. Complete update of MU Soil Test Interpretations and Recommendations Handbook based on approved changes.
6. Develop a list of priority research projects to improve MU soil test and fertilizer recommendations.

This will complete an overhaul of the MU soil test and fertilizer recommendations. Upon completion of the project arrangements will need to be made to implement the approved changes in the software used by the Missouri Soil Testing Laboratory to generate soil test reports.

Proposed Budget

In 2010 we spent approximately 20% of the total budget on Vicki Hubbard's activities in support of the project. We propose to spend the remaining 43% of project funds in 2011 for her support in completing the project.

Salary:	\$15,061
Benefits:	\$6,455
Total:	\$21,516

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