

**Missouri
Soil Fertility and Fertilizers
Research Update
2011**

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

Thank You

Missouri Fertilizer and Ag Lime Distributors

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

Fertilizer/Ag Lime Control Service
Attn: Joe Slater
University of Missouri-Columbia
Columbia, MO 65211-8080

or email them to slaterj@missouri.edu

or phone 573-882-0007

Contributors to Report

Blevins, Dale. Professor Emeritus, Agronomy, University of Missouri
Burdick, Bruce. Div. of Plant Sciences, University of Missouri, Albany, MO
Dudenhoeffer, Chris. Dep. of Soil, Environ. & Atmos. Sci. University of Missouri
Dunn, David. Supervisor Soil Test Lab, Delta Center, Southeast Region-ANR, University of Missouri
Fritschi, Felix. Asst. Professor, Div. of Plant Sciences, University of Missouri
Harper, Joni Ross. Agronomy Specialist, Morgan County, Ctrl Missouri Region, ANR
Heiser, Jim. Research Assoc., Plant Sciences, Delta Center, University of Missouri
Houx, III, James H. Research Specialist, Plant Sciences, University of Missouri
Hubbard, Vicky. Research Specialist, Agronomy, University of Missouri
Jones, Andrea. Research Assoc., Plant Sciences, Delta Center, University of Missouri
Kallenbach, Robert. Assoc. Professor, Div. of Plant Sciences, University of Missouri
Kitchen, Newell. Adjunct Assoc. Professor of Soil Science, Soil Environment & Atmospheric Sciences, University of Missouri
Kleinsorge, David. Research Specialist, Agronomy, University of Missouri
Kremer, Robert. USDA-ARS, Dept. of Soils, Environmental, and Atmospheric Sciences
Lorenz, Todd. Horticulture/Agronomy Specialist – Cooper County Program Director Ctrl Region
Lloyd, Daniel. Research Specialist, Plant Sciences, University of Missouri
Motavalli, Peter. Assistant Professor, Soil and Atmospheric Sciences, University of Missouri
Mueller, Larry. Research Specialist, Agronomy, University of Missouri
Nash, Pat. Dept. of Soil, Environmental and Atmospheric Sciences, University of Missouri
Nathan, Manjula. Director, University of Missouri Soil Testing Lab
Oliveira, Luciane.
Nelson, Kelley A. Asst. Research Professor, Greenley Research, University of Missouri
Reinbott, Timothy. Research Assoc. & Superintendent Bradford Research & Extension
Rhine, Matthew. Research Assoc., Plant Sciences, Delta Center, University of Missouri
Scharf, Peter. Professor, State Nutrient Management Specialist, Div. of Plant Sciences, University of Missouri
Schmitz, Gene. Livestock Specialist Benton County, Ctrl Missouri Region - ANR
Shannon, Kent. Region Natural Resources Engineer
Stevens, Gene. Assistant Professor, Ag Extension Plant Sciences, University of Missouri
Udawatt, Ranjith. Assistant Professor Dep. Of Soil, Environ, & Atmos. Sci. University of Missouri
Xiong, Xi. Assistant Professor, Plant Sciences, University of Missouri

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Agricultural Lime

Progress Reports

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 coarse 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 2010 and 2011 at both locations are presented in Table 3. In 2011 at both locations all lime treatments numerically increased crop yields relative to the untreated check. At the Marsh Farm, where corn was cultivated in 2011, yields for the untreated check were statistically less than treatments receiving either aglime or ¼ minus lime. Yields for treatments receiving less than more than 500 ENM (53% of the recommended rate) were also statistically equivalent. The treatment which received 1485 ENM as ag lime produced the greatest numerical yields. At the Rhodes

Farm where cotton was cultivated all treatments that received less than 850 ENM as either aglime or ¼ minus lime produced yields that were statistically equivalent to the untreated check. The treatment which received 1420 ENM as ¼ minus lime produced the greatest numerical yields. The yield data from the first two years of this study 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 for 2010 and 2011 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 initially produced a greater pH change in a shorter time than corresponding rates of ¼ minus material. At the Marsh Farm, where soybeans (2010) and corn (2011) 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) in 2010. This pH level was produced for the July, 2011 sampling date for the aglime (1485 ENM) compared to the August, 2011 sampling data for the ¼ minus (1136 ENM). At season's end in 2011 only the highest rate for each product produced pH levels above the 6.1 soil pH target. In 2010 at the Rhodes Farm where cotton was cultivated the initial 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. At season's end in 2011 only the lowest application rate for each product produced pH levels below the 6.1 soil pH target. 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:

| <u>Expenses</u> | <u>2010</u> | <u>2011</u> | <u>2012</u> |
|---------------------|-----------------------|-----------------------|-----------------------|
| 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 |
| <u>Total</u> | <u>\$7,850</u> | <u>\$8,169</u> | <u>\$8,498</u> |

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 & 2011.

| Trt# | Soybeans (2010)/Corn (2011) | | | Cotton | | |
|----------|-----------------------------|--------------|--------------|--------------------|--------------|--------------|
| | Material | 2010 bu/a | 2011 bu/a | Material | 2010 lb/a | 2011 lb/a |
| 1 | Check | 24.7 b | 131c | Check | 854 b | 821b |
| 2 | Aglime (495 ENM) | 30.0 ab | 140b | Aglime (495 ENM) | 935 ab | 850b |
| 3 | Aglime (990 ENM) | 31.5 ab | 151a | Aglime (990 ENM) | 1010 a | 993a |
| 4 | Aglime (1485 ENM) | 37.3 a | 156a | ¼ minus (568 ENM) | 922 ab | 892b |
| 5 | ¼ minus (710 ENM) | 32.0 ab | 149a | ¼ minus (852 ENM) | 992 a | 877b |
| 6 | ¼ minus (852 ENM) | 36.8 a | 155a | ¼ minus (1136 ENM) | 968 a | 983a |
| 7 | ¼ minus (1136 ENM) | 38.2 a | 154a | ¼ minus (1420 ENM) | 1016 a | 1016a |
| lsd 0.05 | | 5.9 | 8.1 | | 77 | 66 |
| CV % | | 12.0 | 3.7 | | 5.4 | 4.9 |

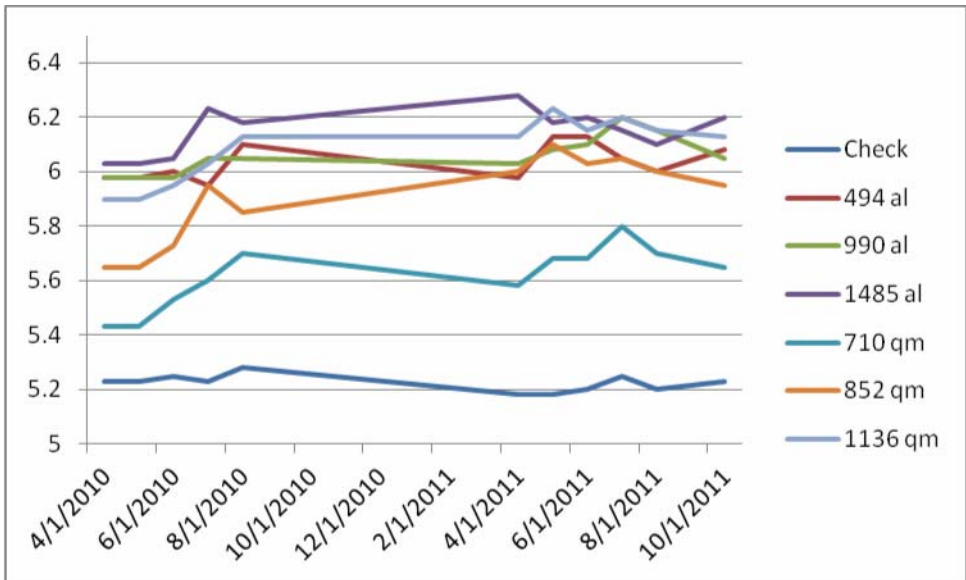


Figure 1 pH change with time for liming materials on a low pH soil at the University of Missouri Marsh Farm Portageville, MO 2010 through 2011.

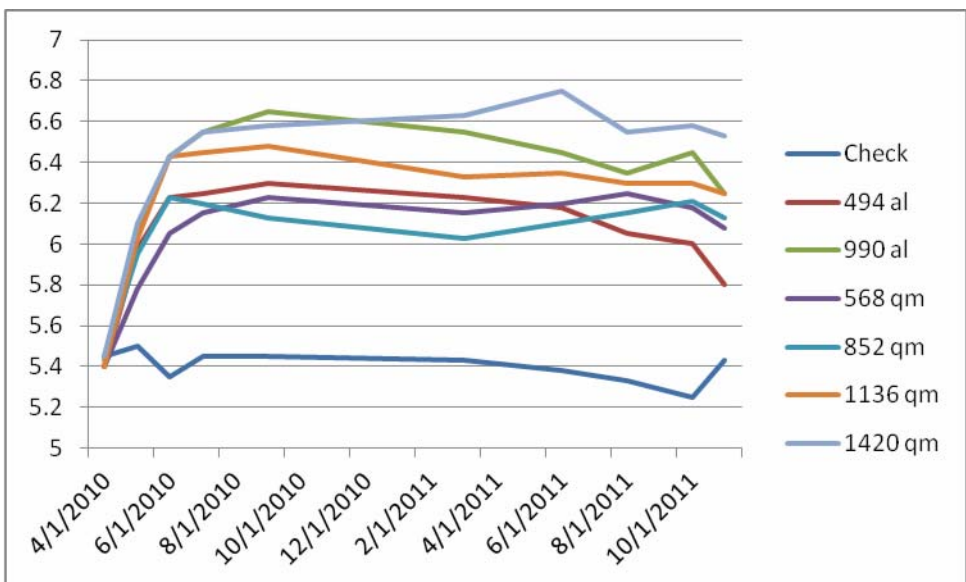


Figure 2. pH change with time for liming materials on a low pH soil at the University of Missouri Rhodes Farm Clarkton, MO 2010.

Liming in a Rice/Soybean Rotation

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

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. In 2011 favorable rainfall conditions returned. Both the rice and soybean crops were established brought to harvest and yield measured.

Crop yields for 2010 and 2011 are presented as Table 1. In 2011 liming inconsistently effected rice yields. For both years, the 0.8 ton/a lime rate (1/2 of recommended rate) produced the numerically greatest rice yields. However, the numerical lowest yields for rice were obtained with the greatest lime rate (1.6 ton/a) in 2011. Soybean yields in 2011 were positively affected by lime treatments, with all lime treatments yielding numerically greater than the untreated check. The greatest soybean yields were obtained with the 1.2 ton/a rate of lime.

Soil pH was measured for each plot at the beginning (May) and end (September) of each season. This data is presented in Tables 2 and 3

Table 1. Rice and soybean yields for lime treatments at Qulin, MO 2010 and 2011.

| Trt# | Lime Rate | 2010 | | 2011 | |
|------|--------------------------|------|-------|----------------------|----------------------|
| | | rice | beans | beans (rice 2010) | rice (beans 2010) |
| 1 | check | 141 | ---- | 34 | 138 |
| 2 | 0.4 ton (200 ENM) | 141 | ---- | 40 | 139 |
| 3 | 0.8 ton (400 ENM) | 149 | ---- | 42 | 146 |
| 4 | 1.2 ton (600 ENM) | 140 | ---- | 45 | 140 |
| 5 | 1.6 ton (800 ENM) | 144 | ---- | 44 | 136 |
| 6 | 200 lb pel lime (60 ENM) | 142 | ---- | 37 | 140 |

Table 2a and 2b. Average soil pH values for lime treatments on rice 2010 followed by soybeans 2011 at Qulin, MO.

Table 2a, Soil pH values for lime treatments for rice 2010 followed by soybeans 2011

| Trt# | Lime Rate | 2010 | | 2011 | |
|------|--------------------------|------|-----------|------|-----------|
| | | May | September | May | September |
| 1 | check | 5.6 | 5.8 | 5.6 | 5.4 |
| 2 | 0.4 ton (200 ENM) | 5.6 | 6.0 | 6.0 | 5.9 |
| 3 | 0.8 ton (400 ENM) | 5.5 | 6.1 | 6.2 | 6.2 |
| 4 | 1.2 ton (600 ENM) | 5.6 | 6.1 | 6.3 | 6.3 |
| 5 | 1.6 ton (800 ENM) | 5.6 | 6.2 | 6.4 | 6.4 |
| 6 | 200 lb pel lime (60 ENM) | 5.5 | 5.9 | 5.7 | 5.9 |

Table 2b, Soil pH values for lime treatments for soybeans 2010 followed by rice 2011

| Trt# | Lime Rate | 2010 | | 2011 | |
|------|--------------------------|------|-----------|------|-----------|
| | | May | September | May | September |
| 1 | check | 5.6 | 5.4 | 5.5 | 5.7 |
| 2 | 0.4 ton (200 ENM) | 5.6 | 5.8 | 5.9 | 6.1 |
| 3 | 0.8 ton (400 ENM) | 5.5 | 5.9 | 6.1 | 6.2 |
| 4 | 1.2 ton (600 ENM) | 5.5 | 6.1 | 6.2 | 6.2 |
| 5 | 1.6 ton (800 ENM) | 5.6 | 6.3 | 6.3 | 6.4 |
| 6 | 200 lb pel lime (60 ENM) | 5.6 | 5.8 | 5.7 | 5.8 |

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 |

Updating University of Missouri Soil Test Based Fertilizer and Lime Recommendations Program: Status Report

Manjula Nathan, Peter Scharf, and David Dunn

Manjula Nathan, Associate Professor/Director, MU Soil and Plant Testing Laboratory

Division of Plant Sciences, University of Missouri

Peter Scharf, Professor, State Nutrient Management Specialist, Division of Plant Sciences, University of Missouri

David Dunn, Extension Associate/Manager, Delta Soil Testing Lab

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

- Update and re-write the University of Missouri Soil Test Recommendations Program to include the revisions and updates made by the University of Missouri Soil Fertility Working Group.
- Update the soil test to a web based system that is independent of operating systems, offices systems, and web browsers.

University of Missouri (MU) soil test and fertilizer recommendation program is used by the MU Soil Testing Laboratories located at Columbia and Portageville to provide fertilizer and lime recommendations for row and forage crops to about 40,000 farmers each year. The soil test based recommendations from University of Missouri soil testing labs are being used to apply fertilizer and lime for about 4,000,000 acres of row crops and forages for efficient use of fertilizer and lime, and to achieve economical returns from crop production. In addition, the state and federal agencies such as the Natural Resources Conservation Service (NRCS), Farm Service Agency (FSA), Missouri Department of Natural Resources (MDNR), Missouri Department of Agriculture, and agricultural industry personnel, (crop consultants and fertilizer dealers) and individual producers rely on the MU soil testing database program to get unbiased, research based fertilizer and lime recommendations from University of Missouri.

During the past 15 years, there has been significant research in Missouri and other states on soil testing and crop fertilizer needs relevant to Missouri conditions. Some of that research was due to the result of support by the Missouri Fertilizer and Ag Lime Board.

The Soil Fertility Working Group is the committee charged with reviewing and approving changes to MU recommendations. This committee includes research and extension faculty working on soil fertility issues at MU and the heads of the Columbia and Delta soil testing labs. The members of these committee has been working for the past two years on revising the fertilizer and lime recommendations based on research findings, and has come up with significant updates. Some areas where significant changes have been made in the soil test based fertilizer recommendations include:

- Integrating economics into corn nitrogen recommendations.
- Updates to the buildup equations for soil test phosphorus and potassium.
- Updates on crop removal values.
- Revisions to Missouri lime and magnesium recommendations.
- Changes to the soil test recommendation rating system.

Implementing recommendation changes has been limited by the ability to include the revisions in the MU Soil Testing Database Program that benefits thousands and thousands of growers who receive the fertilizer and lime recommendations from the MU soil testing labs each year. The soil test database program that we currently use is a client based system that was written in VB6. Within the code for this

system is where all of our calculations and recommendations are stored. This has limited our ability to implement new calculations and recommendations. Our current program was also written for specific versions of Microsoft Office and this has limited our ability to generate new reports for our customers. One of our biggest challenges is that VB6 is no longer a supported system and every time there is an update to either operating system or Microsoft Office we have to find someone to fix our program. Therefore, the new soil test database program will be developed as a web-based system (independent of the operating systems) with enhancements to include the revisions in the future with ease.

The main objective of this proposal is to provide support for a 0.5 FTE of programmer's salary for three years. We estimate that it will take three years to design a new system, launch the new system, convert the old data, test the new system, and to support the system in its beginning stages to work out any issues. The programmer will ensure that the future recommendation changes to the MU soil test and fertilizer and lime recommendations can be made in the database. This will allow us to make the change as soon as it goes into effect and make the recommendations available online to be accessed by all citizens of Missouri.

Procedures:

We need three years to design a new system, launch the new system, convert the old data, test the new system, and to support the system in its beginning stages to work out any issues. The new system will have a table in the database for soil calculations, and soil recommendations, this is critical for future updating of the soil recommendations. The new system will be a web based system that is independent of operating systems, office systems, and web browsers. Updating the soil test data base programs will include managing lab data with sample identification, developing soil test based recommendation using current revisions, creating soil test reports in user friendly formats, enabling queries of the databases, and generating annual reports. The MU soil testing labs will fund 0.5 FTE of the position and request the fertilizer and lime advisory committee to fund the other 0.5 FTE of the programmer's salary to re-write the MU soil test database program. I will be mainly working with the programmer in updating the soil test database fertilizer and lime recommendation program with inputs from CO-PIs and members of the MU Soil Fertility Working Group.

Status Report:

A contract has been signed with Center of applied Research and Environmental Systems (CARES), University of Missouri to develop the web-based data base for soil test and recommendations. Mr. James Cutts, Computer Project Manager, CARES has been contracted to develop the database. The progress update on the project provided by the programmer is provided below:

The needs assessment of the soil testing lab database was performed prior to the official start of the project. The assessment was done through meetings with Manjula Nathan and John Stecker of the Columbia soil testing lab and David Dunn and Ann Garcia of the Portageville soil testing lab. A site visit was undertaken at Portageville soil testing lab. This helped the developer understand the material and data flow through the lab as well as determined the immediate needs for additional data collection software there.

The system is being designed as a web-based application which will allow for centralized administration. The use of a web based application will allow significantly easier updates to be provided to end users. The system is also being designed in such a manner that it will support the addition of new tests, centers and testing technologies without the need for significant revision to the application.

Considerable progress has been made in the design of the new database that will underlie the application. The database analysis has taken into consideration the database in use in the Mississippi State's soil testing lab as well as the existing SoilMain database structure. The first draft of the new database structure has been created in Microsoft Visio and has been implemented in the Microsoft SQL database in which the data will finally reside.

Initial development of this web-based system has begun. A rough draft of the websites initial layout and navigation system has been implemented in the ASP.Net development environment. These beginning pages of the application are being focused on development of a standard look and feel for the application.

Budget:

| Category | 2012 | 2013 |
|-----------------------|----------------------|--------------------|
| Salaries and benefits | | |
| Salaries | \$28,325 (0.5FTE) | 28,325 (0.5FTE) |
| Benefits | \$8498 | \$8498 |
| Operating | | |
| Equipment | | |
| | | |
| Total | \$36,823 | \$36,823 |

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, Bruce Burdick
Manjula Nathan, Robert Kallenbach, Division of Plant Sciences, University of Missouri
Kallenbach, Robert, Division of Plant Sciences, University of Missouri
Kelly Nelson, Division of Plant Sciences, University of Missouri
David Dunn, MU Soil Testing Lab, Delta Center, University of Missouri
Tim Reinbott, Bradford Research and Extension Center, University of Missouri
Bruce Burdick, Hundley-Whaley Research 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 for pH ranges of 5.5 to 6.0; 6.0 to 6.5 and 6.5 to 7.0.
4. Compare field calibration results with incubation study results in evaluating 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; Southwest center site was planted with forages. The Delta and Hundley-Whaley sites were disked, minimum tilled and the Bradford and Greenley sites were under no-till system.
- Each 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 with the exception of Southwest Center site (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 for buffer pH using Woodruff, Mehlich and Sikora buffers.
- The 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 will be compared with the incubation studies results.
- In-situ field incubation study, 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. So, soils from control plots which did not receive any lime from the five field sites were used in conducting in-situ/field and lab incubations to study the mechanisms involved with differences in lime requirement from field studies versus laboratory incubations.
- Soil samples collected at 0-6" depth from the control plots in the field study were air dried, ground and sieved and incubated with lime using four methods. Three of the methods involved incubation of lime with soils in the field in heavy duty plastic cylindrical wide mouth containers, placed vertically in soil at six-inch depth. To simulate thorough mixing of lime and soil in

conventional tillage, Method A: soil was mixed well with lime and placed. The bottom of the container was cut and covered with a screen to contain the soil intact when removed at the end of the incubation and at the same time allow water to leach as normally occurs in the field. Method B: was the same as Method A but have a closed 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: lime was surface applied to simulate application of lime in no-till field conditions. Method D: laboratory incubation where soil water was maintained at field capacity or slightly less.

- Each soil was treated with five lime rates (0, 750, 1500, 2250 and 3000 ENM, lbs/ac) using high quality Ag lime. The Ag lime source chosen had an ENM of 770. Liming material was thoroughly mixed before use in the in-situ field, and lab incubation studies. The soils were incubated for a period of 6 months in the field and lab. At the end of incubation, soil samples were collected from each treatment, air-dried, and ground to pass a 2-mm screen. The samples were analyzed for pHs and three buffer tests (MWB, SB, MMB-not completed yet).

Data Analysis: Lime response curves will be determined for the various measurements of soil pH (pHs 1:1 0.01 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.

Progress Report for 2011:

A field calibration study was established at University of Missouri at Bradford (BF), Delta (DE), Greenley (GR), Hundley-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 minimum tilled. Each site received seven lime treatments to cover a wide range from low, recommended LR, and 2xLR rates. Soil samples were collected (0 to 6”) at the beginning and at 45d, 90d, 120d, and 365d 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 in 2009, 2010 and 2011(except SW).

a. Lab incubation study:

The incubation study was conducted in Missouri 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 requirement for soils selected for the incubation 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 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 pHs 5.8, 6.3 and 6.8. The MMB and SB were found to be slightly better predictors of LR than MWB at target pHs of 5.8, as demonstrated by the slightly higher R² values than MWB (Fig. 1.a). At target pHs 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 pHs 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 pHs 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.

Soil samples were collected (0-6" depth) at the end of the season after harvest from the field sites (missing data from DE and SWC). The soil pHs and other chemical characteristics for fall, 2011 samples are provided in Table 1. The high rates of lime treatments at HW and GR sites (1500 ENM/ac and higher at HW and 1000 ENM/ac and higher at GR) had significantly high pHs than control plots even at three years after lime application. Similar trend was observed at BR site however the differences were not statistically significant. This was due to the high variability within reps observed at the BR site.

The yield response for three years after lime treatment application at the BR, DE, HW, and GR locations are presented in Table 2. The yield responses to lime treatments were not consistent. The corn grain yield response at DE, HW, and GR indicated peak yield at 1500 ENM/ac lime rate. The yield response for lime treatments was high enough to be economic in most cases as long as the rate was not excessive.

Since 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. The soil test results from the lab and field incubation study using soil samples collected from the control plots of the five field sites are presented in Tables 3 and 4 respectively. The six months duration incubation study (In-situ field and lab) was completed in November, 2011. In the field incubation study, soil samples were taken at 0-2" depth and 2-6" depth and a total of 420 samples were collected (2 reps only at the surface application treatments). Along with it, 75 soil samples were collected from the lab incubation study (using five field site soils). We have a total of 495 samples to be analyzed for soil pHs, and buffer pHs using MMB, MWB and SB. At this time of the report, we have completed all analysis except for MMB test. The lab incubation test results is provided in Table 3 and field incubation test results are provided in Tables 4 a, b, c, d, e, f. Due to time limitations we do not have all the analysis completed to estimate the lime requirements based on the field and lab incubation studies conducted in 2011. So only data collected to date are provided in this report.

The soil pHs and buffer pH data (MWB and SB only) from the lab incubation study (using all five field sites soils) is provided in table 3. As expected, there was significant increase in soil pHs with different rates of lime application on all five soils. The soil pHs and buffer pH (MWB and SB only) data from the in-situ field incubation study for samples taken at 0-2" and 2-6" depths for three methods (lime thoroughly mixed and incubated in closed, and open bottom containers, and lime surface applied and

incubated in close bottom containers) are provided in Table 4 a, b, c, d, e, f. On both lime mixed with soil and incubated in closed and open bottom containers (Table 4 a, b, c, d) soil pHs increased significantly with each lime treatments on both 0-2” and 2-6” depths. But as expected, on the surface applied lime treatments only the 0-2” depth samples had significant increase in pHs whereas the pHs in the 2-6” depth samples were not affected by lime treatments. This indicates lime when surface applied under No-till conditions would not easily move down to neutralize the acidity in subsoil.

A complete final report of this study will be presented next year after all the analyses are completed.

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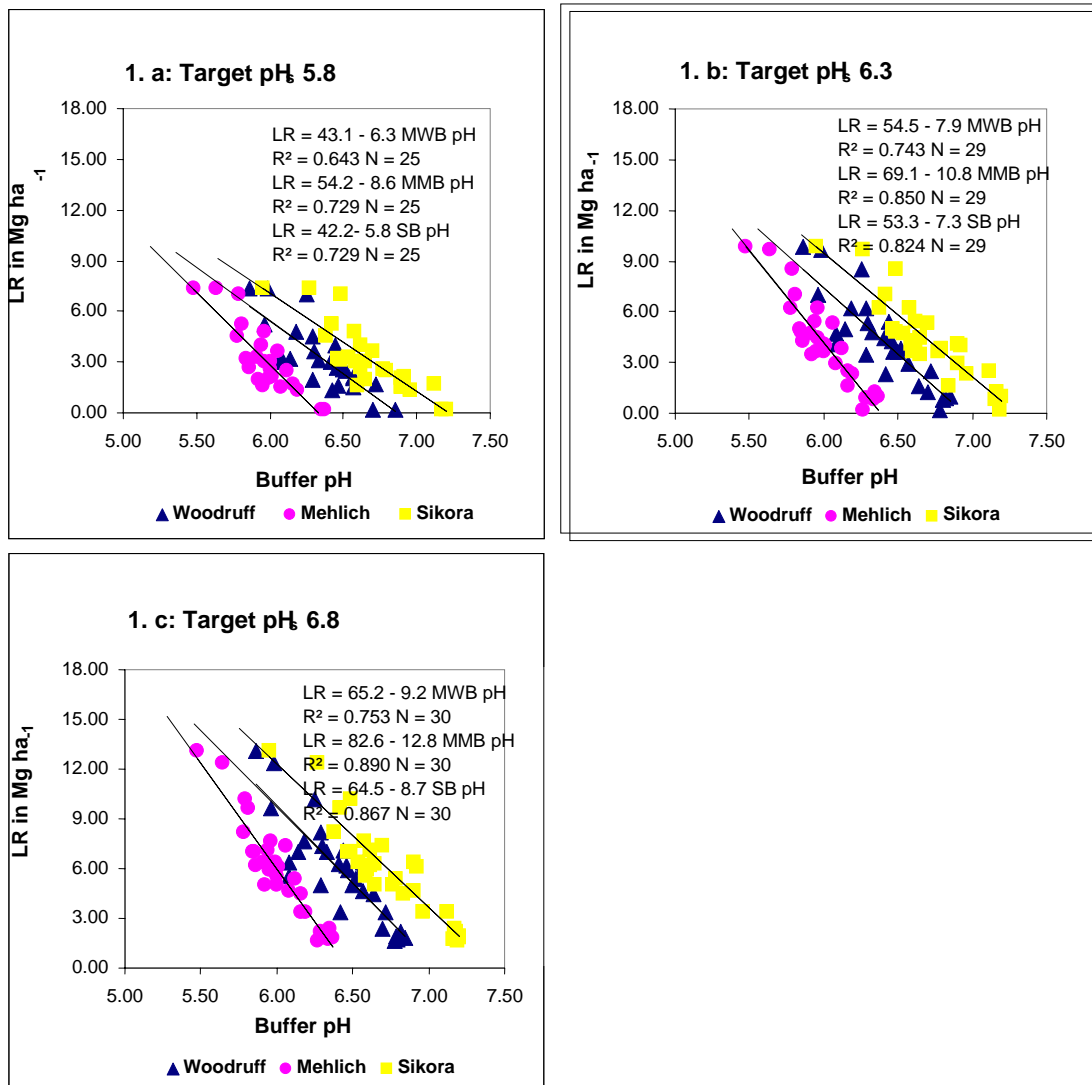


Fig. 1. Buffer pH vs. lime requirement for (2a) target pHs 5.8, (2b) target pHs 6.3, and (2c) target pHs 6.8 based on lab incubation study.

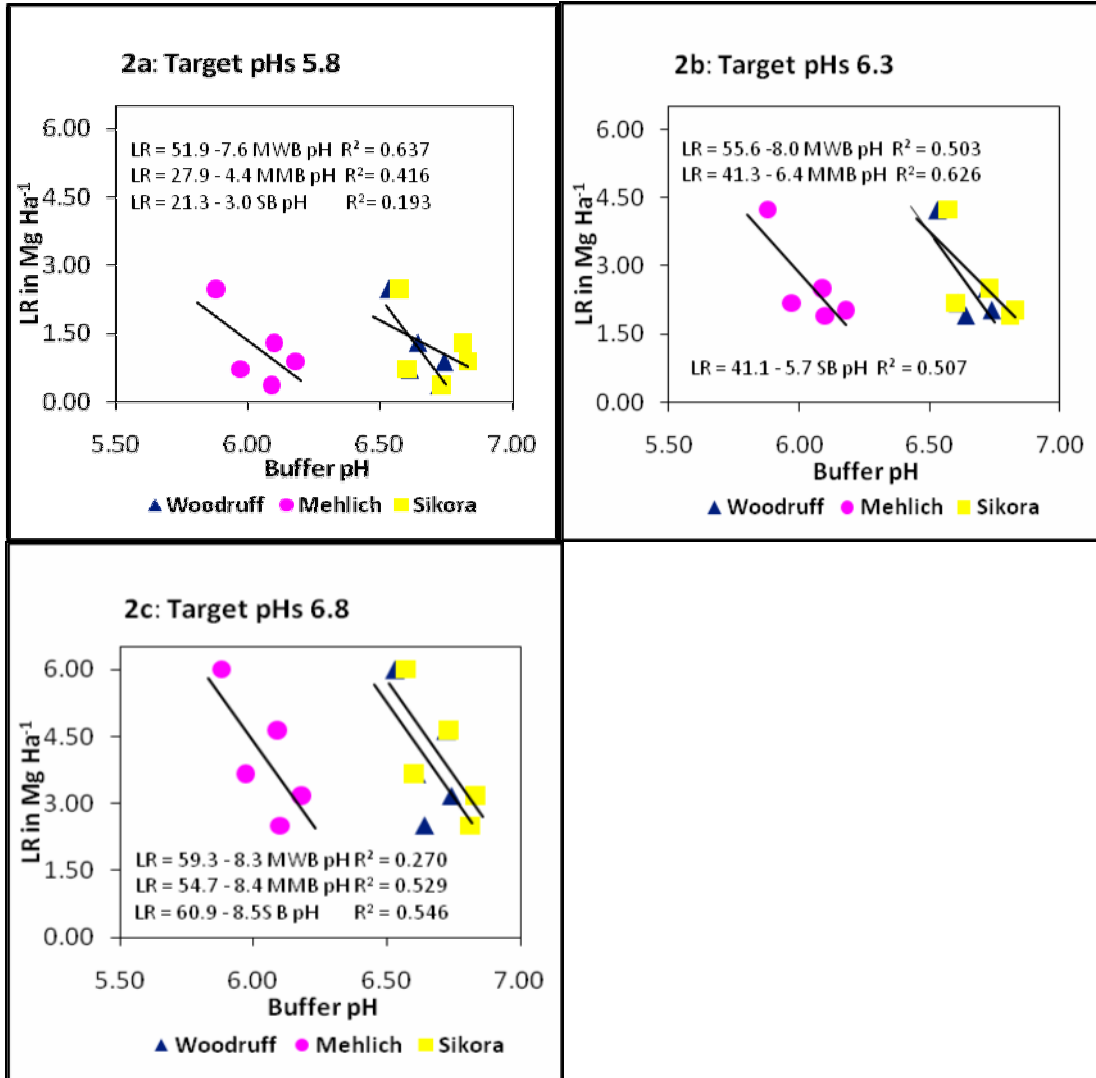


Fig. 2. Buffer pH vs. lime requirement for (2a) target pHs 5.8, (2b) target pHs 6.3, and (2c) target pHs 6.8 based on field calibration study at 365 days after application.

Table 1: Soil Chemical Characteristics for Field Sites, Fall 2011

Bradford

| Lime ENM lbs/a | pHs | N. A. meq/100g | Mehlich Buffer pH | Sikora Buffer pH | OM % | Bray1-P lbs/Ac | Ca lbs/Ac | Mg lbs/Ac | K lbs/Ac |
|----------------|-------|----------------|-------------------|------------------|--------|----------------|-----------|-----------|----------|
| 0 | 5.28a | 4.63a | 6.08b | 6.73c | 3.70ab | 12.8ab | 2957a | 345a | 143b |
| 250 | 5.60a | 3.00bc | 6.21ab | 6.92ab | 3.70ab | 12.5ab | 3198a | 313a | 156b |
| 500 | 5.35a | 4.00ab | 6.12ab | 6.79bc | 3.75ab | 9.0b | 3062a | 335a | 157b |
| 1000 | 5.40a | 4.25ab | 6.11b | 6.74c | 3.88a | 14.5ab | 3145a | 354a | 187a |
| 1500 | 5.93a | 2.25c | 6.29a | 7.03a | 3.80a | 21.3a | 3321a | 294a | 157ab |
| 2000 | 5.63a | 3.38bc | 6.17ab | 6.90bc | 3.53ab | 11.3ab | 2976a | 297a | 134b |
| 2500 | 5.90a | 2.625c | 6.26ab | 6.99ab | 3.33b | 15.8ab | 3229a | 310a | 142b |
| Pr > F | 0.294 | 0.161 | 0.183 | 0.079 | 0.184 | 0.291 | 0.919 | 0.397 | 0.037 |

Hundley Whaley

| Lime ENM lbs/a | pHs | N. A. meq/100g | Mehlich Buffer pH | Sikora Buffer pH | OM % | Bray1-P lbs/Ac | Ca lbs/Ac | Mg lbs/Ac | K lbs/Ac |
|----------------|--------|----------------|-------------------|------------------|-------|----------------|-----------|-----------|----------|
| 0 | 5.70d | 2.63a | 6.12c | 6.83d | 3.23a | 70.8ab | 5198ab | 656a | 276a |
| 250 | 5.73cd | 2.50ab | 6.21bc | 6.86d | 3.35a | 68.8ab | 4873b | 545a | 287a |
| 500 | 5.90c | 2.00ab | 6.20bc | 6.87d | 3.25a | 65.0b | 5529ab | 672a | 284a |
| 1000 | 6.00c | 1.75bc | 6.27ab | 7.00c | 3.35a | 74.8ab | 5447ab | 599a | 286a |
| 1500 | 6.23b | 1.25dc | 6.33ab | 7.04bc | 3.38a | 71.8ab | 5523ab | 621a | 273a |
| 2000 | 6.50a | 0.63d | 6.37a | 7.15a | 3.35a | 71.3ab | 5906a | 584a | 280a |
| 2500 | 6.45a | 0.75d | 6.39a | 7.14ab | 3.30a | 79.8a | 5400ab | 548a | 257a |
| Pr > F | 0.001 | 0.001 | 0.006 | 0.001 | 0.806 | 0.479 | 0.317 | 0.627 | 0.911 |

Greenley

| Lime ENM lbs/a | pHs | N. A. meq/100g | Mehlich Buffer pH | Sikora Buffer pH | OM % | Bray1-P lbs/Ac | Ca lbs/Ac | Mg lbs/Ac | K lbs/Ac |
|----------------|--------|----------------|-------------------|------------------|-------|----------------|-----------|-----------|----------|
| 0 | 5.20d | 3.25a | 6.03d | 6.73f | 3.13a | 23.8ab | 3288c | 298a | 94ab |
| 250 | 5.58c | 2.00b | 6.18c | 6.90e | 2.90a | 19.5b | 3551bc | 307a | 90ab |
| 500 | 5.50dc | 2.25b | 6.16c | 6.89e | 3.03a | 24.8ab | 3799ab | 310a | 95ab |
| 1000 | 6.00b | 1.25c | 6.29b | 7.02bc | 3.05a | 25.5ab | 3491bc | 285a | 88ab |
| 1500 | 6.18b | 1.00dc | 6.35b | 7.07bc | 2.95a | 26.0ab | 4115a | 311a | 116a |
| 2000 | 6.55a | 0.25e | 6.46a | 7.20a | 3.10a | 25.8ab | 3845ab | 273a | 82b |
| 2500 | 6.58a | 0.38de | 6.45a | 7.19a | 3.15a | 28.0a | 3981ab | 277a | 95ab |
| Pr > F | 0.001 | 0.001 | 0.001 | 0.001 | 0.482 | 0.277 | 0.036 | 0.276 | 0.413 |

Table 2: Grain yield response to lime treatments for three years after application

| Lime ENM lbs/ac | BR corn bu/a 2009 | BR beans bu/a 2010 | BR corn bu/a 2011 | DE corn bu/a 2009 | DE beans bu/a 2010 | DE corn bu/a 2011 | HW corn bu/a 2009 | HW beans bu/a 2010 | HW corn bu/a 2011 | GR corn bu/a 2009 | GR beans bu/a 2010 | GR corn bu/a 2011 |
|-----------------|-------------------|--------------------|-------------------|-------------------|--------------------|-------------------|-------------------|--------------------|-------------------|-------------------|--------------------|-------------------|
| 0 | 90 ab | 52 ab | 48 a | 146 a | 22 d | 78 c | 205 b | 51 ab | 149 b | 122 c | 66 a | 137 a |
| 250 | 87 ab | 57 a | 59 a | 158 ab | 33 c | 84 c | 221 ab | 49 b | 162 ab | 136 bc | 65 a | 144 a |
| 500 | 90 ab | 46 b | 57 a | 162 a | 35 c | 102 b | 227 ab | 47 b | 161 ab | 159 ab | 69 a | 143 a |
| 1000 | 86 ab | 51 ab | 55 a | 166 a | 48 a | 110 b | 229 ab | 50 ab | 158 ab | 168 a | 66 a | 150 a |
| 1500 | 101 a | 50 ab | 56 a | 163 a | 36 c | 119 a | 232 a | 51 ab | 159 ab | 171 a | 65 a | 153 a |
| 2000 | 77 ab | 51 ab | 44 a | 162 a | 46 ab | 123 a | 231 a | 51 ab | 162 ab | 150abc | 66 a | 156 a |
| 2500 | 72 b | 48 b | 56 a | 168 a | 38 bc | 121 a | 233 a | 54 a | 168 a | 137 bc | 64 a | 149 a |

Note: BR-Bradford; DE: Delta; HW: Hundley Whaley; GR: Greenley;

Table 3: Soil pHs and Buffer pH data for all five site soils-Lab Incubation Study, 2011

| Lime ENM lb/a | Bradford | | | Delta | | | Hundley-Whaley | | | Greenley | | | Southwest Center | | |
|------------------|----------|-------|-------|-------|-------|-------|----------------|-------|-------|----------|-------|-------|------------------|-------|-------|
| | pHs | MWB | SB | pHs | MWB | SB | pHs | MWB | SB | pHs | MWB | SB | pHs | MWB | SB |
| 0 | 6.17d | 6.86c | 7.01c | 4.92e | 6.64d | 6.79e | 5.28e | 6.61e | 6.61e | 4.99e | 6.47e | 6.44e | 5.36e | 6.74e | 6.87e |
| 750 | 6.53c | 6.94b | 7.13b | 5.67d | 6.81c | 7.07d | 5.92d | 6.79d | 6.83d | 5.48d | 6.64d | 6.67d | 6.23d | 6.90d | 7.12d |
| 1500 | 7.04b | 7.05a | 7.30a | 6.42c | 6.95b | 7.28c | 6.49c | 6.92c | 7.04c | 5.95c | 6.79c | 6.87c | 6.81c | 7.00c | 7.28c |
| 2250 | 7.25ab | 7.08a | 7.36a | 7.03b | 7.04a | 7.42b | 6.93b | 7.02b | 7.18b | 6.37b | 6.90b | 7.03b | 7.15b | 7.05b | 7.35b |
| 3000 | 7.27a | 7.09a | 7.36a | 7.23a | 7.07a | 7.45a | 7.19a | 7.08a | 7.27a | 6.75a | 6.99a | 7.16a | 7.28a | 7.07a | 7.39a |
| <i>Pr > F</i> | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 |

Note: MWB: Modified Woodruff Buffer; SB: Sikora Buffer

Table 4: Soil pHs and Buffer pH data for all five site soils-Field Incubation Study, 2011

a. Closed Bottom (Depth 0 - 2")

| Lime ENM lb/a | Bradford | | | Delta | | | Hundley-Whaley | | | Greenley | | | Southwest Center | | |
|------------------|----------|-------|-------|-------|-------|-------|----------------|-------|-------|----------|-------|-------|------------------|--------|-------|
| | pHs | MWB | SB | pHs | MWB | SB | pHs | MWB | SB | pHs | MWB | SB | pHs | MWB | SB |
| 0 | 6.21e | 6.89e | 7.02e | 5.25e | 6.69e | 6.85e | 5.38e | 6.63e | 6.65e | 5.21e | 6.53e | 6.59d | 5.71e | 6.77d | 7.00d |
| 750 | 6.47d | 6.95d | 7.13d | 5.76d | 6.83d | 7.07d | 6.04d | 6.82d | 6.89d | 5.59d | 6.68d | 6.77c | 6.18d | 6.86c | 7.13c |
| 1500 | 6.73c | 7.01c | 7.21c | 6.40c | 6.94c | 7.25c | 6.30c | 6.89c | 7.00c | 5.75c | 6.73c | 6.83c | 6.79c | 6.95b | 7.24b |
| 2250 | 6.92b | 7.04b | 7.27b | 6.98b | 7.04b | 7.41b | 6.80b | 7.00b | 7.15b | 6.46b | 6.91b | 7.08b | 6.96b | 6.99ab | 7.31a |
| 3000 | 7.01a | 7.06a | 7.30a | 7.17a | 7.07a | 7.46a | 7.13a | 7.07a | 7.26a | 6.84a | 6.98a | 7.19a | 7.15a | 7.02a | 7.36a |
| <i>Pr > F</i> | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 |

b. Closed Bottom (Depth 2 - 6")

| Lime ENM lb/a | Bradford | | | Delta | | | Hundley-Whaley | | | Greenley | | | Southwest Center | | |
|------------------|----------|--------|--------|-------|-------|-------|----------------|-------|-------|----------|-------|-------|------------------|-------|-------|
| | pHs | MWB | SB | pHs | MWB | SB | pHs | MWB | SB | pHs | MWB | SB | pHs | MWB | SB |
| 0 | 6.42d | 6.93d | 7.09d | 4.96e | 6.63d | 6.76e | 5.39e | 6.62e | 6.61e | 5.09e | 6.49e | 6.50e | 5.33d | 6.70d | 6.88d |
| 750 | 6.74c | 6.99c | 7.18c | 5.79d | 6.83c | 7.09d | 5.97d | 6.79d | 6.86d | 5.56d | 6.65d | 6.74d | 6.20c | 6.85c | 7.11c |
| 1500 | 6.90b | 7.03b | 7.25b | 6.51c | 6.97b | 7.30c | 6.58c | 6.94c | 7.09c | 6.17c | 6.82c | 6.96c | 6.74b | 6.94b | 7.26b |
| 2250 | 6.99ab | 7.05ab | 7.29ab | 6.84b | 7.02a | 7.38b | 7.00b | 7.03b | 7.22b | 6.52b | 6.91b | 7.09b | 7.11a | 7.01a | 7.33a |
| 3000 | 7.04a | 7.07a | 7.31a | 7.18a | 7.07a | 7.47a | 7.19a | 7.07a | 7.27a | 6.85a | 6.99a | 7.19a | 7.23a | 7.02a | 7.37a |
| <i>Pr > F</i> | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 |

c. Open Bottom (Depth 0 - 2")

| Lime ENM lb/a | Bradford | | | Delta | | | Hundley-Whaley | | | Greenley | | | Southwest Center | | |
|------------------|----------|-------|--------|-------|-------|-------|----------------|-------|-------|----------|-------|-------|------------------|-------|-------|
| | pHs | MWB | SB | pHs | MWB | SB | pHs | MWB | SB | pHs | MWB | SB | pHs | MWB | SB |
| 0 | 6.53d | 6.93c | 7.14d | 5.59d | 6.76d | 6.93e | 5.65e | 6.66e | 6.69d | 5.16e | 6.50e | 6.57e | 5.51d | 6.73d | 6.90e |
| 750 | 6.78c | 6.99b | 7.22c | 6.29c | 6.92c | 7.16d | 6.23d | 6.84d | 6.93c | 5.69d | 6.69d | 6.80d | 6.13c | 6.87c | 7.07d |
| 1500 | 6.92b | 7.01b | 7.26b | 6.74b | 7.01b | 7.30c | 6.65c | 6.95c | 7.07b | 6.10c | 6.82c | 6.96c | 6.73b | 6.98b | 7.24c |
| 2250 | 7.03a | 7.03a | 7.29ab | 7.16a | 7.07a | 7.39b | 6.97b | 7.02b | 7.18a | 6.39b | 6.90b | 7.03b | 7.09a | 7.06a | 7.32b |
| 3000 | 7.08a | 7.05a | 7.31a | 7.29a | 7.09a | 7.43a | 7.20a | 7.09a | 7.25a | 6.77a | 6.99a | 7.16a | 7.16a | 7.07a | 7.35a |
| <i>Pr > F</i> | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 |

Note: MWB: Modified Woodruff Buffer; SB: Sikora Buffer

d. Open Bottom (Depth 2 - 6")

| Lime ENM lb/a | Bradford | | | Delta | | | Huntley-Whaley | | | Greenley | | | Southwest Center | | |
|------------------|----------|-------|-------|-------|-------|-------|----------------|-------|-------|----------|-------|-------|------------------|--------|-------|
| | pHs | MWB | SB | pHs | MWB | SB | pHs | MWB | SB | pHs | MWB | SB | pHs | MWB | SB |
| 0 | 6.66d | 6.94d | 7.13d | 5.06e | 6.64d | 6.79d | 5.64e | 6.66e | 6.65e | 5.29e | 6.52e | 6.56e | 5.51d | 6.77d | 6.87e |
| 750 | 6.78c | 6.96c | 7.17c | 5.82d | 6.84c | 7.07c | 6.12d | 6.80d | 6.86d | 5.69d | 6.68d | 6.73d | 6.25c | 6.91c | 7.08d |
| 1500 | 6.94b | 6.99b | 7.22b | 6.64c | 6.98b | 7.29b | 6.65c | 6.94c | 7.05c | 6.09c | 6.80c | 6.89c | 6.86b | 7.00b | 7.25c |
| 2250 | 7.05a | 7.02a | 7.26a | 7.08b | 7.05a | 7.39a | 6.99b | 7.03b | 7.16b | 6.58b | 6.93b | 7.06b | 7.12a | 7.03ab | 7.31b |
| 3000 | 7.13a | 7.03a | 7.27a | 7.22a | 7.06a | 7.42a | 7.20a | 7.08a | 7.23a | 6.90a | 7.00a | 7.16a | 7.29a | 7.06a | 7.34a |
| <i>Pr > F</i> | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 |

e. Surface Applied (Depth 0 - 2")

| Lime ENM lb/a | Bradford | | | Delta | | | Huntley-Whaley | | | Greenley | | | Southwest Center | | |
|------------------|----------|-------|--------|--------|--------|-------|----------------|-------|--------|----------|-------|-------|------------------|-------|-------|
| | pHs | MWB | SB | pHs | MWB | SB | pHs | MWB | SB | pHs | MWB | SB | pHs | MWB | SB |
| 0 | 6.86c | 6.94c | 7.24b | 5.17c | 6.71c | 6.93b | 5.71b | 6.73b | 6.75b | 5.34d | 6.59d | 6.66c | 5.54c | 6.78c | 6.97c |
| 750 | 7.02b | 6.97b | 7.27ab | 6.04b | 6.88b | 7.07a | 6.51a | 6.91a | 6.95ab | 6.05c | 6.79c | 6.92b | 6.22b | 6.90b | 7.13b |
| 1500 | 7.04b | 6.98b | 7.28ab | 6.41ab | 6.93ab | 7.12a | 6.83a | 6.99a | 7.07a | 6.41b | 6.88b | 7.00b | 6.73a | 6.97a | 7.22a |
| 2250 | 7.13a | 7.00a | 7.28ab | 6.91a | 7.00a | 7.22a | 6.83a | 6.97a | 7.02a | 6.84a | 6.97a | 7.11a | 6.83a | 6.98a | 7.25a |
| 3000 | 7.20a | 7.01a | 7.31a | 6.81a | 6.98ab | 7.17a | 7.05a | 7.03a | 7.09a | 6.90a | 6.97a | 7.15a | 6.93a | 6.99a | 7.26a |
| <i>Pr > F</i> | 0.002 | 0.002 | 0.177 | 0.008 | 0.010 | 0.010 | 0.039 | 0.039 | 0.092 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 |

f. Surface Applied (Depth 2 - 6")

| Lime ENM lb/a | Bradford | | | Delta | | | Huntley-Whaley | | | Greenley | | | Southwest Center | | |
|------------------|----------|-------|-------|--------|--------|-------|----------------|-------|--------|----------|--------|-------|------------------|--------|-------|
| | pHs | MWB | SB | pHs | MWB | SB | pHs | MWB | SB | pHs | MWB | SB | pHs | MWB | SB |
| 0 | 6.95a | 6.98c | 7.26a | 4.87b | 6.66ab | 6.78a | 5.53a | 6.71a | 6.75a | 5.27a | 6.59b | 6.63a | 5.33b | 6.75b | 6.93a |
| 750 | 6.97a | 6.99b | 7.28a | 4.90ab | 6.68ab | 6.81a | 5.50a | 6.64a | 6.61b | 5.31a | 6.63ab | 6.73a | 5.32b | 6.74b | 6.94a |
| 1500 | 6.97a | 6.99b | 7.26a | 4.86b | 6.62b | 6.74a | 5.53a | 6.68a | 6.72ab | 5.37a | 6.64ab | 6.72a | 5.50b | 6.77ab | 6.97a |
| 2250 | 6.99a | 7.01a | 7.23a | 4.99a | 6.67ab | 6.80a | 5.70a | 6.69a | 6.69ab | 5.40a | 6.64ab | 6.72a | 5.42b | 6.77ab | 6.97a |
| 3000 | 7.00a | 7.02a | 7.27a | 5.01a | 6.70a | 6.85a | 5.66a | 6.69a | 6.70ab | 5.50a | 6.69a | 6.76a | 5.77a | 6.82a | 7.03a |
| <i>Pr > F</i> | 0.209 | 0.002 | 0.711 | 0.064 | 0.147 | 0.285 | 0.343 | 0.300 | 0.141 | 0.223 | 0.131 | 0.347 | 0.013 | 0.077 | 0.213 |

Nitrogen Management

Final Reports

Addressing nitrogen controversies

Peter Scharf, Vicky Hubbard, Larry Mueller, David Kleinsorge

Peter Scharf, Professor, State Nutrient Management Specialist
Vicky Hubbard, Research Specialist, Agronomy
Larry Mueller, Research Specialist, Agronomy
David Kleinsorge, Research Specialist, Agronomy
University of Missouri, Plant Sciences Division

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:

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

Long-term nitrogen rate recommendation systems experiment

- The three years of this project, 2008-2010, all had excessive rainfall during the April-June period and adequate rainfall through July and August.
- In all three years, plots receiving their nitrogen pre-plant appeared severely nitrogen-deficient in August (Figure 1). It seems clear that much of the pre-plant N was lost during these wet springs. In contrast, sidedress nitrogen treatments all looked substantially better in August (Figure 2).



- Nitrogen treatments were applied as broadcast ammonium nitrate.
 - Three fixed pre-plant N rates
 - A preplant N rate adjusted based on soil nitrate measured to 2 feet deep before planting
 - Sidedress N rates based on:

- Crop canopy sensor (Crop Circle 210)
 - Chlorophyll meter
 - Sidedress soil nitrate test to 1 foot depth
 - Check (zero N).
- This experiment was also conducted in 2007 prior to funding by the Fertilizer & Ag Lime Council, giving a total of four years of study.
- **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 and Crop Circle sensor) (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.
- Among pre-plant treatments, the high-rate treatment (180 lb N/acre) gave the highest yields and highest profit over the 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 was still 46 bushels below the average of the two color-based sidedress treatments.

Table 1. N rates and corn yields for eight N recommendation systems from 2007-2010.

| Nitrogen Recommendation System | Nitrogen Application Timing ¹ | 2007-2010 Ave. N rate (lb/ac) | 2007-2010 Ave. yield (bu/ac) | 2007-2010 Ave. gross - N cost (\$/ac/year) ² |
|--------------------------------|--|-------------------------------|------------------------------|---|
| Chlorophyll meter | V7 | 171 | 146 | 481 |
| Crop Circle sensor | V7 | 149 | 142 | 479 |
| Sidedress soil test | V7 | 123 | 131 | 450 |
| High | Pre-plant | 180 | 98 | 284 |
| Yield goal/ MRTN | Pre-plant | 140 | 86 | 260 |
| Pre-plant soil test | Pre-plant | 134 | 84 | 256 |
| Low | Pre-plant | 100 | 76 | 244 |
| Check | Pre-plant | 0 | 47 | 188 |

¹Growth stage V7 is about knee high corn

²Gross 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 50 lb 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 to corn that was approximately waist high and again on corn that was approximately shoulder high.
- In-season nitrogen treatments were:
 - foliar CoRoN, N rate matching other treatments (8 gal/ac)
 - foliar CoRoN, manufacture's rate (3 gal/ac) (not included first year of study)
 - foliar UAN
 - foliar urea
 - dribbled UAN (between rows)
 - broadcast ammonium nitrate
 - broadcast urea with Agrotain
 - check (no in-season N)
- Data for this experiment are from 2008, 2010, and 2011. Although the experiment was conducted in 2009, it was accidentally harvested by the farm crew without recording yields.
- **Foliar treatments did not show superior ability to deliver in-season N to a corn crop relative to soil-applied treatments.** See Table 2.
 - Average yield with foliar N (excluding the lower-rate CoRoN treatment) was 94bu/acre, with soil-applied N was 100bu/acre.
 - Concerns about the ability of dry N to reach roots when broadcast in-season may be unfounded. Although there was good moisture to help deliver N to roots in 2008 and 2010, dry N was delivered as efficiently as foliar N in the dry summer of 2011.
 - Foliar UAN gave the highest burn rating (Table 2) 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 2. Corn yields with foliar or dry N sources for 2011 and over the 3-year study period. All treatments were applied at a rate of 20 lb N/acre at V10 and again at V13 except for the manufacturer rec rate CoRoN treatments which were applied at a rate of 7.5 lb N/acre at the same timings. Before planting, urea-ammonium nitrate solution was broadcast on all plots at a rate of 40 lb N/acre and incorporated with light tillage.

| In-season source | 2011 Ave. Yield (Bu/ac) ¹ | 3 yr Yield (Bu./ac) ¹ | 2 yr. Ave. Burn Rating ² |
|--|--------------------------------------|----------------------------------|-------------------------------------|
| Urea with Agrotain(dry) | 52 ^A | 102 ^A | 0.9 |
| Ammonium Nitrate(dry) | 47 ^A | 99 ^{AB} | 3.2 |
| Foliar Urea | 49 ^A | 98 ^B | 6.0 |
| Foliar CoRoN 8 Gal/acre(Study rate) | 50 ^A | 94 ^C | 3.8 |
| UAN Dribbled | 43 ^B | 91 ^{CD} | 0.0 |
| Foliar UAN | 48 ^A | 90 ^D | 8.4 |
| Foliar CoRoN 3 gal/acre (Manufacturer recommended rate) | 32 ^C | 80 ^E | 1.0 |
| No in-season N | 15 ^D | 61 ^F | 0.0 |

¹Values within a column that are followed by a shared letter are not different from one another by 90% confidence.

² Burn rating shown is the average of ratings 7 days after each application (V10 and V13). (10 = Severe, 0 = None). Burn ratings not taken in 2011 due to hail damage to leaves.

- 2011 yields were very low due to hail damage and drought.
- Average yields over the study period were low due to low N rates, which were designed to test the efficiency of these different N delivery systems.
- The top-yielding treatments were the two dry N sources. Over the 3-year study, broadcast dry urea with Agrotain gave significantly higher yield than any other N source/placement except ammonium nitrate.
 - This treatment also 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.
- **CoRoN was not more effective than other N sources as has been claimed in advertising.** Foliar N sources gave statistically different yields (90% confidence):
 - Urea solution highest
 - CoRoN intermediate
 - UAN solution lowest (probably due to causing the highest leaf burn)
- The lower (manufacturer's recommended) rate of CoRoN gave an average yield response of 19 bushels with a total of 15 lb N/acre applied. This was a highly efficient delivery of nitrogen. However, the label rate of CoRoN still came out 14 bushels below CoRoN applied at the full study rate, and significantly below ALL treatments that received 40 lb N in-season. The label rate of CoRoN is too low to correct a serious N deficiency.

New N products and N-enhancement products experiment

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

| Nitrogen source | 2010 yield | 2009 yield | 2008 yield | 3-yr ave. yield ¹ |
|--------------------------|------------|------------|-------------------|------------------------------|
| 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 |

¹3-year average yields are different from each other if they are 8 or more bushels apart. (95%confidence)

²Check treatment omitted in 2008.

Enhanced Efficiency Liquid N Applications for Corn

Kelly Nelson, Peter Motavalli, Bruce Burdick

Investigators:

Kelly Nelson, Div. of Plant Sciences, Univ. of Missouri, Novelty, 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 covers an average area of approximately 2.9 million acres since 2004 and has a value of \$1.2 billion in total production (NASS, 2009). High yield corn production systems have integrated fungicide applications (Nelson and Meinhardt, 2011) 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 in 2010 and 2011. 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 2010 and 8 July 2011 at Novelty, and 13 July 2010 and 15 July 2011 at Albany when corn was at the VT stage of development (Ritchie et al., 1993). Foliar fertilizer and fungicide treatments were applied with a CO₂ propelled hand boom at 3 gal/acre. Field and management information is reported in Table 1. Supplemental irrigation was scheduled using the Woodruff chart.

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 zea-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 15.5% 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:

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 in 2010. Corn plant population at harvest was 26,000 to 28,000/acre at both locations (Table 2). The severity of disease was less than 1% at VT (Table 3). Chlorophyll meter readings indicated differences among soil applied N rates as expected at the time of the foliar VT applications (Table 3, Figure 1). The Albany site was greener than Novelty indicating less N loss at Albany in 2010 while both sites had higher chlorophyll meter readings in 2011 (Figure 1). 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. The different N rates provided different yielding environments that may respond to a slow-release liquid N application. 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, in 2010. In 2011, less than 25 lbs N/acre was needed based on absolute chlorophyll meter readings at the time of application. Since 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 (Table 2). Nitamin at 3 gal/acre injured corn 3 to 4% (Table 4) which probably negated any yield increase from this treatment. There was no interaction with pyraclostrobin on crop injury and pyraclostrobin had no effect on crop injury ($P = 0.57$).

Nitamin at 1 or 3 gallons/acre had no effect on corn yield in a low (soil applied N at 75 lbs/acre at Novelty and Albany in 2010 and 2011) or medium (soil applied N at 150 lbs/acre at Novelty and Albany in 2010 and 2011) yield environments (Table 2). This indicated that too much N was needed to overcome N deficiency with a Nitamin application. A rescue N application (Nelson et al., 2011) was necessary in this situation. However, rescue N applications of liquid UAN at high rates 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). Grain yields were reduced 7 to 10 bu/acre with Nitamin at 3 gal/acre at Novelty in a medium yield environment which was probably due to increased crop injury as a result of the Nitamin application. In a high yield environment (soil applied N at 300 lbs/acre at Novelty and Albany), Nitamin increased grain yields 6 bu/acre compared to the non-treated control. Similarly, Headline increased yield 6 to 9 bu/acre compared to the non-treated control in a high yield (>150 bu/acre) environment. 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.

Soil-applied N, foliar applied N, fungicide treatment, and site-year affected the severity of foliar disease in this research. The severity of grey leaf spot was less than 5% (Table 5). The severity of grey leaf spot increased slightly as preplant N rate increased and Nitamin rate increased from 1 to 3 gal/acre. Headline generally decreased the severity of grey leaf spot in a high yield environment (300 lbs N/acre), and with Nitamin at 1 gal/acre or in the absence of Nitamin. Northern corn leaf blight and common rust severity was affected by site-years and interactions among factors were observed (Tables 6 and 7). The severity of Northern corn leaf blight was <2% at Albany and Novelty in 2010 (Tables 6 and 7). The severity of Northern corn leaf blight increased slightly as the Nitamin rate increased at Novelty and Albany in 2011 (Table 6), and increased 3 to 6% at Novelty and 1 to 2% at Albany in 2011 (Table 7). Common rust was not present at Novelty or Albany in 2011 and was < 2% at Novelty in 2010 (Tables 6 and 7). As preplant N rates increased and Nitamin rates increased to 3 gal/acre, the severity of common rust generally increased (Table 7).

Headline had no effect on grain moisture ($P = 0.95$), but grain moisture was affected by preplant N rates (Table 8) and Nitamin rates (Table 9). At Novelty, grain disease (Diplodia) increased as the rate of preplant N increased 4% (Table 8) and slightly as the Nitamin rate increased (Table 9) in 2010, but no differences were observed at Novelty or Albany in 2011 or Albany in 2010. Headline did not affect grain disease ($P = 0.27$) similar to other research (Nelson and Meinhardt, 2011). There was an interaction between Nitamin rates and soil applied N rates on protein concentration with a 1.1 to 1.3% point increase as the soil applied N rate increased. Nitamin increased protein concentration 0.2% points as the rate increased from 0 to 3 gal/acre in a high yield environment (300 lbs N/acre), but there was no effect of Headline on protein concentrations ($P = 0.36$). There was a significant interaction between Headline and Nitamin rates ($P = 0.04$), but minimal differences in starch concentrations were observed (Table 9).

In summary, Nitamin at 1 gal/acre increased grain yields 11 bu/acre when chlorophyll meter readings at VT were greater than 45 in 2010, greater than 55 at Novelty in 2011, and greater than 63 at Albany in 2011. Nitamin at 1 or 3 gallons/acre had no effect on corn yield in a low (soil applied N at 75 lbs/acre at Novelty and Albany in 2010 and 2011) or medium (soil applied N at 150 lbs/acre at Novelty and Albany in 2010 and 2011) yield environments (Table 2). This indicated that too much N was needed to overcome N deficiency with a Nitamin application. Grain yields were reduced 7 to 10 bu/acre with Nitamin at 3 gal/acre at Novelty in a medium yield environment which was probably due to increased crop injury as a result of the Nitamin application. In a high yield environment (soil applied N at 300 lbs/acre at Novelty and Albany), Nitamin increased grain yields 6 bu/acre compared to the non-treated control. Similarly, Headline increased yield 6 to 9 bu/acre compared to the non-treated control in a high yield (>150 bu/acre) environment. 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. The severity of diseases in this research was <12% depending on the treatment and was affected by N fertility, Nitamin rate, and fungicide management in some instances depending on the location. Headline and Nitamin at 1 gal/acre shows promise in high yielding environments.

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Table 1. Field and management information at Novelty and Albany in 2010 and 2011.

| Management information | Novelty | | Albany | |
|-----------------------------|---|--|--|---|
| | 2010 | 2011 | 2010 | 2011 |
| Previous crop | Soybean | Soybean | Soybean | Soybean |
| Hybrid or cultivar | DK 63-42 VT3 | DK 63-42 VT3 | DK 63-42 VT3 | Pioneer 33D49 |
| Planting date | 13 Apr. | 1 Apr. | 26 Apr. | 3 May |
| Seeding rate (seeds/acre) | 32,000 | 30,800 | 29,500 | 29,500 |
| Harvest date | 30 Sept. | 12 Sept. | 19 Oct. | 26 Sept. |
| Maintenance fertilizer | 13 Apr., MAP 32-160-300 (N-P-K) | NA | 15 Apr., DAP 18-46-80 (N-P-K) | NA |
| Ammonium nitrate | 7 May, Between-row at 75, 150, or 300 lbs N/acre | 18 May, Between-row at 75, 150, or 300 lbs N/acre | 26 May, Between-row at 75, 150, or 300 lbs N/acre | 6 May, Between-row at 75, 150, or 300 lbs N/acre |
| Weed management | | | | |
| Preemergence | 15 Apr., Atrazine (2 qt/acre) + Outlook (21 oz/acre) | 13 Apr., Lumax (2.5 qt/acre) | 27 Apr., Lumax (3.2 qt/acre) | 3 May, Lumax (3.2 qt/acre) |
| Postemergence | 22 June, Roundup PowerMAX (30 oz/acre) + DAS (17 lbs/100 gal) | NA | NA | NA |
| Disease management | Pyraclostrobin +/- Nitamin | Pyraclostrobin +/- Nitamin | Pyraclostrobin +/- Nitamin | Pyraclostrobin +/- Nitamin |
| Date & Time | 12 July, 1700 to 2100 h | 8 July, 1000 to 1300 | 13 July, 1100 to 1600 h | 15, July 800 to 1100 h |
| Air temperature (°F) | 72-83 | 79-84 | 84-89 | 83-87 |
| Relative humidity (%) | 63-83 | 62-70 | 61-77 | 66-83 |
| Wind speed (MPH, direction) | 1-3, E | 0-1, W | 3-4, S | 2-5, S |
| Height (inches) | 72-96 | 90-100 | 84-108 | 88-120 |
| Leaf moisture | Dry | Dry | Dry | Dry |

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

Table 2. Corn grain yield for the low (75 lbs N/acre), medium (150 lbs N/acre at Novelty and Albany), and high (300 lbs N/acre) yield environments, and severity of disease for preplant N rates at VT. Main effects were presented in the absence of interactions.

| Treatment | Plant population No./acre | Low | Medium | | High |
|---|------------------------------|-----|--------|---------|------|
| | | | Albany | Novelty | |
| Non-treated | 26,300 | 116 | 129 | 149 | 162 |
| Nitamin (1 gal/acre) | 26,000 | 113 | 126 | 152 | 168 |
| Nitamin (3 gal/acre) | 28,000 | 117 | 134 | 142 | 161 |
| LSD ($P = 0.1$) [†] | NS | NS | NS | 7 | 5 |
| Non-treated | 26,900 | 117 | 131 | 146 | 157 |
| Headline (3 oz/acre) + Nitamin [‡] | 26,200 | 113 | 131 | 147 | 163 |
| Nitamin + Headline (3 oz/acre) [‡] | 27,600 | 117 | 128 | 151 | 166 |
| Headline (6 oz/acre) + Nitamin [‡] | 27,800 | 114 | 129 | 147 | 168 |
| LSD ($P = 0.1$) [§] | NS | NS | NS | NS | 6 |

[†]Data were averaged over Headline treatments, years (2010 and 2011) and locations (Albany and Novelty, except the medium yield environment).

[‡]Listed order is the mixing order.

[§]Data were averaged over Nitamin treatments, years (2010 and 2011) and locations (Albany and Novelty, except the medium yield environment).

Table 3. 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.

| Preplant N rates lbs N/acre | Chlorophyll meter | | | | | Severity of disease [†] | | | |
|--------------------------------|-------------------|----------------|-----------------|----------------|---------|----------------------------------|----------------|------------------------------|----|
| | Novelty 2010 | Albany 2010 | Novelty 2011 | Albany 2011 | Average | Grey leaf spot | Common rust | Northern corn leaf blight | |
| | SPAD units | | | | | % | | | |
| 75 | 32.5 | 36.6 | 47.7 | 60.3 | 44.3 | < 1 | 0 | < 1 | |
| 150 | 37.3 | 44.2 | 52.6 | 62.0 | 49.0 | < 1 | 0 | < 1 | |
| 300 | 43.2 | 50.3 | 54.6 | 63.0 | 52.8 | < 1 | 0 | < 1 | |
| LSD ($P = 0.01$) | 1.0 | | | | | 0.5 | NS | NS | NS |

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

Table 4. Corn injury as affected by preplant N management and foliar Nitamin rate 14 d after treatment. Data were combined over four site-years and fungicide treatments.

| Preplant N rates (lbs/acre) | Nitamin 0 gal/acre | Nitamin 1 gal/acre | Nitamin 3 gal/acre |
|-----------------------------|--------------------|--------------------|--------------------|
| | ----- % ----- | | |
| 75 | 0 | 1 | 4 |
| 150 | 0 | 1 | 4 |
| 300 | 0 | 1 | 3 |
| LSD ($P = 0.05$) | ----- 1 ----- | | |

Table 5. Severity of grey leaf spot 42 d after treatment as affected by preplant N and Headline, and Nitamin rate and Headline. Data were combined over four-site years and main effects presented.

| Fungicide treatment | Preplant N rate (lbs N/acre) | | | Nitamin rate (gal/acre) | | |
|--|-------------------------------------|-----|-----|-------------------------|---|---|
| | 75 | 150 | 300 | 0 | 1 | 3 |
| | ----- Severity of disease (%) ----- | | | | | |
| Non-treated | 3 | 4 | 5 | 4 | 4 | 4 |
| Headline at 3 oz/acre + NIS fb Nitamin | 3 | 3 | 4 | 3 | 3 | 4 |
| Nitamin fb Headline at 3 oz/a + NIS | 3 | 4 | 4 | 3 | 3 | 4 |
| Headline at 6 oz/acre + NIS fb Nitamin | 3 | 4 | 4 | 3 | 3 | 4 |
| LSD ($P = 0.1$) | ----- 1 ----- | | | ----- 1 ----- | | |

Table 6. Severity of northern corn leaf blight severity as and common rust severity as affected by preplant N rate and location 42 d after treatment.

| Preplant rate (gal/acre) | Northern corn leaf blight | | | | Common rust | | | | | | | | | | | |
|-----------------------------|-------------------------------------|------|--------|------|---------------|---|---|--------------|---|---|-------------|---|---|-------------|---|---|
| | Novelty | | Albany | | Novelty 2010 | | | Novelty 2011 | | | Albany 2010 | | | Albany 2011 | | |
| | 2010 | 2011 | 2010 | 2011 | 0 | 1 | 3 | 0 | 1 | 3 | 0 | 1 | 3 | 0 | 1 | 3 |
| | ----- Severity of disease (%) ----- | | | | | | | | | | | | | | | |
| 75 | 0 | 7 | 1 | 3 | 1 | 1 | 2 | 0 | 0 | 0 | 2 | 2 | 2 | 0 | 0 | 0 |
| 150 | 1 | 8 | 1 | 4 | 1 | 1 | 2 | 0 | 0 | 0 | 3 | 2 | 2 | 0 | 0 | 0 |
| 300 | 1 | 8 | 1 | 4 | 1 | 2 | 2 | 0 | 0 | 0 | 7 | 4 | 2 | 0 | 0 | 0 |
| LSD ($P = 0.1$) | ----- 1 ----- | | | | ----- 1 ----- | | | | | | | | | | | |

Table 7. Effect of pyraclostrobin (Headline) treatment, location, and Nitamin rate on the severity of northern corn leaf blight and common rust 42 d after treatment.

| Fungicide treatment [†] | Northern corn leaf blight | | | | | | | | | | | | Common rust | | | | | | | | | | | |
|--|-------------------------------------|---|---|--------------|---|----|-------------|---|---|-------------|---|---|---------------|---|---|--------------|---|---|-------------|---|---|-------------|---|---|
| | Novelty 2010 | | | Novelty 2011 | | | Albany 2010 | | | Albany 2011 | | | Novelty 2010 | | | Novelty 2011 | | | Albany 2010 | | | Albany 2011 | | |
| | 0 | 1 | 3 | 0 | 1 | 3 | 0 | 1 | 3 | 0 | 1 | 3 | 0 | 1 | 3 | 0 | 1 | 3 | 0 | 1 | 3 | 0 | 1 | 3 |
| | ----- Severity of disease (%) ----- | | | | | | | | | | | | | | | | | | | | | | | |
| Non-treated | 0 | 1 | 1 | 8 | 9 | 12 | 1 | 1 | 1 | 3 | 4 | 5 | 2 | 2 | 2 | 0 | 0 | 0 | 3 | 3 | 3 | 0 | 0 | 0 |
| Headline at 3 oz/acre + NIS fb Nitamin [‡] | 0 | 0 | 1 | 6 | 6 | 10 | 1 | 1 | 1 | 3 | 3 | 5 | 1 | 1 | 2 | 0 | 0 | 0 | 2 | 2 | 4 | 0 | 0 | 0 |
| Nitamin fb Headline at 3 oz/a + NIS [†] | 0 | 0 | 1 | 6 | 6 | 12 | 1 | 1 | 2 | 3 | 3 | 4 | 1 | 1 | 2 | 0 | 0 | 0 | 2 | 2 | 4 | 0 | 0 | 0 |
| Headline at 6 oz/acre + NIS fb Nitamin [†] | 0 | 1 | 1 | 5 | 5 | 11 | 1 | 1 | 1 | 3 | 3 | 4 | 1 | 1 | 2 | 0 | 0 | 0 | 2 | 2 | 5 | 0 | 0 | 0 |
| LSD ($P = 0.1$) | ----- 1 ----- | | | | | | | | | | | | ----- 1 ----- | | | | | | | | | | | |

[†]Mixing order for fungicide treatments.

[‡]Abbreviations: fb, followed by; NIS, non-ionic surfactant.

Table 8. Effect of preplant N rate on grain moisture, disease (Diplodia) at each site-year, and protein concentration for Nitamin rates. Data were combined over site-year in the absence of interactions.

| Soil applied N (lbs/acre) | Grain moisture | Grain disease (Diplodia) | | | | Protein concentration | | |
|------------------------------|-------------------|--------------------------|--------------|-------------|-------------|-----------------------|-----|-----|
| | | Novelty 2010 | Novelty 2011 | Albany 2010 | Albany 2011 | 0 | 1 | 3 |
| 75 | 20.5 | 5 | 0 | 2 | 0 | 7.3 | 7.2 | 7.3 |
| 150 | 20.1 | 6 | 0 | 2 | 0 | 7.7 | 7.8 | 7.8 |
| 300 | 20.7 | 9 | 0 | 2 | 0 | 8.4 | 8.5 | 8.6 |
| LSD ($P = 0.05$) | 0.3 | ----- 1 ----- | | | | ----- 0.2 ----- | | |

Table 9. Effect of Nitamin rates on grain moisture, disease (Diplodia) at each site-year, and starch concentration for different Headline (pyraclostrobin) applications.

| Nitamin rate (gal/acre) | Grain moisture | Grain disease (Diplodia) | | | | Starch concentration | | | |
|----------------------------|-------------------|--------------------------|-----------------|----------------|----------------|----------------------|--|---|--|
| | | Novelty 2010 | Novelty 2011 | Albany 2010 | Albany 2011 | Non- treated | Headline at 3 oz/acre + NIS fb Nitamin [†] | Nitamin fb Headline at 3 oz/a + NIS [†] | Headline at 6 oz/acre + NIS fb Nitamin [†] |
| 0 | 20.6 | 6 | 0 | 2 | 0 | 73.0 | 73.1 | 72.9 | 73.0 |
| 1 | 20.5 | 7 | 0 | 2 | 0 | 73.0 | 73.0 | 73.0 | 73.0 |
| 3 | 20.3 | 7 | 0 | 2 | 0 | 73.1 | 72.9 | 73.0 | 72.9 |
| LSD ($P = 0.05$) | 0.3 | ----- 1 ----- | | | | ----- 0.2 ----- | | | |

[†]Mixing order for fungicide treatments.

[‡]Abbreviations: fb, followed by; NIS, non-ionic surfactant.

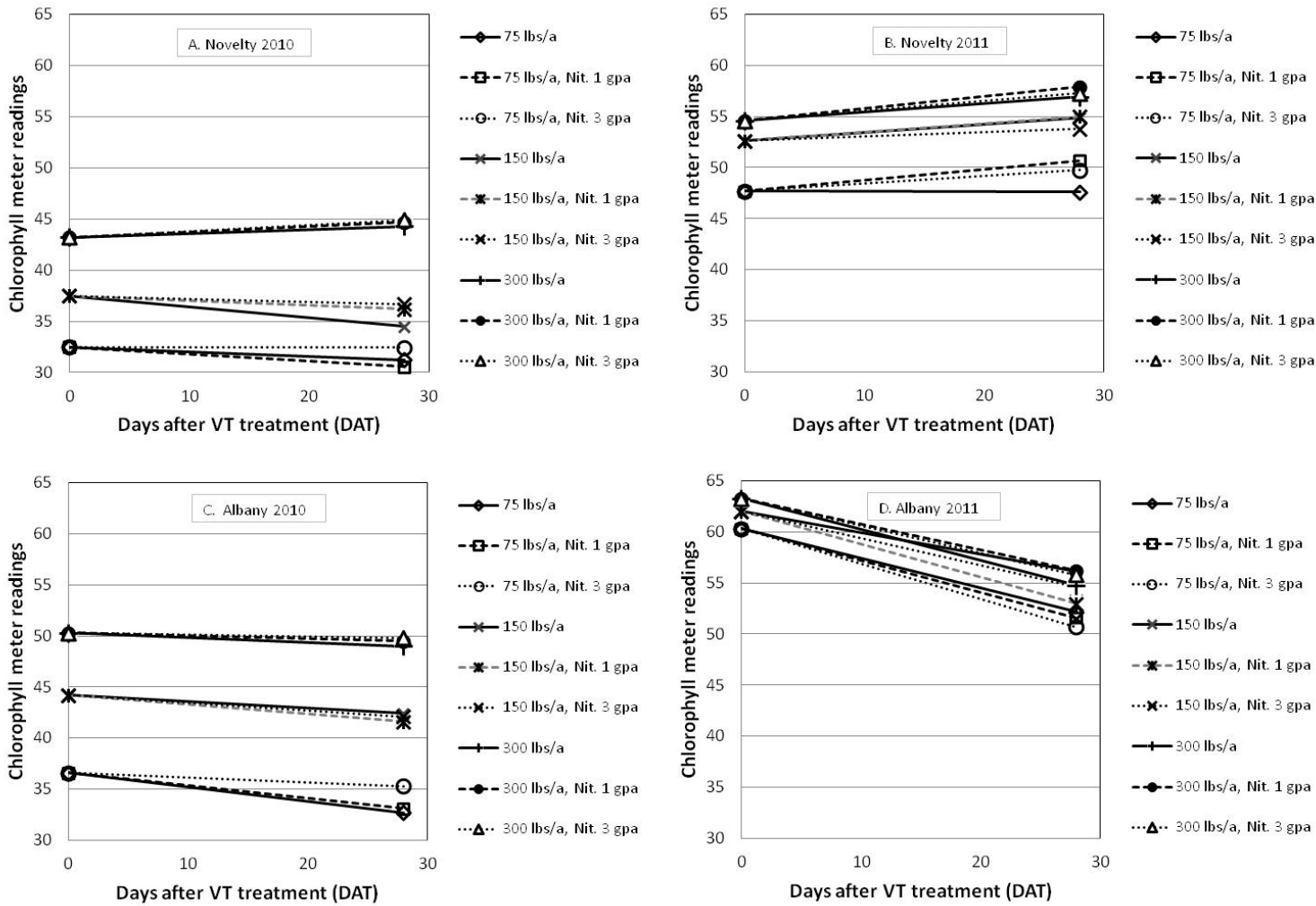


Figure 1. Chlorophyll meter readings at the time of application (VT) and 28 days after treatment (DAT) soil applied N treatments (75, 150, or 300 lbs N/acre) and Nitamin (Nit.) rates (0, 1 or 3 gallons per acre = gpa) at Novelty (2010 and 2011) and Albany (2010 and 2011). Data were combined over Headline treatments. LSD ($P=0.1$) is 1.

Nitrogen dynamics of standard and enhanced urea in corn

James H. Houx III and Felix B. Fritsch

INTRODUCTION:

Concerns about illegal uses of anhydrous ammonia and ammonium nitrate may make urea a preferred 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 goal of this project was to evaluate different Urea-N management products on the fate of fertilizer N and corn yields.

The specific objectives were:

- 1) Evaluate corn yield response to fertilization with standard urea and enhanced N-urea products.
- 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.

Procedures: The experiment was arranged as a randomized complete block design with four replications and repeated in 2009, 2010, and 2011. All years, corn (Pioneer 33M16) was sown in 30" rows in no-till plots previously planted in soybean at Bradford Research and Extension Center (Mexico silt loam) in plots 20' x 100' (2009) and 30' x 100' (2010, 2011). In 2009 seven treatments were applied (Nutrisphere-treated urea, Agrotain-treated urea, urea, ESN urea, Duration PCU urea, 32% UAN, no-fertilizer N) and in 2010 and 2011, an additional treatment, SuperU, was applied. All nitrogen treatments were applied at 150 lbs N acre⁻¹. All urea treatments were applied at planting and UAN treatments were applied post plant. Agrotain and Nutrisphere were applied to pre-weighed urea using a small concrete mixer at rates according to manufacturer's suggestions.

To determine in-season plant growth one meter-row of plants in each plot was harvested five times in each growing season and separated into leaves, stems, and reproductive parts and dried at 60°C for 96 hrs and weighed. Growth stage was determined within each plot when biomass was assayed. Plant N status was determined by gas-fusion with a LECO TruSpec N nitrogen determinator from plant parts used for growth analysis. Soil N status was determined at three depths (0-5, 5-15, and 15-25 cm) four times each season by compositing five samples taken from within each plot. Samples were extracted with 2M KCl and extracts were analyzed for nitrate and ammonia N by flow injection analysis with a Lachat QuikChem 8500 FIA system. Nitrogen fate was determined by ^{15}N labeling from microplots (2 x 2 m) established in each plot fertilized with agrotain-treated urea, PCU, and untreated urea. Microplots were covered during the application of fertilizer treatments at planting and subsequently fertilized with ^{15}N labeled urea either treated with Agrotain, a polymer coating, or left untreated. Leaf discs (9.6 mm) were taken from each leaf from five plants in each microplot and dried and soil samples from the microplots

were taken when aforementioned soil sampling occurred. Leaf tissue and soil samples from microplots are being analyzed at the University of California-Davis Stable Isotope Facility.

Corn yields were determined by harvesting two rows (2009) and four rows (2010, 2011) from each plot using a small plot combine and correcting grain moisture content to 15.5%. All data were analyzed with Statistical Analysis Software (SAS) using PROC MIXED. Soil sampling data, growth (biomass) data, and developmental stage (vegetative) data were further analyzed as repeated measures. Pair-wise mean comparisons using Tukey's Honest Significant Test at an alpha of 0.05 were used to determine treatment differences. Grain yield differed between years so each year was analyzed and presented separately. Soil sampling data and growth (biomass) data were similar in 2010 and 2011 so data were combined across these years. Developmental stage data from 2011 was incomplete due to hail damage so only 2009 and 2010 data are presented. Data for tissue nitrogen, ^{15}N , and 2010 and 2011 soil N are still being analyzed and are not available for this report.

Results: Corn yield differed between years and between urea enhancement products and N source in most years (Table 1). In 2009, yields were good compared to yields that are typical at the Bradford Research and Extension Center (BREC) and yields in 2010 were low in comparison. In 2011, yields were generally considered poor across all research plots at BREC and this is mostly attributed to unseasonably cool and wet weather during the month of May. This was followed by a hail storm on July 5 and severe drought through most of the remaining season. Considering all years, the only broadcast-applied urea N treatments that resulted in yields that were greater than the untreated urea control were Duration PCU in 2009, Duration PCU, ESN, and SuperU in 2010, and Duration PCU and ESN in 2011. As a grower's standard, UAN is used as treatment to compare these products to a typical N treatment. It is soil-injected so its comparison to the urea treatments is considered for check treatment purposes only. Further, Duration PCU is a polymer coated urea that is currently not marketed for agricultural use and is designed for use in turf and ornamental markets and on golf course turf. Its use in this study was to compare a "true" polymer coated urea to the other urea enhancement products. As for agriculture use products, ESN (2010, 2011) and SuperU (2010) were the only products that resulted in corn yields that were greater than untreated urea.

Soil sampling data for 2009 (Fig. 1) illustrate some of the N dynamics associated with the different treatments. Agrotain, Nutrisphere, and untreated urea appear similar in their soil N dynamics in that the highest nitrate levels were found at the June 9 sampling date. This response is reasonable considering that these products resulted in similar grain yields in 2009. ESN and Duration PCU resulted in nitrate levels that were highest at the third sampling date. This result corresponds to their slow-release characteristics that delayed N release. Nonetheless, only Duration PCU resulted in yields that were greater than the untreated control in 2009.

Biomass growth during the 2009 growing season (Fig. 2) differed from that in 2010 and 2011 (Fig. 3). By June 6th, growth in Agrotain-, Nutrisphere-, and ESN-treated corn appears greater than that in PCU- and UAN-treated corn. This suggests that N release was greater in the aforementioned products during the first few weeks of growth resulting in the greater biomass. However, by the end of the season, biomass accumulation appears greater in the UAN and PCU treatments and this corresponds with yield results from 2009. In 2010 and 2011 (Fig.3), biomass yields reached their peak early in the growing seasons for ESN, SuperU, Agrotain, and untreated urea and little biomass accumulation occurred after the July 9 sampling date. Meanwhile, UAN and PCU biomass accumulation peaked in late July. These results from 2010 and 2011 are difficult to interpret as the corresponding yields did not always follow these trends each year. Hail damage did not allow for an accurate estimate of vegetative development in 2011 so only data for 2009 and 2010 (Fig. 4) is shown. For each treatment, development occurred sooner in 2009 than 2010 and this is reflected in grain yields. Nonetheless, differences between treatments did not correspond well with yields.

Conclusions: In this research, ESN improved yields in two of three years relative to untreated urea, and SuperU improved yields in one of three years. Other agriculture-use products evaluated did not improve yields relative to untreated urea. Results were year-dependent and neither ESN nor SuperU consistently improved yields. Yield responses to these treatments were inconsistent and yield responses across years were inconsistent and highlight the effect of environment on the activity of these nitrogen products. Yield responses in 2009 across all treatments were consistent with yields of other non-related research at BREC. However, yield responses in 2010 were inconsistent across treatments. Yield responses in 2011 were consistent with other research at BREC. Because of cool, wet conditions in May, a destructive hail storm in early July, and then severe drought throughout much of the remaining season, 2011 yields were considerably lower than normal across BREC.

Table 1. Corn yield response to various urea enhancement products.

| Treatment ^a | Year | | |
|--------------------------|--|----------|---------|
| | 2009 | 2010 | 2011 |
| | ----- Yield (bu/ac) ^b ----- | | |
| Duration PCU | 171.9 A | 112.1 BC | 77.4 A |
| UAN (32%) | 155.1 A | 143.1 A | 75.5 A |
| ESN | 138.9 AB | 84.3 C | 78.6 A |
| SuperU | ----- | 120.7 AB | 66.9 B |
| Agrotain-treated urea | 137.5 B | 47.1 D | 71.2 AB |
| Nutrisphere-treated urea | 124.5 B | 50.3 D | 65.5 B |
| untreated urea | 129.1 B | 61.2 D | 57.8 B |
| No N treatment | 47.2 C | 17.6 E | 28.5 C |

^a Nitrogen treatments applied at rates equivalent to 150 lbs N/ac.

^b Means within a column followed by the same letter are not significantly different (P<0.05)

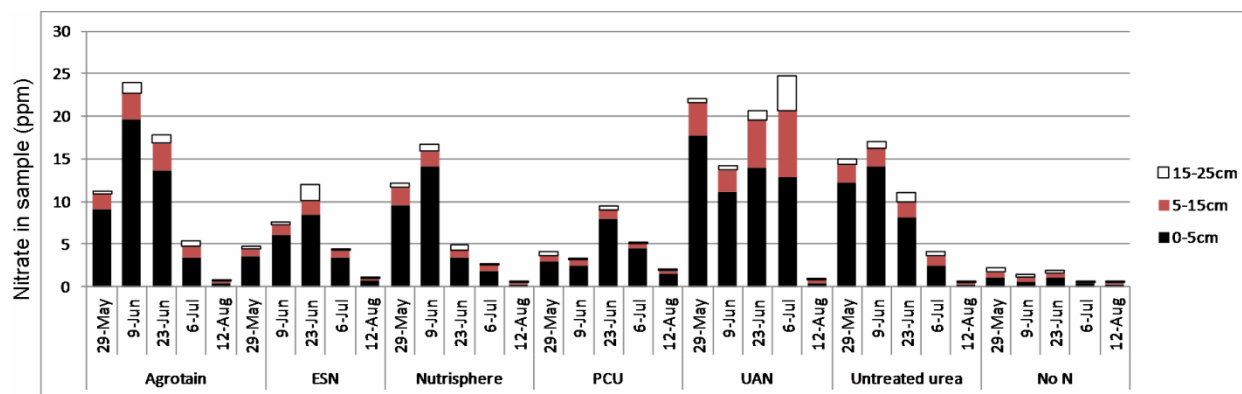


Figure 1. Soil sample nitrate at different depths and different sampling times in 2009

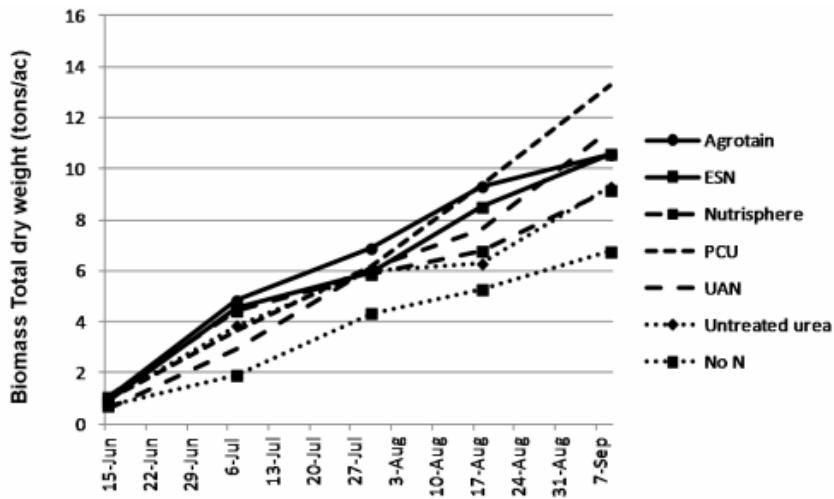


Figure 2. Biomass total dry weight of corn during the 2009 growing season.

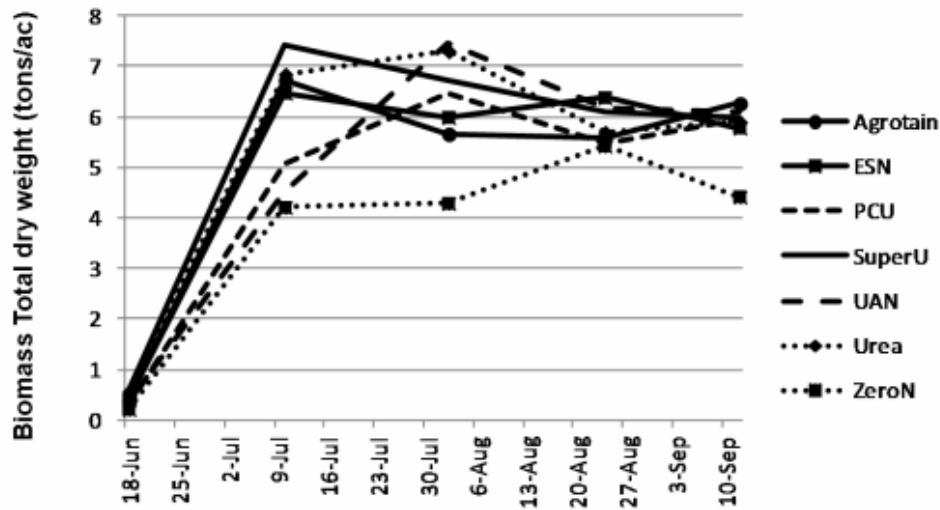


Figure 3. Biomass Total dry weight of corn during the growing season. Data from 2010 and 2011 were combined.

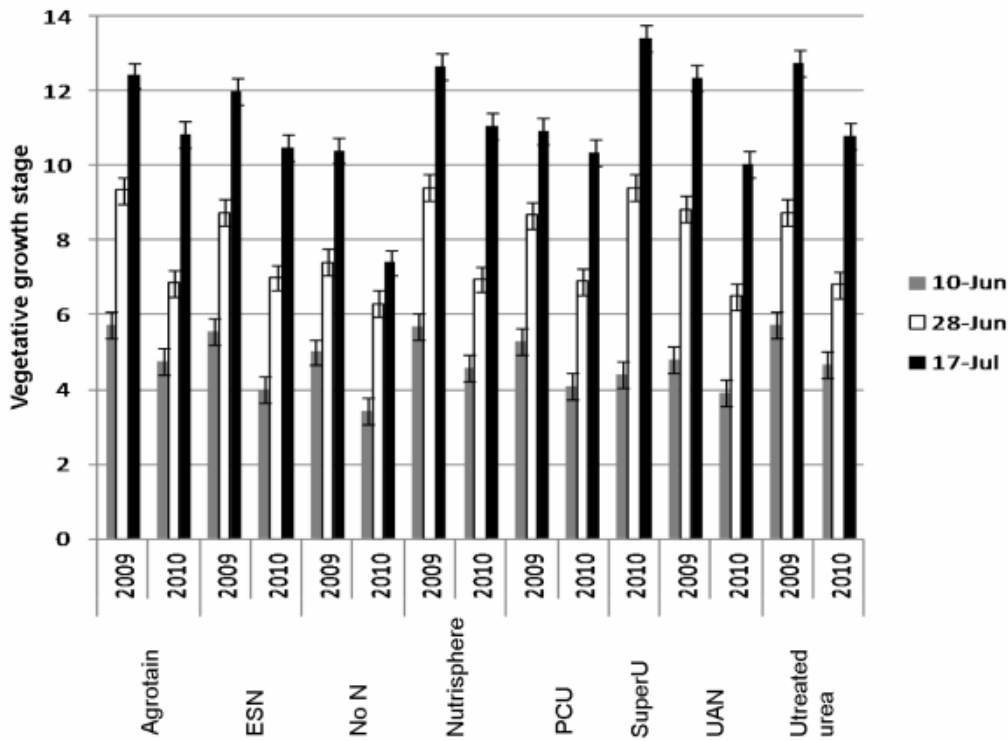


Figure 4. Vegetative growth stage of corn at three sampling dates in 2009 and 2010. Bars represent mean +/- standard error (P<0.05)

Progress Reports

Sensor-based Topdressing for Winter Wheat

Peter Scharf, Larry Mueller, David Kleinsorge, Newell Kitchen, and Luci Oliveira

Objective:

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

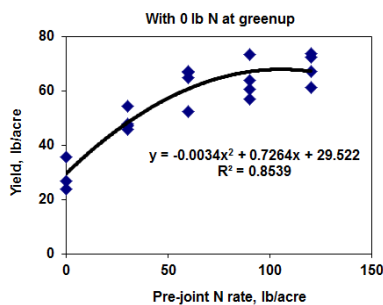
Accomplishments for 2011:

- Three nitrogen rate experiments were carried out in conjunction with sensor measurements at the pre-jointing growth stage.
- As with 2009, **N applications at greenup were not very effective.**
 - Yield with all N applied at greenup was, on average, 9 bushels/acre less than when all N was applied a month later at the pre-joint stage (see table below).
 - Optimal N rate was higher (average 29 lb N/acre) at greenup than at pre-joint despite producing lower yields.
 - For N applications split between greenup and pre-joint, every 30 lb N/acre reduced optimal N rate applied at prejoint by 9 lb N/acre. This suggests that N applied at greenup was about 1/3 as effective as N applied at pre-joint.

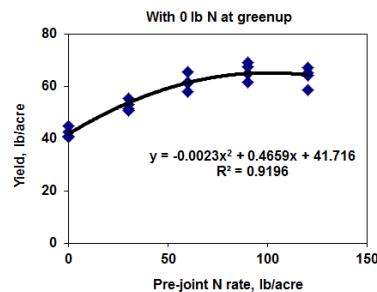
| Experiment | optimal yield with all N applied at: | | optimal N rate with all N applied at: | |
|------------|--------------------------------------|-----------|---------------------------------------|-----------|
| | | pre-joint | Greenup | pre-joint |
| 1 | 58 | 68 | 120 | 96 |
| 2 | 60 | 65 | 120 | 87 |
| 3 | 51 | 64 | 120 | 120 |

- **Applying all N pre-joint worked fine in these experiments**

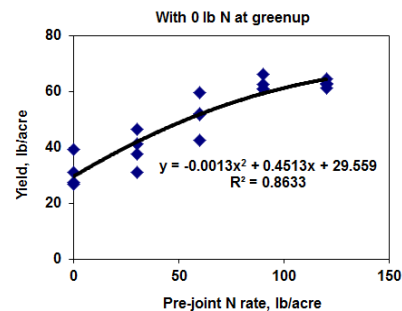
- There was weak evidence that split spring applications may have given higher profit in 2 of the 3 experiments, but if so it wasn't much higher
- Yield response to different N rates at the prejoint stage is shown in the graphs below



Experiment 1

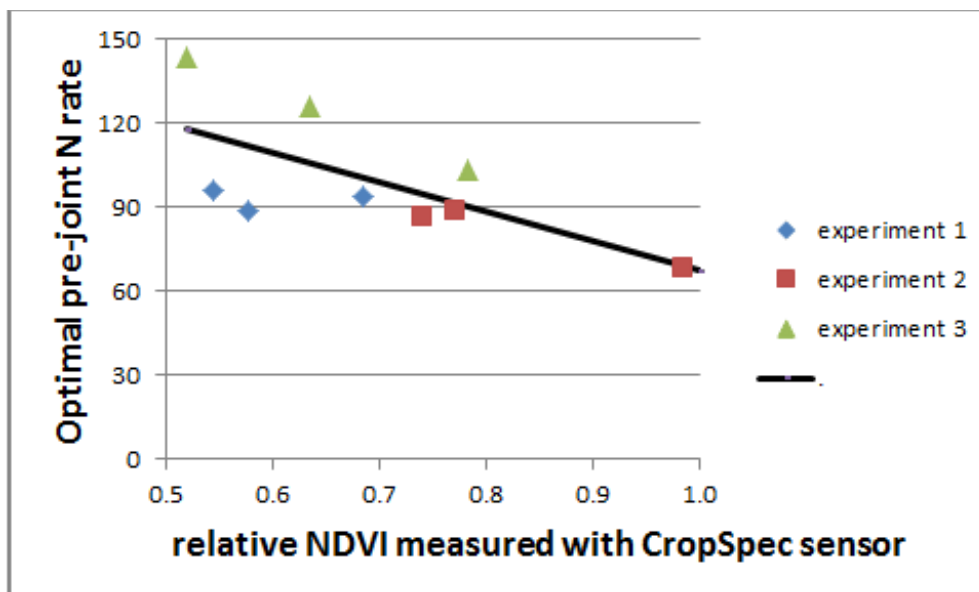


Experiment 2



Experiment 3

- The most profitable N rates were higher than in 2009 and in most previous Missouri experiments on N rate for wheat (see table).
 - 101 lb N/acre average optimal N rate at pre-joint
 - 77 lb N/acre average optimal pre-joint N rate in 2009
 - but 120+ lb N/acre for all 3 experiments when applied at greenup
- There was probably not enough variability in optimal N rate (from 87 to 120) to justify use of precision agriculture techniques to diagnose and apply the correct N rate.
 - Using a rate of 100 lb N/acre would have given \$6/acre less profit than applying the exact optimal N rate to each experiment.
- However, applying the average optimal N rate from 2009 (77 lb N/acre) would have reduced profit by an average of \$18/acre for the three 2011 experiments. Correctly diagnosing this need for higher N rates in our 2011 experiments would have value.
- Part of this higher N need may be due to previous crop. Experiments 1 and 3 followed corn and had higher optimal N rates than Experiment 2, which followed soybean. In 2009, all experiments followed soybean.
- A range of crop appearances and N sufficiencies at the pre-jointing stage was created by applying either 0, 30, or 60 lb N/acre at greenup. Each of these greenup N rates was followed by a complete range of N rates and by sensor measurements at the pre-jointing stage.
- Each experiment thus produces three data points of sensor value and optimal N rate:
 - One with no N applied at greenup
 - One with 30 lb N/acre applied at greenup
 - One with 60 lb N/acre applied at greenup
- The relationship between readings from the CropSpec sensor and optimal N rate for the three 2011 experiments is shown in the graph below.



- NDVI is the Normalized Difference Vegetative Index, an index that has widely been used to quantify the amount and health of vegetation.
- The CropSpec sensor is a new sensor designed by TopCon that is in the pilot stages of commercialization. It was not available, or in this study, in 2009. In 2011, it did a considerably better job of discerning N need than the Greenseeker sensor.
- Relative sensor reading is the average sensor reading for a given greenup N rate (0, 30, or 60) divided by the average sensor reading taken from the high-N plot. A value of 1 indicates that the two plots looked the same. The farther this value is from 1, the more difference there is in appearance between the two N rates, which is inferred to be due to N limitation on growth at the lower N rate.
- The equation for the line in the graph above could potentially be used to translate sensor values to N rates in the future. However, there is reason to believe that this line could change as more data is added.
 - Especially in experiments 1 and 2, the greenup N applications (30 or 60 lb N/acre) changed the sensor measurements quite a bit by the pre-joint stage, but had minimal effect on the optimal N rate to apply then. This can be seen in the graph above.
 - In experiment 2, the plots with greenup N = 60 looked almost exactly like the plots with greenup N = 120. Thus relative green = 1.0. Despite this excellent appearance, the crop still needed about 65 lb N/acre.
 - Although a wheat crop that looks excellent may still need more N for optimal yield, it should be less (and usually will be less) than 65 lb N/acre.
 - The sensors were 'fooled' into thinking that the wheat that got greenup N looked better and thus needed less N, when in fact it still needed quite a lot.
 - Sensors may only be useful for pre-joint N applications when no N has been applied at the greenup stage.
- Sensor readings were also taken on these experiments using the Crop Circle 210 and OptRx sensors. However, we used a new device to record these sensor readings and had a lot of problems with it. We believe that we have finally retrieved all of the data taken with these sensors, but have not yet had time to analyze them.

Budget for 2012:

We plan to conduct these experiments again in 2012 due to the failure of our wheat crop establishment in 2009-2010. Wheat is planted and looking good. We are not requesting any additional funds, we have funds remaining in this account that will cover these expenses.

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
University of Missouri, Plant Sciences Division and Delta Center

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 management is compared with typical producer N management and with other N rate decision systems.

Accomplishments for 2011:

- 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

- 2011 is the 5th year of this study, with each plot getting the same N decision and management system every year.
- This experiment is conducted in continuous no-till corn to magnify the effects of any problems related to N management.
- Populations and yields were very low in this experiment, and yield was determined almost entirely by population.
- Average population at harvest was 13,400 plants/acre, less than half of what we planted. There were three factors that contributed to these very low populations:
 - Wet soil conditions at planting followed by cold and rain after planting. Corn was planted on May 9 (see table) with average temperature of 79 degrees that day. In the first four days after planting, 1.25 inches of rain fell, then it turned cold with an average temperature of 53 degrees for May 13-19. From May 20-25, 2.7 inches of rain fell. These cold and wet conditions led to stand loss in all of our experiments, but they were worst in this experiment with continuous no-till corn. The corn residue holds water in the soil, leading to cooler and wetter soil conditions.
 - A hailstorm on July 3 that stripped most of the leaves off of the plants, killing some (see photo in Figure 1).
 - Drought stress following the hailstorm. Only 0.4 inches of rain fell from July 4 to July 29, accompanied by high temperatures, leading to the death of plants stressed by hail damage and by early-season conditions.
- Because of the very low populations, very low yields, and strong dependence of yield on population, we believe that nothing of value about nitrogen fertilizer management can be learned from the 2011 data in this study.
- The study will be continued in 2012 with the same treatments on the same plots.
- For the period 2007-2010, the two systems based on crop color to guide sidedress N rate outperformed all-preplant systems by an average of \$95/acre or more. This was mainly due to serious N loss with preplant N applications during the wet springs of 2008-2010.

Experiment 2: Effect of pre-plant nitrogen on sensor-based N rate performance

- Experiment 2 is designed to complement Experiment 1 and address concerns that sidedress systems with no N applied preplant may cost yield.
 - 2011 is the second year for this experiment.
 - Three of the four treatments in Experiment 2 are shared with Experiment 1.
 - 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 sensor-based treatments should be avoided.
- It is right next to Experiment 1, so soils and weather are very similar. Seed, herbicide, planting date, and application dates are identical to Experiment 1 (Table 2).
- Although the same adverse conditions affected this Experiments 1 and 2, populations did not suffer nearly as much in Experiment 2 as they did in Experiment 1. Average harvest population was 22,150. This experiment is in only its second year of no-till corn. Residue appeared similar in the two experiments but was probably heavier in Experiment 1 which is in its fifth year of no-till corn. Lower residue cover would lead to lower soil water content and higher soil temperature during germination, reducing the stress and mortality during that cold, wet period.
- Yields were low due to hail and drought. Nitrogen was not a yield-limiting factor for any of the treatments. Thus all treatments gave statistically equivalent yields (Table 1).
- One of the concerns with sidedress N management with no N applied pre-plant is that the crop development will be slowed. In years with a July drought, slower development could push reproductive stages farther into the drought, causing additional yield loss
- Sidedress-only N management did not cause yield loss despite drought stress and the potential for slower development to push reproductive growth into a more stressful time.
- Over the 2 years of this study, there has been no indication that sensor-based N rate recommendations perform better with preplant N than without.
- Over 2 years, sensor-based N management out-yielded preplant N management by about 16 bushels and gave about \$95/acre higher profit (Table 1). This is due to 2010 results, since there were no differences between treatments in 2011.

Table 1. Nitrogen rates recommended and corn yields produced by different recommendation systems in Experiment 2, 2010-11

| Nitrogen Recommendation System | 2011 preplant N rate, lb N/ac | 2011 Sidedress N rate at V8 ¹ , lb N/acre | 2011 Total N rate, lb N/ac | 2011 yield, bu/ac ³ | 2011 Gross - N cost, \$/ac ^{3,4} | 2010 preplant N rate, lb N/ac | 2010 Sidedress N rate at V7.5 ¹ , lb N/acre | 2010 Total Nitrogen rate, lb N/ac | 2010 yield, bu/ac ³ | 2010 Gross - N cost, \$/ac ^{3,4} | 2 yr. average N rate, lb N/ac | 2 yr Avg. yield, bu/ac ³ | 2 yr Avg. Gross - N cost, \$/ac ^{3,4} |
|---|-------------------------------|--|--|--------------------------------|---|-------------------------------|--|--|--------------------------------|---|-------------------------------|-------------------------------------|--|
| Crop Circle sensor ² | 0 | 145,116,137 92,158,137 <u>Avg. rate = 131</u> | 145,116,137 92,158,137 <u>Avg. rate = 131</u> | 83 ^A | \$349 ^A | 0 | 135,113,108 84,163,167 <u>Avg. rate = 128</u> | 135,113,108 84,163,167 <u>Avg. rate = 128</u> | 135 ^A | \$608 ^A | 130 | 108 ^A | \$479 ^A |
| 50 lb N pre + Crop Circle sensor ² | 50 | 93,103,69 117,137,74 <u>Avg. rate = 99</u> | 143,153,119 167,187,124 <u>Avg. rate = 149</u> | 81 ^A | \$333 ^A | 50 | 60, 74, 60 157, 160,96 <u>Avg. rate = 101</u> | 110,124,110 207,210,146 <u>Avg. rate = 151</u> | 139 ^A | \$616 ^A | 150 | 110 ^A | \$475 ^A |
| Yield goal/ MRTN | 140 | 0 | 140 | 78 ^A | \$318 ^A | 140 | 0 | 140 | 104 ^B | \$450 ^B | 140 | 91 ^B | \$384 ^B |
| High | 180 | 0 | 180 | 80 ^A | \$310 ^A | 180 | 0 | 180 | 107 ^B | \$445 ^B | 180 | 94 ^B | \$378 ^B |

¹ Growth stage V7.5 is just above knee high, stage V8 is about 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 Values within a column that are followed by a shared letter are not statistically different from one another with 90% confidence.

⁴ Gross calculated using \$5/bu. corn price, \$0.50/lb. N cost as estimates of current (2011) corn prices and N cost.



Figure 1. Hail damage typical of 2011 corn experiments two weeks after the hailstorm.

Table 2. Procedures for long term sensor N rate experiments on corn (experiments 1 & 2).

| Description | Experiment 1 | Experiment 2 |
|--|--|--|
| Previous Crop | Corn 70-75% Residue cover | Corn 70-75% Residue cover |
| Fall Prep Work | Stalks shredded Fall 2010 | Stalks shredded Fall 2010 |
| Pre-plant Soil Sampling (2' depth) | 4/1/2011 | none |
| Tillage | No-till | No-till |
| Early Nitrogen Application | 3 Fixed rate treatments & pre-plant soil nitrate test treatment 4/6/2011 | 3 Fixed rate treatments & pre-plant soil nitrate test treatment 4/7/2011 |
| Weed Control Broadcast Herbicide Application | Burn down, Round-up 32 oz./ac 17 lbs.AMS/100 gal water 4/9/2011 | Burn down, Round-up 32 oz./ac 17 lbs.AMS/100 gal water 4/9/2011 |
| Plant Plots | Planter: JD7000 w/finger pickup Variety:Pioneer P1395XR RR2, HXX, LL, Cruiser Seed drop: 31,300 Depth: 1.25" – 1.50" Conditions: Damp Emergence – Slow, stand poor 5/9/2011 | Planter: JD7000 w/finger pickup Variety:Pioneer P1395XR RR2, HXX, LL, Cruiser Seed drop: 31,300 Depth: 1.25" – 1.50" Conditions: Damp Emergence – Slow, stand fair 5/9/2011 |
| Weed Control Broadcast Herbicide Application | Residual, Lexar 3.0 qts/ac 5/10/2011 | Residual, Lexar 3.0 qts/ac 5/10/2011 |
| Soil Sample | sidedress soil nitrate test 6/22/2011 | None |
| Sensor Measurements | Crop Circle 210 sensor, chlorophyll meter 6/23/2011 | Crop Circle 210 sensor 6/23/2011 |
| Weed Control Broadcast Herbicide Application | Burn down, Round-up 32 oz./ac 17 lbs.AMS/100 gal water 6/24/2011 | Burn down, Round-up 32 oz./ac 17 lbs.AMS/100 gal water 6/24/2011 |
| Side-dress N Treatment Applications | Chlorophyll meter, crop sensor & side- dress soil nitrate test treatments applied 6/28/2011 | Crop sensor treatments applied 6/28/2011 |
| Harvest | 10/4/2011 | 10/4/2011 |

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.
- 2010 yield data were not included in the 2010 report as analyses had not been completed. Analyses for both 2010 and 2011 are now completed and included in this report.
- Yield in the zero-N (check) treatment was high in both years, averaging 1180 lb lint/acre over the two years (Table 3).
 - This is a very good yield.
 - It indicates that the soil supplied a substantial amount of N to the crop, even in the second year after receiving no N fertilizer in the first year.
- Yield in the fertilized treatments averaged 1290 lb lint/acre over the two years (Table 3), an average yield response of only 110 lb lint/acre.
 - Any of the N treatments should have been able to supply enough N to the crop to support a 110 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 N treatments.**
- In this situation there is potential for N applications to hurt yields, quality, or harvestability. However, **we did not see any evidence that N over-application caused problems with yield or quality in either year.** Significant differences in quality parameters were rare.
- 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 25 lb N/acre was applied.
 - **The sensors correctly diagnosed that the soil was supplying a high level of N in both years and that minimal fertilization was needed.**
- **Only 3 treatments were significantly more profitable than the check (zero N) treatment over 2 years (Table 3):**
 - **Standard N management**
 - **Soil nitrate test-based N management**
 - **Sensor-based N management with no N preplant**

Table 3. Nitrogen rates recommended and cotton yields produced by different recommendation systems in 2010-11

| Nitrogen Recommendation System | 2011 Nitrogen Rate lbs. N/ac @ Each timing | | | 2011 Total Nitrogen Rates lbs./ac | 2011 Yields lbs./ac ² | Gross - N Cost \$/ac ^{2,3} | 2010 Nitrogen Rate lbs. N/ac @ Each timing | | | 2010 Total Nitrogen Rates lbs./ac | 2010 Yields lbs./ac ² | Gross - N Cost \$/ac ^{2,3} | 2 yr. N rate lbs./ac | 2 yr Avg. Yields bu./ac ² | 2 yr Avg. Gross - N Cost \$/ac ^{2,3} |
|--------------------------------|--|-----------------|--|-----------------------------------|----------------------------------|-------------------------------------|--|----|--|-----------------------------------|----------------------------------|-------------------------------------|----------------------|--------------------------------------|---|
| | PP ¹ | ES ¹ | MS ¹ | | | | PP | ES | MS ¹ | | | | | | |
| Standard | 50 | 50 | 0 | 100 | 1286 ^A | 1874 ^A | 50 | 50 | 0 | 100 | 1392 ^A | 2044 ^A | 100 | 1341 ^A | 1962 ^A |
| Soil Test | 60 | 20 | 0 | 80 | 1260 ^A | 1845 ^{AB} | 60 | 20 | 0 | 80 | 1385 ^A | 2044 ^A | 80 | 1325 ^{AB} | 1947 ^{AB} |
| Sensor | 0 | 0 | 23, 33, 30 29, 28, 30 Avg. rate = 29 | 29 | 1242 ^{AB} | 1848 ^{AB} | 0 | 0 | 23, 23, 24 25, 20, 17 Avg. rate = 22 | 22 | 1329 ^{AB} | 1989 ^{AB} | 25 | 1287 ^{ABC} | 1918 ^{AB} |
| Sensor with Pre-plant N | 30 | 0 | 25, 23, 21 25, 18, 13 Avg. rate = 20 | 50 | 1269 ^A | 1874 ^A | 30 | 0 | 20, 26, 25 20, 25, 12 Avg. rate = 22 | 52 | 1253 ^{BC} | 1860 ^{BC} | 51 | 1263 ^{BC} | 1869 ^{ABC} |
| Low | 20 | 50 | 0 | 70 | 1236 ^{AB} | 1814 ^{AB} | 20 | 50 | 0 | 70 | 1297 ^{ABC} | 1918 ^{ABC} | 70 | 1269 ^{ABC} | 1868 ^{ABC} |
| High | 50 | 80 | 0 | 130 | 1240 ^{AB} | 1790 ^{AB} | 50 | 80 | 0 | 130 | 1314 ^{AB} | 1912 ^{ABC} | 130 | 1278 ^{ABC} | 1853 ^{ABC} |
| Petiole nitrate test | 50 | 0 | 0 | 50 | 1225 ^{AB} | 1812 ^{AB} | 50 | 0 | 0,0,0 0,0, 25 Avg. rate = 4 | 54 | 1267 ^{BC} | 1881 ^{BC} | 52 | 1248 ^{CD} | 1847 ^{BC} |
| Check | 0 | 0 | 0 | 0 | 1136 ^B | 1703 ^B | 0 | 0 | 0 | 0 | 1215 ^C | 1830 ^C | 0 | 1178 ^D | 1767 ^C |

¹A PP=pre-plant ES=early square stage MS= mid-square stage (about 10 days after early square stage)

²Values within a column that are followed by a shared letter are not statistically different from one another with 90% confidence.

³Gross calculated using \$1.50/lbs. cotton price, \$5.00/ac cost for 2nd N application, \$0.50/lb. N cost as estimates of current cotton prices and N cost during these years.

⁴A 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.

Utilization of Enhanced Efficiency Nitrogen Fertilizer and Managed Drainage to Reduce Nitrate-N Loss

Patrick Nash, Kelly Nelson, Peter Motavalli, Manjula Nathan, Ranjith Udawatta

Investigators:

Patrick R. Nash, Dep. of Soil, Environ., and Atmos. Sci., Univ. of MO, Columbia; Kelly Nelson, Div. of Plant Sci., Univ. of MO, Novelty; Peter Motavalli, Dep. of Soil, Environ., and Atmos. Sci., Univ. of MO, Columbia; Manjula Nathan, Div. of Plant Sci., Univ. of MO, Columbia; and Ranjith Udawatta, Dep. of Soil, Environ., and Atmos. Sci., Univ. of MO, Columbia.

Objective and Relevance:

Enhanced efficiency fertilizers such as polymer-coated urea have been shown to reduce nitrate concentrations in lysimeters in claypan soils (Nelson et al., 2009). These fertilizers may further reduce $\text{NO}_3\text{-N}$ loss through subsurface drainage systems that utilize managed drainage for corn production, but no research has been conducted to evaluate both best management practices. Agricultural drainage is not a new concept; however, utilizing managed drainage as part of an integrated water management system (IWMS) is a relatively new concept that has been shown to improve water quality by reducing $\text{NO}_3\text{-N}$ load up to 75% (Drury et al., 1996; Frankenberger et al., 2006; Drury et al., 2009) and sustain agricultural viability (Belcher and D'Itri 1995). Groundwater quality is affected by nitrate (NO_3^-) pollution that may result from excessive N fertilizer applications and other practices (Knox and Moody, 1991). Since $\text{NO}_3\text{-N}$ is soluble in water and is not retained by soil particles, it is susceptible to be leached to groundwater prior to crop growth or following harvest. In the United States, N losses in crop production are a concern due to relatively high N fertilizer application rates and considerable amounts of $\text{NO}_3\text{-N}$ released in drainage waters from agricultural soils (Cambardella et al., 1999). As a result, $\text{NO}_3\text{-N}$ concentration is regulated to prevent negative health impacts and eutrophication (Shaviv and Mikkelsen, 1993; USEPA, 1995; Hunter, 2001).

Soil and water conservation systems for productivity and environmental protection are key components of this enhanced efficiency N fertilizer and managed drainage project. In order for rural communities to remain competitive in a rapidly changing agricultural environment, technology that integrates current best management practices must also maintain a highly productive, safe, and efficient food supply. Water conservation, reduced fertilizer loss, increased nutrient use efficiency, and reduced sediment loss while improving crop production combined with managed drainage that is based on solid research is a win-win situation for farmers, consumers, and the environment. It is expected that there will be a reduction in $\text{NO}_3\text{-N}$ loading of up to 75% (Zucker and Brown, 1998; Frankenberger et al., 2006; Drury et al., 2009) and an additive effect of the enhanced efficiency fertilizer on reducing N loss in the crop production system and increasing corn grain yield. The hypothesis of this research is that managed drainage and enhanced efficiency fertilizer (polymer-coated urea) will synergistically increase corn yields and reduce $\text{NO}_3\text{-N}$ loss.

The objective of this research is to determine the effects of managed drainage systems and enhanced efficiency nitrogen fertilizer (polymer-coated urea) on corn production, nitrogen use efficiency, and nitrogen loss through the subsurface drainage system.

Accomplishments for First Year:

Research was initiated in 2011 at two locations (Greenley and Bee Ridge sites) to determine the effects of managed drainage systems and enhanced efficiency N fertilizer (polymer-coated urea) on corn production, carbon sequestration, N use efficiency, and nitrogen, ortho-phosphate, and sediment loss with managed drainage systems. Corn production data including corn plant uptake of nitrogen, silage, and

grain yields were collected at both field sites. Water samples and flow were collected from the drainage systems at both sites over the growing season using automated collection systems and samples analyzed for nitrate-N, orthophosphate-P, and sediment concentration. Water flowing out of subsurface drainage systems was restricted over the period of Oct. 2010 to Apr. 2011 with managed subsurface drainage systems, while conventional systems had unrestricted water flow.

Supplemental data including ammonia volatilization, nitrous oxide gas loss, and soil nitrogen concentration data was also collected at the Greenley site which will allow us to better understand how subsurface drainage systems and enhanced efficiency nitrogen fertilizer impacted corn production, nitrogen loss, and fertilizer use efficiency in 2011. However, this data is currently being analyzed.

Corn grain yields in 2011 at the Greenley site were generally low (<80 bu/acre) for all treatment combinations, which may have been a function of a wet spring followed by dry summer conditions (Fig. 1). Polymer-coated urea nearly doubled grain yields compared to non-coated urea in the non-drained system. The addition of subsurface tile drainage increased yields 20 bu/acre compared to non-coated urea. No grain yield differences were detected with managed subsurface drainage compared to conventional subsurface drainage. When averaging over drainage systems, polymer-coated urea fertilizer increased grain yield 15 bu/acre compared to non-coated urea (Fig. 2). Differences in grain yields among subsurface drainage systems and N fertilizer sources may have been a function of differences in soil moisture conditions, N loss, and plant uptake. Trends in silage yield based on dry weight at maturity due to the subsurface drainage systems and nitrogen fertilizer source followed similar trends to that previously discussed with grain yields (Fig. 3 and 4). The Bee Ridge site grain yields were approximately 6 to 8 bu/acre greater with PCU compared to non-coated urea, but no differences among drainage management systems were observed in 2011 (data not presented).

Nitrate-N, ortho phosphate-P, and sediment concentrations in the drainage water exiting the subsurface drainage systems were collected over a portion of the 2011 growing season at the Greenley and Bee Ridge sites (Fig. 5 and 6). Prior to the 2011 N application, polymer-coated urea treatment plots had minimal nitrate-N concentrations in the drainage water. At the Greenley site, nitrate-N concentration in subsurface drainage water was generally greater after non-coated urea was applied compared to polymer-coated urea (Fig. 5). Additional flow data was collected at both study sites and is currently being analyzed to calculate flow-weighted means and nutrient loading for each system. The addition of subsurface drainage flow data will allow us to determine if polymer-coated urea significantly reduced nitrate-N loss through subsurface drainage systems. No noticeable trends in ortho phosphate-P and total suspended solids concentrations due to subsurface drainage systems and nitrogen fertilizer sources were observed from Mar. to May (data not presented).

Procedures for Second Study Year:

- The second year of a three-year corn trial will continue to be conducted on claypan (Greenley) and silty clay (Bee Ridge) soil types.
 - Greenley site (Putnam silt loam). Two subsurface drain tiles were installed on 20 ft centers with a water level control structure in four of the six plots. Treatments include drainage only, managed drainage, and a non-drained control in a factorial arrangement with an enhanced efficiency fertilizer (polymer-coated urea) or non-coated urea. A plastic barrier was installed between the non-drained controls, drainage only, and managed drainage treatments. A levee plow used to construct rice levees was used to separate plots and prevent surface water movement between treatments.
 - Bee Ridge site (Wabash silty clay). Subsurface drain tiles were installed on 20 ft centers with four water level control structures installed per replication. There is a 40 ft spacing between treatments since the soil permeability is very slow. Fertilizer treatments are similar to the Greenley site.

- Plant Nutrient Uptake, Silage and Grain Yields. Plant samples will be harvested from a transect perpendicular to the tile lines to determine total N uptake. Whole-plant tissue samples will be collected from each treatment at physiological maturity, ground in a portable chopper, and a 1-kg subsample will be collected for determination of silage moisture content and total N. Silage yields will be determined on a dry weight basis. Grain yield will be determined using a yield monitor and plot weights at the Greenley site. Grain yield will be determined using a yield monitor from between the tiles at the Bee Ridge site. The combine will be able to quantify yield from a 20 ft harvest width in a single pass. Grain samples will be collected to determine N removal.
- Tile Flow Measurements. A pressure transducer, data logger, and minisat are being used to document water flow at each water level control structure to determine total N loading throughout the year. Calibrations for a V-weir installed in drainage systems have been determined (Norm Fausey, personal communication). Water level control structures were installed in the drainage only treatment with a V-notched weir as the bottom board in the control structure which is being used to determine tile water flow.
- Water and Soil Sampling for nitrate-N, orthophosphate-P, and total suspended solids. Flow proportional samples of subsurface drainage water for NO₃-N are being collected with individual auto samplers at each water level control structure. Auto samplers are being utilized to capture grab samples to determine concentrations during the winter periods. The minisat are being used to identify water flow events during the winter months and obtain grab samples. Deep soil samples (3 ft. depth; 2 in diameter) will be collected at both locations using a Giddings probe to determine soil N and organic C concentration in a transect perpendicular to the tile lines to determine residual N in the soil and indicate carbon sequestration differences among treatments.
- Nitrous Oxide and Ammonia Gas Efflux Measurements. The Greenley site is being utilized to monitor gaseous N fertilizer loss over the growing season Nitrous oxide and ammonia flux data will be collected multiple times a week over a four month period following nitrogen application.
- Nitrogen Use Efficiency. The collection of nitrogen loss, plant nitrogen uptake, and soil nitrogen concentration data at the Greenley site will be used to determine the impact of managed subsurface drainage and enhanced efficiency nitrogen fertilizer on nitrogen use efficiency.

Timetable:

2012

| | |
|-----------|--|
| Jan.-Dec. | Monitor for water flows and nitrate-N concentration |
| April | Corn planting for the 2012 trials. Monitor for nitrous oxide and ammonia efflux. |
| September | Harvest tissue and grain samples for N uptake |
| Nov.-Dec. | Soil sample for nitrate and ammonium |
| December | Submission of annual report |

2013 Repeat 2012 timetable

Proposed Budget:

| CATEGORIES | Year 2012 | Year 2013 | Total |
|---|------------------|------------------|-----------------|
| A. Salaries | | | |
| Ph.D. student | \$16,890 | \$17,397 | \$34,287 |
| B. Fringe Benefits | \$2,383 | \$2,454 | \$4,837 |
| Fringe for graduate student | | | |
| TOTAL SALARIES AND FRINGE BENEFITS | \$19,273 | \$19,851 | \$39,124 |
| C. Travel | | | |
| Travel to field site | \$0 | \$0 | \$0 |
| To present research findings at National Meetings | \$0 | \$1,000 | \$1,000 |
| TOTAL TRAVEL COSTS | \$0 | \$1,000 | \$1,000 |
| D. Equipment | \$0 | \$0 | \$0 |
| TOTAL EQUIPMENT use and maintenance COSTS | \$0 | \$0 | \$0 |
| E. Other Direct Costs | | | |
| Soil analysis | \$840 | \$840 | \$1,680 |
| Grain analysis | \$900 | \$900 | \$1,800 |
| Tissue analysis | \$1,000 | \$1,000 | \$2,000 |
| Water analysis | \$5,600 | \$5,900 | \$11,500 |
| Field supplies | \$2,000 | \$2,000 | \$4,000 |
| Publication cost | \$250 | \$0 | \$250 |
| TOTAL OTHER DIRECT COSTS | \$10,590 | \$10,640 | \$21,230 |
| TOTAL REQUEST | \$29,863 | \$31,491 | \$61,354 |

Budget narrative:

Salaries and fringe benefits: Funds are requested for partial support of a Ph.D. student.

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.

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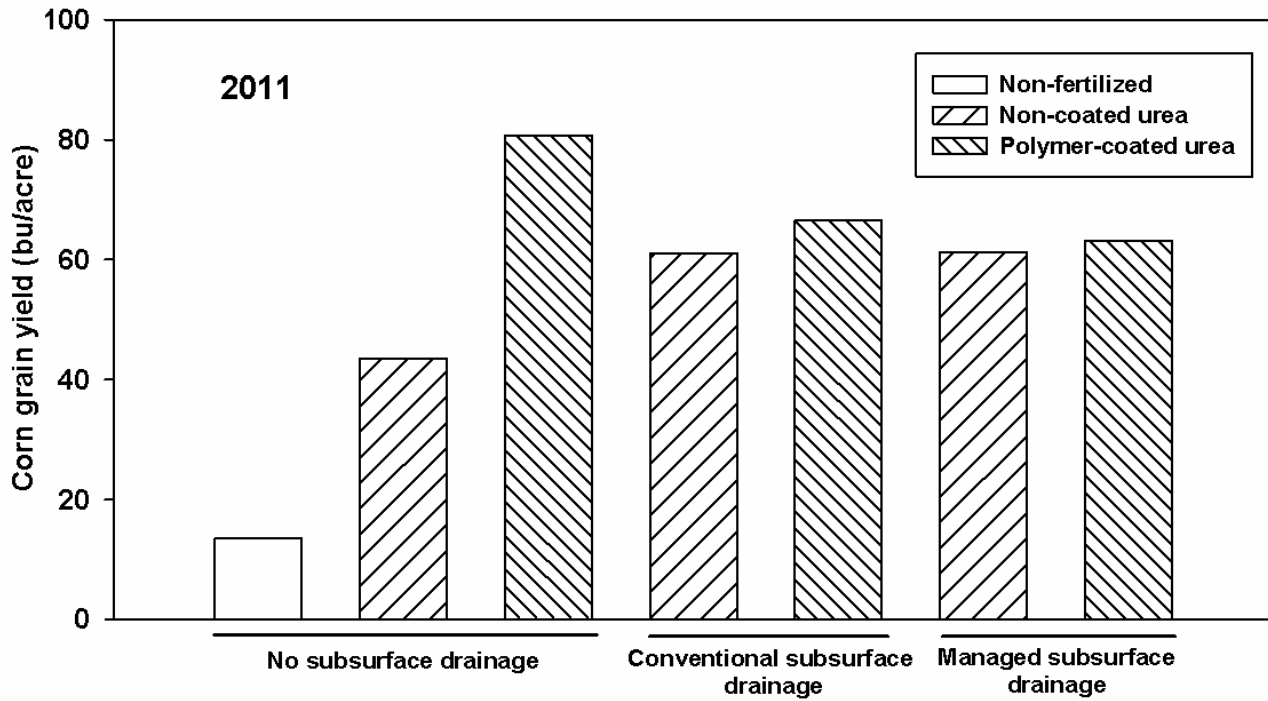


Figure 1. Corn grain yields from the 2011 growing season at the Greenley site due to the interaction of subsurface drainage type and nitrogen fertilizer source.

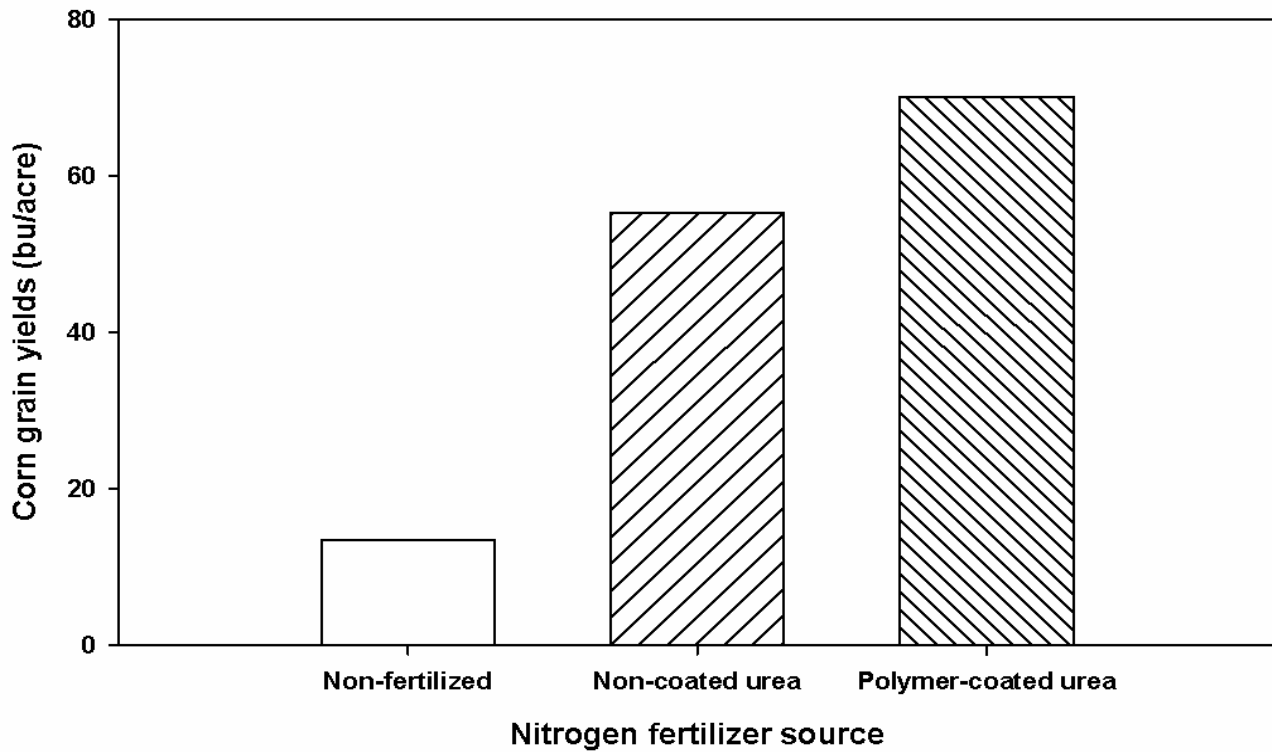


Figure 2. Corn grain yields from the 2011 growing season at the Greenley site due to the main effect of nitrogen fertilizer source.

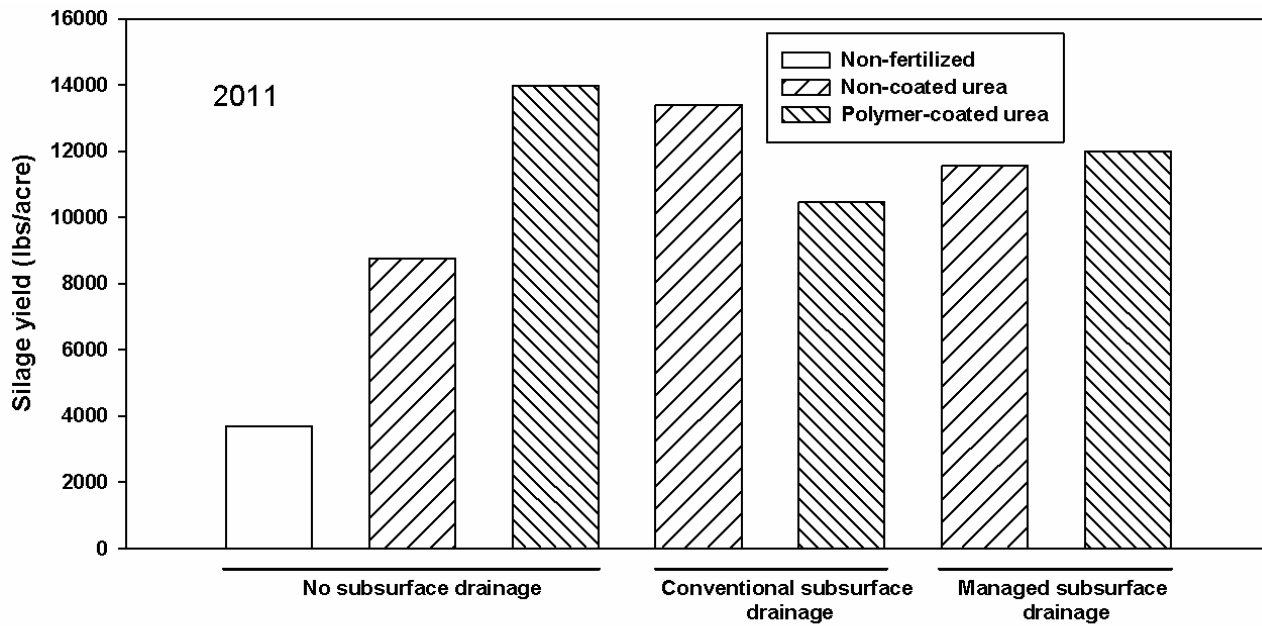


Figure 3. Silage yields at the Greenley site from the 2011 growing season due to subsurface drainage type and nitrogen fertilizer source.

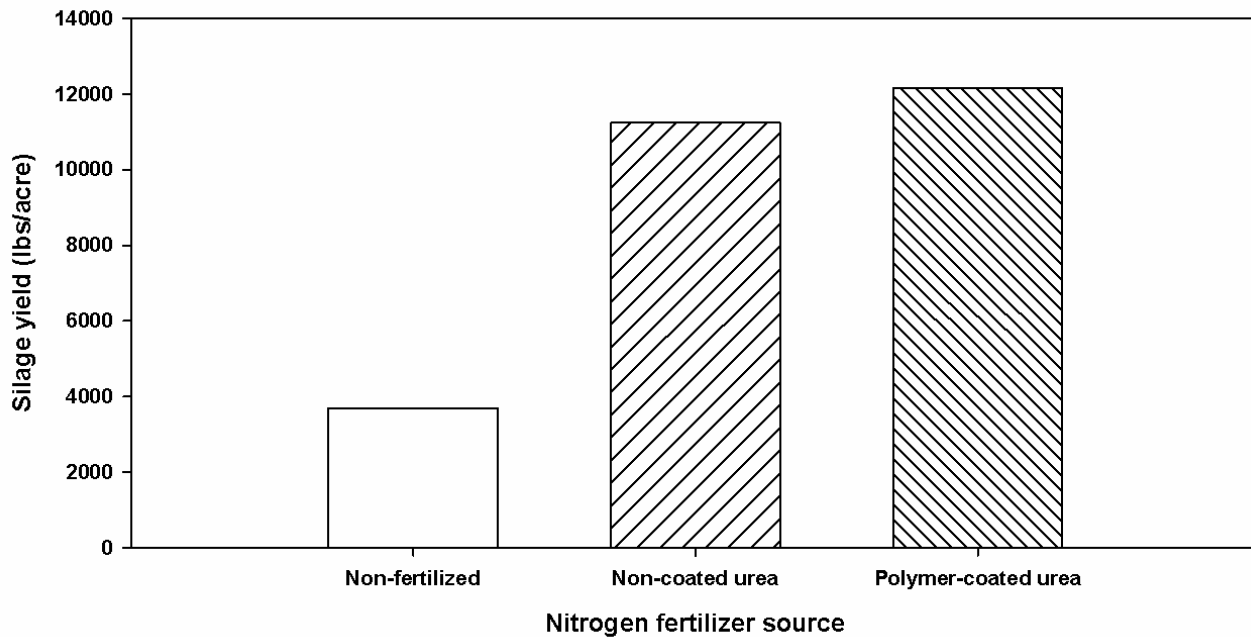


Figure 4. Silage yield at the Greenley site from the 2011 growing season due to the main effect of nitrogen fertilizer source.

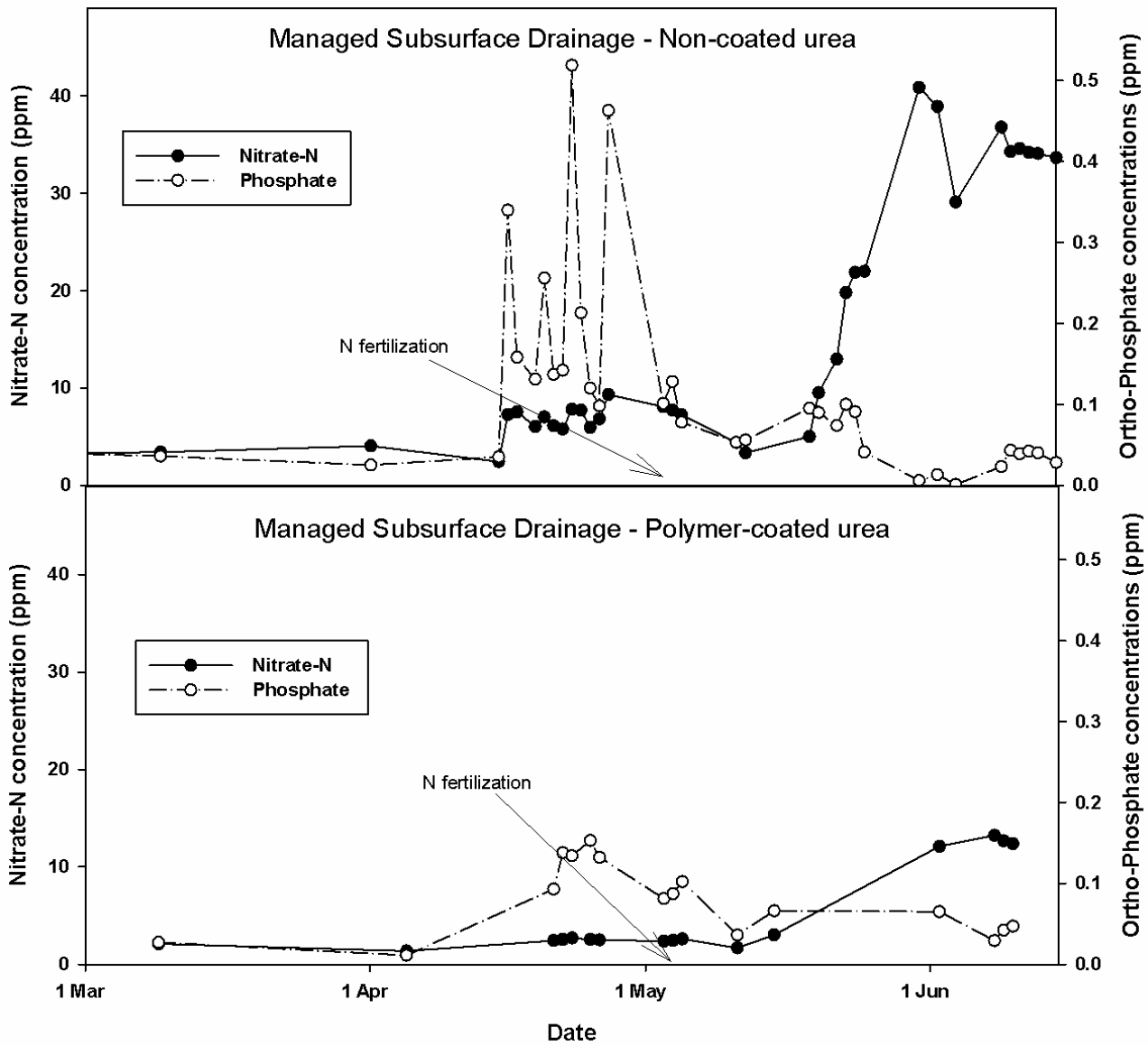


Figure 5. Nitrate-N and orthophosphate P concentrations in the drainage water exiting the subsurface tile drainage systems over the period of Mar. through June, 2011 at the Greenley site.

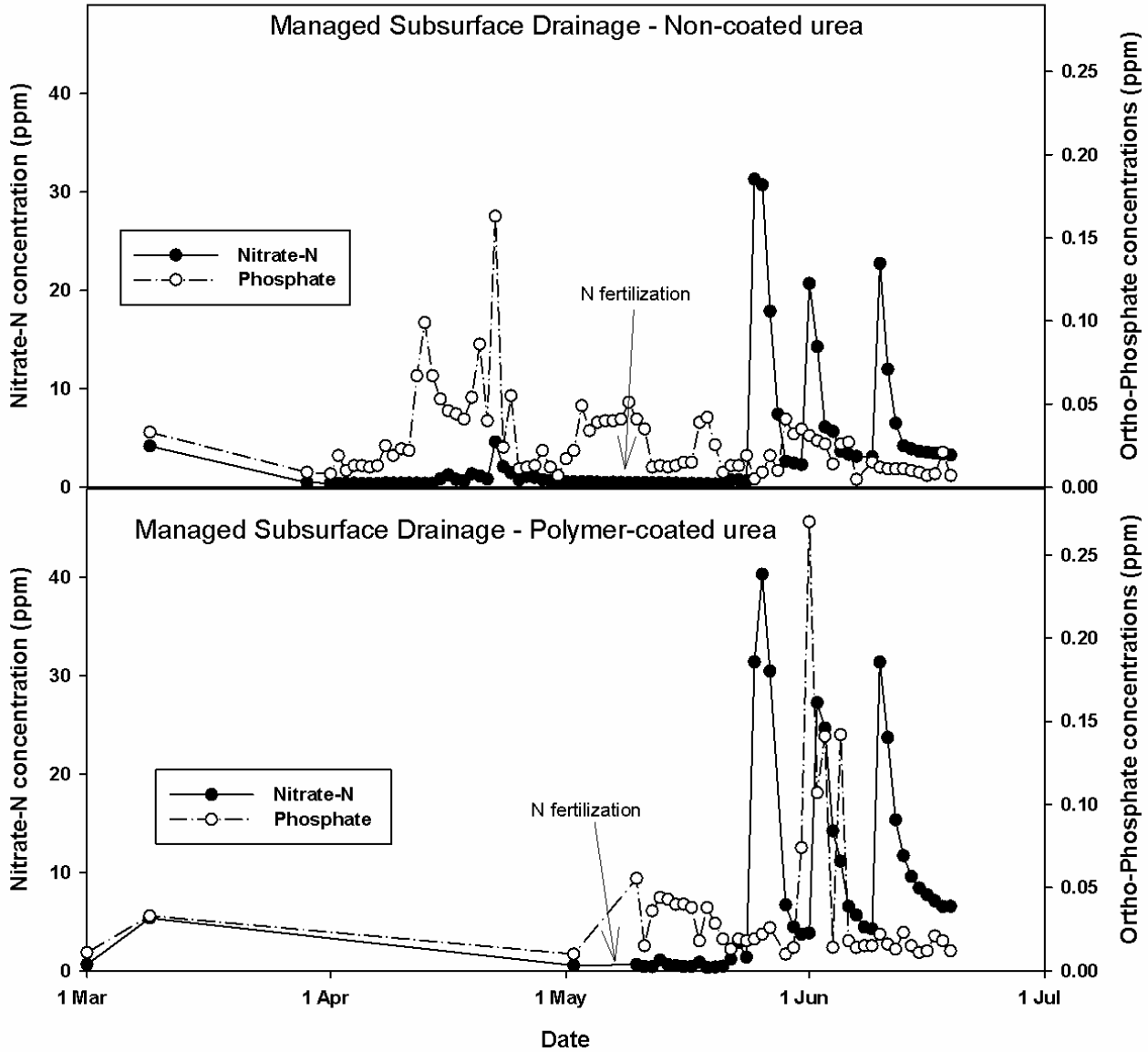


Figure 6. Nitrate-N and orthophosphate P concentrations in the water exiting the subsurface tile drainage systems over the period of Mar. through June, 2011 at the Bee Ridge site.

Phosphorus Management

Progress Reports

Enhanced Efficiency Phosphorus Application for a Corn-Soybean Rotation

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

Investigators:

Chris Dudenhoefter, Dep. of Soil, Environ., and Atmos. Sci., Univ. of MO, Columbia; Kelly Nelson, Div. of Plant Sci., Univ. of MO, Novelty; 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) and P₂O₅ Max[®] (P-Max, Rosen's Inc., Fairmont, MN) are two 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 P₂O₅/acre and applied as a broadcast or banded treatment. Dunn (2009) reported increased Bray-P1 soil test P availability and a 4 bu/acre increase in soybean yield after applying 50 lbs P₂O₅/acre with AVAIL. Similarly, rice yields increased 8 bu/acre when reduced rates of triple super phosphate were applied (25 lbs P₂O₅/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). 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 evaluated 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 total organic C, pH (0.01 M CaCl₂), and exchangeable K, Ca and Mg at each site (Table 1 and 2). Soil test P (Bray P1) concentrations were determined prior to application from each replication at each site. Soil test P was 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). Whole plant tissue samples were collected at plant maturity and nitrogen, phosphorus, and potassium levels were determined. Phosphorus fertilizer efficiency was calculated as $[(\text{lbs tissue P/acre})/(\text{lbs fertilizer applied P/acre}) * 100]$. Grain moisture was adjusted to 15.5% prior to analysis. All data were subjected to analysis of variance and means separated using Fisher's Protected LSD ($P = 0.05$ or 0.1). Data were combined over factors and locations when appropriate as indicated by the analysis of variance (data not presented). The soybean yield data from 2011 is currently being analyzed (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 or 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 P₂O₅ 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 coulters. 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 3. Tissue samples were collected to determine crop P uptake due to the effects of the treatments at both locations and 2011 samples 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 in 2010 and 2011 and Portageville in 2010. 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 and P₂O₅ Max[®] (P-Max, Rosen's Inc., Fairmont, MN) at 1 gal/ton], and broadcast surface application of ag lime [0 and recommended (3.6 ton/acre at Novelty 2010, 1.5 ton/acre at Novelty 2011, and 2.0 ton/acre at Portageville 2010)]. 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 4. 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 P stabilizer. Strip-till/deep banding increased plant populations 6,200 plants/acre at Novelty and 1,400 plants/acre at Albany (Table 5). There was no effect of fertilizer placement on silage dry weights, but grain moisture was 0.3% greater in no-till compared to strip-till. Yields increased 24 bu/acre with use of strip-till/deep banding over no-till/broadcast at Novelty, but yields at Albany were affected by placement and MAP rate. When no MAP was added at Albany, no-till/broadcast increased grain yields 9 bu/acre over strip-till/deep banding. However, no difference was observed between no-till/broadcast and strip-till/deep banding with MAP at 50 or 100 lbs P₂O₅/acre. MAP at 0 lbs P₂O₅/acre yielded 11 bu/acre more than MAP at 50 lbs P₂O₅/acre rate under no-till/broadcast, but no difference was observed with MAP at 100 lbs P₂O₅/acre. This difference may be due to the ammonium nitrate that was added to balance the N contribution as the MAP rate increased. Grain protein and starch showed had interaction between year and placement at Novelty, but not Albany (Table 6). No-till/broadcast had 1.4 % higher protein concentration point in 2010 than strip-till/deep banding and 0.6 % higher protein concentration in 2011. In 2010, strip-till/deep banding increased starch by 0.8 %, starch increased 0.3 % in 2011. Grain oil concentration was affected by location, placement, and MAP rate. At Novelty, no-till/broadcast with MAP rate 0 lbs P₂O₅/acre had lower oil concentration than any other placement- MAP rate combinations. At Albany, strip-till/deep banding with MAP at 0 lbs P₂O₅/acre had a lower oil concentration than any other placement-MAP rate combination except for no-till/broadcast MAP at 100 lbs P₂O₅/acre. No-till/broadcast increased tissue K 14 lbs/acre over strip-till/deep banding, while no effect of placement tissue N and P fertilizer efficiency was observed (Table 7).

Plant population, silage dry weights, and grain moisture were not affected by MAP rate at the four site-years evaluated in this research (Table 8). MAP rate had a significant ($P=0.1$) effect on yields with P₂O₅ at 0 lbs/acre yielding 4 to 6 bu/acre more than MAP at 50 or 100 lbs P₂O₅/acre. This difference may be due to the ammonium nitrate that was added to balance the N contribution as the MAP rate increased. Grain protein concentration increased 0.3% with MAP at 50 and 100 lbs P₂O₅/acre compared to the non-treated control at Novelty in 2011, but no differences were observed at Novelty in 2010 or Albany. MAP at 0 and 100 lbs P₂O₅/acre increased starch concentration 0.2% over MAP at 50 lbs P₂O₅/acre at Novelty, but not at Albany. Plant tissue N and tissue P uptake was not affected by MAP rate (Table 9). However, MAP at 0 and 100 lbs P₂O₅/acre increased tissue K by 19 to 31 lbs/acre over MAP at 50 lbs P₂O₅/acre. At both locations, MAP at 50 lbs P₂O₅/acre had a higher P fertilizer efficiency than MAP at 100 lbs P₂O₅/acre in 2010.

Enhanced efficiency P products did not affect plant population, silage dry weights, grain moisture, yield, grain protein, or starch concentrations at the four site-years (Table 10). The non-treated control oil concentration at Albany was 0.2% greater than the P-Max treatment. Plant N uptake, P fertilizer efficiency, and plant K uptake were not affected by P stabilizer (Table 11). Tissue P concentrations were affected by fertilizer placement and P stabilizer. No-till/broadcast MAP with P-Max increased tissue P concentration 8 lbs/acre compared to a strip-till/deep banding, but AVAIL increased tissue P concentration 6 lbs/acre with strip-till/deep banding compared to a broadcast surface application. However, no increase in tissue P uptake with P enhancers compared to the non-treated control was observed.

P source, P stabilizer, and ag lime. The recommended liming rate was 3.6 ton/acre at Novelty in 2010, 1.5 ton/acre at Novelty in 2011, and 2.0 ton/acre at Portageville in 2010. Plant population was 1,000 plants/acre greater in the non-limed control compared to the recommended rate in 2011 at Novelty, while plant population was not affected at Portageville (Table 12). The recommended amount of lime increased grain yields 12 bu/acre at Portageville, but there was no effect at Novelty. Grain moisture, oil, protein, and starch concentrations were not affected by the lime treatment at either location.

Silage dry weights increased 1.0 ton/acre with an application of lime in the non-treated control, but no dry weight differences between lime treatments were observed in the presence of DAP or TSP (Table 13). TSP increased silage dry weights 0.9 ton/acre over the non-treated control when no lime was applied. An application of TSP or DAP decreased grain moisture 0.9 to 1.3% compared to the non-treated control. Grain yield increased 5 bu/acre with TSP compared to the non-treated control. However, grain oil, protein, and starch concentration was not affected by P source. Enhanced efficiency P products did not affect plant populations, silage dry weights, grain moisture, yield, grain oil, protein, or starch (P= 0.31 to 0.97) compared to the non-treated control (Table 14).

Plant tissue N, tissue P at Portageville, P fertilizer efficiency, and tissue K was not affected by a lime application (Table 15). However, the recommended lime treatment increased tissue P concentration 15 lbs/acre compared to the non-limed control with P at 0 lbs/acre. In the non-limed control, tissue P uptake was 12 lbs/acre greater when TSP was applied. Tissue K and P fertilizer efficiency was affected by location, P source, and P stabilizer (Table 16). The non-treated P source and non-treated P-stabilizer treatment had K uptake that was 258 lbs/acre. K uptake was lower in the non-treated control when TSP was applied, but K uptake increased 129 lbs/acre when TSP was treated with AVAIL. P fertilizer efficiency was 26 and 30% greater with AVAIL treated TSP than the P-Max and the non-treated control, respectively at Novelty in 2010. TSP increased P fertilizer efficiency 32% compared to MAP at Portageville in 2010; however, P fertilizer efficiency was 27% greater with DAP compared to TSP at Novelty in 2010.

Summary and Accomplishments for Years 1 and 2:

- Strip-till increased plant populations 6,200 plants/acre at Novelty and 1,400 plants/acre at Albany. Yields increased 24 bu/acre with use of strip-till/deep banding over no-till/broadcast at Novelty, but yields at Albany were affected by placement and MAP rate. When no MAP was added at Albany, no-till/broadcast increased grain yields 9 bu/acre over strip-till/deep banding. However, no difference was observed between no-till/broadcast and strip-till/deep banding, with MAP at 50 or 100 lbs P₂O₅/acre.
- Enhanced efficiency P products did not affect corn plant population, dry weights, grain moisture, or yield in either objective at any of locations or site years.
 - In objective #1, no-till/broadcast MAP with P-Max increased tissue P concentration 8 lbs/acre compared to a strip-till/deep banding while AVAIL increased tissue P concentration 6 lbs/acre with strip-till/deep banding compared to a broadcast surface application in 2010. However, no increase in tissue P uptake with P enhancers compared to the non-treated control was observed.
 - In objective #2, P fertilizer efficiency was 26 and 30% greater with AVAIL treated TSP than the P-Max and the non-treated control, respectively at Novelty in 2010.
- TSP increased yields 5 bu/acre compared to the non-treated control in 2010 and 2011 at Novelty and in 2010 at Portageville. However, grain oil, protein, and starch concentration was not affected by P source.
- Lime increased grain yields 12 bu/acre at Portageville in 2010, but had no effect at Novelty.
- The corn plots will rotate into soybean for the 2012 growing season. Soybean data in 2011 is currently being analyzed.

Objectives for Year 3:

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.

We will complete the soybean portion of the experiment in 2012.

Timetable:

2012

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

Budget:

| CATEGORIES | Year 3 (2012) | Total* |
|---|----------------------|-----------------|
| A. Salaries | | |
| Technical assistance or graduate research assistant (50%) | \$14,670 | \$42,875 |
| B. Fringe Benefits | | |
| Fringe for graduate student | \$2,095 | \$6,080 |
| TOTAL SALARIES AND FRINGE BENEFITS | \$16,765 | \$48,955 |
| C. Travel | | |
| Travel to field site | \$0 | \$0 |
| To present research findings at National Meetings | \$1000 | \$1000 |
| TOTAL TRAVEL COSTS | \$1000 | \$1000 |
| D. Equipment | \$0 | \$0 |
| TOTAL EQUIPMENT use and maintenance COSTS | \$0 | \$0 |
| E. Other Direct Costs | | |
| Soil analysis | \$1020 | \$4080 |
| Grain analysis | \$2560 | \$7680 |
| Tissue analysis | \$2560 | \$7680 |
| Field supplies | \$500 | \$1500 |
| Publication cost | \$500 | \$500 |
| Off-site PI's (2) | \$6,000 | \$18,000 |
| TOTAL OTHER DIRECT COSTS | \$13,140 | \$39,440 |
| TOTAL REQUEST | \$30,905 | \$89,395 |

*Included the 2010 and 2011 (Year 1 and 2) 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.

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- Minor, H. C., J. Stecker, and J. R. Brown. 1993. Phosphorus in Missouri Soils. Uni. of MO Ext., G9180.
- Pierzynski, G.M., R.W. McDowell, and J.T. Sims. 2005. Chemistry, cycling, and potential movement of inorganic phosphorus in soil. p. 53-86. In Sims, J.T., and A.N. Sharpley (eds.) Phosphorus: Agriculture and the environment. Agronomy #46. American Society of Agronomy, Madison, WI.
- Rosen's Diversified Inc. 2010. Rosen's Inc. - Serving Agribusiness. <http://rosensdiversifiedinc.com/contentpage.asp?contentid=10>. Accessed July 16, 2010.

Table 1. Soil analysis information for the P placement, rate, and enhancer experiment at Novelty and Albany in 2010 and 2011(Objective 1).

| | Novelty | | Albany | |
|-----------------------------------|------------|------------|------------|-------------|
| | 2010 | 2011 | 2010 | 2011 |
| pHs | 6.8 ±0.3 | 6.6 ±0.2 | 6.4 ±0.4 | 6.0 ±0.3 |
| Phosphorus (lbs/acre) | 45 ±23 | 24 ±7 | 80 ±43 | 80 ±10 |
| Potassium (lbs/acre) | 245 ±37 | 141 ±22 | 261 ±22 | 281 ±39 |
| Calcium (lbs/acre) | 5387 ±471 | 4982 ±216 | 5768 ±372 | 5810 ±617 |
| Manganese (lbs/acre) | 419 ±74 | 448 ±48 | 636 ±178 | 695 ±97 |
| Zinc (ppm) | 0.75 ±0.24 | 0.35 ±0.13 | 0.8 ±0.24 | 0.875 ±0.17 |
| Organic matter (%) | 2.4 ±0.8 | 2.6 ±0.1 | 2.5 ±0.1 | 2.7 ±0.7 |
| Neutralizable acidity (meq/100 g) | 0.25 ±0.5 | 0.75 ±0.29 | 1.25 ±1.19 | 2 ±0.82 |
| Cation Exch. Capacity (meq/100 g) | 16 ±1 | 15 ±1 | 19 ±2 | 20 ±3 |

Table 2. Soil analysis for the P source, P enhancer, and ag lime experiment at Portageville in 2010 and Novelty in 2010 and 2011(Objective 2).

| | Novelty | | Portageville |
|-----------------------------------|------------|------------|--------------|
| | 2010 | 2011 | 2010 |
| pHs | 5.4 ±0.1 | 5.8 ±0.1 | 5.2 ±0.3 |
| Phosphorus (lbs/acre) | 27 ±7 | 9 ±2 | 105 ±27 |
| Potassium (lbs/acre) | 254 ±24 | 71 ±12 | 248 ±77 |
| Calcium (lbs/acre) | 4467 ±138 | 3495 ±307 | 1726 ±342 |
| Manganese (lbs/acre) | 402 ±75 | 290 ±29 | 307 ±85 |
| Zinc (ppm) | 0.78 ±0.15 | 0.35 ±0.06 | |
| Organic matter (%) | 2.6 ±0.2 | 2.2 ±0.1 | 1.4 ±0.2 |
| Neutralizable acidity (meq/100 g) | 4 ±0.8 | 1.9 ±0.3 | 2.9 ±0.8 |
| Cation Exch. Capacity (meq/100 g) | 17 ±1 | 12 ±1 | 9 ±1 |

Table 3 . Field and management information for the P placement, rate, and enhancer experiment at Novelty and Albany in 2010 and 2011.

| Management Information | Novelty | | Albany | |
|--|--|--|---|--|
| | Corn 2010 | Corn 2011 | Corn 2010 | Corn 2011 |
| Previous crop | Soybeans | Soybeans | Soybeans | Soybeans |
| Plot size | 10 by 75 ft | 10 by 75 ft | 10 by 75 ft | 10 by 75 ft |
| Hybrid or cultivar | DK 62-54 | DK 62-54 VT3 | DK 63-84 | DK 63-84 |
| Planting Date | 14 Apr. | 31 Mar. | 30 May | 13 April |
| Seeding rate | 30,000 seeds/acre | 30,000 seeds/acre | 30,000 seeds/acre | 29,500 |
| Tissue harvest date | 7 Sep. | 25 Aug. | 9 Sep. | 26 Aug. |
| Harvest date | 30 Oct. | 8 Sep. | 15 Oct. | 27 Sept. |
| Fertilizer | | | | |
| P application (date & 1x rate) | 13 Apr., 100 lbs P ₂ O ₅ /acre | 30 Mar., 100 lbs P ₂ O ₅ /acre | 15 Apr., 100 lbs P ₂ O ₅ /acre | 15 Nov., 100 lbs P ₂ O ₅ /acre |
| Additional fertilizer (date, source, & rate) | 6 May, Urea (180 lbs N/acre)+ Agrotain (1 gal/ton) | NA | 19 Apr., urea (150 lbs N/acre)+ Agrotain (1 gal/ton) | 14 Apr., urea (150 lb) |
| Weed management | | | | |
| Burndown | NA | 11 Apr., Roundup PowerMAX (22 oz/acre)+ 2,4-D (2/3 pt/acre)+ Quest (7 oz/acre) | NA | NA |
| Preemergence | 16 Apr., Lumax (3 qt/acre)+ Banvel (1 pt/acre) | 13 Apr., Keystone (2.8 qt/acre) | 15 Apr., Lumax (3.2 qt/acre); 30 May, Balance Pro (4 oz/acre) | 16 April., Lumax (3.2qt/acre) |
| Postemergence | 22 June, Roundup PowerMAX (30 oz/acre)+ AMS (17 lbs/100 gal) | NA | 21 June, Roundup PowerMAX (24 oz/acre) | 7 June, Roundup PowerMAX (24 oz/acre) |
| Insect management | 16 Apr., Warrior (1.5 oz/acre) | NA | NA | NA |

†Abbreviations: NA, None applied.

Table 4. Field and management information for the P source, P enhancer, and ag lime experiment at Portageville in 2010 and Novelty in 2010 and 2011.

| Management information | Novelty | | Portageville |
|--|---|--|--|
| | Corn 2010 | Corn 2011 | Corn 2010 |
| Previous crop | Corn | Wheat | Corn |
| Plot size | 10 by 45 ft | 10 by 45 ft | 10 by 45 ft |
| Hybrid or cultivar | DK 61-69 VT3 | DKC 63-42 | Croplan Genetics 68-31 |
| Planting date | 26 May | 10 May | 7 Apr. |
| Seeding rate | 30,000 seeds/acre | 30,800 seeds/acre | 30,000 seeds/acre |
| Tissue harvest date | 7 Sep. | 25 Aug. | 16 Aug. |
| Harvest date | 1 Oct. | 14 Sep. | 8-9 Sep. |
| Fertilizer | | | |
| P application (date & rate) | 27 Apr. 105 lbs P ₂ O ₅ /acre | 31 Mar., 100 lbs P ₂ O ₅ /acre | 6 Apr. 50 lbs P ₂ O ₅ /acre |
| Lime application (date & rate) | 1 Apr., 3.6 ton/acre | 29 Mar., 1.5 ton/acre | 1 Apr., 2 ton/acre |
| Additional fertilizer (date, source, & rate) | 12 Apr., Anhydrous ammonia (235 lbs N/acre) | 31 Mar., Anhydrous ammonia (180 lbs N/acre) | 7 Apr., Urea (50 lbs N/acre) + Agrotain (1 gal/ton) |
| Sidedress N | 11 June, 32% UAN (150 lbs N/acre) | NA | 5 May, Urea (150 lbs N/acre) + Agrotain (1 gal/ton) |
| Weed management | | | |
| Burndown | 21 Apr., Roundup PowerMAX (15 oz/acre) | 11 Apr., Roundup PowerMax (22 oz/acre) + 2,4-D (2/3 pt/acre) + Quest (7 oz/acre) | 5 Apr., Conerstone 32 oz/acre |
| Preemergence | 21 Apr., Bicep II Magnum (1.65 qt/acre) | 13 Apr., Bicep II Magnum (2.5 qt/acre) | 9 Apr., Bicep II Magnum (1.5 qt/acre) + Atrazine (2 qt/acre) |
| Postemergence | 22 June, Roundup PowerMAX (22 oz/acre) | NA | 8 May, Atrazine (1 qt/acre) + Glyphosate (32 oz/acre) |

†Abbreviations: NA, None applied.

Table 5. Phosphorus placement effect on plant population, silage dry weights, grain moisture, and yield. Data were combined over site-year, location, MAP rate, and P stabilizer except for plant population and yield.

| Placement | Plant population | | Silage dry weights ton/acre | Grain moisture % | Novelty [†] | Yield | | |
|--------------------------|-------------------------|--------|--------------------------------|---------------------|----------------------|-------------------------|-----|-----|
| | Novelty [†] | | | | | Albany [†] | | |
| | MAP rate (lb P O /acre) | | | | | MAP rate (lb P O /acre) | | |
| Novelty [†] | Albany [†] | 0 | 50 | 100 | Novelty [†] | 0 | 50 | 100 |
| | ----plants/acre---- | | | | | -----bu/acre----- | | |
| Broadcast | 20,500 | 23,300 | 6.5 | 17.2 | 100 | 139 | 128 | 133 |
| Strip-till | 26,700 | 24,700 | 6.6 | 16.9 | 124 | 130 | 132 | 135 |
| LSD [‡] (P=0.1) | 1,300 | 1,200 | NS | 0.3 | 5 | -----7----- | | |

[†]Data were combined over years (2010 and 2011).

Table 6. Placement effect on grain protein, starch, and oil. Data were combined over MAP rate and P stabilizer except for grain oil which was combined over site year and P stabilizer.

| Placement | Protein | | | Starch | | | Oil | | | | | |
|--------------|-------------|------|---------------------|-------------|------|---------------------|-------------------------|-----|-----|-------------------------|-----|-----|
| | Novelty | | Albany [†] | Novelty | | Albany [†] | Novelty [†] | | | Albany [†] | | |
| | 2010 | 2011 | | 2010 | 2011 | | MAP rate (lb P O /acre) | | | MAP rate (lb P O /acre) | | |
| | 2010 | 2011 | Albany [†] | 2010 | 2011 | Albany [†] | 0 | 50 | 100 | 0 | 50 | 100 |
| | -----%----- | | | -----%----- | | | -----%----- | | | | | |
| Broadcast | 8.4 | 9.3 | 8.4 | 73.9 | 72.9 | 72.3 | 3.5 | 3.7 | 3.7 | 3.7 | 3.7 | 3.7 |
| Strip-till | 7.0 | 8.7 | 8.5 | 74.7 | 73.2 | 72.2 | 3.7 | 3.7 | 3.7 | 3.6 | 3.8 | 3.7 |
| LSD (P=0.05) | 0.3 | 0.2 | NS | 0.20 | 0.24 | NS | -----0.1----- | | | -----0.1----- | | |

[†]Data were combined over years (2010 and 2011).

Table 7. Total N and K uptake, and P fertilizer efficiency. Data were combined over site-year, location, P stabilizer, and MAP rate.

| Placement | Tissue N | Tissue K | P fertilizer efficiency |
|-----------------|----------|----------|-------------------------|
| | lbs/acre | lbs/acre | % |
| Broadcast | 238 | 185 | 129 |
| Strip-till | 236 | 171 | 122 |
| LSD ($P=0.1$) | NS | 12 | NS |

Table 8. Plant population, silage dry weights, grain moisture, yield, protein, and starch as affected by MAP rate. Data were combined over site-year, location, placement, and P stabilizer except for grain protein and starch.

| MAP Rate | Plant population | Silage dry weights | Grain moisture | Yield | Protein | | | Starch | |
|-----------------|------------------|--------------------|----------------|---------|-------------|------|---------------------|-------------|---------------------|
| | | | | | Novelty | | Albany [†] | Novelty | Albany [†] |
| | | | | | 2010 | 2011 | | | |
| lbs/acre | plants/acre | ton/acre | % | bu/acre | -----%----- | | | -----%----- | |
| 0 | 23,800 | 6.8 | 17.1 | 126 | 7.7 | 8.8 | 8.5 | 73.7 | 72.3 |
| 50 | 23,900 | 6.5 | 17.0 | 120 | 7.7 | 9.1 | 8.4 | 73.5 | 72.2 |
| 100 | 23,800 | 6.5 | 17.0 | 122 | 7.6 | 9.1 | 8.4 | 73.7 | 72.3 |
| LSD ($P=0.1$) | NS | NS | NS | 4 | NS | 0.2 | NS | 0.2 | NS |

[†]Data were combined over years (2010 and 2011).

Table 9. The effect of MAP rate on tissue N, tissue P, tissue K, and fertilizer efficiency in 2010. Data were combined over location, P stabilizer, and placement except for fertilizer efficiency.

| MAP rate | Tissue N | Tissue P | Tissue K | P Fertilizer Efficiency | |
|--|--------------------|----------|-------------|-------------------------|--------|
| | | | | Novelty | Albany |
| lb P ₂ O ₅ /acre | -----lbs/acre----- | | -----%----- | | |
| 0 | 242 | 38.6 | 192 | | |
| 50 | 232 | 36.7 | 161 | 202.42 | 133.71 |
| 100 | 238 | 36.2 | 180 | 97.94 | 68.08 |
| LSD ($P=0.05$) | NA | NA | 17 | 28.46 | 17.94 |

Table 10. The effect of P stabilizer on plant population, silage dry weights, moisture, yield, grain oil, grain protein, and grain starch. Data were combined over site-year, location, placement, and MAP rate except for grain oil.

| P Stabilizer | Plant population | Silage dry weights | Grain moisture | Yield | Oil | | Protein | Starch |
|------------------|------------------|--------------------|----------------|---------|----------------------|---------------------|---------|--------|
| | | | | | Novelty [†] | Albany [†] | | |
| | | | | | % | % | | |
| | plants/acre | ton/acre | % | bu/acre | -----%----- | | % | % |
| Non-treated | 24,200 | 6.7 | 17.2 | 122 | 3.7 | 3.8 | 8.3 | 72.9 |
| AVAIL | 23,600 | 6.5 | 17.0 | 123 | 3.6 | 3.7 | 8.4 | 73.0 |
| P-Max | 23,700 | 6.6 | 17.0 | 122 | 3.7 | 3.6 | 8.4 | 73.0 |
| LSD ($P=0.05$) | NS | NS | NS | NS | NS | 0.1 | NS | NS |
| P-value | 0.51 | 0.83 | 0.54 | 0.83 | 0.74 | 0.01 | 0.74 | 0.63 |

[†]Data were combined over years (2010 and 2011).

Table 11. Tissue N, P, and K uptake as well as P fertilizer efficiency as affected by P stabilizer in 2010. Data were combined over site-year, placement, MAP rate except for Tissue P which was combined over site year, and MAP rate.

| P Stabilizer | Tissue N | Tissue P | | P Fertilizer Efficiency | Tissue K |
|-----------------|----------|--------------------|------------|-------------------------|----------|
| | | Broadcast | Strip-till | | |
| | lbs/acre | -----lbs/acre----- | | % | lbs/acre |
| Non-treated | 236 | 39 | 37 | 131 | 176 |
| AVAIL | 229 | 34 | 40 | 124 | 181 |
| P-Max | 247 | 41 | 33 | 121 | 177 |
| LSD ($P=0.1$) | NS | -----5----- | | NS | NS |

Table 12. Plant population, grain moisture, yield, grain oil, protein, and starch results based on liming rate. Data were combined over 2010 and 2011 at Novelty, and at Portageville in 2010, P source, and P stabilizer except for yield and plant population.

| Liming Rate | Plant population | | | Grain moisture ^{††} % | Yield | | Oil ^{††} % | Protein ^{††} % | Starch ^{††} % |
|--------------------------|-----------------------|--------|--------------|-----------------------------------|-------------------|--------------|------------------------|----------------------------|---------------------------|
| | Novelty | | Portageville | | Novelty | Portageville | | | |
| | 2010 | 2011 | | | | | | | |
| | -----plants/acre----- | | | | -----bu/acre----- | | | | |
| None | 24,200 | 23,500 | 15,200 | 25.4 | 151 | 105 | 3.9 | 9.1 | 71.7 |
| Recommended [§] | 26,100 | 22,500 | 14,300 | 25.5 | 146 | 117 | 3.9 | 9.0 | 71.8 |
| LSD (<i>P</i> =0.05) | NS | 1,000 | NS | NS | NS | 4 | NS | NS | NS |

[†]Novelty location only.

[‡]Data were combined over years (2010 and 2011).

[§]The recommended liming rate was 3.6 ton/acre at Novelty 2010, 1.5 ton/acre at Novelty 2011, and 2.0 ton/acre at Portageville 2010.

Table 13. P source effects on silage dry weights, grain moisture, yield, grain oil, protein, and starch. Data were combined over 2010 and 2011 at Novelty, and at Portageville in 2010, liming rate, and P stabilizer except for silage dry weight.

| P source | Silage dry weights | | Grain moisture [§] % | Yield bu/acre | Oil [§] % | Protein [§] % | Starch [§] % |
|-----------------------|--------------------|--------------------------|----------------------------------|------------------|-----------------------|---------------------------|--------------------------|
| | Liming rate | | | | | | |
| | None | Recommended [‡] | | | | | |
| | -----ton/acre----- | | | | | | |
| Non-treated | 6.5 | 7.5 | 26.2 | 132 | 3.9 | 9.1 | 71.7 |
| DAP [†] | 6.8 | 7.2 | 25.3 | 135 | 3.9 | 9.0 | 71.8 |
| TSP [†] | 7.4 | 7.1 | 24.9 | 137 | 3.9 | 9.0 | 71.9 |
| LSD (<i>P</i> =0.05) | -----0.7----- | | 0.8 | 5 | NS | NS | NS |

[†]DAP and TSP was applied at a 105 lbs P₂O₅/acre at Novelty in 2010, 100 lbs P₂O₅/acre at Novelty in 2011, and 50 lbs P₂O₅/acre at Portageville in 2010.

[‡]The recommended liming rate was 3.6 ton/acre at Novelty 2010, 1.5 ton/acre at Novelty 2011, and 2.0 ton/acre at Portageville 2010.

[§]Novelty location only.

Table 14. P stabilizer effect on plant population, silage dry weights, grain moisture, yield, grain oil, protein, and starch. Data were combined over 2010 and 2011 at Novelty, and at Portageville in 2010, liming rate, and P source.

| P stabilizer | Plant population | Silage dry weights | Grain moisture [†] | Yield | Oil [†] | Protein [†] | Starch [†] |
|--------------|------------------|--------------------|-----------------------------|---------|------------------|----------------------|---------------------|
| | plants/acre | ton/acre | % | bu/acre | % | % | % |
| Non-treated | 21,100 | 7.2 | 25.6 | 135 | 3.9 | 9.0 | 71.8 |
| AVAIL | 21,400 | 7.2 | 25.6 | 134 | 3.9 | 9.1 | 71.7 |
| P-Max | 20,400 | 6.9 | 25.3 | 136 | 3.9 | 9.0 | 71.7 |
| LSD | NS | NS | NS | NS | NS | NS | NS |
| P-value | 0.31 | 0.48 | 0.69 | 0.65 | 0.44 | 0.97 | 0.48 |

[†]Novelty location only.

Table 15. Tissue N, tissue P, P fertilizer efficiency, and tissue K as affected by liming rate. Data were combined over P stabilizer, and P source for Novelty and Portageville in 2010 except for tissue P.

| Liming Rate | Tissue N lbs/acre | Tissue P | | | Portageville lbs/acre | P fertilizer efficiency % | Tissue K lbs/acre |
|--------------------------|----------------------|--------------|------------------|------------------|--------------------------|------------------------------|----------------------|
| | | Novelty | | | | | |
| | | Non-treated | DAP [†] | TSP [†] | | | |
| None | 393 | 28 | 37 | 40 | 45 | 143 | 236 |
| Recommended [‡] | 415 | 43 | 43 | 37 | 44 | 144 | 248 |
| LSD (<i>P</i> =0.05) | NS | -----10----- | | | NS | NS | NS |

[†]DAP and TSP was applied at a 105 lbs P₂O₅/acre at Novelty in 2010, 100 lbs P₂O₅/acre at Novelty in 2011, and 50 lbs P₂O₅/acre at Portageville in 2010.

[‡]The recommended liming rate was 3.6 ton/acre at Novelty 2010, 1.5 ton/acre at Novelty 2011, and 2.0 ton/acre at Portageville 2010.

Table 16. Tissue K and fertilizer efficiency results based on P source. Data were combined over lime treatments for Novelty and Portageville in 2010.

| P source | Tissue K | | | | P fertilizer efficiency | | | |
|----------------------|--------------|-------|-------|--------------------------|-------------------------|-------|-------|-------------------|
| | Novelty | | | Portageville lbs/acre | Novelty | | | Portageville % |
| | P stabilizer | | | | P stabilizer | | | |
| | Non-treated | AVAIL | P-Max | | Non-treated | AVAIL | P-Max | |
| Non-treated | 258 | 197 | 261 | 247 | -----%----- | | | 186 |
| DAP [†] | 253 | 241 | 229 | 235 | 99 | 85 | 78 | 218 |
| TSP [†] | 191 | 326 | 237 | 238 | 72 | 102 | 76 | 218 |
| LSD (<i>P</i> =0.1) | -----66----- | | | NS | -----23----- | | | 27 |

[†]DAP and TSP was applied at a 105 lbs P₂O₅/acre at Novelty in 2010, 100 lbs P₂O₅/acre at Novelty in 2011, and 50 lbs P₂O₅/acre at Portageville in 2010.

Evaluating the phosphorus runoff potential of current home lawn fertilization practices and recommendations based on soil test results

Xi Xiong and Dan Lloyd

Objectives:

- 1) Determine surface phosphorus runoff from different fertility programs applied to lawns with low (<40 lbs P₂O₅/acre) and high (>60 lbs P₂O₅/acre) soil phosphorus.
- 2) Evaluate the quality of turfgrass in response to phosphorus treatments applied to soils with different concentrations of available phosphorus.
- 3) Visually demonstrate to home owners through permanent demonstration plots the differences in turfgrass quality and phosphorus runoff potential of different fertilization scenarios as related to soil test values.

Current status/importance of research area:

In Missouri, approximately 850,700 acres were used for turfgrass cultivation in 2005, which according to current estimates would make turfgrass the fourth largest crop in Missouri by acreage. Turfgrass is fertilized to apply between 100-200 lbs of N/acre annually. Many home owners regularly use products such as 12-12-12 and apply them at recommended rates for nitrogen (100-200 lbs/acre), which over time has greatly elevated the soil phosphorus and potassium levels. Continual fertilization of phosphorus on soils that are in excess of available phosphorus will increase the likelihood of nutrient loss through surface runoff and without providing additional benefits to turfgrass health. Furthermore, surface runoff of sediment and nutrients, especially phosphorus, into surface water is a growing concern that can lead to eutrophication of lakes and streams. On January 31st of 2011, the EPA issued a final mandate to the Missouri Department of Natural Resources to reduce storm-water runoff into Hinkson Creek by 39.6% because of excessive pollutants from runoff. This EPA mandate validates the importance of this research, as the Missouri DNR will be seeking areas which can be regulated to reduce pollutants into Hinkson Creek and other surface waters of Missouri. If residential fertilizer restrictions are proposed, this Fertilizer and Lime Council funded project will provide reliable and local data to assist in reasonable and research based regulations in hopes of preventing an unnecessary burden on the turf fertilizer industry.

Procedures:

Design - Twelve plots were established on a laser leveled 4% slope measuring 5 ft by 20 ft with a two foot buffer between each plot. Initial soil phosphorus levels were determined through soil test and plots were assigned to 'high' (>60 lbs P/acre) and 'low' <40 lbs P/acre) soil phosphorus designations. The differences in soil P were further magnified through triple super phosphate (46% of P₂O₅) fertilization to develop a substantial difference in soil phosphorus levels for the four corresponding treatments with three replications. The treatments are a homeowner scenario with high soil P (treatment 1), a soil test scenario with high soil P (treatment 2), a soil test scenario with low soil P (treatment 3), and a restricted scenario with low soil P (treatment 4) (Table 1). Once the soil phosphorus level had been adjusted, one single fall phosphorus application in the amount of 50 lbs P/acre was applied to treatment 1 (homeowner scenario with high soil P), and treatment 3 (soil test scenario with low soil P). Treatment 2 (soil test scenario with high soil P) did not receive any phosphorus treatment as based on soil test (no additional P were needed). Similarly, no phosphorus treatments were applied to treatment 4 as it is designated as low soil P, yet is a restricted use scenario. After the fall phosphorus application, simulated rainfalls (4 inches) were applied twice in the fall at 0 day after treatment (DAT) and 5 DAT to induce runoff. The reason 0 day when

rainfall was applied was to simulate the extreme condition when homeowners ignored the weather condition and applied the phosphorus fertilizer at the same day when significant rainfall occurs. We also simulated the second rainfall event at 5 DAT to evaluate if residue phosphorus exits. Since we had an unusually dry year, 4 inches of rainfall was necessary to induce runoff from treatment area.

Table 1. Phosphorus fertilizer treatments applied to the runoff plots in 2011.

| Treatment | Phosphorus fertilization | Soil available phosphorus |
|------------------------------|--|--|
| 1. Common homeowner scenario | 150 lbs P ₂ O ₅ /acre | High (>60 lbs P ₂ O ₅ /acre) |
| 2. Soil test recommendation | None (as recommended by soil test) | High (>60 lbs P ₂ O ₅ /acre) |
| 3. Soil test recommendation | 50-150 lbs P ₂ O ₅ /acre (as recommended by soil test) | Low (<40 lbs P ₂ O ₅ /acre) |
| 4. Restricted use scenario | None | Low (<40 lbs P ₂ O ₅ /acre) |

Construction – Each 5 ft by 20 ft plot is enclosed by galvanized steel edges that have been imbedded around all the edges. Galvanized steel runoff collection boxes measuring five feet wide, six inches deep, and eight inches wide were constructed and installed down slope from each of the twelve plots (Figure 1). The collection boxes have a built in sample splitter with about one third of the runoff directed to the sample collection bins which consists of 32 gallon collection bins buried 3 ft deep and a removable five gallon bucket for runoff collection. The remaining two thirds of the runoff not collected are directed into a drain tile traversing the plot. Drainage pipe is 4 inch round drainage tile that runs down a roughly 3% slope at a 14 inch depth for about 100 feet, which then takes a 90 degree turn for another 100 feet down a 4% slope at the same depth which eventually discharges into a swale. Each collection box has been individually calibrated to determine the precise percentage of runoff that is directed to the sample collection bins.

Figure 1. Field plots constructed.

Measurements – Runoff water is collected within 12 hours of simulated rainfall event. Total volume is determined and a representative one liter sample is collected and sent to the MU Soil and Plant Testing Laboratory for determination of total phosphorus, dissolved phosphorus, and percent sediments. Plant tissue samples and soil samples are also taken and analyzed by the Soil and Plant Testing Laboratory for total plant and soil nutrients including phosphorus. Weekly measurements (when weather condition permits) include chlorophyll index (Field Scout CM1000), NDVI (GreenSeeker[®]), and overall turf quality on a 1-9 scale.

Project Accomplishments:

Soil phosphorous concentrations at the initial estimation date (August 25) demonstrated that numerical but not statistically significant differences existed between treatments (Figure 2, blue bars). However, on November 22, treatments 1 and 2 could be classified as high soil P while treatments 3 and 4 could be categorized as low soil P (Figure 2, red bars). This would indicate that we had established treatments within our intended parameters.



Based upon fertilization of treatments 1 and 3 on Day 0, there were significantly higher levels of both total P and dissolved P collected in runoff water compared to treatments 2 and 4 (Table 2). Total P was 6.94-fold higher for treatment 1 compared to treatment 2. This suggests that for soils with high P levels, high rainfall shortly after application of P fertilizer results in a significant loss of that P. Similarly, high rainfall shortly after application of P fertilizer on soils with low P levels also results in a significant loss of P (7.04-fold) compared to treatment 4. However, P application applied on soil with high P level (treatment 1) resulted in significantly higher total runoff P loss than applied to plots with low soil P level (treatment 3). This result indicated that accumulated higher soil P level will likely increase the chance of runoff P loss. These same trends and level of significance were also measured for P dissolved in water (Table 2). In examining the sediment P levels, we observed that some differences were noted among treatments, but this was not significant. It was quite interesting to note that of the total P estimated from treatments 2 and 4 (no additional P added at day 0), 92.3% and 94.4% were represented by sediment P from treatments 2 and 4, respectively. These data suggest that some P was lost from treatments 2 and 4, but this was represented primarily by P attached to sediment. For treatments 1 and 3, only up to 34% of the P was lost in sediment. The amount of runoff was similar for the four treatments. For 5 DAT, numerical differences in total, dissolved, and sediment P were noted between treatments, but differences were not statistically significant. The impact of the P levels was influenced by the numerical differences in runoff water collected.

On a concentration basis (amount of runoff water collected taken into consideration), total P (mg/L) and total dissolved P (mg/L) were significantly higher for plots receiving P just prior to a high rainfall event (0 DAT) compared to plots that did not receive P (Figure 3A and B). At 5 DAT, levels of total P and dissolved P were quantitatively similar at both the high and low soil P levels. These data indicate that a majority of the potential P lost with high rainfall events will occur with the first event.

Mineralization of tall fescue tissue on December 9 (18 DAT) showed differences for P among treatments but not N or K (Table 3). The P (in %) in tissue samples from high P soils (treatment 1 and 2) were significant higher than the tissue samples collected from the low soil P plots (treatment 3 and 4). This result corresponds with the soil P level presented at Figure 2.

Estimates of turf health over a 25 day period following application of P and high rainfall were similar for the four treatments (Table 4). Among all the variables of turf health, only NDVI measured at 10 DAT showed differences between treatments. Higher NDVI values would correlate with better turf color and coverage, but differences between treatments could not be associated with P levels. Our data indicate that the relative P levels in the soil did not contribute to an ability to assess the tall fescue growing in plots with that treatment as healthier.

Rainfall amounts in the experimental area were low over the duration of the study (Figure 4). As a result, the soil moisture potential was low and high rainfall events of 4 inches were necessary to induce runoff from the plots.

In summary, our preliminary data demonstrate that improper application of P fertilization does increase the chance of loss P through runoff.

Objective for year two (2012):

The second year of this experiment will be repeating the treatments and measurements as we conducted in 2011. It is important for a field-based project to validate results by collecting data from different growing seasons, as the year-to-year variance of environmental conditions are expected. This past year has been extremely dry and we were not able to collect any runoff data from natural rainfalls. In 2012, we plan to put down treatments both in spring and fall, and hopefully we are able to collect data from both simulated and natural rainfalls. For the second year of this study, we are also ready to demonstrate and present the results to the general public through the Turf and Ornamental Field day in summer, and Lawn-care workshop in spring. At the end of the second season, we are also planning to present the results to the Missouri Green Industry Conference in December.

Proposed budget for year two (2012):

| Category | Year 2 |
|---|--------|
| Salary and benefits (20% Research Specialist) | 9,373 |
| Supplies (fertilizer, sampling bags) * | 500 |
| Soil testing services** | 5,000 |
| Total | 14,873 |

* Supplies include fertilizer, sampling bags, seeds, pesticides, and other necessary consumables.

** Soil testing services include estimates for two soil samples, two tissue samples, and six runoff water samples in 2012 from each plot.

Figure 2. Soil phosphorus (P) concentration (lb/ac) measured by Bray I P before and after P fertilizer treatments. Soil samples were randomly taken from 5 different locations within each plot and mixed for analysis. Bars labeled by different letters before or after P treatment are not significantly different using Fisher’s Protected LSD ($P=0.05$).

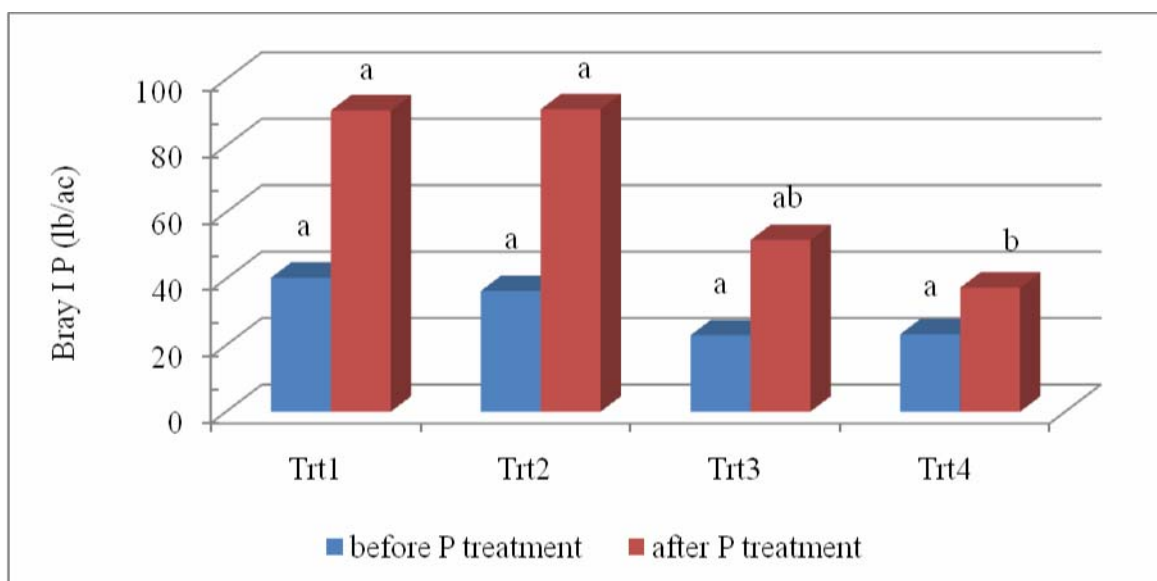


Figure 3. Concentrations of total P (mg/L) and dissolved P (mg/L) in runoff water collected at 0 (A) or 5 (B) days after the P fertilizer treatment (DAT). Bars labeled by different letters at 0 or 5 DAT are not significantly different using Fisher's Protected LSD ($P=0.05$).

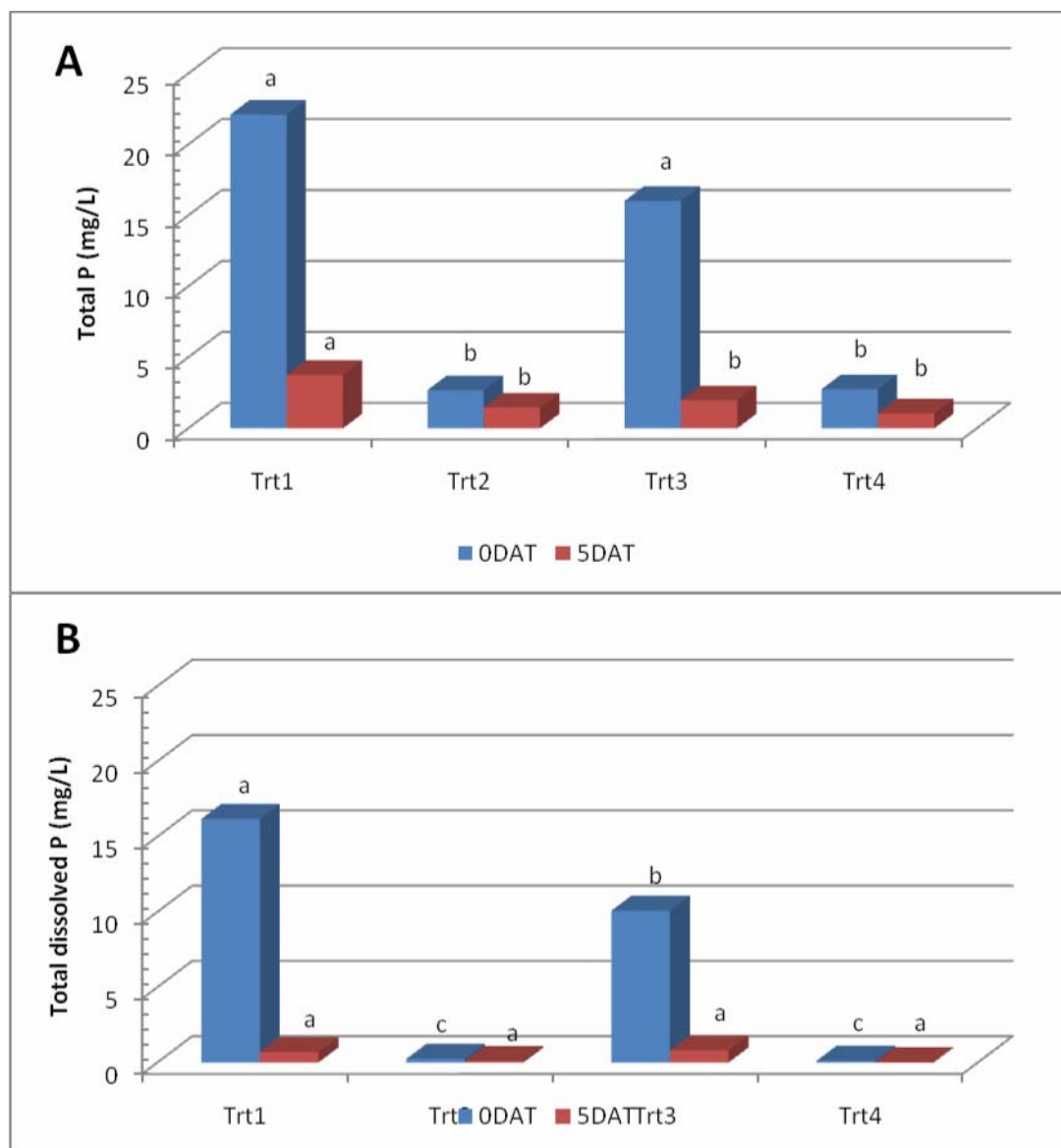


Figure 4. Precipitation (inches) at the South Farm during fall, 2011.

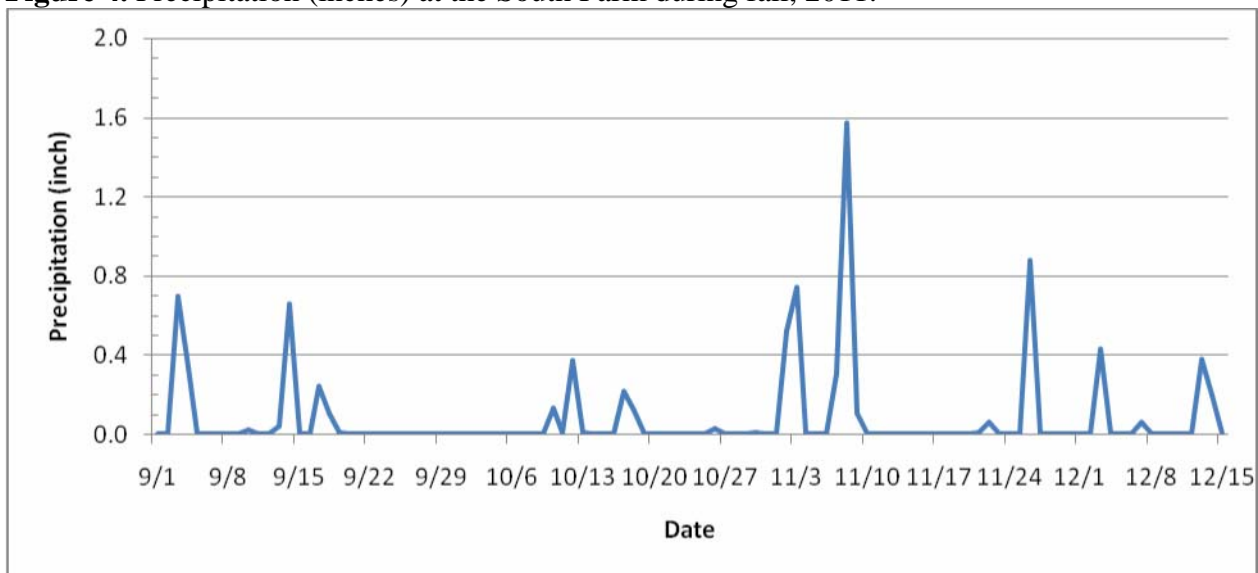


Table 2. Total phosphorus loss in the runoff water from the plot area affected by the P fertilizer treatments at the different days after treatments (DAT). Data included are total P (mg), dissolved P (mg), sediment P (mg), and the total runoff (L) from the plot area.

| Trt # | Soil P | Practice | ---Total P (mg) --- | | --Dissolved P (mg) --- | | ---Sediment P (mg)* --- | | -----Runoff (L) ----- | |
|-------|--------|----------------|----------------------|-------|------------------------|------|-------------------------|-------|-----------------------|------|
| | | | 0DAT | 5DAT | 0DAT | 5DAT | 0DAT | 5DAT | 0DAT | 5DAT |
| 1 | High P | Home owner | 333.9a ^{**} | 371.8 | 237.9a | 93.7 | 96.0 | 278.0 | 16.4 | 98.1 |
| 2 | High P | Soil test | 48.1c | 85.3 | 3.7c | 6.0 | 44.4 | 79.3 | 15.9 | 58.4 |
| 3 | Low P | Soil test | 199.9b | 157.3 | 132.0b | 67.8 | 67.9 | 89.5 | 12.7 | 71.2 |
| 4 | Low P | Restricted use | 28.4c | 106.6 | 1.6c | 2.1 | 26.8 | 104.5 | 14.9 | 97.1 |

* Sediment P (mg) is indirectly presented by the difference between the total P and dissolved P.

** Mean separation is conducted only when significant differences were found by ANOVA. Means within a column followed by the same letter are not significantly different using Fisher's Protected LSD ($P=0.05$).

Table 3. Turfgrass tissue mineral concentrations, percent nitrogen (N%), phosphorous (P%), and potassium (K%) influenced by the P fertilizer treatments.

| Trt # | Soil P | Practice | N%* | P% | K% |
|-------|--------|----------------|------|-------|------|
| 1 | High P | Home owner | 2.22 | 0.36a | 1.70 |
| 2 | High P | Soil test | 1.85 | 0.32b | 1.33 |
| 3 | Low P | Soil test | 1.87 | 0.29c | 1.49 |
| 4 | Low P | Restricted use | 2.04 | 0.29c | 1.56 |

* Clipping samples were collected from the plot area and analyzed in the Soil and Plant Testing Laboratory and reported as percent (%) dry matter.

Table 4. Turf quality, canopy chlorophyll index, and Normalized Difference Vegetation Index (NDVI) affected by P fertilizer treatments. Data were collected at different days after treatments (DAT).

| Trt # | Soil P | Practice | -----Turf quality*----- | | | | -----Chlorophyll Index**----- | | | | -----NDVI†----- | | |
|-------|--------|----------------|-------------------------|-------|-------|-------|-------------------------------|-------|-------|-------|-----------------|-------|-------|
| | | | 1DAT | 10DAT | 19DAT | 25DAT | 1DAT | 10DAT | 19DAT | 25DAT | 10DAT | 19DAT | 25DAT |
| 1 | High P | Home owner | 7.0 | 7.3 | 7.2 | 7.0 | 240.7 | 205.7 | 234.0 | 204.3 | 0.79a‡ | 0.67 | 0.73 |
| 2 | High P | Soil test | 7.2 | 7.2 | 7.0 | 7.0 | 213.0 | 197.0 | 215.7 | 183.3 | 0.63b | 0.59 | 0.63 |
| 3 | Low P | Soil test | 7.2 | 7.2 | 7.0 | 7.0 | 220.3 | 196.7 | 217.0 | 189.7 | 0.69ab | 0.64 | 0.69 |
| 4 | Low P | Restricted use | 7.3 | 7.5 | 7.2 | 7.0 | 234.7 | 210.0 | 235.0 | 200.0 | 0.72ab | 0.68 | 0.76 |

*Turf quality were visually assessed at 1-9 scale where 9 represents ideal turf, 1 represents dead turf, and 6 represents minimally acceptable turf quality;

**Chlorophyll index were collected by using a field scout CM1000 reflectance meter (Spectrum technologies, Plainfield, IL) and averaged three random readings per plot;

†Normalized difference vegetation index (NDVI) were recorded using a GreenSeeker (NTech Industries, Inc., Ukla, CA);

‡Means followed within a column followed by the same letter are not significantly different using Fisher's Protected LSD ($P=0.05$).

Phosphorus & Potash Management

Progress Reports

Yield response to P & K fertilizers over landscapes

Peter Scharf, Kent Shannon, and Vicky Hubbard
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 2011:

- We set up four on-farm, field-scale P and K response tests with producers for 2011
 - Three tests were in northwest Missouri, the only quadrant of the state where we had not previously had one of these tests.
 - One test was in southwest Missouri.
 - We do not yet have the yield maps associated with any of these tests. We know that yields were low in the southwest Missouri test due to drought stress.
 - Outcomes of these tests will be analyzed during the winter.
 - Additional analyses have been completed during 2011 on 2010 fields and are presented in this report.
- Locations of field-scale P and K response tests to date are shown on the map below.

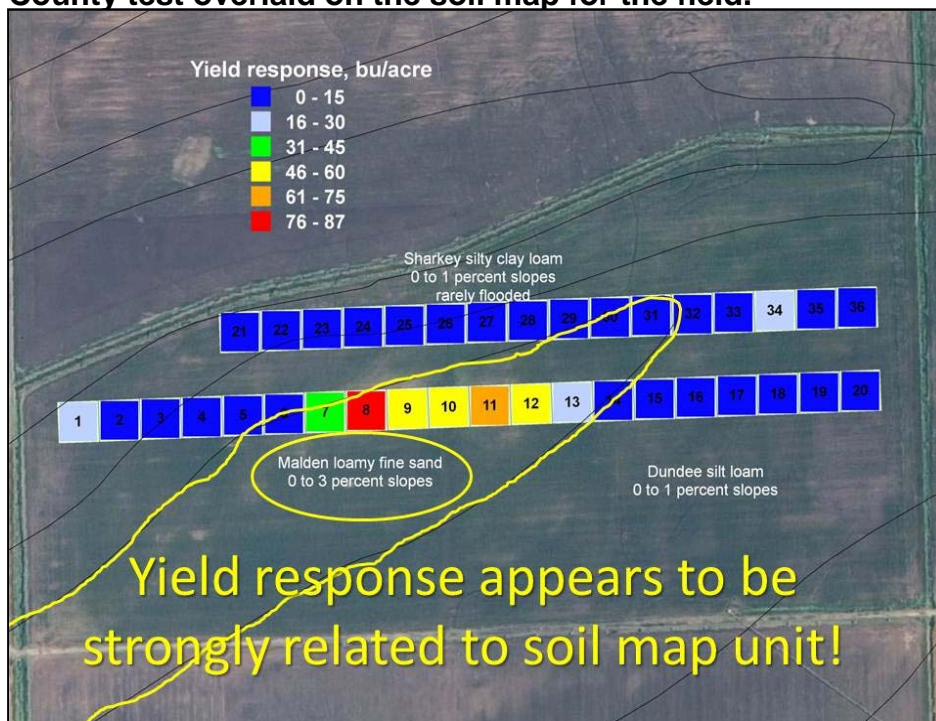
Figure 1. Locations of field-scale trials to measure yield



Mississippi County field

- Additional analyses of the results from this field were completed during 2011.
- Geographic Information Systems analysis of soil effects on corn yield response was completed during 2011.
 - This analysis showed that yield response to P and K depended strongly on soil type.
 - There was a 41 bushel/acre yield response to P and K on the Malden loamy fine sand in the middle of the field (Figure 2). Statistical confidence in this yield response is 99.6%.
 - Average yield response to P and K on the Dundee silt loam was -12 bushels/acre. There is no plausible mechanism for the P and K application to reduce yield, so I attribute this result to soil variability other than nutrients causing the yield difference.
 - Average yield response to P and K on the Sharkey silty clay loam was -1 bushels/acre.
 - The Malden fine sandy loam was also the highest-yielding soil in this field, with an average yield of 190 bushels/acre with P and K applied. This yield was higher than the yield obtained with P and K on the other two soils with 93% confidence.
 - Average yield on the Sharkey soil was 169 bushels/acre and on the Dundee soil was 164 bushels/acre.
- Because the three soils in this field fall into three different drainage classes, yield response to P and K was also strongly related to drainage class.
 - The Malden soil, where a large yield response to P and K was seen, is excessively well-drained.
 - The Dundee soil is somewhat poorly-drained, and the Sharkey soil is poorly-drained.
 - This result is similar to what we reported for the Vernon County test in last year's report, where the largest yield response to P and K was seen on well-drained soils.

Figure 2. Yield response to P and K in the Mississippi County test overlaid on the soil map for the field.



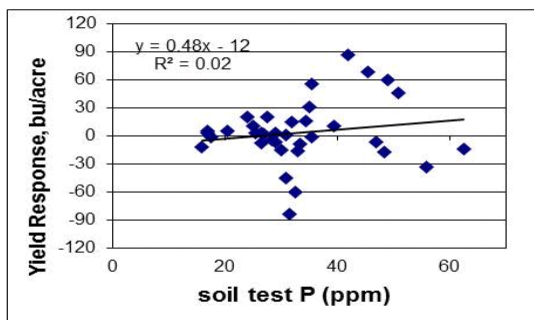
- We also received and analyzed grid-sampled soil test data for this field during 2011.
- These analyses showed that soil test value was not a useful predictor of where yield

response to P and K was seen (Figure 3).

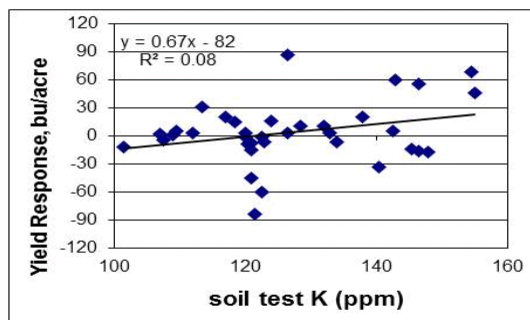
- If anything, soil test values were higher in the areas where yield response was largest.
- It appears that factors other than soil test levels controlled yield response to P and K in this field.

Figure 3. Yield response to P and K was not predicted by grid-sampled soil test P and K values in the Mississippi County field. Higher yield response is expected to occur where soil test values are lower, but we did not see that. However, there were no low-testing soils in this field.

Is yield response predicted by soil test?



Not by soil test P!



Not by soil test K either

- Summary for the Mississippi County P and K response test:
 - P and K targeted to the Malden soil were highly profitable.
 - P and K targeted to the other soils were not.
 - P and K applied over the whole field was not profitable; average yield response over the whole test area was 3 bushels/acre.
 - Soil test values were of no value in predicting the location where response would occur.
 - Soil map unit was a useful indicator of where response would occur, with a large yield response in the Malden soil and none in the other soils.
 - This would need to be confirmed with further tests before it would be a reasonable management strategy to target Malden soils for higher P and K rates than other soils.
 - The agreement between this field and the Vernon County field that the largest yield responses were on the best-drained soils suggests the possibility that soil drainage class could become a useful indicator for P and K management decisions.
 - This concept needs further testing.

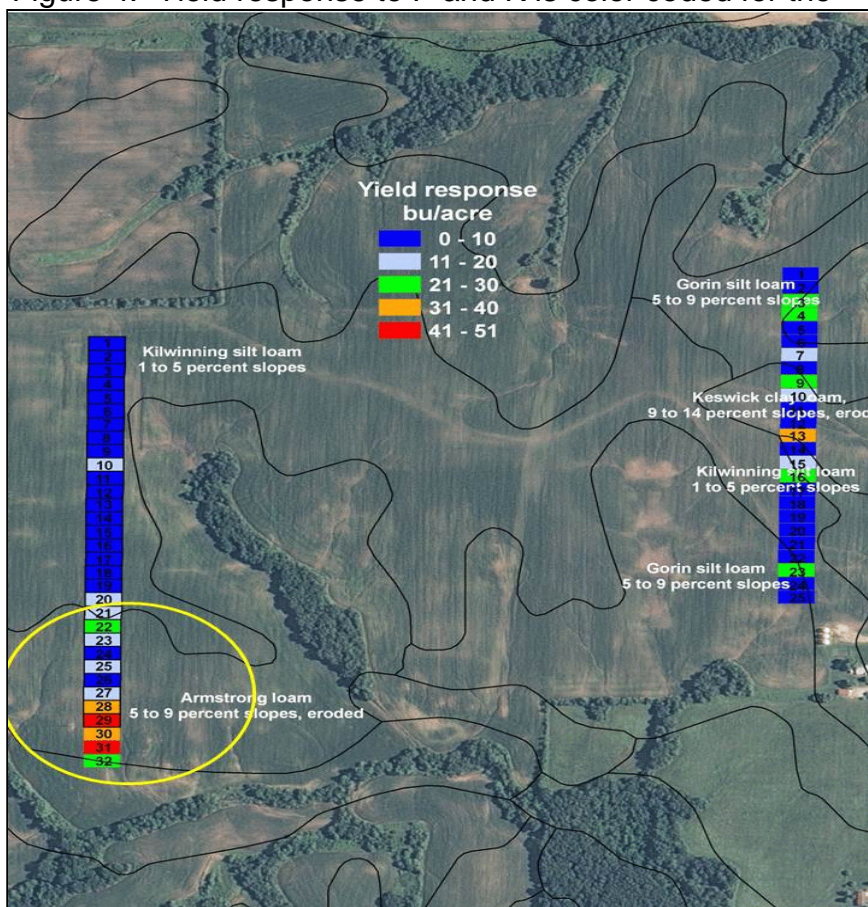
Lewis County field

- Additional analyses of this 2010 field were completed during 2011 as well.
- As with the Vernon and Mississippi County fields, yield response to P and K differed between soil map units.
- The largest yield response to P and K was seen on the Armstrong loam soil. This yield

response was 24 bushels/acre (99.9% statistical confidence that this was a true yield response).

- A yield response was also seen on the Keswick clay loam, 12 bushels/acre with 97% confidence that the response was real.
- No yield response to P and K was seen on the Kilwinning or Goring soils.
- As with the Mississippi County field, the largest yield response was on the soil that produced the highest yield. Average yields for the four soils in the test area were:
 - Armstrong 123
 - Gorin 110
 - Keswick 108
 - Kilwinning 93
- Unlike the Mississippi and Vernon County fields, the soil with the largest P and K response was not the best-drained soil. However, we did see a statistically significant yield response to P and K on the best-drained soil (Keswick, moderately well-drained).

Figure 4. Yield response to P and K is color coded for the



- This is the only field in this project where we have found a relationship between soil test values and yield response. It is also the field with, by far, the lowest soil test values.
- For each grid sample point within the test area, we related the soil test value from that grid point to the yield response that we measured.
- When soil test P (Bray-1) was 1 to 4 ppm, average yield response to P and K was 16 bushels/acre. At soil test P of 5 and above, no yield response to P and K was seen. Of the 18 soil samples taken within the test area, 7 had soil test P values between 5 and 7 ppm, which is very low, and still had no yield response to P and K fertilizer. It was unexpected to see no response with soil test values this low, and shows the value of testing on-farm where responses are occurring.
- When soil test K was below 80 ppm, average yield response to P and K was 23 bushels/acre. The larger yield response at low soil test K values than at low soil test P values suggests that K was more yield-limiting in this field than P. When soil test K was above 80 ppm, no yield response to P and K was seen.

SUMMARY

- Yield response to P and K was concentrated in one or two soils in each field that we have analyzed.
- There is a tendency for the most responsive soil to also be:
 - The highest yielding soil
 - The best-drained soil
- Soil test values had no relationship to yield response to P and K in 2 of the 3 fields that we have completed our analyses on.
- In the third field, soil test values for both P and K were low, and yield responses were seen in areas with soil test P below 5 ppm or soil test K below 80 ppm. No yield response was seen in this field with soil test P of 5 ppm or greater, or soil test K of 80 ppm or greater.
- Strip trials to measure yield response to P and K are a practical and fairly simple way for producers to better understand how to optimize P and K management on their own farm.

Nutrient Management for Biofuel Crop Production

Tim Reinbott, Manjula Nathan, Kelly Nelson Robert 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, 0 K
- 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, 2) continuous corn for grain and stover removal, 3) corn-soybean rotation for grain, 4) soybean-corn rotation for grain, 5) sweet sorghum-wheat double crop, 6) Miscanthus, 7) switch grass and 8) tall fescue.

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. ANOVA was performed using SAS. Soil quality measurements are currently being analyzed and a brief summary of 2010 results are provided

Fertilizer Treatments:

Fertilizer treatments in 2011 was determined using the University of Missouri recommendations from spring 2011 soil test measurements (Tables 1 and 2) or based upon crop removal from 2010 (Tables 3 and 4) calculated based on grain, stover, and dry matter nutrient concentration (Tables 3 and 4) and yields (Tables 6 and 7). Each plot was measured individually and fertilizer treatments were applied based upon individual measurements. A summary of the average fertilizer treatment applied based on soil test recommendations and nutrient removal at Bradford and Greenley for 2011 is listed in Table 5.

Results:

Soil Test Results:

Soil test levels of P and K at both locations were greater than the control when MU recommendations were followed or based upon removal (Tables 1-4). For the most part K fertilization in both treatments was very similar whereas, P fertilizer amounts were greater in the MU recommendation treatments (Table 5). In some corn and biomass treatments P and K values are slightly greater when MU recommendations were utilized particularly at the Greenley Center. At Bradford soil test levels tended to be lower across all treatments.

Grain and Biomass Yield:

The growing season in 2011 was characterized by wet conditions during the spring and early summer and then an extended hot/dry period from mid-July through mid-August. At Bradford an hour long hail storm occurred on July 3rd when corn was at the V-15 stage and soybeans at R1. Corn losses varied depending upon the location in the field and plot and as a result corn yield was quite variable. Overall corn yield was less with the 0 P and K treatment at Bradford and there was no significant difference in yield with P and K treatment at either location (Table 6) although there was a trend for a yield advantage of applying University of Missouri Soil Test recommendations rather than those based upon removal (Tables 1-4).

There was little difference in biomass yield in 2011 based upon fertility treatment except for corn stover and Miscanthus at Bradford (Table 7). Surprisingly, biomass based upon the previous year's removal had the greatest yield although it had the least amount of P applied. The significantly lower corn stover biomass in the 0 P and K treatment at Bradford was correlated to lower grain yield. It is possible that the hail storm resulted in more leaf and stalk damage in the lower fertility treatments. A deficiency in K would result in weaker stalks and more susceptible to injury and breakage. Biomass production of Miscanthus and sweet sorghum was higher but not significant at Greenley when P and K was applied based upon the previous year's removal.

Nutrient Uptake:

Corn and Soybean Grain:

There were some slight increases in P and K concentration of corn and soybean when P and K was applied at either the MU recommendations or based upon removal (Tables 8 and 9). The positive yield response at Bradford from P and K treatment resulted in a greater amount of P and K removed. Based upon P and K concentration in the corn kernels, there does not seem to be luxury uptake at either location. Soybean nutrient response to P and K treatment was similar at each location with higher but non-significant increases in P and K concentration.

Corn Stover:

Potassium concentration in corn stover at both locations was higher regardless of P and K treatment. Phosphorus concentration from P treatment was slightly greater at Greenley but was less at Bradford. However, since corn stover dry matter increased slightly with P and K treatment at both locations there was a modest amount of P and a large amount of K removed. Growers must be aware that removing corn stover from the field will result in large losses of K which are more than four times what is removed from grain yield and that P loss from stover removal is similar to the amount removed from grain yield. With prices of P₂O₅ and K₂O at more than \$0.50/lb. the value of the P and K removed from the corn stover is valued at \$65-90/acre.

Grass Biomass:

There was little difference in the P concentration in any biomass crop regardless of the rate of P applied (Tables 8 and 9). However, since there was some biomass yield increases associated with fertilizer treatment there was more P removed particularly in sweet sorghum and tall fescue. However, there was a large significant increase in biomass K concentration depending on the grass species. This is somewhat surprising since the perennial grasses, Miscanthus and switchgrass, remobilize much of their K back into their root systems in early fall. This large removal of K demonstrates that there was luxury uptake of K with these grasses since concentration increased when dry matter yield did not (switchgrass) and increased when dry matter also increased (Miscanthus). Furthermore, Miscanthus has been advertised as requiring minimal fertilization. This data clearly shows that large amounts of K are exported from the field at levels similar to a 150 bu/acre corn crop. In the summer of 2010 we dug soil pits at the edge of the Miscanthus, corn, and switchgrass and which showed that Miscanthus roots penetrated more deeply than the others. Harvesting subsoil P and K maybe the reason that early harvests of Miscanthus seem to not respond to P and K fertilizer but eventually those reserves will be depleted. Also, at both locations these plots were on a clay pan soil with a fairly high P and K subsoil content. A serious concern is "What happens in marginal soils south of the Missouri River where much of the Miscanthus is planned to be grown"? Switchgrass also removed large amounts of K with fertilizer treatment but did not result in a yield response. Again this needs to be considered when selling biomass for energy production. In this study Switchgrass yields of four tons/acre contained a P and K value of at least \$10/ton (\$40/acre) which was removed.

The annual sweet sorghum and perennial cool season forage, tall fescue which is harvested in the vegetative stage, removed large amounts of K. Clearly this demonstrates a luxury uptake of K and to a lesser extent P. This luxury consumption is evident by the much larger amount of K required based upon removal as compared to the MU buildup plus maintenance recommendations. For these crops an eight year buildup maybe more appropriate rather than a four year build up.

Conclusions:

Although grain and biomass yields may not have large positive yield responses each year by P and K application care must be taken not to over apply since luxury consumption will take place. This is particular true with K in corn stover and perennial and annual biomass crops. Often these biomass crops remove the equivalent K of a 150 bu/acre corn crop. Fertilizer P and K might best be applied upon an 8-year build up to avoid luxury consumption and export of P and K.

Soil Quality Analysis

During the first two sampling dates the initial trend for improved soil quality based on WSA and enzyme activity analyses was becoming evident in perennial crops (data not presented). 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. 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 (Table 10).

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 first three to four years of this study. The initial differences between the two sites, primarily in soil C content and glucosaminidase activity, may require separate analyses for the sites as the project progresses.

Outreach and Extension Activities:

These plots are very unique to the University System and even to the United States. We were told that this is the only P and K study with *Miscanthus* in the US. We have utilized these plots at many field days, workshops, and specialty tours over the past three years. At the Greenley Center these plots were used as a stop at the annual field day in August. These plots were also part of the Crop Injury and Diagnostic Clinic in 2010 and the Biofuel, Beef, and Birds Field Day in 2010. It has also been showcased at the “Integrating Bobwhite Quail Management in an Agricultural Setting” field day in 2011. These plots also serve as an education tool for the NRCS, MDC, and FSA tours each year. Each year at both locations these plots are part of the tour route for visitors from across Missouri, USA, and the world. We have presented this data at the annual American Society of America meetings for the past two years and at the Missouri Natural Resources Conference in 2010 and North Central Soil Fertility Extension-Industry Conference in 2011 at Des Moines, IA.

Request for Extension:

The data from this study is extremely important and we would like to have one more year of data to have the full four year buildup plan in place and to get more soil quality data. It is also important that we continue this research for one more year to have three years of data from *Miscanthus* plots at Novelty. Since it takes 6 to 9 months for *Miscanthus* to get established, we had zero yields at Greenley during the first year of establishment in 2009. Also the hail damage and drought conditions that prevailed in 2011 resulted in high variability within reps masking the treatment effects. So it is important that we extend this project by one more year to collect valuable data. In addition, it takes at least three if not four years before the soil quality begins to change drastically. So by extending this project by one more year we will have good information to draw valuable conclusions from this study.

Budget:

| CATEGORIES | Year 2012 |
|--|------------------|
| A. Salaries | |
| Senior Lab Technician (20%) | \$5,767 |
| General Labor for help with field work at the rate of \$9:00 per hour 1000 man hours | \$9,000 |
| B. Fringe Benefits | |
| Fringe for Lab Technician (25%) | \$1,730 |
| TOTAL SALARIES AND FRINGE BENEFITS | \$16,497 |
| C. Travel | |
| Travel to field site | \$600 |
| To present research findings at National Meetings | \$600 |
| TOTAL TRAVEL COSTS | \$1,200 |
| D. Equipment | \$0 |
| TOTAL EQUIPMENT use and maintenance COSTS | \$1000 |
| E. Other Direct Costs | |
| Soil analysis | \$1680 |
| Plant Analysis | \$5880 |
| Soil physical and Microbiological measurements | \$3100 |
| Field supplies | |
| Publication cost | \$500 |
| TOTAL OTHER DIRECT COSTS | \$11,160 |
| TOTAL REQUEST | \$29,857 |

Justification:

Salaries and Fringe Benefits: Funds are requested support of a senior lab technician for 2.5 months based on an annual salary of \$28,835, 30% fringe benefits.

Travel: Covers cost of travel to farm research centers filed sites for treatment application, sample collections, taking field measurements, harvesting in Missouri and for field days presentations and to present the research work in national meetings.

Field supplies: seeds, fertilizer, soil and plant samplers, sample bags and other field supplies.

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Table 1. Soil test characteristics at Bradford in spring, 2011.

| Cropping Systems | Fertilizer | pHs | P lb/acre | K lb/acre | OM % |
|----------------------------------|--------------|------|--------------|--------------|---------|
| Continuous Corn (Grain only) | 0 P and K | 6.0a | 19b | 83b | 2.68a |
| | MU Recommend | 5.9a | 26ab | 93b | 2.50a |
| | Removal | 5.7b | 34a | 137a | 2.60a |
| Continuous Corn (Stover removed) | 0 P and K | 6.2a | 23b | 80a | 2.68a |
| | MU Recommend | 6.0a | 29ab | 91a | 2.65a |
| | Removal | 5.9a | 35a | 138a | 2.60a |
| Corn/Soybean Rotation | 0 P and K | 5.8a | 24a | 90a | 2.35a |
| | MU Recommend | 5.9a | 27a | 91a | 2.13a |
| | Removal | 5.9a | 29a | 102a | 2.43a |
| Miscanthus | 0 P and K | 6.0a | 23a | 89a | 2.88a |
| | MU Recommend | 5.8a | 30a | 117a | 2.70a |
| | Removal | 5.9a | 32a | 117a | 2.73a |
| Soybean/Corn Rotation | 0 P and K | 5.8a | 19a | 85b | 2.55a |
| | MU Recommend | 5.6a | 34a | 112ab | 2.80a |
| | Removal | 5.7a | 32a | 131a | 2.75a |
| Sweet Sorghum-Wheat | 0 P and K | 5.8a | 29a | 84a | 2.65a |
| | MU Recommend | 5.9a | 33a | 101a | 2.55a |
| | Removal | 5.9a | 37a | 129a | 2.70a |
| Switchgrass | 0 P and K | 5.9a | 23a | 82b | 2.48a |
| | MU Recommend | 5.9a | 27a | 128a | 2.60a |
| | Removal | 5.9a | 25a | 103ab | 2.53a |
| Tall Fescue | 0 P and K | 5.9a | 20b | 103a | 2.75a |
| | MU Recommend | 5.9a | 30a | 192a | 2.75a |
| | Removal | 5.9a | 29a | 166a | 2.68a |

| Cropping Systems | pHs | P lb/acre | K lb/acre | OM % |
|----------------------------------|-------|--------------|--------------|---------|
| Continuous Corn (Grain only) | 5.9ab | 26b | 104b | 2.6bc |
| Continuous Corn (Stover removed) | 6.0a | 29ab | 103b | 2.6abc |
| Corn/Soybean Rotation | 5.9ab | 27ab | 94b | 2.3d |
| Miscanthus | 5.9ab | 28ab | 108b | 2.8a |
| Soybean/Corn Rotation | 5.7c | 28ab | 109b | 2.7abc |
| Sweet Sorghum-Wheat | 5.8bc | 33a | 105b | 2.6abc |
| Switchgrass | 5.9ab | 25b | 104b | 2.5c |
| Tall Fescue | 5.9ab | 26b | 154a | 2.7ab |

Table 2. Soil test characteristics at Greenley in spring, 2011

| Cropping Systems | Fertilizer | pHs | P lb/acre | K lb/acre | OM % |
|----------------------------------|--------------|------|--------------|--------------|---------|
| Continuous Corn (Grain only) | 0 P and K | 5.7a | 23b | 177a | 3.0a |
| | MU Recommend | 5.6a | 43a | 203a | 3.3a |
| | Removal | 5.8a | 34ab | 200a | 2.9a |
| Continuous Corn (Stover removed) | 0 P and K | 6.1a | 28a | 181b | 3.1a |
| | MU Recommend | 6.1a | 39a | 225a | 3.2a |
| | Removal | 6.2a | 49a | 210ab | 3.2a |
| Corn/Soybean Rotation | 0 P and K | 5.7a | 19b | 175a | 3.3a |
| | MU Recommend | 5.8a | 31ab | 196a | 3.3a |
| | Removal | 5.9a | 37a | 182a | 2.9a |
| Miscanthus | 0 P and K | 5.9a | 16b | 198a | 3.0ab |
| | MU Recommend | 5.7a | 26a | 226a | 3.1a |
| | Removal | 6.2a | 19b | 202a | 2.8b |
| Soybean/Corn Rotation | 0 P and K | 5.8a | 22b | 183a | 3.3a |
| | MU Recommend | 5.7a | 34a | 193a | 2.9a |
| | Removal | 5.9a | 33a | 197a | 3.2a |
| Sweet Sorghum-Wheat | 0 P and K | 5.6b | 21a | 161a | 3.5a |
| | MU Recommend | 5.6b | 58a | 183a | 3.5a |
| | Removal | 6.1a | 52a | 203a | 3.3a |
| Switchgrass | 0 P and K | 6.1a | 26a | 212a | 2.7a |
| | MU Recommend | 5.9a | 24a | 225a | 3.0a |
| | Removal | 6.0a | 29a | 236a | 2.9a |
| Tall Fescue | 0 P and K | 5.6a | 15b | 156a | 3.2a |
| | MU Recommend | 5.7a | 25ab | 144a | 3.3a |
| | Removal | 5.8a | 34a | 178a | 3.2a |

| Cropping Systems | pHs | P lb/acre | K lb/acre | OM % |
|----------------------------------|-------|--------------|--------------|---------|
| Continuous Corn (Grain only) | 5.7b | 33ab | 193bc | 3.1cd |
| Continuous Corn (Stover removed) | 6.1a | 39ab | 205ab | 3.2bc |
| Corn/Soybean Rotation | 5.8b | 29bc | 185dc | 3.2bc |
| Miscanthus | 5.9ab | 20d | 209ab | 3.0cd |
| Soybean/Corn Rotation | 5.8b | 30bc | 191bc | 3.1bc |
| Sweet Sorghum-Wheat | 5.8b | 43a | 183dc | 3.4a |
| Switchgrass | 6.0ab | 26dc | 225a | 2.9d |
| Tall Fescue | 5.7b | 25dc | 160d | 3.3ab |

Table 3. Grain and biomass nutrient concentration, and nutrient removal based on 2010 harvest grain, stover, and biomass at Bradford.

| Cropping Systems | Fertilizer | P % | K % | P ₂ O ₅ lb/acre | K ₂ O lb/acre |
|--------------------------------------|-------------|-------|--------|---------------------------------------|--------------------------|
| Continuous Corn (Grain only) | 0 P and K | 0.33a | 0.37a | 35.4b | 20.8b |
| | MURecommend | 0.32a | 0.37a | 50.8a | 30.4a |
| | Removal | 0.30a | 0.37a | 43.6ab | 28.2ab |
| Continuous Corn (Stover removed) | 0 P and K | 0.31a | 0.32b | 40.1a | 21.1a |
| | MURecommend | 0.29a | 0.41a | 39.4a | 30.0a |
| | Removal | 0.32a | 0.39a | 49.9a | 31.8a |
| Corn/Soybean Rotation (soybean 2010) | 0 P and K | 0.65b | 1.75c | 54.7a | 76.7a |
| | MURecommend | 0.68a | 1.93a | 60.4a | 89.1a |
| | Removal | 0.64b | 1.86b | 59.3a | 90.2a |
| Miscanthus | 0 P and K | 0.09a | 0.42a | 35.2a | 87.5a |
| | MURecommend | 0.08a | 0.43a | 25.4a | 68.0a |
| | Removal | 0.08a | 0.40a | 34.0a | 90.4a |
| Soybean/Corn Rotation (corn 2010) | 0 P and K | 0.32a | 0.35b | 53.7a | 31.1a |
| | MURecommend | 0.33a | 0.37ab | 47.0a | 28.9a |
| | Removal | 0.32a | 0.41a | 48.8a | 31.1a |
| Sweet Sorghum | 0 P and K | 0.22a | 1.04b | 21.0a | 47.2a |
| | MURecommend | 0.22a | 1.14ab | 16.6a | 44.7a |
| | Removal | 0.25a | 1.37a | 19.8a | 53.6a |
| Switchgrass | 0 P and K | 0.14a | 0.51a | 23.6a | 46.1a |
| | MURecommend | 0.17a | 0.60a | 26.4a | 49.1a |
| | Removal | 0.14a | 0.57a | 21.8a | 48.3a |
| Tall Fescue | 0 P and K | 0.26a | 1.72b | 78a | 263b |
| | MURecommend | 0.27a | 2.03a | 88a | 342a |
| | Removal | 0.28a | 2.00a | 88a | 323a |

| Cropping Systems | P % | K % | P ₂ O ₅ lb/acre | K ₂ O lb/acre |
|----------------------------------|-------|--------|---------------------------------------|--------------------------|
| Continuous Corn (Grain only) | 0.32b | 0.37d | 43.3c | 26.4d |
| Continuous Corn (Stover removed) | 0.31b | 0.37d | 43.2c | 27.6d |
| Corn/Soybean Rotation | 0.66a | 1.85a | 58.1b | 85.3b |
| Miscanthus | 0.09f | 0.42dc | 31.5d | 82.0b |
| Soybean/Corn Rotation | 0.32b | 0.38d | 49.8bc | 30.3cd |
| Sweet Sorghum | 0.23d | 1.18b | 19.1e | 48.5c |
| Switchgrass | 0.15e | 0.56c | 23.9de | 47.8c |
| Tall Fescue | 0.27c | 1.92a | 84.8a | 309a |

Table 4. Grain and biomass nutrient concentration, and nutrient removal based on 2010 harvest grain, stover, and biomass at Greenley

| Cropping Systems | Fertilizer | P % | K % | P ₂ O ₅ lb/acre | K ₂ O lb/acre |
|--------------------------------------|-------------|--------|--------|---------------------------------------|--------------------------|
| Continuous Corn (Grain only) | 0 P and K | 0.27a | 0.36b | 29.1a | 20.5a |
| | MURecommend | 0.30 | 0.42a | 39.4a | 29.7a |
| | Removal | 0.30a | 0.36b | 36.1a | 22.7a |
| Continuous Corn (Stover removed) | 0 P and K | 0.27b | 0.38a | 44.3b | 67.0a |
| | MURecommend | 0.31a | 0.39a | 63.0a | 64.9a |
| | Removal | 0.31a | 0.40a | 74.4a | 95.1a |
| Corn/Soybean Rotation (Soybean 2010) | 0 P and K | 0.53a | 1.80b | 49.7a | 88.5b |
| | MURecommend | 0.59a | 1.92a | 56.1a | 97.3ab |
| | Removal | 0.58a | 1.92a | 56.1a | 100.1a |
| Miscanthus | 0 P and K | 0.16a | 0.79a | 12.0a | 31.9a |
| | MURecommend | 0.13b | 0.84a | 24.6a | 84.2a |
| | Removal | 0.17a | 0.83a | 17.0a | 44.1a |
| Soybean/Corn Rotation (corn 2010) | 0 P and K | 0.26b | 0.39a | 47.0b | 38.0a |
| | MURecommend | 0.33a | 0.38a | 59.0a | 36.6a |
| | Removal | 0.31ab | 0.39a | 64.6a | 41.9a |
| Sweet Sorghum | 0 P and K | 0.222a | 1.13a | 52.9a | 131a |
| | MURecommend | 0.230a | 1.53a | 48.4a | 165a |
| | Removal | 0.253a | 1.47a | 62.6a | 194a |
| Switchgrass | 0 P and K | 0.119a | 0.45a | 31.0a | 61.9a |
| | MURecommend | 0.134a | 0.54a | 47.6a | 100.2a |
| | Removal | 0.135a | 0.49a | 48.4a | 93.1a |
| Tall Fescue | 0 P and K | 0.205b | 1.57b | 54.9b | 225.5a |
| | MURecommend | 0.252a | 2.00ab | 69.6a | 291.1a |
| | Removal | 0.276a | 2.12a | 74.1a | 300.1a |

| Cropping Systems | P % | K % | P ₂ O ₅ lb/acre | K ₂ O lb/acre |
|----------------------------------|-------|-------|---------------------------------------|--------------------------|
| Continuous Corn (Grain only) | 0.29b | 0.38d | 34.9c | 24.3e |
| Continuous Corn (Stover removed) | 0.30b | 0.39d | 60.6a | 75.7dc |
| Corn/Soybean Rotation | 0.56a | 1.88a | 54.0ab | 95.3c |
| Miscanthus | 0.15d | 0.82c | 17.9d | 53.4de |
| Soybean/Corn Rotation | 0.30b | 0.38d | 56.9ab | 38.8e |
| Sweet Sorghum | 0.24c | 1.38b | 54.6ab | 163.3b |
| Switchgrass | 0.13d | 0.50d | 42.4bc | 85.1cd |
| Tall Fescue | 0.24c | 1.89a | 66.2a | 272.2a |

Table 5. Average fertility treatments based on soil test recommendations and crop removal at Bradford and Greenley in spring , 2011

| Cropping Systems | Fertilizer | N | P ₂ O ₅ | K ₂ O | N | P ₂ O ₅ | K ₂ O |
|----------------------------------|--------------|---------|-------------------------------|------------------|---------|-------------------------------|------------------|
| | | lb/acre | lb/acre | lb/acre | lb/acre | lb/acre | lb/acre |
| | | ----- | Bradford | ----- | ----- | Greenley | ----- |
| Continuous Corn (Grain only) | 0 P and K | 240 | 0 | 0 | 220 | 0 | 0 |
| | MU Recommend | 240 | 140 | 190 | 220 | 100 | 120 |
| | Removal | 240 | 50 | 40 | 220 | 65 | 45 |
| Continuous Corn (Grain + stover) | 0 P and K | 240 | 0 | 0 | 220 | 0 | 0 |
| | MU Recommend | 240 | 135 | 195 | 220 | 100 | 110 |
| | Removal | 240 | 95 | 125 | 220 | 75 | 100 |
| Soybean/Corn Rotation | 0 P and K | 0 | 0 | 0 | 0 | 0 | 0 |
| | MU Recommend | 0 | 135 | 195 | 0 | 120 | 120 |
| | Removal | 0 | 65 | 95 | 0 | 65 | 110 |
| Miscanthus | 0 P and K | 60 | 0 | 0 | 60 | 0 | 0 |
| | MU Recommend | 60 | 35 | 190 | 60 | 45 | 120 |
| | Removal | 60 | 40 | 105 | 60 | 25 | 60 |
| Corn/Soybean Rotation | 0 P and K | 240 | 0 | 0 | 220 | 0 | 0 |
| | MU Recommend | 240 | 80 | 205 | 220 | 80 | 150 |
| | Removal | 240 | 60 | 40 | 220 | 65 | 45 |
| Sweet Sorghum-Wheat | 0 P and K | 120 | 0 | 0 | 120 | 0 | 0 |
| | MU Recommend | 120 | 125 | 175 | 120 | 120 | 140 |
| | Removal | 120 | 40 | 65 | 120 | 50 | 200 |
| Switchgrass | 0 P and K | 60 | 0 | 0 | 60 | 0 | 0 |
| | MU Recommend | 60 | 30 | 140 | 60 | 30 | 90 |
| | Removal | 60 | 25 | 55 | 60 | 45 | 80 |
| Tall Fescue | 0 P and K | 120 | 0 | 0 | 120 | 0 | 0 |
| | MU Recommend | 120 | 85 | 210 | 120 | 100 | 265 |
| | Removal | 120 | 100 | 315 | 120 | 80 | 285 |

Table 6: Grain yields at Bradford and Greenley sites, 2011

| Cropping Systems | Fertilizer Treatments | Yield | Mean | Yield | Mean |
|--------------------------------------|-----------------------|----------|-------|----------|-------|
| | | bu/ac | bu/ac | bu/ac | bu/ac |
| | | Bradford | | Greenley | |
| Continuous Corn (Grain only) | 0 P and K | 115a | 148a | 115a | 107b |
| | MU Recommend | 168a | | 110a | |
| | Removal | 162a | | 95a | |
| Continuous Corn (Grain+stover) | 0 P and K | 100a | 144a | 126a | 132a |
| | MU Recommend | 170a | | 136a | |
| | Removal | 163a | | 133a | |
| Corn-Soybean Rotation (Corn 2011) | 0 P and K | 89a | 132a | 154a | 145a |
| | MU Recommend | 157a | | 142a | |
| | Removal | 152a | | 137a | |
| Soybean-Corn Rotation (Soybean-2011) | 0 P and K | 31a | 32 | 56a | 56 |
| | MU Recommend | 30a | | 56a | |
| | Removal | 36a | | 55a | |

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

Table 7: Biomass yields at Bradford and Greenley sites, 2011

| Cropping Systems | Fertilizer Treatments | Biomass | Mean | Biomass | Mean |
|--------------------------|-----------------------|----------|---------|----------|---------|
| | | tons/ac | tons/ac | tons/ac | tons/ac |
| | | Bradford | | Greenley | |
| Continuous Corn (Stover) | 0 P and K | 2.2b | 2.8c | 3.8a | 3.9b |
| | MU Recommend | 2.8ab | | 4.1a | |
| | Removal | 3.5a | | 3.9a | |
| Miscanthus | 0 P and K | 6.0b | 6.9a | 4.2a | 4.4b |
| | MU Recommend | 5.8b | | 4.0a | |
| | Removal | 8.9a | | 4.9a | |
| Sweet sorghum | 0 P and K | 2.9a | 2.9c | 9.4a | 9.7a |
| | MU Recommend | 2.9a | | 9.5a | |
| | Removal | 2.9a | | 10.4a | |
| Switchgrass | 0 P and K | 4.7a | 4.3b | 3.9a | 3.8b |
| | MU Recommend | 4.0a | | 3.9a | |
| | Removal | 4.1a | | 3.5a | |
| Tall Fescue | 0 P and K | 4.5a | 4.6b | 3.6a | 3.9b |
| | MU Recommend | 4.4a | | 4.3a | |
| | Removal | 4.9a | | 3.9a | |

Table 8. Grain and biomass nutrient concentration, and nutrient removal based on 2011 harvest grain, stover, and biomass at Bradford.

| Cropping Systems | Fertilizer | P % | K % | P ₂ O ₅ lb/acre | K ₂ O lb/acre |
|----------------------------------|------------|--------|-------|---------------------------------------|--------------------------|
| Continuous Corn (Grain only) | 0 P and K | 0.32a | 0.36a | 47.4a | 27.4a |
| | Buildup | 0.34a | 0.36a | 71.8a | 41.5a |
| | Removal | 0.35a | 0.34a | 72.0a | 36.7a |
| Continuous Corn (Grain + Stover) | 0 P and K | 0.34a | 0.33a | 85.6a | 60.5b |
| | Buildup | 0.32a | 0.35a | 117.0a | 105.7ab |
| | Removal | 0.35a | 0.35a | 131.3a | 119.4a |
| Corn/Soybean Rotation (corn) | 0 P and K | 0.34a | 0.33a | 43.8a | 22.1a |
| | Buildup | 0.33a | 0.33a | 64.3a | 34.5a |
| | Removal | 0.32a | 0.34a | 62.8a | 34.1a |
| Miscanthus | 0 P and K | 0.13a | 0.63a | 33.9ab | 90.4b |
| | Buildup | 0.11a | 0.63a | 31.0b | 90.1b |
| | Removal | 0.12a | 0.75a | 48.2a | 159.8a |
| Soybean/Corn Rotation (soybean) | 0 P and K | 0.51b | 1.75b | 21.9a | 39.4a |
| | Buildup | 0.54ab | 1.88a | 22.3a | 40.9a |
| | Removal | 0.55a | 1.87a | 27.2a | 48.8a |
| Sweet Sorghum | 0 P and K | 0.23a | 0.71b | 31.2a | 50.1b |
| | Buildup | 0.24a | 0.90a | 31.7a | 63.2a |
| | Removal | 0.26a | 1.04a | 34.2a | 72.7a |
| Switchgrass | 0 P and K | 0.18a | 0.43a | 37.9a | 48.5a |
| | Buildup | 0.16a | 0.60a | 29.0a | 57.4a |
| | Removal | 0.17a | 0.61a | 32.5a | 60.0a |
| Tall Fescue | 0 P and K | 0.28a | 2.10b | 58.6a | 224.6b |
| | Buildup | 0.30a | 2.71a | 59.6a | 289.4ab |
| | Removal | 0.31a | 2.75a | 68.9a | 321.6a |
| <hr/> | | | | | |
| Cropping Systems | | P % | K % | P ₂ O ₅ lb/acre | K ₂ O lb/acre |
| Continuous Corn (Grain only) | | 0.33b | 0.35f | 63.7b | 35.2de |
| Continuous Corn (Grain + Stover) | | 0.34b | 0.34f | 111.3a | 95.2b |
| Corn/Soybean Rotation | | 0.33b | 0.33f | 56.9b | 30.2e |
| Miscanthus | | 0.12f | 0.67d | 37.7c | 113.4b |
| Soybean/Corn Rotation | | 0.53a | 1.83b | 23.8d | 43.0cd |
| Sweet Sorghum | | 0.24d | 0.88c | 32.4cd | 62.0c |
| Switchgrass | | 0.17e | 0.55e | 33.1cd | 55.3cd |
| Tall Fescue | | 0.29c | 2.52a | 62.4b | 278.5a |
| <i>Pr>F</i> | | 0.001 | 0.001 | 0.001 | 0.001 |

Table 9. Grain and biomass nutrient concentration, and nutrient removal based on 2011 harvest grain, stover, and biomass at Greenley.

| Cropping Systems | Fertilizer | P % | K % | P ₂ O ₅ lb/acre | K ₂ O lb/acre |
|----------------------------------|------------|--------|--------|--|-----------------------------|
| Continuous Corn (Grain only) | 0 P and K | 0.29a | 0.34a | 43.9a | 26.6a |
| | Buildup | 0.29a | 0.35a | 40.6a | 25.8a |
| | Removal | 0.30a | 0.38a | 36.5a | 24.7a |
| Continuous Corn (Grain + Stover) | 0 P and K | 0.29a | 0.37a | 83.3a | 136.8a |
| | Buildup | 0.33a | 0.41a | 100.7a | 162.6a |
| | Removal | 0.32a | 0.36a | 99.3a | 164.9a |
| Corn/Soybean Rotation | 0 P and K | 0.33a | 0.34a | 65.1a | 35.7a |
| | Buildup | 0.32a | 0.33a | 58.8a | 31.1a |
| | Removal | 0.30a | 0.34a | 52.7a | 31.9a |
| Miscanthus | 0 P and K | 0.07a | 0.72a | 14.1a | 72.1a |
| | Buildup | 0.07a | 0.87a | 12.5a | 85.5a |
| | Removal | 0.06a | 0.79a | 14.7a | 93.7a |
| Soybean/Corn Rotation | 0 P and K | 0.54a | 1.84a | 42.5b | 75.0a |
| | Buildup | 0.58a | 1.95a | 44.4a | 79.1a |
| | Removal | 0.57a | 1.95a | 43.2ab | 77.1a |
| Sweet Sorghum | 0 P and K | 0.13a | 0.62b | 45.2a | 112.5b |
| | Buildup | 0.15a | 1.20a | 54.6a | 228.5a |
| | Removal | 0.14a | 1.33a | 56.1a | 275.8a |
| Switchgrass | 0 P and K | 0.14a | 0.66a | 24.2a | 61.6a |
| | Buildup | 0.14a | 0.85a | 24.3a | 78.8a |
| | Removal | 0.14a | 0.78a | 22.0a | 65.2a |
| Tall Fescue | 0 P and K | 0.27a | 2.09a | 44.4a | 181.7a |
| | Buildup | 0.28a | 2.03a | 55.5a | 213.2a |
| | Removal | 0.29a | 2.91a | 51.1a | 273.9a |
| Cropping Systems | | P % | K % | P ₂ O ₅ lb/acre | K ₂ O lb/acre |
| Continuous Corn (Grain only) | | 0.29cd | 0.36e | 40.3e | 25.7d |
| Continuous Corn (Grain +Stover) | | 0.32b | 0.38e | 94.5a | 154.8b |
| Corn/Soybean Rotation | | 0.32b | 0.34e | 58.9b | 32.9d |
| Miscanthus | | 0.07f | 0.79d | 13.8g | 83.8c |
| Soybean/Corn Rotation | | 0.56a | 1.91b | 43.4de | 77.1c |
| Sweet Sorghum | | 0.14e | 1.05c | 52.0bc | 205.6a |
| Switchgrass | | 0.14e | 0.76d | 23.5f | 68.5c |
| Tall Fescue | | 0.28d | 2.34a | 50.4cd | 222.9a |
| <i>Pr>F</i> | | 0.001 | 0.001 | 0.001 | 0.001 |

Table 10: Total organic carbon, total nitrogen and C:N ratios for bio-fuel cropping systems, Fall 2010

| 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 | | | Greenley | |
| Continuous Corn (Grain only) | 15.9b | 1.55c | 10.40ab | 16.1bc | 1.60cd | 10.2bc |
| Continuous Corn (Grain +Stover) | 18.8a | 1.67bc | 11.20ab | 15.8bc | 1.51e | 10.6a |
| Corn/Soybean Rotation | 16.3b | 1.63c | 10.08bc | 17.8b | 1.73bc | 10.3ab |
| Miscanthus | 18.8a | 1.84ab | 10.35ab | 15.9bc | 1.57cd | 10.1bc |
| Soybean/Corn Rotation | 18.8a | 1.71bc | 11.46a | 17.4bc | 1.83ab | 9.5c |
| Sweet Sorghum | 18.8a | 1.89a | 10.15bc | 20.1a | 1.94a | 10.4ab |
| Switchgrass | 16.8ab | 1.53c | 11.35a | 15.6c | 1.56ed | 10.0bc |
| Tall Fescue | 16.7ab | 1.69bc | 9.99c | 16.8bc | 1.74bc | 9.7c |
| <i>Pr>F</i> | <i>0.023</i> | <i>0.007</i> | <i>0.062</i> | <i>0.003</i> | <i>0.001</i> | <i>0.056</i> |
| 0 P and K | 17.6a | 1.69a | 10.65ab | 17.1a | 1.68ab | 10.2a |
| Buildup | 17.3a | 1.74a | 10.13b | 16.4a | 1.62b | 10.1a |
| Removal | 17.9a | 1.64a | 11.09a | 17.4a | 1.75a | 10.0a |
| <i>Pr>F</i> | <i>0.735</i> | <i>0.238</i> | <i>0.041</i> | <i>0.281</i> | <i>0.057</i> | <i>0.575</i> |

Miscellaneous Tests

Final Reports

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

Dale G. Blevins

Professor & Kemper Fellow
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 and conduct this study are shown in the Timetable (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.

Sept 30 2009 Strips were visible, and plots were treated with triple super phosphate or urea-N as shown in **Fig.1** with treatments randomly assigned. These treatments were repeated in Fall 2010. See treatments listed below.

Around Dec 18 of each winter, plots were treated with their second application of P and N fertilizer

June 22 2010 and June 28 2011. Seed was harvested with a plot combine, and air-dried in the attic of the main bldg at Bradford Farm

July 14, 2011 Seeds were cleaned, weighted and yields were calculated

July 15, 2011 Data were analyzed and graphs were drawn

December 2011 Final report was prepared

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 systems: Conventional pasture or Stripkill

Replications: Five replications of each treatment

Total plots = 90 (10' x 25') plots with 5' borders

(3 Ntrtmnts x 3 Ptrtmnts 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 Results

In summer 2011, the strip-kill tall fescue seed production system clearly produced higher seed yield than the conventional system (Fig. 2). Although tall fescue seed yields were low around the state in 2011, the strip-kill system produced seed yields over 300 lbs/acre. With the strip-kill system, the split N application (50-50 N Sept-Dec) produced slightly higher yield than the two other N treatments. The 0-50 and 50-0 P treatments were slightly better than the 25-25 P treatments with strip-kill. The 50-0 P treatment produced higher yields than the other two P treatments across all three N treatments with the conventional production system (Fig. 3). The 0-50 P treatment produced conventional seed yields that were over 50 lbs/acre lower than the 50-0 P treatment. With strip-kill, the 0-50 and 50-0 P treatments produced the highest seed yields with the split 50-50 N treatment (Fig. 4). When all N treatments were pooled, the strip-kill system produced yields that were from 50 to 100 lbs seed/acre higher than conventional with the various P treatments (Fig. 5). When all P treatments were pooled, the strip-kill system produced yields that were around 100 lbs seed/acre higher with the 50-50 and 0-100 N treatments (Fig. 6). These two N treatments were superior to the 100-0 N treatment. When all N and P treatments were combined, tall fescue seed yield was around 70 lbs seed/acre greater with strip-kill than with conventional production (Fig. 7).

Project Summary

2010 was a very unusual year for tall fescue seed production with the strip-kill system. In our research program with about ten years of data, 2010 was the only year where conventional tall fescue seed production was greater than strip-kill seed production. In 2011, strip-kill was clearly superior to conventional with 0-50 and 50-0 P treatments producing the best yield increases when combined with the 50-50 N treatment. Therefore with the strip-kill system, P can be applied either in September or December, but splitting the N application may be best for tall fescue seed production. Adding the 100 lbs N in September produced massive vegetative growth and caused lodging resulting in lower seed yields with both production systems. For conventional seed production on a pasture, 50 lb P in September was best.



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.

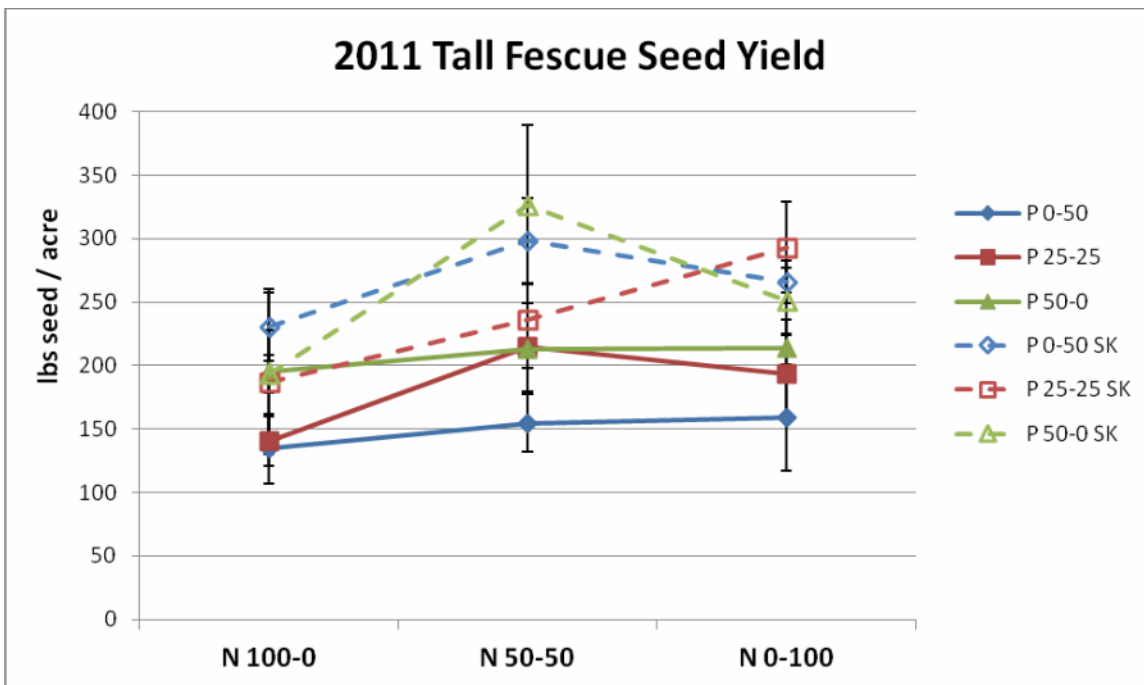


Figure 2. The June 2011 tall fescue seed yield from strip-kill and conventional plots treated with N and/or P in either September or December of 2010.

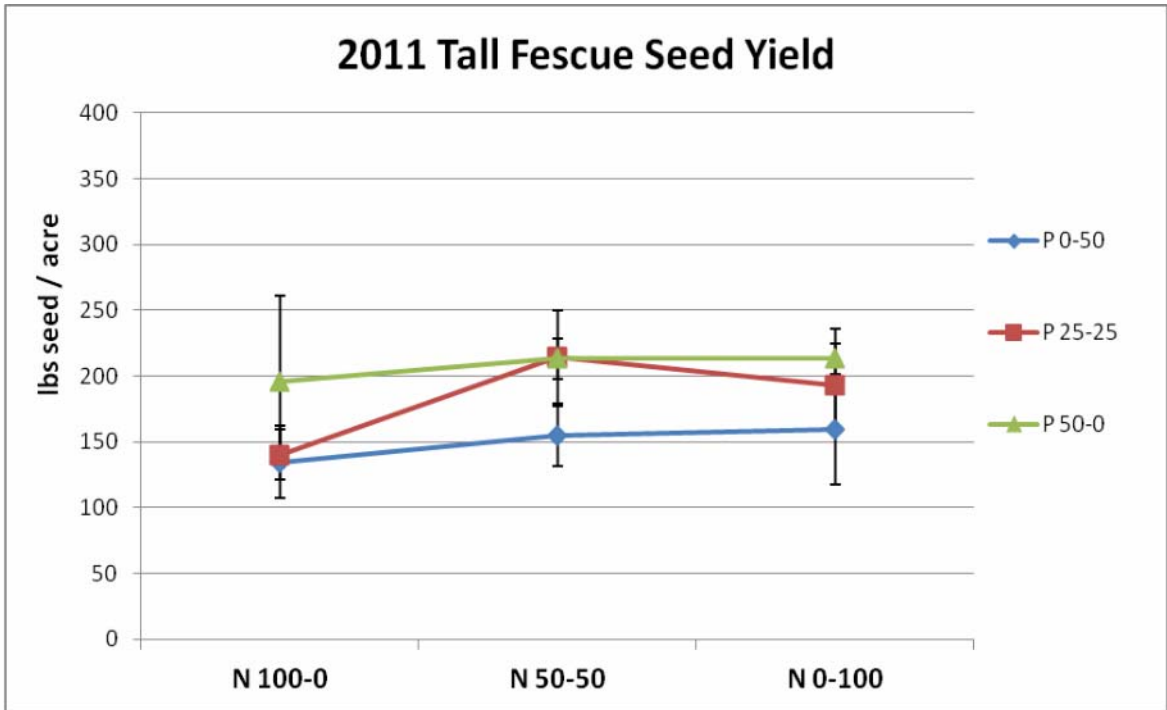


Figure 3. 2011 tall fescue seed yield from conventional plots treated with N and /or P in September and/or December 2010.

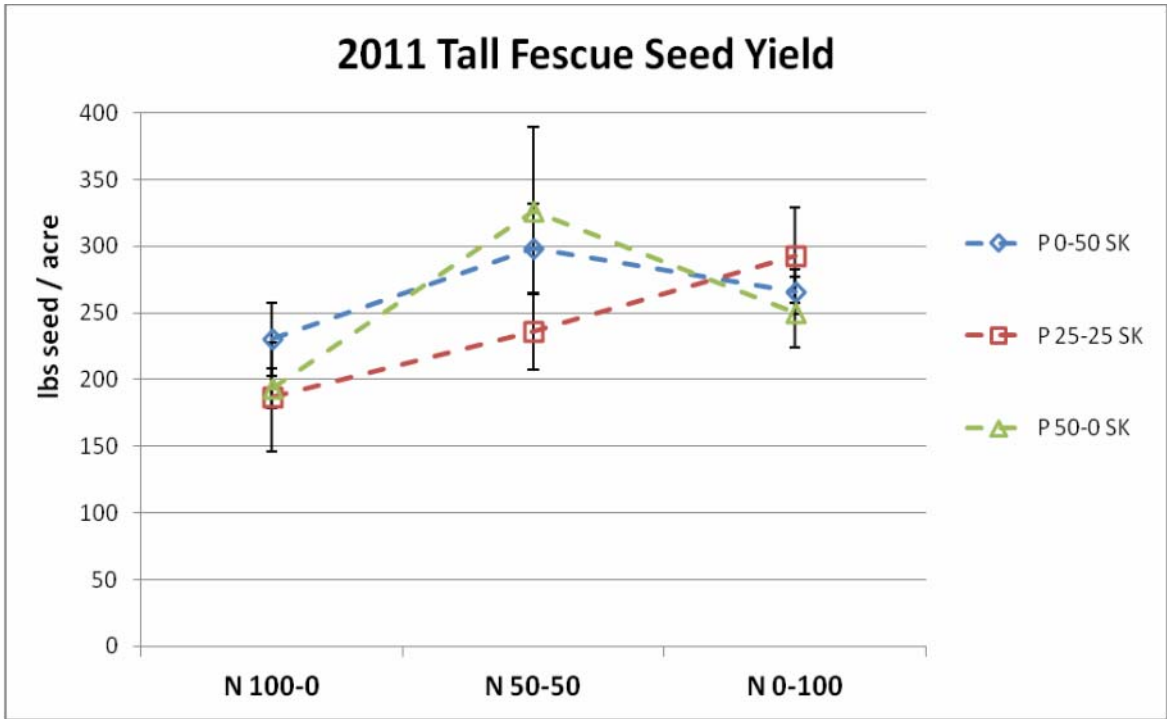


Figure 4. 2011 tall fescue seed yield from strip-kill (SK) plots treated with N and /or P in September and/or December 2010.

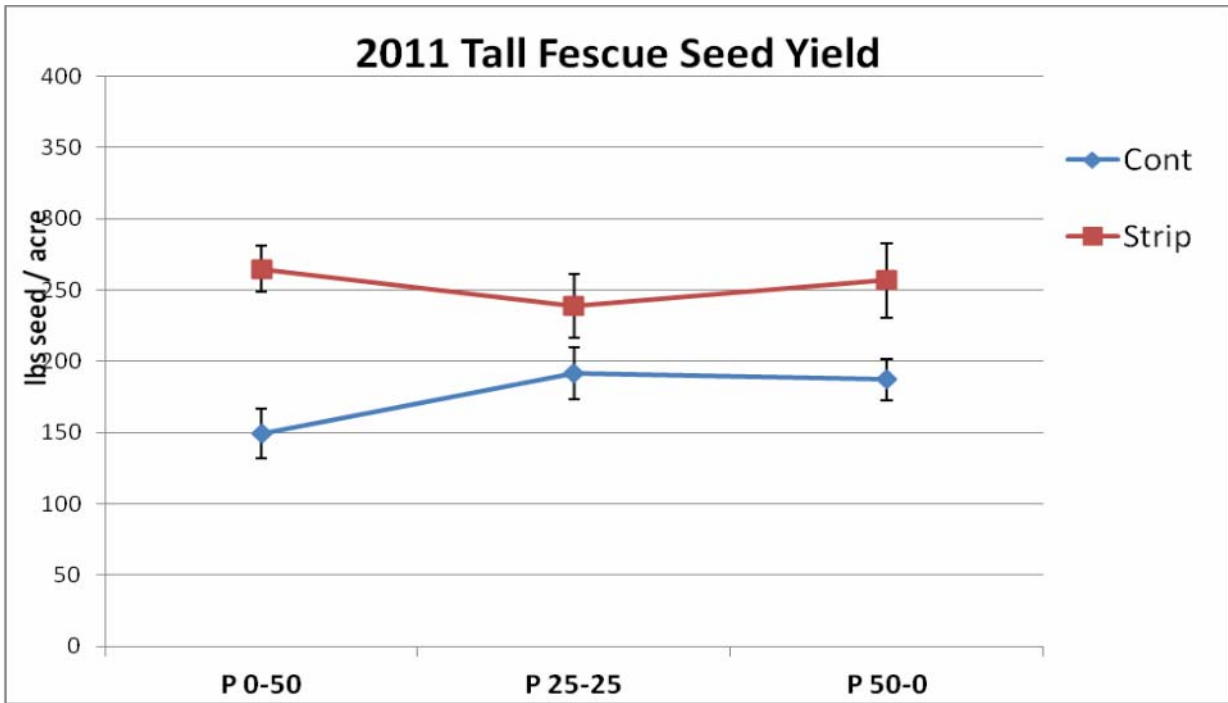


Figure 5. Tall fescue seed production in summer 2011 with various P treatments after pooling N treatments.

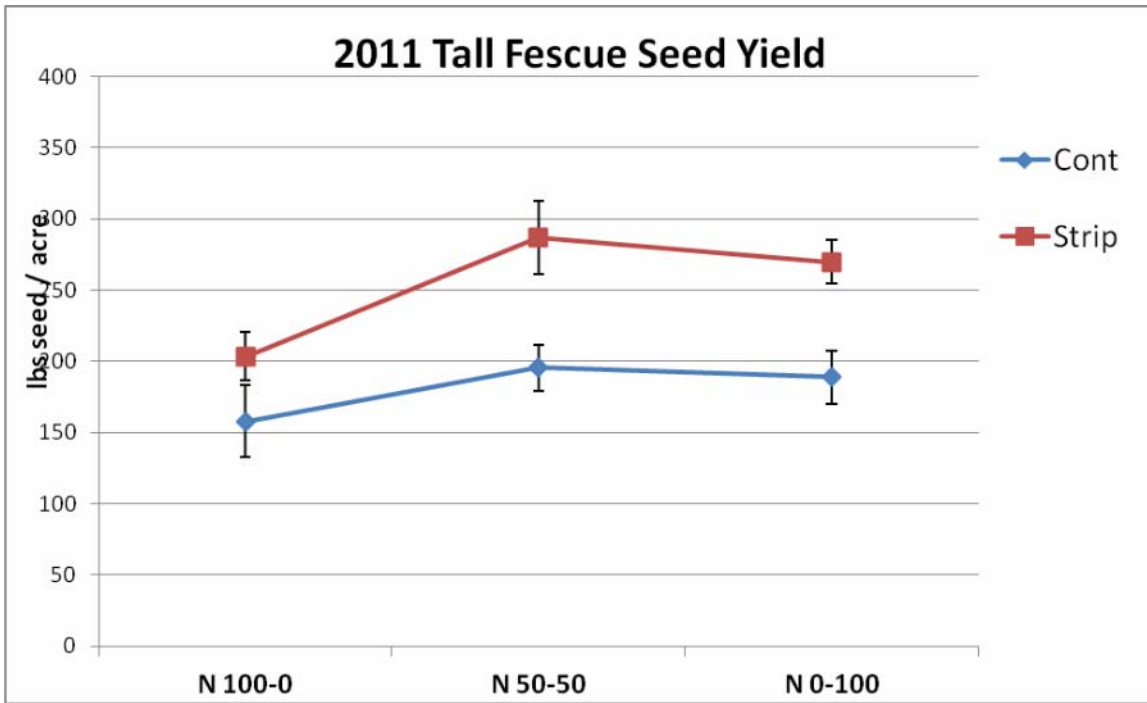


Figure 6. Conventional and strip-kill tall fescue seed yield from summer 2011 with various N treatments after pooling all P treatments.

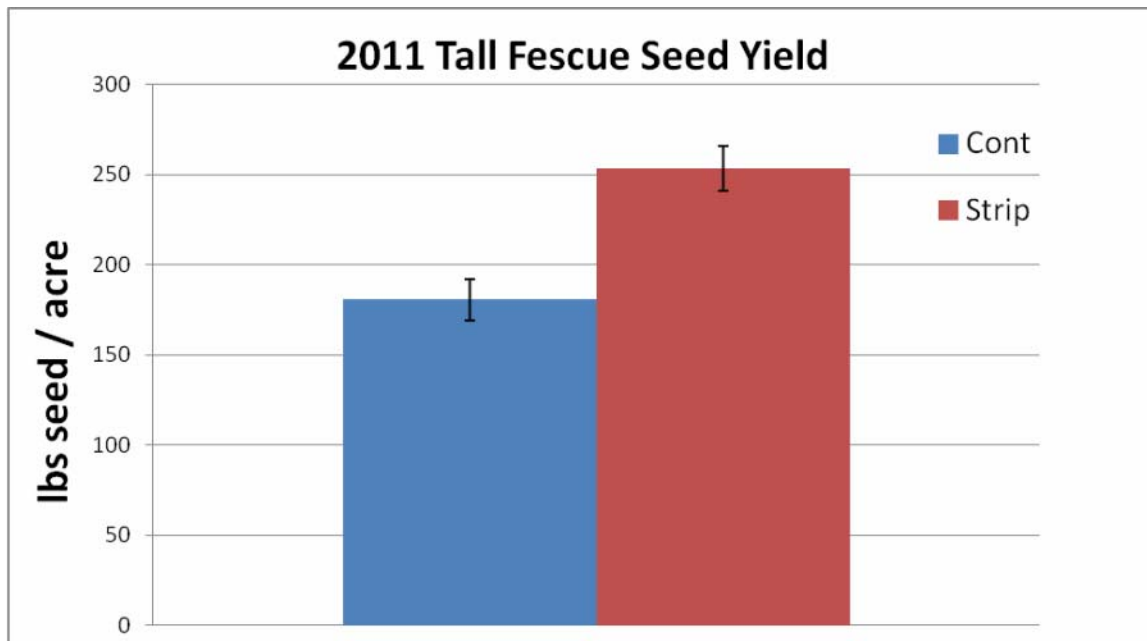


Figure 7. Conventional and strip-kill tall fescue seed yield from summer 2011 with all N and P treatments combined.

Progress Reports

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

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. The fields selected are in a corn-soybean rotation for the duration of the project with the possible addition of wheat depending on the year. All three fields have been grid soil sampled on a 1 acre grid. The three fields received fertility 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 least 12 times in each of the three fields where treatments were applied in the spring of 2011. 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 three fields implemented can be seen in Figures 1. 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.

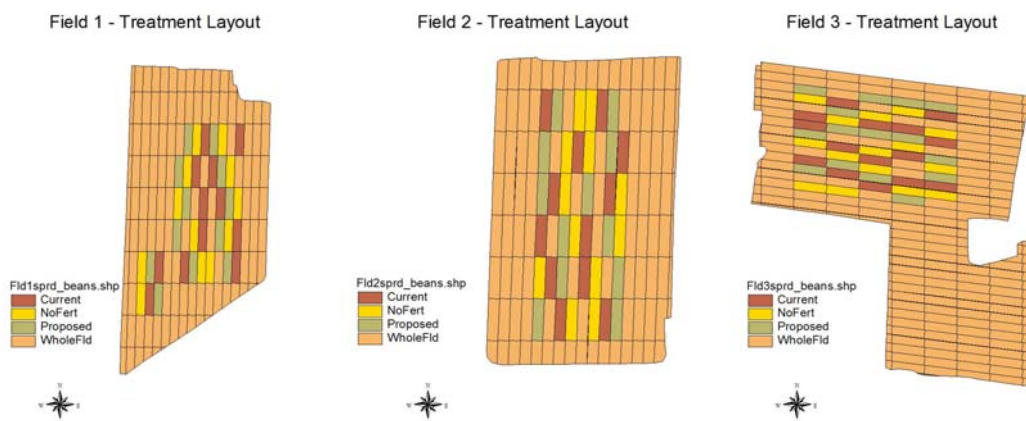


Figure 2. Plot Layout for Field 1, 2, and 3

Results for 2011:

Soybean 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 50 to 60 bu/acre with the mean being 54 bu/acre for Field 1. Field 2 had plot yield ranging from 37 to 57 bu/acre with a mean of 47 bu/acre. Field 3 had plot yield ranging from 44 to 54 bu/acre with a mean of 48 bu/acre. There were no significant yield differences between treatments at the 5% probability level in all fields. Though there were significant yield differences between replications in Fields 1 and 3 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 each of the three fields. 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 | 51.4 | 59.2 | 51.1 | 56.9 | 49.8 | 53.7 |
| Whole Field | 60.0 | 55.8 | 51.8 | 54.6 | 52.9 | 55.0 |
| Current Recommendations | 51.1 | 58.0 | 52.8 | 54.5 | 49.7 | 53.2 |
| Proposed Recommendations | 56.1 | 55.8 | 51.6 | 59.9 | 53.1 | 55.3 |
| Block Mean | 54.7 | 57.2 | 51.8 | 56.5 | 51.4 | 54.3 |
| No significant treatment differences (P=0.05) | | | | | | LSD 3.5 |

Yield Results for Field 2

| | Rep 1 | Rep 2 | Rep 3 | Rep 4 | Rep 5 | Treatment Mean |
|--|-------------------|-------|-------|-------|-------|--------------------|
| Treatment | ---- bu/acre ---- | | | | | |
| No Fertilizer | 51.4 | 47.2 | 47.1 | 38.1 | 51.0 | 47.0 |
| Whole Field | 51.6 | 49.7 | 48.1 | 43.5 | 43.6 | 47.3 |
| Current Recommendations | 44.5 | 49.5 | 38.7 | 43.9 | 47.1 | 44.8 |
| Proposed Recommendations | 49.2 | 36.9 | 56.7 | 46.9 | 45.4 | 47.0 |
| Block Mean | 49.2 | 45.9 | 47.7 | 43.1 | 46.8 | 46.5 |
| No significant treatment differences (P=0.05) | | | | | | LSD 7.5 |

Yield Results for Field 3

| | Rep 1 | Rep 2 | Rep 3 | Rep 4 | Rep 5 | Treatment Mean |
|--|-------------------|-------|-------|-------|-------|--------------------|
| Treatment | ---- bu/acre ---- | | | | | |
| No Fertilizer | 52.0 | 48.7 | 44.3 | 47.9 | 48.2 | 48.2 |
| Whole Field | 51.5 | 48.8 | 45.4 | 48.0 | 45.2 | 47.8 |
| Current Recommendations | 53.8 | 48.2 | 43.6 | 48.5 | 45.3 | 47.9 |
| Proposed Recommendations | 49.7 | 52.9 | 49.1 | 45.5 | 51.2 | 49.7 |
| Block Mean | 51.8 | 49.7 | 45.6 | 47.5 | 47.5 | 48.4 |
| No significant treatment differences (P=0.05) | | | | | | LSD 3.1 |

Also included are tables summarizing fertilizer recommendations for P and K for the three fields by treatment. As in 2010, it should be noted by using the proposed University of Missouri fertilizer recommendations decreased fertilizer requirements of both P and K in all fields. These

differences were considerably less than current University of Missouri recommendations. In Field 1, the P recommendation was 1950 lbs less and the K recommendation was 4879 lbs less. Field 2 and 3 shows the same trend. The P recommendation was 4886 lbs less and the K recommendation was 4708 lbs/acre less for Field 2. In Field 3, the P recommendation was 1393 lbs less and the K recommendation was 7753 lbs less.

Fertilizer Recommendations for P and K by Treatment for Field 1

| Treatment | Total Pounds of P | Total Pounds of K |
|--------------------------|-------------------|-------------------|
| Whole Field | 2494 | 9265 |
| Current Recommendations | 2790 | 8017 |
| Proposed Recommendations | 840 | 3138 |

Fertilizer Recommendations for P and K by Treatment for Field 2

| Treatment | Total Pounds of P | Total Pounds of K |
|--------------------------|-------------------|-------------------|
| Whole Field | 8866 | 7916 |
| Current Recommendations | 9299 | 8371 |
| Proposed Recommendations | 4413 | 3663 |

Fertilizer Recommendations for P and K by Treatment for Field 3

| Treatment | Total Pounds of P | Total Pounds of K |
|--------------------------|-------------------|-------------------|
| Whole Field | 2046 | 14322 |
| Current Recommendations | 1393 | 13935 |
| Proposed Recommendations | 0 | 6182 |

Objectives for 2011:

1. Applied fertilizer treatments to Fields 1 and 3 in the fall of 2011. Field 1 and 3 was planted to wheat and Field 2 will be planted to corn and receive fertilizer treatments in the spring of 2012.
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 2012 to discuss results from 2011.

BUDGET for 2011 and 2012

| Item | Description | 2011 | 2012 |
|----------------|------------------------|---------|---------|
| Field Days | | 500 | 500 |
| Publication | | 300 | 300 |
| Travel | | 260 | 260 |
| Sub total | by year | \$1,060 | \$1,060 |
| Support Salary | 25% of the above total | \$265 | \$265 |
| Grant Total | by year total | \$1,325 | \$1,325 |

Budget Request for 2012

\$1,325

Plant Sap Test for Foliar N, K, Mn, and Lime on Soybean and Cotton

Gene Stevens, Matt Rhine, Kelly Nelson, Jim Heiser, and David Dunn

Objective and Relevance: Soybean and cotton farmers could benefit from rapid, inexpensive methods to evaluate crop tissue or sap to determine when mid-season foliar sprays are needed to maximize yields. Horticulture crop growers measure plant sap in tomatoes, potatoes, and lettuce as a tool for managing N. Water districts in California published leaf sap nitrate-nitrogen sufficiency guide sheets for testing fresh sap from broccoli, brussel sprouts, cabbage, cauliflower, celery, lettuce, spinach, and onions.

The objective of this study is to evaluate field ion-selective electrode meters, colorimeters, and color indicator strip tests on soybean and cotton plants growing on a range of soil test levels and foliar fertilizer N, K, and Mn applications. We hope to develop a fast testing process which works like a diabetic person pricking his finger and testing for blood sugar.

Procedure: Soil samples were collected from fields at the Fisher Delta Center at Portageville, Rhodes Farm at Clarkton, Greenley Center at Novelty, and Missouri Rice Research Farm at Qulin, Missouri. Soybean and cotton was planted in small plots in fields with soil test levels in the low and medium ranges for potassium and manganese. Cotton was also planted at Clarkton to evaluate N quick tests. Fertilizer treatments for K, Mn, and N included a untreated check, recommended dry preplant fertilizer and several timings and sources of foliar fertilizer. Each treatment was replicated five times. Leaves and petioles from each soybean and cotton plot were collected. Samples were collected at V7, R1, and R1+ 1 week growth stages followed by foliar sprays of each nutrient on treatments using a CO₂ backpack sprayer. Plots were visually rated for leaf burn at 3, 7, and 14 dates after foliar applications. Leaf and petiole samples were frozen in plastic bags until they could be processed. A garlic press was used to squeeze leaf and petiole sap. Cotton tissue nitrate-N was measured by Horiba® Cardy nitrate meter, Hach® Colorimeter, and Quant® Nitrate test Strips. Duplicate samples were oven dried and tested in the Delta Center Lab with a nitrate ion-selective electrode. A plot combine and cotton picker were used to mechanically harvest plots. Yield response to foliar spray will be correlated with leaf sap meter reading to determine best growth stages and leaf stems to sample.

Preliminary Results: Several of the “soluble” potassium fertilizers did not dissolve sufficiently in 15 gallons per acre. To apply the targets amounts, we had to apply more water and spray some plots twice. This would not be practical for farmers. A significant soybean yield increase was found at Novelty and Qulin from applying preplant potash (Table 1). In soybean plots, none of the foliar K treatments produced significant yield increases compared to the untreated check. At Novelty, significant leaf burn occurred with Re-NforceK. For cotton, most of the K treatments showed no yield increases, but three application of KNO₃ did significantly increase lint yield compared to the check. No significant soybean yield increases were found from Mn soil or foliar fertilizers at Novelty or Clarkton (Table 2). Likewise, N did not increase cotton lint yields at Clarkton (Table 3). This field had been used in winter legume cover crop research in the past and may have N released from organic matter during the year. We are currently in the process of making quick test measurements from frozen samples collected during the season and comparing the results to duplicate leaf and petiole samples test at the Delta Center Soil Lab (Figure 1, Table 4). This winter we are going soybean and cotton in vermiculite pots in the greenhouse with nutrient solutions formulated to create deficiencies in N, P, and K. Toxic levels of Mn and Al are also being studied. Quick tests will be used on these plants.

Table 1. Soybean and cotton yield response to soil and foliar potassium treatments at Novelty, Quilin, and Clarkton, Missouri in 2011.

| Trt | Fertilizer | Preplant | V7 | R1 | R1 + 1 wk | Novelty | Quilin | Clarkton |
|--------------------|------------------|----------|------|-----|--------------|----------------|------------|----------|
| | | | | | | soybean | | cotton |
| -----lb K20/a----- | | | | | | -----bu/a----- | lb lint /a | |
| | | | | | | --- | -- | |
| Check | | | 0 | 0 | 0 | 44 ab† | 53 cd | 987 b |
| Soil | Potash | 120 | 0 | 0 | 0 | 47 a | 61 a | 930 b |
| Bdcast | Potash | 0 | 0 | 0 | 60 | 45 ab | 53 cd | 911 b |
| Foliar | White Sol Potash | 0 | 19 | 19 | 19 | 43 bc | 53 cd | 1039 b |
| Foliar | White Sol Potash | 0 | 0 | 19 | 19 | 43 bc | 52 cd | 1010 b |
| Foliar | White Sol Potash | 0 | 0 | 0 | 19 | 44 ab | 57 abc | 949 b |
| | | | | 4.6 | | 46 ab | 55 abc | 1217 a |
| Foliar | KNO3 | 0 | 4.62 | 2 | 4.62 | | | |
| | | | | 4.6 | | 44 ab | 56 abc | 970 b |
| Foliar | KNO3 | 0 | 0 | 2 | 4.62 | | | |
| Foliar | KNO3 | 0 | 0 | 0 | 4.62 | 43 bc | 60 ab | 960 b |
| | | | | 4.6 | | 38 e | 54 bc | 985 b |
| Foliar | Re-NforceK | 0 | 4.68 | 8 | 4.68 | | | |
| | | | | 4.6 | | 41 cd | 48 d | 1048 b |
| Foliar | Re-NforceK | 0 | 0 | 8 | 4.68 | | | |
| Foliar | Re-NforceK | 0 | 0 | 0 | 4.68 | 39 de | 52 cd | 963 b |

†Yields followed by the same letter were not significantly different at the 0.05 level.

Table 2. Soybean yield response to soil and foliar manganese treatments at Novelty and Quilin, Missouri in 2011.

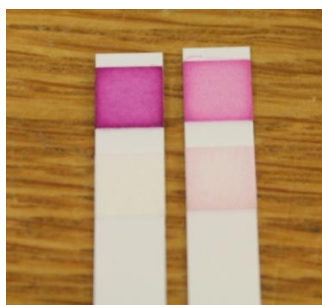
| Trt | Fertilizer | Preplant | V7 | R1 | R1+1 wk | Novelty | Clarkton |
|--------|-------------------------|----------|------|------|------------|----------------------|----------|
| | | | | | | -----lb Mn/acre----- | |
| | | | | | | --- | |
| Check | | 0 | 0 | 0 | 0 | 43 a† | 43 a |
| Soil | Mn sulfate 6% | 4 | 0 | 0 | 0 | 43 a | 40 ab |
| Foliar | Chelated EDTA Mn | 0 | 0.25 | 0.25 | 0.25 | 43 a | 31 cd |
| Foliar | Chelated EDTA Mn | 0 | 0 | 0.25 | 0.25 | 43 a | 40 ab |
| Foliar | Chelated EDTA Mn | 0 | 0 | 0.5 | 0 | 42 a | 32 cd |
| | Chelated EDTA Mn + | | | | | 42 a | 28 d |
| Foliar | glyphosate | 0 | 0 | 0.5 | 0 | | |
| Foliar | Mn sulfate + glyphosate | 0 | 0 | 0.5 | 0 | 44 a | 35 bc |
| Foliar | GlucO Mn + glyphosate | 0 | 0 | 0.5 | 0 | 43 a | 39 ab |
| Foliar | glyphosate alone | 0 | 0 | 0.5 | 0 | 44 a | 42 a |

†Yields followed by the same letter were not significantly different at the 0.05 level.

Table 3. Cotton yield response to soil and foliar nitrogen treatments at Clarkton, Missouri in 2011.

| Treatment | Fertilizer | Preplant | lb N/acre | | | Cotton lb lint/acre |
|-----------|---------------------|----------|-----------|--------------|--------------|------------------------|
| | | | V12 | First Blm | Blm +1 wk | |
| Check | ---- | 0 | 0 | 0 | 0 | 959 a† |
| med N | soil | 40 | 0 | 0 | 0 | 1120 a |
| high N | soil | 120 | 0 | 0 | 0 | 994 a |
| low N | | | | | | 1082 a |
| foliar | Foliar KNO3 | 0 | 4.62 | 4.62 | 4.62 | |
| low N | | | | | | 1070 a |
| foliar | Foliar KNO3 | 0 | 0 | 4.62 | 4.62 | |
| low N | | | | | | 1106 a |
| foliar | Foliar KNO3 | 0 | 0 | 0 | 4.62 | |
| med N | Am nitrate + foliar | | | | | 1136 a |
| foliar | KNO3 | 40 | 4.62 | 4.62 | 4.62 | |
| med N | Am nitrate + foliar | | | | | 1032 a |
| foliar | KNO3 | 40 | 0 | 4.62 | 4.62 | |
| med N | Am nitrate + foliar | | | | | 1122 a |
| foliar | KNO3 | 40 | 0 | 0 | 4.62 | |

†Yields followed by the same letter were not significantly different at the 0.05 level.



and nitrate test strips used to measure sap nitrate.

Table 4. Cotton tissue nitrate-N measured by ion selective electrode (ISE) from oven dried and ground leaves and petioles and quick test sap squeezed from frozen green leaves and petioles collected at V7, first bloom, and R1+ 1 week and measure by Horiba® Cardy nitrate meter, Hach® Colorimeter, and Quant® Nitrate test Strips.

| Plant N | Plant part | Growth stage | Cardy meter | Hach colorimeter | Quant strip | Soil Lab ISE meter |
|---------|------------|--------------|-----------------------------|------------------|-------------|--------------------|
| | | | -----sap ppm Nitrate-N----- | | | dry sample |
| 0 | Leaves | V12 | 767 a† | 760 a | 1116 a | 44,833 b |
| 120 | | V12 | 1366 a | 757 a | 753 a | 103,485 b |
| 0 | | 1st Bloom | 1233 a | 477 a | 146 a | 10,055 b |
| 120 | | 1st Bloom | 1100 a | 263 a | 3866 a | 22,706 b |
| 0 | | R1+1week | 733 a | 453 a | 183 a | 12,197 b |
| 120 | | R1+1week | 666 a | 66 a | 440 a | 20,848 b |
| 0 | Petioles | V12 | 1233 a | 387 a | 2586 a | 1,809,325 a |
| 120 | | V12 | 700 a | 223 a | 1387 a | 2,159,460 a |
| 0 | | 1st Bloom | 267 a | 73 a | 67 a | 13,177 b |
| 120 | | 1st Bloom | 1133 a | 220 a | 100 a | 443,000 b |
| 0 | | R1+1week | 300 a | 240 a | 107 a | 36,649 b |
| 120 | | R1+1week | 1316 a | 433 a | 1727 a | 545,864 b |

†Yields followed by the same letter were not significantly different at the 0.05 level.

Budget:

| | 2012 | 2013 |
|----------------------------|----------|----------|
| Labor- research assistant | \$15,000 | \$15,000 |
| MU Soil Lab tissue testing | \$2500 | \$3000 |
| Supplies and travel | \$2000 | \$2000 |
| Total | \$19,500 | \$20,000 |

Fertilizing Summer-Annual Grasses for Forage Production

Robert L. Kallenbach

Objectives and relevance of project: Summer-annual grasses are becoming more popular each year, especially forage varieties of crabgrass and dwarf, brown mid-rib sorghum sudangrass. These grasses provide high-quality forage for summer grazing and/or stored forage. However, we have almost no information about how to fertilize these grasses for optimum economic production. This is especially true for nitrogen fertilizer. Although these grasses represent a great opportunity for forage/livestock producers at present, there is little data for solid agronomic recommendations.

The **overall objective** is to develop research-based recommendations that help industry personnel and farmers properly fertilize summer annual grasses. Specific objectives are:

Objective 1: Determine the optimum economic N rates for crabgrass, dwarf brown mid-rib (BMR) sorghum-sudangrass hybrids, non-dwarf sorghum-sudangrass hybrids and pearl millet.

Objective 2: Determine if split application of nitrogen fertilizers provides a significant advantage compared to larger single applications.

Objective 3: Determine the influence of N application rates on nitrate accumulation and/or prussic acid concentrations in forage.

Procedures:

Treatments: This experiment has 32 treatments; four forage entries and eight N rates x timing applications. The four forage entries are 'Big-n-Quick' crabgrass, dwarf BMR sorghum x sudangrass, BMR sorghum-sudangrass and pearl millet. The eight nitrogen treatments are described in the table below.

| Treatment | Annual N rate | No. of Applications | Notes |
|-----------|---------------|---------------------|--|
| | lb/acre | # | |
| 1 | 300 | 3 | 1/3 late May, 1/3 late June, 1/3 late July |
| 2 | 300 | 2 | 1/2 in late May, 1/2 late June |
| 3 | 150 | 3 | 1/3 late May, 1/3 late June, 1/3 late July |
| 4 | 150 | 1 | Applied in late May |
| 5 | 100 | 2 | 1/2 in late May, 1/2 late June |
| 6 | 100 | 1 | Applied in late May |
| 7 | 50 | 1 | Applied in late May |
| 8 | 0 | - | Control |

Cultural practices: Stands of each annual forage were established in early May at the Southwest Center, near Mt. Vernon, MO and at the Forage Systems Research Center near Linneus, MO. Both sites were planted using a Truax no-till drill. The seeding rates (PLS) for each species was as follows; crabgrass 4 lb/acre, sorghum-sudangrass 40 lb/acre, and pearl millet 30 lb/acre.

Design: Each treatment was replicated three times in a randomized complete block design in a split-block arrangement. Forage entries were main plots and nitrogen treatments sub-plots.

Measurements:

Forage yield and growth rates. Growth rate of forage was measured weekly using a rising plate meter for crabgrass and by measuring the natural height with a meter stick for the other forage species. Mechanical forage harvest for an individual treatment occurred when forage reached the following thresholds: 18 rising plate meter units for crabgrass, 30 inches for the other species. For those unfamiliar with rising plate meter measurements, this would equate to approximately 8 inches in height for crabgrass. Subsamples for forage nutritive value, prussic acid, and plant nitrates were also collected at the time of a mechanical harvest.

Figure 1. Length of harvest strip being measured in field plots near Mt. Vernon, MO.



Results

At Mt. Vernon, MO summer precipitation was 59% less than the 30 year average in 2011. As a result, dry matter yields of all 4 species were lower than normal (Table 2). For instance, the sorghum x sudangrass hybrids, which commonly yield 4 to 6 tons per acre, produced less than 1 ton per acre. Additionally, pearl millet, which is known as a drought-tolerant species, was the only species of forage that showed a response to N applications, but that response was not economical by most standards.

At Linneus MO, dry matter yields were greater than those at Mt. Vernon (Table 3). However, late summer precipitation limited yields at this location. The pearl millet did not establish well at this site and is not included in the preliminary data analysis. Crabgrass did not respond to N applications but both sorghum x sudangrass hybrids did. The preliminary data show that early applications of N were more favorable than late-summer applications. Dry matter yields were often no better if N was spread out over the summer in 2 or 3 applications. This result was likely influenced by the precipitation shortage in late summer; we expect the later N applications to stimulate more growth when summer precipitation is more evenly distributed.

While the yields for 2011 were below average for both sites, it does show how variable summer annual forage yields can be in Missouri and the need to conduct multi-year studies to develop sound agronomic recommendations.

Table 2. Annual yield of four species of summer annual grasses under eight different N fertilization regimes. Data were collected near Mt. Vernon, MO in the summer of 2011.

| Annual N rate | No. of Applications | Crabgrass | Dwarf Sorg x sudan | BMR Sorg x sudan | Pearl Millet |
|---------------|---------------------|-----------|--------------------|------------------|--------------|
| lb/acre | # | lb/acre | | | |
| 300 | 3 | 4970 a | 2053 a | 1801 a | 2148 bc |
| 300 | 2 | 4262 a | 2296 a | 1502 a | 2938 a |
| 150 | 3 | 4477 a | 1685 a | 1787 a | 2682 abc |
| 150 | 1 | 4417 a | 1786 a | 1908 a | 2764 ab |
| 100 | 2 | 4936 a | 1982 a | 1638 a | 2149 bc |
| 100 | 1 | 4120 a | 1713 a | 1948 a | 2143 bc |
| 50 | 1 | 4825 a | 1835 a | 1873 a | 1977 cd |
| 0 | - | 4352 a | 1483 a | 1529 a | 1261 d |

Table 3. Annual yield of three species of summer annual grasses under eight different N fertilization regimes. Data were collected near Linneus, MO in the summer of 2011.

| Annual N rate | No. of Applications | Crabgrass | Dwarf Sorg x sudan | BMR Sorg x sudan |
|---------------|---------------------|-----------|--------------------|------------------|
| lb/acre | # | lb/acre | | |
| 300 | 3 | 6443 a | 6174 ab | 7961 ab |
| 300 | 2 | 6414 a | 7818 a | 8467 a |
| 150 | 3 | 6045 a | 5897 b | 6751 c |
| 150 | 1 | 6420 a | 7648 a | 7245 bc |
| 100 | 2 | 4659 a | 5857 b | 6888 bc |
| 100 | 1 | 5271 a | 5890 b | 6721 c |
| 50 | 1 | 5785 a | 6156 ab | 5449 d |
| 0 | - | 4451 a | 5414 b | 4823 d |

Timetable for proposed research: This study began in spring of 2011 and will end in December of 2013 (three years of study). The table below gives a brief summary of the project's activities. (* indicates task to be done on an annual basis throughout the three-year study)

| | |
|--|--|
| Spray existing perennial forage in plot areas with glyphosate | 3/15/12 |
| No-till plant forage at the Southwest Center and at the Forage Systems Research Center | *Late April or Early May |
| Take plate meter readings to guide forage harvests | *Weekly from 1 June until frost. |
| Apply appropriate nitrogen fertilizer treatments (see table on page 1 for details) | *May, June, July |
| Harvest appropriate plots for forage yield and retain subsamples for forage quality, prussic acid, and nitrate analysis | *Variable based on plant growth - expect 3 to 5 harvests per yr. |
| Analyze latest results & report findings to Fertilizer/Ag Lime Advisory Council | *December |
| Incorporate results into soil testing reports, grazing school materials and forage conferences. Work with press on articles. | October 2013 through December 2014 |
| Submit manuscript on this research to a peer-reviewed journal | March 2014 |

Year 2 Budget:

Salary and Benefits

| | |
|--|-----------------|
| Research Specialist (20% of \$48,000) | \$ 9,600 |
| Benefits for Research Specialist | \$ 3,072 |
| Total Salary and Benefits | \$12,672 |

Operating Expenses

| | |
|--|-----------------|
| Fertilizer, bags, repair parts for harvester and other field supplies | \$ 1,500 |
| NIR charges for forage quality analysis (1280 samples @ \$4 each) | \$ 3,840 |
| Wet chemistry for NIR calibration (90 samples @ \$10.50 each) | \$ 945 |
| Prussic acid and nitrate analysis | \$ 1,250 |
| Travel to research locations (mileage, lodging, and meals for 8 trips/yr) | \$ 1,600 |
| Total Operating Expenses | \$ 9,135 |

Equipment

| | |
|------------------------|-------------|
| None requested | \$ 0 |
| Total Equipment | \$ 0 |

Total Proposal Request for Year #2 *\$21,807*

Fertilizer/Ag Lime Control Service
University of Missouri-Columbia
Columbia, MO 65211-8080

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